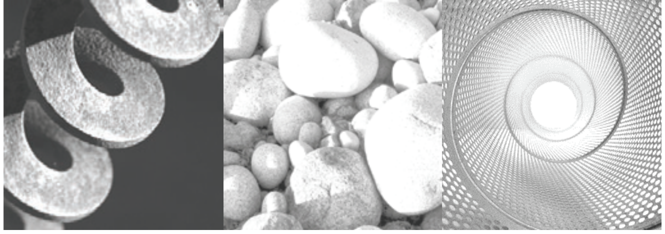


GEI Consultants

Consulting
Engineers and
Scientists

Preliminary Alternatives Evaluation

Bartlet Mall Frog Pond
Newburyport, Massachusetts

Submitted to:
The City of Newburyport – Parks Commission
60 Pleasant Street
Newburyport, MA 01950

Submitted by:
GEI Consultants, Inc.
400 Unicorn Park Drive
Woburn, MA 01801
781-721-4000

June 23, 2021
Project 2101333

Michael Sabulis, LSP
Senior Project Manager

James R. Ash, P.E., LSP
Senior Vice President

Table of Contents

KAW:jam
B:\Working\NEWBURYPORT MA, CITY OF\2101333 Bartlett Mall Frog Pond\01_ADMIN\Alternatives Eval\NBPT Alternatives Evaluation 06-23-2021.docx

Executive Summary

GEI Consultants, Inc. prepared this report to summarize potential alternatives for managing sediment at the Bartlet Mall Frog Pond (the Pond) in Newburyport, Massachusetts (Figs. 1 and 2). We understand that the City of Newburyport Parks Commission (the Commission) is considering an initiative to improve water quality in the Pond to provide a better recreational space for public use. The Commission has requested that GEI help develop strategies and conceptual cost estimates to assist the Commission in understanding the options that exist to remediate the Pond.

Sediment Management Options for Consideration

Costs shown do not address all portions of the project and should not be considered total project costs. They should be used for relative comparison purposes between options only. The estimates generally include cost for items that are central to the option such as transportation and offsite disposal of sediment and material costs for liners, Geotubes, retaining walls, and chemical additives. The cost estimates do not include the full extent of potential construction costs such as design, surveys, additional testing, labor, equipment rental, mobilization/demobilization, and construction observation. The evaluation of alternatives is provided in Section 3.

- Option 1: Sediment Removal to Top of Peat Layer, Offsite Disposal. Estimated Cost: $1,300,000
- Option 2A: Sediment Removal to Top of Peat Layer, Onsite Reuse – Geotubes. Estimated Cost: $350,000
- Option 2B: Sediment Removal to Top of Peat Layer, Onsite Reuse – Retaining Wall. Estimated Cost: $1,100,000
- Option 3: Liner Installation. Estimated Cost: $470,000
- Option 4: Application of Chemical Additives – Phoslock. Estimated Cost: $390,000

Several data gaps were identified for each option during our evaluation. These data gaps may have potential to impact the likelihood of success and overall costs of the options presented. The costs presented are intended to be used to compare the options to each other and, as discussed above, may vary significantly once new data has been generated. Pertinent data gaps are included with discussion of the Options in Section 3.

Additional Information

Additional investigations are warranted to help determine which options are practical and feasible, and may include items such as:

- Bathymetric survey to help determine cut/fill quantities for potential sediment reuse.
- Advancement of sediment cores to obtain additional data on the vertical and horizontal distribution of phosphorus and other contaminants of concern.
- Installation of borings and installation of monitoring wells in targeted areas to evaluate site hydrogeology, specifically water flow in the former feeder stream channel.
- Additional water sampling to evaluate method for managing the existing water during construction.
- Bench scale tests for chemical additives to evaluate the quantity of phosphorus in surface water and sediment and to identify appropriate additives and dosage rates.
- Risk assessments to evaluate potential impacts to ecological and human receptors due to the potential presence of contaminants of concern in sediment.

1. Background

GEI Consultants, Inc. prepared this report to summarize potential alternatives for managing sediment at the Bartlet Mall Frog Pond (the Pond) in Newburyport, Massachusetts (Figs. 1 and 2).

We understand that the City of Newburyport Parks Commission (the Commission) is considering an initiative to improve water quality in the Pond to provide a better recreational space for public use. The Commission has requested that GEI help develop strategies and high-level cost estimates to assist the Commission in understanding the options to remediate the Pond.

We also understand that the Commission has retained Aqueous Consultants LLC (Aqueous) and requested that they evaluate strategies for improving and maintaining water quality post-remedy. Aqueous will submit a summary of their evaluation under separate cover.

2. Evaluation of Available Data

2.1 Higgins Environmental Associates Sediment Evaluation, 2013

The Commission provided information from Higgins Environmental Associates, Inc. of Amesbury, Massachusetts (HEA) summarizing their sediment sampling in April 2013 (Appendix A). HEA collected one composite sample that was comprised of sediment from the top six inches at several locations around the Pond. HEA submitted the composite sample to be analyzed for offsite disposal characterization parameters. HEA also collected 24 discrete sediment samples from the top six inches that were tested for total phosphorus.

HEA compared the testing results to Massachusetts Department of Environmental Protection (MassDEP) Massachusetts Contingency Plan (MCP; 310 CMR 40.0000) Reportable Concentration for soil defined as S-1 (RCS-1) to evaluate potential disposal alternatives. It should be noted that RCS-1 Standards are not applicable to sediment. Therefore, while concentrations of some contaminants in sediment did exceed applicable RCS-1 standards, there is no reporting obligation to MassDEP. HEA's testing results indicated the presence of arsenic, chromium, and nickel above RCS-1. Total phosphorus in the samples ranged from 114 to 2,000 milligram per kilogram (mg/kg) with an average of approximately 930 mg/kg (there is no RCS-1 standard for phosphorus).

2.2 Horsley Witten Sediment Evaluation, 2014

The Commission provided a 2014 Sediment Evaluation Summary by Horsley Witten Group of Newburyport, Massachusetts (HW; Appendix A). HW evaluated sediment conditions, including depth to and thickness of soft sediment, stratigraphy, and chemical contamination. HW also evaluated the option of dredging and offsite disposal of sediment to improve water quality and aesthetic appeal.

HW observed an approximately 3.5-foot-thick layer of dark gray organic silt with sand that was underlain by a dark brown peat layer. HW collected composite sediment samples of the entire vertical thickness of the dark gray organic silt with sand layer from each of five investigation locations. HW also collected one composite sample that was made up of peat from the five investigation locations. HW submitted the six samples for analysis of parameters required by the Massachusetts Water Quality Certification Regulations (310 CMR 9.07[9]) and the parameters identified in the following MassDEP guidance documents for contaminated soil and sediments in landfills.

- Reuse and Disposal of Contaminated Soil at Massachusetts Landfills – Policy #COMM-97-001" (COMM-97-001)

- Interim Policy for Sampling, Analysis, Handling and Tracking Requirements for Dredged Sediment Reused or Disposed at Massachusetts Permitted Landfills - Interim Policy COMM-94-007" (COMM-94-007)

Testing results indicated the presence of arsenic at concentrations that exceeded the acceptance criteria for reuse at a Massachusetts lined landfill. HW opined that although the sediment was not suitable for reuse at a lined landfill, the material may still qualify for Massachusetts lined landfill disposal with a Special Waste Determination from MassDEP. However, they were unable to identify a Massachusetts lined landfill at the time that would accept the material. Therefore, HW identified Waste Management's Turnkey Landfill in Rochester, New Hampshire (Turnkey) as the selected disposal facility for cost estimating purposes.

HW opined that the eutrophication of the Pond is likely fueled by excessive phosphorus and recommended the removal of the dark gray organic silt with sand layer as a remedial alternative. They estimated the cost for offsite transportation and disposal of that material to be approximately $485,000. However, as discussed in Section 3 it is GEI's opinion that the estimated cost will be higher, given HW used a 0.8 tons per cubic yard (cy) conversion factor. For sediment, we recommend using a 1.3 tons per cy conversion factor.

2.3 Novotny Assessment, 2019

GEI reviewed the January 2019 Assessment of Frog Pond Water Quality and Its Restoration by Professor Vladimir Novotny (Appendix A). Professor Novotny opined that:

- the Pond likely suffers from hyper-eutrophication.
- the phosphorus in water is currently at equilibrium with the phosphorus in sediment, however.
- if no remedy is applied to the sediment, the release of phosphorus into water may continue for centuries.

Professor Novotny evaluated the pros and cons of filtration/water treatment, sediment removal, and installation of liners. Based on his evaluation, Professor Novotony recommended removal of six inches of sediment which likely contains dormant but live spores of cyanobacteria, and installation of a one-foot clay liner. He explained that a synthetic liner could be considered. It was Professor Novotony's opinion that this remedy would restore the water quality in the Pond.

3. Evaluation of Alternatives

Based on the data and information discussed in Section 2, GEI evaluated alternatives for managing sediment in the Pond. GEI's evaluation of each alternative considered estimated costs and implementation feasibility. We have evaluated the following potential alternatives:

- Option 1: Sediment Removal to Top of Peat Layer, Offsite Disposal
- Option 2: Sediment Removal to Top of Peat Layer, Onsite Reuse
- Option 3: Liner Installation
- Option 4: Application of Chemical Additives

Estimates below are based on the Pond size of approximately 100,200 square feet. According to HW, the dark gray organic silt with sand layer with the highest levels of phosphorus in the Pond amounts to approximately 8,300 cy of sediment to the top of peat. Our cost estimates are summarized in Table 1.

3.1 Option 1: Sediment Removal to Top of Peat Layer, Offsite Disposal

This alternative consists of sediment removal and offsite disposal. This option includes the following:

- Removal of sediment to the top of peat.
- Offsite disposal of the material at Turnkey.

The following was assumed for Option 1:

- The Pond would be drained completely of water prior to mechanical dredging.
- Support of excavation would likely be necessary, and costs associated with that support have not been included.
- Sediments would gravity drain prior to transport offsite, and no additional amendment to meet transportation or disposal facility requirements would be necessary.
- Water drained from the pond prior to dredging/excavation would likely require treatment prior to discharge. Costs associated with obtaining required permitting and treating/discharging water were not included in this assessment.
- The Pond would remain deeper after sediment removal; therefore, no backfilling of imported materials would be required.

The estimated cost for Option 1 is $1,300,000, subject to the assumptions and limitations described above. This cost estimate includes transportation and disposal fees for offsite removal of the sediment, and a cost for mechanical dredging.

GEI has identified the following data gaps that may have potential to impact the likelihood of success and the overall cost of this option:

- Uncertainty regarding the conversion rate of sediment from cy to tons. HW assumed a conversion factor of 0.8 tons per cy; however, this assumption may be low. We recommend a conversion factor range of 1.2 to 1.6 tons per cy. If a higher conversion factor is more accurate of the likely weight (aka tons) of material, the offsite disposal costs could potentially significantly increase. For our cost estimating purposes, we used a conversion rate of 1.3 tons per cy.
- Reviewed documents indicate that high levels of phosphorus exist in the peat layer below the organic sediment. Further evaluation is required to confirm that the peat will not continue to be a source of phosphorous to the water column post-excavation of the organic sediment.
- A risk assessment is necessary to evaluate the risk to human and environmental receptors due to the presence of other residual contaminants of concern in the peat.

3.2 Option 2: Sediment Removal to Top of Peat Layer, Onsite Reuse

This alternative consists of sediment removal from the Pond and onsite reuse at the adjacent banks. Options 2A and 2B include the following:

- Removal of sediment to the top of peat.
- Reusing the sediment at a nearby upland area.
- Covering the reused sediment with 6 inches of topsoil and hydroseed.

The following was assumed for Options 2A and 2B:

- Support of excavation may be necessary depending on final depth of excavation. Costs associated with design and construction of support of excavation have not been evaluated as part of this effort.
- Sediments would gravity drain prior to reuse onsite, and no additional amendment would be necessary.
- Sediment would have adequate capacity to be consolidated and placed at adjacent upland areas or within the current Pond footprint.

- The Pond would remain deeper after sediment removal; therefore, no backfilling of imported materials would be required.

GEI has identified the following data gaps that may have potential to impact the likelihood of success and the overall cost of this option:

- Reviewed documents indicate that high levels of phosphorus exist in the peat layer below the organic sediment. Further evaluation is required to confirm that the peat will not continue to be a source of phosphorous to the water column post-excavation of the organic sediment.
- A risk assessment is necessary to evaluate the risk to human and environmental receptors due to the presence of other residual contaminants of concern in the peat.

3.2.1 Option 2A: Reuse in Geotubes

Alternative 2A involves hydraulic dredging (draining of the Pond is unnecessary) and reuse of sediment in Geotubes. Geotubes are large geotextile bags that are commonly used to facilitate dewatering of sediment for hydraulic dredging projects. Dredged materials are pumped to Geotubes from the hydraulic dredge and, once sediment is in the Geotube, effluent water drains from the bags and the sediments are retained. The filled Geotubes can be stacked and left in place, then covered with soil. The estimated cost for Option 2A is $350,000, subject to the assumptions and limitations described above. This cost estimate includes Geotubes, topsoil, and hydroseed, a fee for hydraulic dredging, and a mobilization/demobilization fee (as it is specialized equipment).

3.2.2 Option 2B: Reuse Behind Retaining Wall

Alternative 2B involves draining the pond completely of water, mechanical dredging or excavation, and reuse of sediment behind a retaining wall. The following was assumed for Option 2B:

- A retaining wall system, such as driven sheet piles, would be used to retain the sediment. For costing purposes, we conservatively estimated 225 linear feet of driven sheet piles (three sides of a 75-foot square), 15 feet embedded, and 7 feet above the ground. Actual design and implementation may require a different configuration. Additionally, items such as aesthetic finishes (i.e., stone wall to cover the sheet pile) were not included.
- Water drained from the pond prior to dredging/excavation would likely require treatment prior to discharge. Costs associated with obtaining required permitting and treating/discharging water were not included in this assessment.

The estimated cost for Option 2B is $1,100,000, subject to the assumptions and limitations described above. This cost estimate includes the driven sheet pile wall, a fee for mechanical dredging, topsoil, and hydroseed.

3.2.3 Reuse of Sediment at Market Landing Park

During the May 20, 2021, project team call, members of the Commission indicated that a project located in Newburyport may require import of fill material during construction. The project is the expansion of the Market Landing Park, located along the Merrimack River approximately 0.4 miles northeast of the Pond. The Commission asked GEI to explore the option of using hydraulic dredging methods to transporting sediment from the Pond to the Market Landing Park project site. Sediments would be captured, dewatered, and retained for use as fill in Geotubes. GEI will further investigate the regulatory practicality and feasibility of offsite sediment reuse as part of our next phase of work.

3.3 Option 3: Liner Installation

Option 3 includes the following:

- Removal of up to 0.5 foot of sediment to accommodate placement of:
  - A high-density polyethylene (HDPE) liner.
  - Up to 6-inches of 1.5-inch stone.
- Total estimated sediment volume: 1,856 cy.
- Offsite disposal of the material at Turnkey.

This option would prevent phosphorus from leaching from the sediment to water column. The placement of the crushed stone armor material would act as protector for the HDPE. The estimated cost for Option 3 is $470,000, subject to the assumptions and limitations described above. This cost includes the HDPE liner, stone, a fee for mechanical dredging, and transportation and disposal fees for offsite disposal of the sediment.

GEI has identified the following data gaps that may have potential to impact the likelihood of success and the overall cost of this option:

- Similar to Option 1, uncertainty regarding the conversion rate of sediment from cy to tons. For our cost estimating purposes, we used a conversion rate of 1.3 tons per cy.
- The Pond would be drained completely of water prior to mechanical dredging.
- Water drained from the pond prior to dredging/excavation would likely require treatment prior to discharge. Costs associated with obtaining required permitting and treating/discharging water were not included in this assessment.

- Due to the limited nature of the excavation, support would not likely be necessary and is not included in the cost estimate.
- An evaluation of the bearing capacity of the existing sediments to support a liner.
- An evaluation of the source of water to the Pond. This information will be used to evaluate whether the liner installation will cut-off water supply to the Pond or if hydrogeologic conditions will result in an upward pressure on the liner, causing it to lift.
- Installation of a groundwater extraction well in the former feeder stream channel to provide source of water for the Pond.

3.4 Option 4: Application of Chemical Additives

3.4.1 Chemicals for Water Quality

We understand that alum has been previously used in attempt to mitigate phosphorous in the water column but was not successful. Other product such as SeCLEAR (a combination copper-based algicide with proprietary formulas for phosphate binding) or EutroSORB (a pelletized media), both produced by SePRO, may also be useful for improving water quality. Both bind soluble reactive phosphorus in the water column with SeCLEAR providing the additional benefit of an algicide. However, neither of these chemical additives address the continual mobilization of phosphorus from sediment. The Commission may want to consider the use of these chemicals as a temporary measure for water quality while a more permanent solution is being developed. Additional details regarding these chemical additives, if warranted, will be included in Aqueous' evaluation summary.

3.4.2 Option 4: Phoslock

This alternative consists of the application of Phoslock, a modified bentonite clay product containing lanthanum, also produced by SePRO. Based on information from SePRO, Phoslock is applied directly to the water column. The Phoslock binds free reactive phosphorus in the water column as it settles to the bottom of the water body. The Phoslock then continues to bind free reactive phosphorus that is released from sediments. According to SePRO, risk assessment acute and chronic toxicity testing on sensitive species demonstrated no toxicity at the dose rates use to remove the free reactive phosphorus from the water column. Species tested include Daphnia, species of Rainbow fish, freshwater shrimp, and benthic organisms such as amphipods, mayflies, and midge larva. SePRO also suggests that there is no risk to human health at the dose rates used.

We understand that SePRO is pursuing approval for use of Phoslock in Massachusetts, but MassDEP has not issued approval for its use as of the date of this letter. However, because the Pond is likely considered a manmade pond, there may be an opportunity to work with MassDEP and SePRO to use the Pond as a case study or pilot program.

Based on our estimates from historical data, the Pond has approximately 4 pounds of dissolved phosphorus in the water column and approximately 400 pounds of bioavailable phosphorus in the top two inches of sediment. SePRO recommended an application of 100,500 pounds of Phoslock to treat the bioavailable phosphorus in the water column and top two inches of sediment. However, additional investigations and bench-scale tests will be required to confirm phosphorus content and Phoslock dosage rates as detailed in Section 4.

The estimated initial material cost only for using Phoslock to treat water and shallow sediment is $390,000, subject to the assumptions and limitations described above. This cost estimate only includes the material cost for the chemical.

4. Proposed Actions

4.1 Additional Surveys and Investigations

As discussed in Section 3, additional investigations are needed to help determine which options are practical and feasible. Depending on the path, or paths, forward that the Commission would like to evaluate, these investigations may include items such as:

- Bathymetric survey to help determine cut/fill quantities for potential sediment reuse.
- Advancement of sediment cores to obtain additional data on the vertical and horizontal distribution of phosphorus and other contaminants of concern.
- Installation of borings and installation of monitoring wells in targeted areas to evaluate site hydrogeology, specifically water flow in the former feeder stream channel.
- Additional water sampling to evaluate method for managing the existing water during construction.

Additionally, if the Commission is interested in further evaluating the feasibility of chemical additives discussed in Section 3.4, we recommend performing bench-scale tests on the water and sediment. The tests will be used to quantify phosphorus in surface water and sediment and to provide recommended products and dosage rates for the selected product.

If requested by the Commission, GEI will provide a detailed summary of proposed additional surveys and investigations that will help us better understand current conditions in the Pond.

4.2 Risk Assessments

If the Committee elects to pursue Options 1, 2A, 2B, or 4 we recommend that high-level ecological and human health risk evaluations be conducted incorporating both historical data as described in Section 2 and any new data obtained as described in Section 4.1. The risk assessments will be used to evaluate potential impacts to ecological and human receptors due to the potential presence of contaminants of concern in sediment.

Although the Pond is not considered a disposal site under the jurisdiction of the MCP, we can evaluate potential risk to the environment at the Pond in general accordance with the MassDEP MCP Method 3 Ecological Risk Characterization guidance. We can also evaluate potential risk to human receptors, such as a park visitor (including someone wading in the water) and a construction worker, at the Pond by using the MassDEP Short Forms for Human Health Risk Assessment under the MCP.

5. Limitations

This report was prepared for the use of the City of Newburyport, exclusively. The findings provided by GEI in this report are based solely on the information provided in this report. Information that was not available to GEI for this report, or variations from the conditions reported by others, may result in a modification of the findings stated above. This report has been prepared in accordance with generally accepted hydrogeological and engineering practices. No other representations and no warranty, express or implied, is made.

Table

Table 1
Sediment Remediation Cost Estimates
Bartlet Mall Frog Pond
Newburyport, Massachusetts

Option	Estimated Cost
Option 1 - Sediment Removal to Top of Peat Layer, Offsite Disposal	$1,300,000
Option 2A - Sediment Removal to Top of Peat Layer, Onsite Reuse in Geotubes	$350,000
Option 2B - Sediment Removal to Top of Peat Layer, Onsite Reuse Behind Wall	$1,100,000
Option 3 - HDPE Liner	$470,000
Option 4 - Application of Phoslock	$390,000

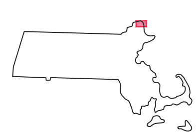
General Notes:
1. All estimates include a 30% contingency.

Figures

0 1000 2000 4000 6000

SCALE, FEET

This Image is from U.S.G.S. Topographic 7.5 Minute Series
Newburyport East, MA-NH Quadrangle, 2021 and
Newburyport West MA-NH Quadrangle, 2021
Datum is North American Vertical Datum of 1988 (NAVD88).
Contour Interval is 10 Feet.



MASSACHUSETTS
QUADRANGLE LOCATION

Preliminary Alternatives Analysis Bartlet Mall Frog Pond Newburyport, Massachusetts	GEI Consultants	SITE LOCATION MAP
City of Newburyport Newburyport, Massachusetts	Project 2101333	June 2021 Fig. 1

B:\Working\NEWBURYPORT MA, CITY OF\2101333 Bartlett Mall Frog Pond\00_CAD\Figures\PAA\2101333-01

Preliminary Alternatives Analysis Bartlet Mall Frog Pond Newburyport, Massachusetts	GEI Consultants	SITE PLAN
City of Newburyport Newburyport, Massachusetts	Project 2101333	June 2021 — Fig. 2

CLINGEN, PAUL B:\Working\NEWBURYPORT MA, CITY OF\2101333 Bartlett Mall Frog Pond\00_CAD\Figures\PAA\2101333-02.dwg - 5/28/2021

Appendix A

Background Information

TABLE 1 - Shallow Sediment Quality
Frog Pond, Bartlet Mall, Newburyport, Massachusetts
Samples collected by Higgins Environmental Associates, Inc., Amesbury, MA

SAMPLE LOCATION	**Whole**	**MCP S-1/S-2**	**MCP Method 1 Standards**		
DEPTH	**0-0.5ft**	**REPORTABLE**	**S-1**	**S-2**	**S-3**
Date Collected	**4/4/2013**	**CONCENTRATIONS**			
VOLATILE ORGANIC COMPOUNDS (only compounds detected at one or more locations shown)					
Toluene	ND(0.34)	30/1000	500	1,000	2,000
Ethylbenzene	ND(0.34)	40/1000	500	1000	1000
m&p Xylene	ND(0.34)	300/300	300	300	300
o-Xylene	ND(0.34)	300/300	300	300	300
1,3,5-Trimethylbenzene	ND(0.34)	NS	NS	NS	NS
Naphthalene	ND(0.34)	4/40	40	40	40
TOTAL PETROLEUM HYDROCARBONS					
TPHs	**1410**	**1000/3000**	**1000**	3000	5000
SEMIVOLATILE ORGANIC COMPOUNDS (only compounds detected at one or more locations shown)					
Naphthalene	ND(0.1)	4/40	40	40	40
2-Methylnaphthalene	ND(0.1)	0.7/80	80	80	80
Acenaphthylene	ND(0.1)	1/10	10	10	10
Acenaphthene	ND(0.1)	4/3000	1000	3000	5000
Dibenzofuran	ND(0.1)	NS	NS	NS	NS
Fluorene	ND(0.1)	1000/3000	1000	3000	5000
Phenanthrene	1.70	1000/3000	500	1000	3000
Anthracene	ND(0.1)	1000/3000	1,000	3,000	5,000
Di-n-butylphthalate	ND(0.1)	NS	NS	NS	NS
Fluoranthene	1.80	1000/3000	1000	3000	5000
Pyrene	1.80	1000/3000	1000	3000	5000
Benzo(a)anthracene	1.50	7/40	7	40	300
Chrysene	2.20	70/400	70	400	3000
Bis(2-Ethylhexyl)phthalate	ND(0.1)	200/700	200	700	3000
Benzo(b)fluoranthene	3.10	7/40	7	40	300
Benzo(k)fluoranthene	1.00	70/400	70	400	3000
Benzo(a)pyrene	2.00	2/4	2	4	30
Dibenzo(a,h)anthracene	ND(0.1)	0.7/4	0.7	4	30
Indeno(1,2,3-cd)pyrene	2.00	7/40	7	40	300
Benzo(g,h,i)perylene	1.70	1000/3000	1000	3000	5000
POLYCHLORINATED BIPHENYLS					
PCBs Total	ND(0.237)	2/3	2	3	3
Arochlor-1254	ND(0.237)				
PRIORITY POLLUTANT 13-LIST METALS					
Antimony	ND(2.68)	20/30	20	30	30
Arsenic	**72.6**	**20/20**	**20**	**20**	**20**
Barium	94	1000/3000	1,000	3,000	5,000
Beryllium	1.96	100/200	100	200	200
Cadmium	ND(1.34)	2/30	2	30	30
Chromium	**31.5**	**30/200**	**30**	200	200
Copper	179	NS	NS	NS	NS
Lead	279	300/300	300	300	300
Mercury	0.391	20/30	20	30	30
Nickel	**30.8**	**20/700**	**20**	700	700
Selenium	ND(2.68)	400/800	400	800	800
Silver	ND(1.34)	100/200	100	200	200
Thallium	ND(0.5)	8/60	8	60	80
Vanadium	68.3	600/1000	600	1,000	1000
Zinc	198	2,500/3,000	2,500	3,000	5,000

Notes for Table 1:

Listing of Reportable Concentrations and Standards are for soil and do not apply to these sediment results. However, it does help to refer to soil criteria when considering direct contact or reuse/disposal options for sediment.

1. Results reported in milligrams per kilogram (parts per million) dry weight.
2. All laboratory analysis completed using EPA-specified methods.
3. Method 1 soil risk characterization criteria reported represent most stringent soil criteria in GW2 and GW3 areas. Results in bold are greater than one or more soil criteria.
4. ND(#) = Not detected at laboratory detection limit noted.
5. NT = Not Tested; NS = No Standard; NA = Not Applicable or Available.
6. TPH impacts were interpreted as being generally consistent with a No. 6 fuel oil.

TABLE 2 - Shallow Sediment Quality
Frog Pond, Bartlet Mall, Newburyport, Massachusetts
Samples collected by Higgins Environmental Associates, Inc., Amesbury, MA

SAMPLE LOCATION	A010	A075	A150	A225	A300	B010	B075	B150	B225	B300	C010	C075	C150	C225	C270
Depth (feet) in Soft Sediment	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5
Date Collected	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013
Total Phosphorus (mg/kg)															
T.Phosphorus	148	1380	1890	1930	1150	162	1010	1710	2000	130	279	1300	1770	1330	185

SAMPLE LOCATION	D010	D075	D150	D225	E010	E075	E150	F075	AA080	DEEP	DEEPD	FPW
Depth (feet) in Soft Sediment	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	0-0.5	3	3	water
Date Collected	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013	4/4/2013
Total Phosphorus (mg/kg)												mg/l
T.Phosphorus	231	1880	1380	114	156	1270	206	342	280	1610	1520	0.17

Notes for Table 2:

1. Results reported in milligrams per kilogram (parts per million) or mg/l for the "FPW" water sample. "FPW" was collected just below the water surface at Station "F075"
2. All laboratory analysis completed using EPA-specified methods.
3. Sample "DEEP" is a soft sediment sample collected three feet below the sediment surface approximate to the center of the Frog Pond near Station "A150". Sample "DEEPD" is a duplicate sample of sample "DEEP".

FIGURE 3 - Frog Pond, Bartlet Mall, Newburyport, MA
Total Phosphorus in Sediment (top 6 inches) April 2013

200 100 0 200 Feet

1 inch equals 100 feet

Legend

Sediment Samples with designations

Total Phosphorus Concentration (dry wgt.)

600 mg/kg

1100 mg/kg

1600 mg/kg

Higgins Environmental Associates, Inc.
Environmental Science and Hydrogeology

Data Source: EOEA/MassGIS Datalayers, Updated through January 2013

FIGURE 4 - Frog Pond, Bartlet Mall, Newburyport, MA
Thickness of Soft Sediment (feet)

200 100 0 200 Feet

1 inch equals 100 feet

Legend

Sediment Samples with designations

Soft Sediment Thickness (feet)

- 1 foot
- 2 feet
- 3 feet
- 4 feet
- 5 feet

Higgins Environmental Associates, Inc.
Environmental Science and Hydrogeology

Data Source: EOEA/MassGIS Datalayers, Updated through January 2013

Horsley Witten Group
Sustainable Environmental Solutions
30 Green Street • Newburyport, MA • 01950
Phone - 978-499-0601 • Fax - 978-499-0602 • www.horsleywitten.com

SEDIMENT EVALUATION SUMMARY

Bartlet Mall Frog Pond

Submitted to:
Newburyport Parks Commission
60 Pleasant Street
Newburyport, MA 01950

Submitted by:
Horsley Witten Group, Inc.

October, 2014

TABLE OF CONTENTS

SEDIMENT EVALUATION SUMMARY
BARTLET MALL FROG POND RESTORATION PROJECT
NEWBURYPORT, MASSACHUSETTS

1.0 INTRODUCTION

Horsley Witten Group, Inc. (HW) has been contracted by the City of Newburyport, Massachusetts (the City), to conduct a screening-level sediment sampling program to characterize sediment from within the Bartlet Mall Frog Pond project area. The Bartlet Mall and Frog Pond together form a central green space in the urban core of historic downtown Newburyport. The pond, which is approximately 2.3 acres in size, currently exhibits excessive algal growth (eutrophication) leading to low water clarity and low dissolved oxygen, and generally poor aesthetic quality. Anecdotal accounts indicate that eutrophication has likely been ongoing for a significant time, but has perhaps accelerated in the past several decades.

To improve the water quality of Frog Pond and the aesthetic appeal of the area, the City has undertaken an assessment of restoration options that includes evaluating the removal (dredging) of sediment from the bottom of Frog Pond for off-site disposal. On August 28, 2014, HW conducted sediment depth profiling and pond bottom sediment core sampling to provide baseline sediment quality data and develop an estimate of sediment volume. The data collected during the investigation, and described in further detail herein, provide an initial assessment of suitable sediment disposal alternatives and costs.

2.0 SEDIMENT DEPTH PROFILING AND CORE SAMPLING

2.1 Sediment Depth Profiling

To measure sediment thickness in the pond, HW probed the sediment at the bottom of the pond at 20 locations across four transects. Three transects were completed across the width of the pond, and one transect was completed across the length of the pond (Figure 1). At each of the 20 measurement locations, a 15-foot long 3/8-inch diameter fiberglass rod was lowered into the pond water until reaching the top of sediment, and an initial measurement of depth below water surface (BWS) was recorded. The rod was then advanced into the soft, shallow sediment until a transition in sediment composition was detected, based on the level of force necessary to push the rod deeper. This transition indicated the bottom of soft, shallow sediment, and the depth BWS was recorded. The rod was then further advanced until refusal, and that depth BWS was recorded. Refusal was encountered between 10 to 14 feet BWS at the profile locations. This depth is more likely reflective of limitations to the sediment profiling methodology, and not indicative of a transition to a more consolidated sediment layer (i.e., native, mineral substrates). It is likely that several more feet of peat material exists beyond the sediment probe refusal depth.

Based on these sediment probe measurements, HW generated cross section profiles of sediment depth for each transect in AutoCAD (Figure 2). Results of the sediment depth profiling indicate approximately 3.5 feet of soft sediment exists above a more consolidated lower layer of material of undetermined thickness. Sediment stratigraphy is described in greater detail in Section 2.3.

2.2 Sediment Core Sampling

HW collected a total of five sediment cores from the pond bottom on August 28, 2014. Sampling locations were distributed across the area of the pond (Figure 1). Sediment cores were completed using ten-foot lengths of two inch inner-diameter PVC tubing. At each sediment core sampling location, the PVC tube was advanced into the pond bottom sediment with a safety hammer until effective refusal was encountered. At each of the sampling locations, the PVC tube could only be advanced approximately four feet into the pond sediment before refusal. The depth to which the core could be advanced is referred to as the penetration. A plug seal was then installed at the top of the PVC tube and the tube was retracted, with the sediment core contained within. The sediment cores were then brought ashore to a work station, where excess water from the sediment core tubes was drained. The PVC tubes were then cut open with a circular saw to allow for inspection. The amount of sediment retained in the core after removal from the pond is referred to as the recovery.

A consistent stratigraphy was observed across all of the core samples, generally described as a layer of dark brown peat beneath several feet of dark gray organic silt with sand. Peat is a consolidated mix of organic and mineral materials containing visible root materials and wood debris, and is the preserved remains of wetland vegetation that has accumulated over long periods of time. Additional details on each of the sediment sampling locations are summarized in Table 1, below:

Table 1. August 28, 2014 Sediment Sampling

Sample ID:	Sample Core Location:	Core Penetration / Recovery:	Description
1 (0’ – 2’)	Eastern Pond	48” / 24”	22” of dark gray organic silt, 2” of dark brown peat at bottom of sample
2 (0’ – 2’)	North Central Pond	54” / 32”	29” of dark gray organic silt, 3” of dark brown peat at bottom of sample
3 (0’ – 2’)	Western Pond	42” / 28”	26” of dark gray organic silt, 2” of dark brown peat at bottom of sample
4 (0’ – 2’)	South Central Pond	57” / 28”	24” of dark gray organic silt, 4” of dark brown peat at bottom of sample
5 (0’ – 2’)	At Pond Fountain (Center)	66” / 24”	17” of dark gray organic silt, 7” of dark brown peat at bottom of sample

2.3 Sediment Stratigraphy

By comparing the results of the sediment profiling with the observed stratigraphy from the five sediment core locations, a well-informed characterization of the pond bottom can be created. Approximately 3.5 feet of soft, organic, and loosely consolidate muck overlays a layer of peat. The thickness of the peat layer could not be confirmed by visual inspection of the sediment core samples, as the PVC tubes could not penetrate more than 7" inches into the peat layer. Based on the sediment depth profiling field measurements, more than four feet of peat may underlie the soft organic sediment. The observed thickness of both peat and muck are generally consistent across the pond, with less of both peat and muck measured in locations closer to the pond shoreline, and slightly more measured toward the center of the pond (Figure 2), consistent with the bowl-shaped geometry of the underlying kettle-hole depression.

Photo 1. Sediment core sample 2 after cutting the PVC tube open, note transition from gray organic silt to dark brown peat.

There are at least two plausible explanations of the observed stratigraphy. One is that the peat layer represents the remains of wetlands vegetation accumulated over thousands of years at the bottom of a kettle-hole depression formed after the last glacial ice retreated north of the Newburyport area, some 15,000 years ago. Sea level, and correspondingly the groundwater table, was lower during the post-glacial period than during current conditions and, therefore, the Frog Pond kettle hole likely existed as a shallow wetland with abundant vegetative growth. The kettle-hole wetland was eventually submerged by rising groundwater levels and preserved as a peat deposit at the bottom of Frog Pond. The overlying, loosely-compacted muck has accumulated since that time from atmospheric deposition, watershed runoff, stormwater inputs, and in-water vegetative growth and decay.

The same stratigraphic sequence could also have formed in a fashion similar that described above if the kettle hole wetland depression had been naturally drained by a stream that was dammed and filled in colonial times. Damming of the stream outlet would have allowed water levels to rise and flood the wetland vegetation at the bottom of the depression. Sedimentation would have occurred above the peat, as described above, but over a shorter and more recent time period. No dating of pond bottom sediments was conducted as part of this project, but anecdotal descriptions of past land use practices suggest that a large portion of the accumulated muck has been deposited in the last several hundred years under the influence of anthropogenic alterations to the pond and its watershed.

3.0 SEDIMENT QUALITY CHARACTERIZATION

3.1 Sediment Core Sample Collection and Analysis

To assess sediment quality characteristics from each of the sediment cores, samples were collected from the recovered material for laboratory analysis. From each core, the complete vertical thickness of sediment above the peat layer was composited by hand-mixing in a stainless steel bowl to create five, location-specific samples. Peat from each of the five sediment cores was then combined into one composite peat sample, which is representative of the peat layer, and mixed in the same manner. The samples were then placed into sample containers and submitted to ESS Laboratory in Cranston, Rhode Island.

Samples were submitted for analysis of key contaminants of concern to help assess the suitability of the sediments for upland disposal / reuse. Samples were analyzed for all parameters required by the Massachusetts Water Quality Certification (WQC) Regulations (310 CMR 9.07(9)) for sediment material management. Per 310 CMR 9.07(9), upland material reuse under a 401 WQC is permitted, provided the concentrations of oil and hazardous material in the dredged material are less than the Reportable Concentrations (RCS-1) soil standards established in the Massachusetts Contingency Plan (MCP 310.CMR 40.0000). Samples were also analyzed for all parameters required by the Massachusetts Department of Environmental Protection (DEP) "*Reuse and Disposal of Contaminated Soil at Massachusetts Landfills – Policy #COMM-97-001"* (COMM-97-001) and *"Interim Policy for Sampling, Analysis, Handling and Tracking Requirements for Dredged Sediment Reused or Disposed at Massachusetts Permitted Landfills - Interim Policy COMM-94-007"* (COMM-94-007). COMM-97-001 and 94-007 establish contaminant thresholds, sampling and analysis requirements, transportation requirements, and management procedures for the reuse or disposal of soil and sediment at Massachusetts landfills.

3.2 Laboratory Analysis Results

Laboratory analysis of the composite and discrete sediment samples indicates the presence of several contaminants at concentrations above the respective MCP RCS-1 or COMM-97-001 / 94-007 standards (highlighted and in bold on Table 2). The contaminants detected above RCS-1 standards are arsenic, chromium, and lead, all of which are heavy metals that are persistent in the environment (i.e., not subject to natural degradation). Several polycyclic aromatic hydrocarbons (PAHs) were also detected above laboratory detection limits, but were below the applicable RCS1 and COMM-97-001 / 94-007 total PAH standard. Table 2 presents a summary of some key contaminants of concern from the 2014 HW sampling program. A complete summary table of all laboratory analytical data is attached (Table 3).

Table 2. Summary of 2014 Sampling Results

Standards (mg/kg)			Sediment Samples – August 28, 2014					
	RCS1	**Lined Landfill Reuse**	**1 (0' – 2')**	**2 (0' – 2')**	**3 (0' – 2')**	**4 (0' – 2')**	**5 (0' – 2')**	**Peat Composite**
Total VOCs	NA	10	0.45	0.51	0.32	0.42	0.47	1.17
Total SVOCs	NA	100	19.92	19.68	16.05	19.16	37.72	33.63
Total PCBs	NA	<2	0.0097	0.0096	0.0089	0.0102	0.0164	0.0221
Total Organic Carbon	NA	NA	63,300	63,800	66,500	52,400	73,400	194,000
Total Phosphate	NA	NA	NC	NC	NC	NC	1,403	704
TPH	1,000	5,000	172	264	130	208	270	550
Total PAH's	NA	100	10.75	3.23	1.85	2.63	2.00	0.35
Conductivity	NA	8,000 umhos/cm	58	46	30	40	59	51
Arsenic	20	40	**52.8**	**49.4**	**47.2**	**47.3**	**58.3**	**25.2**
Cadmium	2	80	0.50	0.39	0.49	0.36	0.32	0.145
Chromium	30	1,000	**64.5**	**60.5**	**49.8**	**59.5**	**71.2**	**31.5**
Lead	300	2,000	**348**	292	**326**	296	294	34.5
Mercury	20	10	0.27	0.20	0.21	0.16	0.15	0.08

Notes:

Lined landfill reuse standards from COMM-97-001 and COMM-94-007."

RCS1 – Massachusetts Contingency Plan reportable concentrations for soil.

Bold text denotes result exceeds MCP RCS1.

Highlighted text denotes result exceeds COMM-97-001 / 94-007 standard for reuse at lined landfills.

NA – Not applicable, no standard established.

NC – Not collected.

TPH – Total petroleum hydrocarbons

PAH – Polycyclic aromatic hydrocarbons

PCB – polychlorinated biphenyls

4.0 SEDIMENT DISPOSAL OPTIONS

The City is prohibited from reusing any pond sediment with contaminants above the RCS1 standard at an upland location (i.e., as fill material). This leaves three remaining disposal options: reuse as daily cover at Massachusetts landfills, export to out-of-state landfills, and export to licensed hazardous waste disposal facilities.

Laboratory analysis indicates the presence of arsenic in the pond sediment at concentrations above the COMM-97-001 / 94-007 standards for reuse at Massachusetts landfills. However, this does not mean that reuse at a Massachusetts landfill is necessarily ruled out. The sediment may still qualify for reuse or disposal (i.e. burial) at a landfill facility, but would require a Special Waste Determination or other approval from MassDEP. There are currently three operating Massachusetts landfills within 50 miles of the Site (Saugus, Peabody, and Haverhill) that are permitted to accept contaminated sediment for reuse or disposal. HW contacted all three facilities and determined that none were able to accept the estimated volume of sediment that would be generated during dredging of the pond, due to operational considerations and/or need for material.

HW also contacted Waste Management's Turnkey Landfill in Rochester, New Hampshire (also within 50 miles of the Site). A preliminary discussion with Turnkey management indicates the material would be accepted for reuse and the facility has adequate capacity. A baseline cost estimate for transportation and disposal of sediment at Turnkey can be found in Table 3. Additional Massachusetts landfill facilities can be contacted during a feasibility evaluation to determine if alternatives to the Turnkey facility exist.

5.0 BASELINE SEDIMENT DISPOSAL COST ESTIMATION

Frog Pond is approximately 2.3 acres (101,000 square feet) in size. Based on field observations during the collection of sediment samples, approximately 3.5 feet of dark gray organic silt exists above a well defined peat layer. Because the peat layer can be considered the "native" or pre-anthropocene pond bottom, this layer was used as the conceptual bottom limit of dredging for developing sediment volume estimates and costs. HW calculated the volume of sediment above the peat layer using the Average End Area Method, a standard method for estimating earthwork calculations. A contingency of 20% was included in the Average End Area Method calculations to account for variations in sediment thickness across the pond during removal and dredging technique, which would increase or decrease the total volume removed. HW's calculations indicate there is approximately 8,300 cubic yards (c.y.) of soft organic sediment in the pond, and used this volume to estimate associated removal and disposal costs.

Dredged sediment would need to be dewatered at the site before it can be transported to a receiving facility for disposal. Dewatering techniques vary between projects, but typically involve the temporary stockpiling of sediment within a bermed containment area to allow water to drain from the material. Once dewatered, the material can be more efficiently managed, and the overall weight of the sediment will be reduced, decreasing transportation and disposal costs, which are priced per ton. To support the preliminary cost estimates for transportation and disposal costs in Table 4, the weight of dewatered sediment was estimated at 0.80 tons per c.y.

Photo 2. Sediment immediately after dredging.

Photo 3. Sediment after several weeks of dewatering.

Table 3. Baseline Sediment Transportation and Disposal Estimates

Estimated Volume of Sediment: 8,300 cubic yards Estimated Weight of Sediment: 6,640 tons		
Estimated Cost:	**Unit Cost:**	**Extended Cost:**
Landfill Disposal	**$55 / ton**	**$365,200**
Transportation Cost	**$18 / ton**	**$119,520**
Total Transportation and Disposal Cost Estimate:		**$484,720**

Notes:
1. Transportation and landfill disposal cost estimate provided by Turnkey Landfill, Rochester, NH.
2. Dredging, project design, permitting, and additional sediment characterization costs not included.

The sediment quality analysis conducted in support of this evaluation provides baseline sediment quality data that are sufficient for preliminary project planning only. Disposal of sediment at a Massachusetts permitted landfill or at the Turnkey facility in Rochester, NH will require additional sediment sampling to meet state permitting requirements of landfill-specific acceptance criteria. The number of samples that will be required will be based on the final volume of sediment planned for removal from the pond. Project design and permitting at the local and state level will also add additional cost, as would any post-construction restoration or improvements to the pond and surrounding park area. Non-monetary cost considerations include aesthetic impacts, temporary loss of recreation space during dredging and dewatering operations.

6.0 SEDIMENT INFLUENCE ON WATER QUALITY

Eutrophication of Frog Pond is likely fueled by an excessive supply of phosphorous, and because a significant portion of the current annual phosphorous load to the pond water column may consist of the regeneration of “legacy” phosphorous from the pond bottom sediments, the composite peat sample and the upper muck sample from core 5 at the center of the pond were submitted for laboratory analysis of total phosphate. That analysis revealed moderately high concentrations of total phosphate (as Phosphorus) in the upper organic muck of approximately 1,400 mg/kg, and about half as much in the underlying peat. The observed concentration of total phosphate from the upper muck samples is consistent with what had been previously observed by Higgins Environmental, Inc. (approximately 1,100 – 1,600 mg/kg) from numerous samples collected from the top six inches of the pond in 2013. Those concentrations are also consistent with data obtained for sediment beneath other ponds (e.g. Lovell’s Pond in Barnstable, MA) for which data were obtained.

The fact that the total phosphate concentration observed for the lower peat level is approximately half of that observed for the upper muck layer is significant because it suggests that a limited dredging of only the muck layer, down to the peat, might be an effective measure to remove the bulk of the legacy phosphorous from the pond bottom sediment. Some recent research suggests that the observed soil profile of decreasing phosphate concentration with depth is characteristic of eutrophic ponds where, below a stabilization depth, organic phosphorous has already been degraded and released to the overlying water column due to the limited capacity of the sediment to retain mineralized phosphorous upon burial (Carey and Rydin, 2011). This thesis is encouraging as it suggests that the relatively low concentrations of phosphorus observed in the deeper peat sediments are unlikely to represent a significant source of available phosphorous that could be remobilized into the water column. Even still, prior to dredging, more detailed water column and sediment profile sampling is recommended to further evaluate the potential for the remobilization of deeply buried phosphorus after dredging.

If necessary, alum treatment could be considered following dredging to further isolate remaining phosphorous in the peat layer from re-suspension in the water column. Alum is effective for permanently binding phosphorous, but phosphorus loading from the watershed needs to be controlled beforehand to avoid simply rebuilding a new pool of available phosphorous following treatment.

7.0 CONCLUSIONS AND NEXT STEPS

This report has confirmed that sediment from the base of Frog Pond contains elevated levels of certain contaminants and would have to be disposed of at a landfill rather than being reused as unregulated upland fill on site, or at some other location. We also confirmed the depth of the mucky sediment to be evenly distributed at approximately 3.5 feet throughout the pond, and confirmed that the sediment overlays a significant peat layer. Dredging is recommended as the primary water quality improvement measure because it offers multiple and long-lasting benefits, including:

- Creation of a deeper water column that would better support long-term water quality and aesthetic/recreational appeal; and

- Physical removal of the impacted sediments so they are no longer available to degrade water quality in the future.

However, dredging is not a static solution, and must be considered along with a host of other management options, including the following:

- **Control of Geese and Ducks**. The City has placed signs around the pond to notify visitors that it is unlawful to feed the ducks and geese. This appears to be successful based on the lack of geese visiting the pond and the small population of ducks that inhabit the area. This effort should be actively continued.

- **Removal of Stormwater Discharges**. There has been ongoing uncertainty among City officials and interested parties about the possible existence of a stormwater discharge from the surrounding streets directly into Frog Pond. The City Engineer has confirmed that his staff will be performing an investigation of the surrounding stormwater infrastructure to determine if such a connection exists. This investigation is anticipated in October 2014 but, at the time of this memorandum, HW has not received any results. In the event that a stormwater outfall is identified in the pond, it should be removed as soon as possible. Given the small size of the pond and the inability of stormwater treatment practices to eliminate nutrients from the runoff, we recommend that the discharge be removed altogether rather than implementing a stormwater BMP to treat the stormwater discharging to the pond.

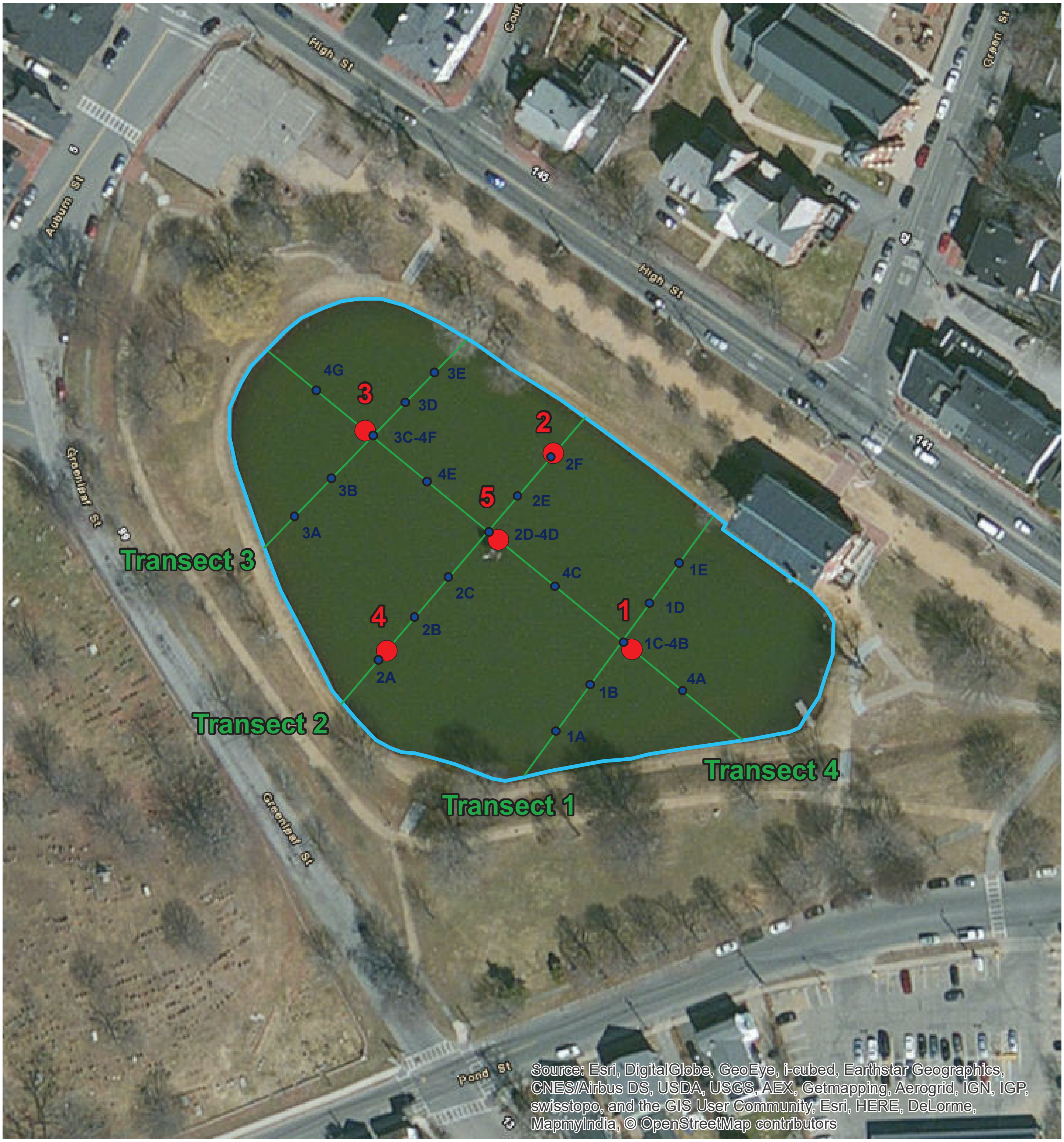
- **Vegetated Buffer**. Sedimentation in ponds is generally due to a combination of sources, including internal growth and cycling of biomass in the pond, which is fed by nutrient loading, as well as erosion from the surrounding watershed. The watershed for Frog Pond is very small and easily identified as the Bartlet Mall Park itself. The Bartlet Mall Park is vegetated primarily with grass, including along edge of the pond and along the very steep slopes, which are prone to erosion over time. This grass is maintained as an important feature of the historic landscape of the park. However, we suggest that the City consider amending the landscape plan to provide an additional vegetated buffer along the edge of all or a significant portion of the pond. In addition, the park maintenance plan should be reviewed to ensure that fertilizers are not used and that grass clippings are collected and disposed of offsite rather than left on the grass.

- **Alum Treatment**. As an additional measure after dredging, the City may also consider treating the pond with buffered alum, which scavenges phosphorus from the water column and precipitates it to the bottom of the pond. It then creates a sort of protective blanket at the bottom of the pond that inhibits the ability of phosphorus in the sediment to reenter the water column as available phosphorus in the water column. This can help to limit algal growth and can increase the clarity of the water.

HW has prepared a Scope of Work to assist the City in developing a management approach for Frog Pond. To date, only a portion of this scope of work has been funded. The remaining tasks include the development of a sediment management plan, an analysis of management alternatives (which would include those options listed above), and a workshop for the City and the interested public to discuss restoration options from a more holistic perspective that includes the recreational and historic landscape aspects of the project in addition to the ecological, engineering and cost details. We are hopeful that the City will pursue funding for these remaining tasks which together will result in working Restoration Plan for Frog Pond.

REFERENCES

Carey and Rydin, 2011. Lake trophic status can be determined by the depth distribution of sediment phosphorus. Limnology and Oceanography, 56(6).



Document Path: H:\Projects\2014\14112 N-Port-Bartlet Mall Frog Pond\GIS\Maps\SedimentDepth_Locs.mxd

Legend

- Sediment Sampling Locations - August 28, 2014
- Sediment Depth Probe Locations - August 28, 2014
- Transect Locations - August 28, 2014

N

0 100

1" = 100 feet

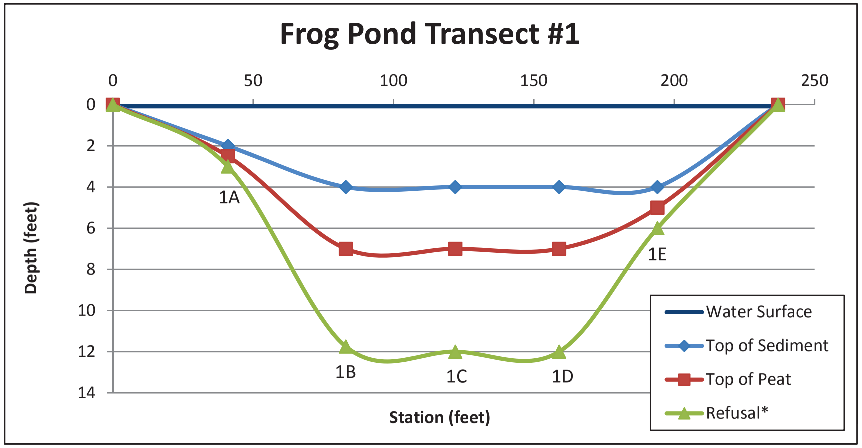
Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Sandwich, MA • 02563
Tel: 508-833-6600 • Fax: 508-833-3150 • www.horsleywitten.com

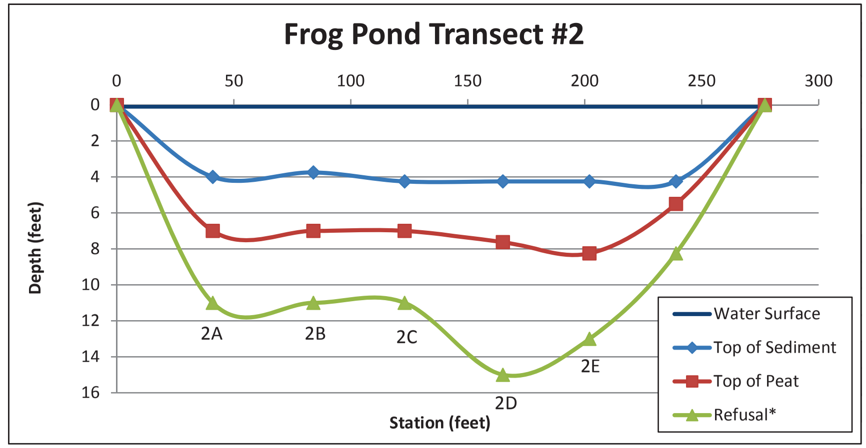
Sediment Sampling &
Depth Transect Locations
Frog Pond
Newburyport, MA

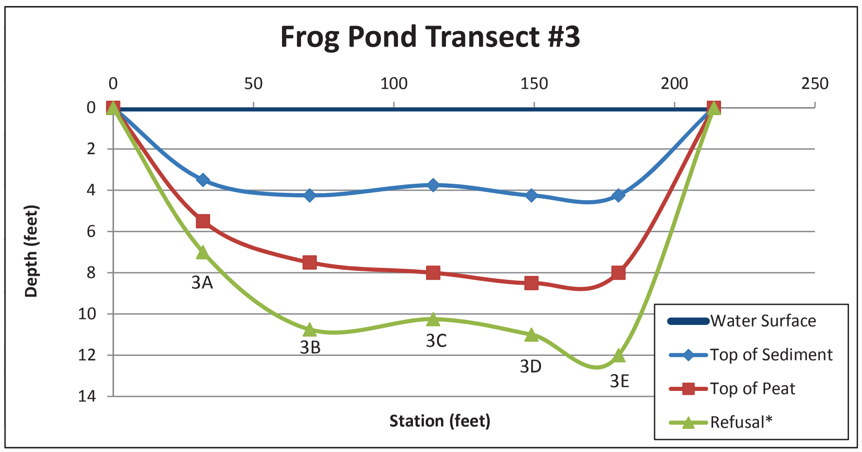
Date: 10/2/2014

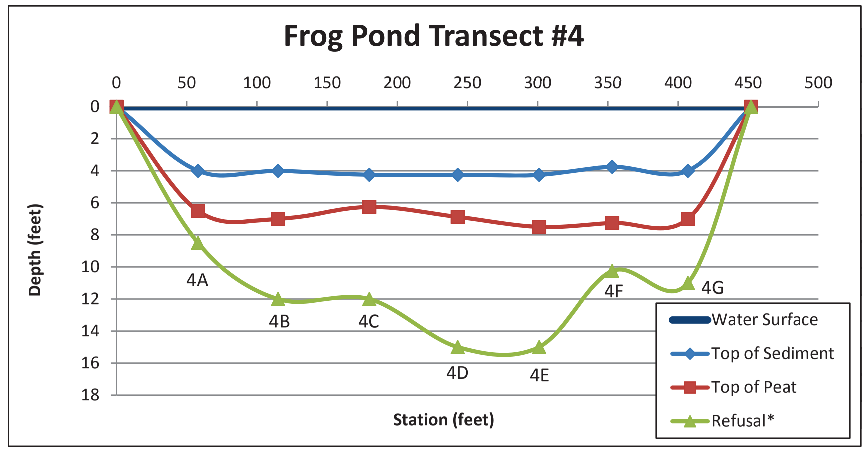
Figure 1

FIGURE 2 - FROG POND TRANSECTS









*Note: Refusal is based on maximum rod depth achieved through hand advancement. Peat bottom likely several feet lower than shown.

Table 3. Bartlet Mall - Frog Pond
Sediment Sampling Results For Comparison With MA-2014-RCS1 and Landfill Reuse Criteria

Sample Location		Lined Landfill		1 0'-2' Comp		2 0'-2' Comp		3 0'-2' Comp		4 0'-2' Comp		5 0'-2' Comp		Peat	
Sample Date	2014-RCS1	Reuse Criteria	Units	08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014	
5035/8260B Volatile Organic Compounds / Low Level															
1,1,1,2-Tetrachloroethane	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,1,1-Trichloroethane	30		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,1,2,2-Tetrachloroethane	0.005		mg/kg dry	0.0032	U	0.0035	U	0.0023	U	0.0028	U	0.0033	U	0.0054	U
1,1,2-Trichloroethane	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,1-Dichloroethane	0.4		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,1-Dichloroethene	3		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,1-Dichloropropene	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2,3-Trichlorobenzene	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2,3-Trichloropropane	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2,4-Trichlorobenzene	2		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2,4-Trimethylbenzene	1000		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2-Dibromo-3-Chloropropane	10		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2-Dibromoethane	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2-Dichlorobenzene	9		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2-Dichloroethane	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,2-Dichloropropane	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,3,5-Trimethylbenzene	10		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,3-Dichlorobenzene	3		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,3-Dichloropropane	500		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,4-Dichlorobenzene	0.7		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
1,4-Dioxane	0.2		mg/kg dry	0.162	U	0.175	U	0.117	U	0.141	U	0.163	U	0.269	U
2,2-Dichloropropane	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
2-Butanone	4		mg/kg dry	0.0162	U	0.018		0.0117	U	0.021		0.0189		0.138	
2-Chlorotoluene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
2-Hexanone	100		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
4-Chlorotoluene	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
4-Isopropyltoluene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
4-Methyl-2-Pentanone	0.4		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Acetone	6		mg/kg dry	0.103	B	0.131	B	0.059	B	0.126	B	0.115	B	0.758	B
Benzene	2		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Bromobenzene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Bromochloromethane	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Bromodichloromethane	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Bromoform	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Bromomethane	0.5		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Carbon Disulfide	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Carbon Tetrachloride	5		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U

Table 3. Bartlet Mall - Frog Pond
Sediment Sampling Results For Comparison With MA-2014-RCS1 and Landfill Reuse Criteria

Sample Location		Lined Landfill		1 0'-2' Comp		2 0'-2' Comp		3 0'-2' Comp		4 0'-2' Comp		5 0'-2' Comp		Peat	
Sample Date	2014-RCS1	Reuse Criteria	Units	08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014	
Chlorobenzene	1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Chloroethane	100		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Chloroform	0.2		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Chloromethane	100		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
cis-1,2-Dichloroethene	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
cis-1,3-Dichloropropene	0.01		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	<u>0.0135</u>	U
Dibromochloromethane	0.005		mg/kg dry	0.0032	U	0.0035	U	0.0023	U	0.0028	U	0.0033	U	<u>0.0054</u>	U
Dibromomethane	500		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Dichlorodifluoromethane	1000		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Diethyl Ether	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Di-isopropyl ether	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Ethyl tertiary-butyl ether	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Ethylbenzene	40		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Hexachlorobutadiene	30		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Isopropylbenzene	1000		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Methyl tert-Butyl Ether	0.1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Methylene Chloride	0.1		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Naphthalene	4		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
n-Butylbenzene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
n-Propylbenzene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
sec-Butylbenzene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Styrene	3		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
tert-Butylbenzene	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Tertiary-amyl methyl ether	NA		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Tetrachloroethene	1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Tetrahydrofuran	500		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Toluene	30		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
trans-1,2-Dichloroethene	1		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
trans-1,3-Dichloropropene	0.01		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	<u>0.0135</u>	U
Trichloroethene	0.3		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Trichlorofluoromethane	1000		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Vinyl Chloride	0.7		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Xylene O	100		mg/kg dry	0.0081	U	0.0088	U	0.0059	U	0.007	U	0.0082	U	0.0135	U
Xylene P,M	100		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
Xylenes (Total)	100		mg/kg dry	0.0162	U	0.0175	U	0.0117	U	0.0141	U	0.0163	U	0.0269	U
TOTAL VOCs		10	mg/kg dry	0.45565		0.5128		0.3228		0.4273		0.4764		1.17615	

Table 3. Bartlet Mall - Frog Pond
Sediment Sampling Results For Comparison With MA-2014-RCS1 and Landfill Reuse Criteria

Sample Location Sample Date	2014-RCS1	Lined Landfill Reuse Criteria	Units	1 0'-2' Comp 08/28/2014		2 0'-2' Comp 08/28/2014		3 0'-2' Comp 08/28/2014		4 0'-2' Comp 08/28/2014		5 0'-2' Comp 08/28/2014		Peat 08/28/2014	
8082 Polychlorinated Biphenyls (PCB) / Congeners															
BZ#101	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00091	U	0.00122	U
BZ#105	NA		mg/kg dry	-	-	-	-	-	-	-	-	-	-	0.00122	U
BZ#105 [2C]	NA		mg/kg dry	0.0013		0.00153		0.00141		0.00201	P	0.00245	P	-	-
BZ#118	NA		mg/kg dry	0.0019		0.00222		0.00197		0.00275		0.00392		0.00122	U
BZ#128	NA		mg/kg dry	-	-	-	-	0.00055	LC, P	-	-	0.00122		0.00122	U
BZ#128 [2C]	NA		mg/kg dry	0.0007		0.00085		-	-	0.00101		-	-	-	-
BZ#138	NA		mg/kg dry	0.00226	LC, P	0.00258	LC, P	0.00229	LC, P	0.00327	LC, P	0.00443	LC, P	0.00122	U
BZ#153	NA		mg/kg dry	0.00203		0.00246		0.00216		0.00293		0.00418		0.00122	U
BZ#170	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00065	LC, P	0.00091	U	0.00122	U
BZ#18	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00091	U	0.00122	U
BZ#180	NA		mg/kg dry	0.00074		-	-	-	-	-	-	0.00129		0.00122	U
BZ#180 [2C]	NA		mg/kg dry	-	-	0.00075		0.00068		0.00114		-	-	-	-
BZ#187	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	-	-	0.00091	U	0.00122	U
BZ#187 [2C]	NA		mg/kg dry	-	-	-	-	-	-	0.00097	P	-	-	-	-
BZ#195	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00091	U	0.00122	U
BZ#206	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	-	-	0.00091	U	0.00122	U
BZ#206 [2C]	NA		mg/kg dry	-	-	-	-	-	-	0.00131		-	-	-	-
BZ#209	NA		mg/kg dry	-	-	-	-	0.00049	U	-	-	0.00091	U	0.00122	U
BZ#209 [2C]	NA		mg/kg dry	0.00099		0.00075		-	-	0.0013		-	-	-	-
BZ#28	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00091	U	0.00122	U
BZ#44	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00091	U	0.00122	U
BZ#52	NA		mg/kg dry	0.00099	P	-	-	0.00065		0.00114		0.00159	P	0.00122	U
BZ#52 [2C]	NA		mg/kg dry	-	-	0.00067		-	-	-	-	-	-	-	-
BZ#66	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00098	LC, P	0.00122	U
BZ#8	NA		mg/kg dry	0.00053	U	0.00053	U	0.00049	U	0.00056	U	0.00091	U	0.00122	U
Total PCB Congeners	NA	<2	mg/kg dry	0.00968		0.00966		0.00886		0.0102		0.0164		0.0221	
8100M Total Petroleum Hydrocarbons															
Total Petroleum Hydrocarbons	1,000	5,000	mg/kg dry	172		264		130		208		270		550	
8270D Semi-Volatile Organic Compounds															
1,1-Biphenyl	0.05		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
1,2,4-Trichlorobenzene	2		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
1,2-Dichlorobenzene	9		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
1,3-Dichlorobenzene	3		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
1,4-Dichlorobenzene	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U

Table 3. Bartlet Mall - Frog Pond
Sediment Sampling Results For Comparison With MA-2014-RCS1 and Landfill Reuse Criteria

Sample Location		Lined Landfill		1 0'-2' Comp		2 0'-2' Comp		3 0'-2' Comp		4 0'-2' Comp		5 0'-2' Comp		Peat	
Sample Date	2014-RCS1	Reuse Criteria	Units	08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014	
2,4,5-Trichlorophenol	4		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2,4,6-Trichlorophenol	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2,4-Dichlorophenol	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2,4-Dimethylphenol	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2,4-Dinitrophenol	3		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
2,4-Dinitrotoluene	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2,6-Dinitrotoluene	100		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2-Chloronaphthalene	1000		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2-Chlorophenol	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2-Methylphenol	500		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2-Nitroaniline	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
2-Nitrophenol	100		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
3,3´-Dichlorobenzidine	3		mg/kg dry	0.905	U	0.895	U	0.729	U	0.871	U	1.72	U	1.53	U
3+4-Methylphenol	500		mg/kg dry	0.905	U	0.895	U	0.729	U	0.871	U	1.72	U	1.53	U
3-Nitroaniline	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
4,6-Dinitro-2-Methylphenol	NA		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
4-Bromophenyl-phenylether	100		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
4-Chloro-3-Methylphenol	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
4-Chloroaniline	1		mg/kg dry	0.905	U	0.895	U	0.729	U	0.871	U	1.72	U	1.53	U
4-Chloro-phenyl-phenyl ether	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
4-Nitroaniline	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
4-Nitrophenol	100		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
Acetophenone	1000		mg/kg dry	0.905	U	0.895	U	0.729	U	0.871	U	1.72	U	1.53	U
Aniline	1000		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
Azobenzene	50		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Benzidine	NA		mg/kg dry	0.905	U	0.895	U	0.729	U	0.871	U	1.72	U	1.53	U
Benzoic Acid	NA		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
Benzyl Alcohol	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
bis(2-Chloroethoxy)methane	500		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
bis(2-Chloroethyl)ether	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
bis(2-chloroisopropyl)Ether	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
bis(2-Ethylhexyl)phthalate	90		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Butylbenzylphthalate	100		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Carbazole	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Dibenzofuran	100		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Diethylphthalate	10		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Dimethylphthalate	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Di-n-butylphthalate	50		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U

Table 3. Bartlet Mall - Frog Pond
Sediment Sampling Results For Comparison With MA-2014-RCS1 and Landfill Reuse Criteria

Sample Location		Lined Landfill		1 0'-2' Comp		2 0'-2' Comp		3 0'-2' Comp		4 0'-2' Comp		5 0'-2' Comp		Peat	
Sample Date	2014-RCS1	Reuse Criteria	Units	08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014		08/28/2014	
Di-n-octylphthalate	1000		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Hexachlorobenzene	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Hexachlorobutadiene	30		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Hexachlorocyclopentadiene	NA		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
Hexachloroethane	0.7		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Isophorone	100		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Nitrobenzene	500		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
N-Nitrosodimethylamine	50		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
N-Nitroso-Di-n-Propylamine	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
N-nitrosodiphenylamine	NA		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
Pentachlorophenol	3		mg/kg dry	2.27	U	2.24	U	1.83	U	2.18	U	4.29	U	3.83	U
Phenol	1		mg/kg dry	0.452	U	0.447	U	0.364	U	0.435	U	0.856	U	0.763	U
TOTAL SVOCs	NA	100		19.9255		19.688		16.0535		19.16		37.719		33.6345	
Classical Chemistry															
Conductivity	NA	8,000	umhos/cm	58	WL	46	WL	30	WL	40	WL	59	WL	51	WL
Percent Solid	NA	NA	%	37		37		45		38		29		22	-
Total Organic Carbon	NA	NA	mg/kg	63300		63800		66500		52400		73400		194000	
Total Phosphate as P	NA	NA	mg/kg dry	-	-	-	-	-	-	-	-	1430	D	704	D
MADEP-EPH Extractable Petroleum Hydrocarbons															
2-Methylnaphthalene	0.7		mg/kg dry	0.069		0.039	U	0.031	U	0.037	U	0.049	U	0.051	U
Acenaphthene	4		mg/kg dry	0.038	U	0.039	U	0.031	U	0.037	U	0.049	U	0.051	U
Acenaphthylene	1		mg/kg dry	0.25		0.068		0.034		0.057		0.049	U	0.051	U
Anthracene	1000		mg/kg dry	0.272		0.071		0.037		0.059		0.042		0.021	U
Benzo(a)anthracene	7		mg/kg dry	0.579		0.159		0.105		0.147		0.106		0.021	U
Benzo(a)pyrene	2		mg/kg dry	0.961		0.288		0.163		0.232		0.171		0.021	U
Benzo(b)fluoranthene	7		mg/kg dry	1.4		0.449		0.232		0.34		0.253		0.051	U
Benzo(g,h,i)perylene	1000		mg/kg dry	0.785		0.253		0.132		0.184		0.139		0.051	U
Benzo(k)fluoranthene	70		mg/kg dry	0.416		0.12		0.078		0.089		0.076		0.051	U
C11-C22 Aromatics1,2	1000		mg/kg dry	62.3		29.5	U	24	U	28.5	U	37.3	U	43.5	
C11-C22 Unadjusted Aromatics1	1000		mg/kg dry	73		29	U	23.5	U	28	U	36.6	U	43.5	
C19-C36 Aliphatics1	3000		mg/kg dry	101		52.2		41.4		37.2		41.2		45.7	
C9-C18 Aliphatics1	1000		mg/kg dry	28.8	U	29	U	23.5	U	28	U	36.6	U	38.6	U
Chrysene	70		mg/kg dry	0.979		0.302		0.182		0.237		0.187		0.051	U
Dibenzo(a,h)Anthracene	0.7		mg/kg dry	0.186		0.055		0.029		0.043		0.031		0.021	U
Fluoranthene	1000		mg/kg dry	1.5		0.461		0.281		0.403		0.288		0.051	U

Table 3. Bartlet Mall - Frog Pond

Sediment Sampling Results For Comparison With MA-2014-RCS1 and Landfill Reuse Criteria

Sample Location Sample Date	2014-RCS1	Lined Landfill Reuse Criteria	Units	1 0'-2' Comp 08/28/2014	2 0'-2' Comp 08/28/2014	3 0'-2' Comp 08/28/2014	4 0'-2' Comp 08/28/2014	5 0'-2' Comp 08/28/2014	Peat 08/28/2014
Fluorene	1000		mg/kg dry	0.161	0.04	0.019	0.036	0.026	0.021 U
Indeno(1,2,3-cd)Pyrene	7		mg/kg dry	0.859	0.264	0.14	0.217	0.16	0.051 U
Naphthalene	4		mg/kg dry	0.119	0.039 U	0.031 U	0.037 U	0.049 U	0.051 U
Phenanthrene	10		mg/kg dry	0.914	0.25	0.131	0.213	0.163	0.051 U
Pyrene	1000		mg/kg dry	1.28	0.39	0.245	0.321	0.252	0.051 U
Total PAHs	NA	100	mg/kg dry	10.75	3.23	1.85	2.63	2	0.35
Metals									
Arsenic	20	40	mg/kg dry	**52.8**	**49.4**	**47.2**	**47.3**	**58.3**	**25.2**
Cadmium	70	80	mg/kg dry	0.507 D	0.395 D	0.498 D	0.365 D	0.324 D	0.145 U, D
Chromium	30	1,000	mg/kg dry	**64.5**	**60.5**	**49.8**	**59.5**	**71.2**	**31.5**
Copper	NA	NA	mg/kg dry	59	53.1	52.7	48.4	54.8	20.4
Lead	200	2,000	mg/kg dry	**348**	**292**	**326**	**296**	**294**	34.5
Mercury	20	10	mg/kg dry	0.271	0.202	0.21	0.166	0.152	0.084 U
Nickel	600	NA	mg/kg dry	51.3	48	40.8	47.5	58.1	24
Zinc	1000	NA	mg/kg dry	178	158	159	149	169	58.6

Notes:

1. Bold Font - result for this analyte exceeds the MCP RCS-1 Standard.
2. Shaded Font - results for this analyte exceeds the COMM-97-001 or WSC-94-007 standard for reuse of contaminated soil at Massachusetts landfill facilities.
3. Underlined Text - The method requested for this analysis does not meet criteria for all compounds. The compound is undetected, however, the Method Reporting Limit is greater than the State limit.
3. NA - Not Applicable / No Standard
4. RCS1 - Massachusetts Contingency Plan reportable concentrations for soil contaminants.
5. Lined landfill reuse criteria standards from COMM-97-001 and COMM-94-007.

Qualifiers

D = Sample was diluted in order to obtain a value within the calibration range.

U = Not Detected

Assessment of Frog Pond (Newburyport.MA) Water Quality and Its Restoration

Vladimir Novotny

Updated January 28, 2019

Preface

My name is Vladimir Novotny. I am a retired CDM Chair Professor Emeritus of Environmental and Water Resources Engineering at Northeastern University in Boston, residing now in Newburyport. I have almost fifty years of experience in research, teaching and consulting of environmental engineering, specializing in water quality, nonpoint pollution, hydrology, and water resources. Before Northeastern, I was a professor and became a Professor Emeritus at Marquette University wherein, years ago, I started my US research career by becoming a member of an international team of scientists working on the identification of pollution in the Great Lakes, focusing on eutrophication. I wrote several books on water quality and many scientific papers. As a Visiting Professor in China and the Czech Republic I also advised on problems with poor water quality caused by potential and real eutrophication and hyper-eutrophication of water supply reservoirs for Prague and Beijing and published on these topics. Since 2011, I have been an advisor to the South Florida Water Management District in West Palm Beach evaluating their program of water quality improvements and controlling eutrophication of the Everglades and Lake Okeechobee.

In the last 15 years I have also been involved in the international movement of researchers toward the sustainability of cities and published books and articles in this field. The goal of this movement is triple zero neutrality of future cities which implies zero water waste, net zero greenhouse gas (GHG) emissions, and zero solid waste to landfills by 2050. Sustainable urban drainage and healthy urban water bodies such as ponds and lakes are significant components of these efforts and urban sustainability.

Since we moved to Newburyport in 2013 and living near the Frog Pond, I could not have missed the problems this water body has. Cities and village ponds historically played a very important role in urban life. People have enjoyed them for swimming, fishing, aesthetics, skating and, picnicking. But they were also important as places to store water to control flooding and provide water for firefighting and often also for water supply. Based on my observation, with exception of some limited skating and enjoying the beautiful fountain, none of the above services and amenities are available with the Frog Pond. Swimming is not possible and could even be dangerous (rash) to accidental swimmers and possibly lethal to small animals.

There is a caveat to my assessment. On the request of neighbors who care about the pond, I am presenting my expert assessment and suggestions as a concerned citizen. I have not been hired to

27 Hill Street, Newburyport, MA 01950
Ph 617 2404918 vnovotny@aquanovaLLC.com

prepare an expert document and cannot be liable for any actions that may transpire from this report and have not received compensation for preparing this report. Furthermore, I do not have all necessary data on the pond to make a full assessment. In the future, I would be willing to serve as an expert adviser to the restoration team.

First Observations

Hydrology.

The Bartlet Mall and Frog Pond are a central green space in the urban core of historic downtown Newburyport. Per the Horsley Witten Group (2014) report, the pond area is about 2.3 acres (100,188 sqft). Frog Pond does not have a defined inlet of fresh water nor an outlet; therefore, the only way water leaving the pond is by evaporation that has no chemical composition. Essentially, the pond receives its water input from precipitation, some surface runoff that may contain lawn fertilizers and, mainly from groundwater seepage permeating through the phosphorus rich bottom muck.

Frog Pond is not a functioning pond based on biology, hydrology and hydraulics. It is a depression in the ground with polluted sediment filled with rain water and some groundwater seepage. Consequently, all pollutants brought in by past stormwater flows from surrounding streets and today from surrounding fertilized lawns remain in the depression, increasing in concentration and, eventually, most are incorporated in the sediments. A typical pond is an impounded deeper standing water body with a fresh water inlet and outlet that would discharge potential and real pollutants. It should also have a healthy biota.

The water in the depression is shallow, per local information the average depth of water in the pond is about 2-3 feet which fluctuates depending on rain and evaporation. Based on field observations by the Horsley Witten Group during the collection of sediment samples, approximately 3.5 feet of dark gray organic polluted silt (muck) exists above a well-defined peat.

Visual observation of water quality.

By observing the pond with an “expert” eye, I noted that the pond suffers from severe eutrophication, most likely hyper-eutrophication. The difference between eutrophication and hyper-eutrophication can be assessed by observing transparence of water, measuring the phosphorus content of water, and composition and concentration of phytoplankton. The transparency can be simply measured by submerging a white disc and measuring the depth at which the visibility of the disc disappears. Generally, if the transparency measured during summer algal blooms is less than 3.5 ft, the pond can be considered as hyper-eutrophic. My observations of the pond during summers of 2016 and 2017 noted but not measured this very low transparency. Simply stated, if one cannot see the bottom, bottom stones and wood, the pond may be hyper trophic.

The difference between eutrophic and hyper eutrophic water quality is also in the phytoplankton population. Eutrophic water bodies are populated mainly by species of green algae and support lower quality fish and biota while hypertrophic water bodies are exhibited by harmful algal blooms (HAB) dominated by cyanobacteria producing toxins lethal to small animals and causing rash to swimmers. Allegedly, workers who worked on the restoration of the fountain several years ago had a rash attack. Consequently, the hyper-eutrophic conditions could be suspected. However, no microbiological investigation of phytoplankton composition was found.

How much phosphorus is in the pond.

The third parameter that is used in the classification of eutrophic conditions is phosphorus concentration. Phosphorus is a limiting nutrient that controls that growth of algae and other aquatic flora. No data were found on total phosphorus (TP) concentrations in the water column but TP concentrations in the sediment were measured by the Horsley Witten Group in 2013 and 2014. Organization for Economic Co-operation and Development - OECD (1982) Guidelines for eutrophication assessment show that water TP concentrations in eutrophic water bodies are between 0.035 to 0.1 mg/L and that for hypereutrophic water bodies exceed 0.1 mg/L. OECD table below show a classification of trophic (nutrient) status of impounded water bodies. Oligotrophic (oligo=few, trophic = nourishment) water bodies are pristine lakes with little algae and very high transparency of more than 10 ft. Eutrophic water bodies are infested by algae and transparency about 3.5 ft. and phosphorus content less than 0.1 TP mg/liter.

Hypertrophic water bodies are ponds and lakes with very high algal content, sometimes of specific species called cyanobacteria, Figure 1, that produce toxins. There is an anecdotal confirmation that cyanobacteria pea soup algal blooms causing rash appeared in the pond several years ago. Based on transparency only, Frog Pond could be borderline eutrophic to hyper trophic. In short, because the depth of Frog Pond is around 2 ft if one cannot see the bottom the pond is most likely hypertrophic.

Table Quality characteristics of eutrophication categories of impounded surface waters based on OECD (1982) criteria (annual mean values).

Trophic Index	Chlorophyll a µg/L	Total P µg/L	Transparency ft*	Trophic class	Characteristics
<30-40	≤8	≤ 10	≥10	Oligotrophic	Low primary productivity, low algae, high clarity
40-50	8-25	10-35	10-.5	Mesotrophic	Intermediate level of product-ivity, submerged aquatic vege-tation, good clarity, balanced and diversified aquatic biota
50-70	25-75	35-100	5-2.3	Eutrophic	High productivity, dominated by algae and aquatic plants
>70	>75	>100	<2.3	Hypertrophic	Harmful (toxic) blooms dominated by cyanobacteria, loss of submerged aquatic vegetation, zero oxygen, low quality fish, loss of swimming

* during algal development

Using the area of the pond of 100 000 sqft and the average depth of 2.5 ft to calculate the volume of the water in the pond (approximately 9,250 cu yards) and the borderline TP concentration of 0.1 mg/L, the total TP content of the water column would be on the order of about 2 lbs (one kilogram or less). Runoff from streets and lawns has TP concentrations that are higher and street runoff is far more polluted by toxic compounds.

Sediment observations. The Horsley Witten Group (2014) Laboratory analysis of composite and discrete sediment samples indicated the presence of several contaminants at concentrations above the standards which included arsenic, chromium, and lead, all of which are heavy metals that are persistent in the environment. Several polycyclic aromatic hydrocarbons (PAHs) were also detected above laboratory detection limits but did not violate the standards. Lead, chromium and PAHs are very likely caused by legacy pollution of stormwater discharges from streets with heavy traffic decades ago. Also, arsenic was used decades ago as an herbicide to control algae and weeds. Because these priority pollutants are immobile and are tightly bound to the organic and clay particles in the sediment, the level of toxic contamination would not warrant sediment dredging, a simple bottom sealing might be acceptable to authorities.

That HWG analyses revealed "moderately high" concentrations of TP in the upper organic muck of approximately 1,400 mg/kg, and about half as much in the underlying peat. The observed concentration of total phosphate from the upper muck samples is consistent with what had been previously observed by Higgins Environmental, Inc. (approximately 1,100 – 1,600 mg/kg) from numerous samples collected from the top six inches of the pond in 2013. The total mass of TP in the top 3.5 ft muck layer is much larger than that in water. Using the data from the HWG report the mass of the TP in the upper 3.5 ft represents 300,000 cuft of muck which contains about 12 metric tons of mostly organic TP, more than twelve thousand times that in the water column. An unknown but high mass of additional TP is stored in the peat below the top muck. This estimate is important when considering the removal of TP from the water (e.g., by filtration). There is plenty of TP in the muck. What prevents a massive escape of TP from the muck into water is oxygen in water and equilibrium between the TP in water and that in the muck layer below the oxygenated top layer of the sediment. Nevertheless, the TP concentration is in water is in equilibrium with the TP in the sediment, and if the TP in the water is filtered out it is replaced by diffusion with the TP from the sediment. This replacement may continue for centuries.

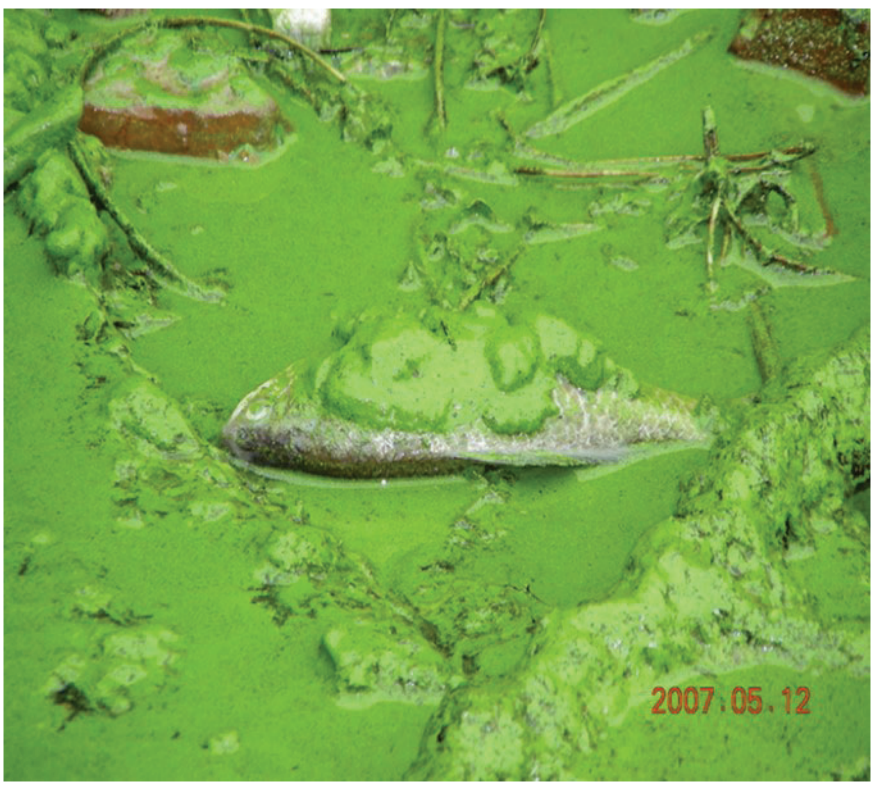


Figure 1

Highly hypertrophic water body Lake Taihu in China

Is there a hope for Frog Pond?

Of course, there is, depending on how much the community wants to invest in pond restoration, beautification, obtaining grants and do some fundraising. There are a few remediation measures available that can be divided into temporary "swimming pool" measures without addressing the problem and more permanent and more natural solutions. However, as stated before, Frog Pond is not a natural pond so the best that can be achieved is to restore the water body to a status that would mimic nature and be an asset to the community again, including safe boating, enjoying the fountain, picnicking, and , maybe, some wading.

The "swimming pool solution first", which would be *filtration without any other remediation*. Having owned a swimming pool in the past I can attest that maintaining the water in the pool clear and transparent, as it was promised by the filtration manufacturer, is a struggle at best and close to impossible at worst. To keep the swimming pool clear, filtration had to be run weekly and high levels of chlorine serving as disinfectant and herbicide had to be maintained. Furthermore, a swimming pool does not have a sediment layer because it is lined, and any sediment accumulation must be removed by vacuum cleaning. Because a swimming pool is filled after installation and frequently refilled with potable water, the total TP concentrations are miniscule compared to Frog Pond, yet algae (not cyanobacteria) do develop if the maintenance is lagging. Without a bottom seal in the Frog Pond, phosphorus will permeate with groundwater from the phosphorus rich sediment back to water during and after filtration and the spores of cyanobacteria residing in the sediment will rise and develop as bloom again. All swimming pools are separated from soil by plastic or concrete lining.

To complicate the matter, if cyanobacteria, unlike green algae, are the ones dominating the harmful algal bloom (HAB), the problem is magnified by the fact that they are "smart" microorganisms that have propagated on earth for billions of years (they are credited for putting oxygen into primal atmosphere) and will respond to the reduction of phosphorus by mass settling into sediment which is rich in TP for nourishment and reappear as HAB next year. They can survive in sediment for years and some species can fix atmospheric nitrogen as nutrient.

The Newburyport Daily News article (Henrickson, 2017) reported that the filtration system installed in the courthouse at a cost of $70 000 is reverse osmosis. Operation of reverse osmosis nanofiltration is costly because it requires very high pressure to push water through the filter with nanometer size pores (reverse the osmotic pressure), pretreatment, frequent replacement of the filter media and need for a qualified technician during the operation. As stated above, filtration only is not a solution but after the full pond restoration is done, it could be used, like in swimming pools, for filtering maintenance and improving clarity of the water in the pond if the city is willing to continue paying the high cost of treatment.

Because of water contamination it is not certain whether the pond water could be pumped into a storm sewer. However, if it is done outside of the algal bloom season (June to mid-September) the amount of pollutants would be very small, far smaller than that from street runoff from the area surrounding the pond. The pond water is mainly rain water with groundwater contributions. Nevertheless, addendum to the city stormwater permit would be needed.

Sediment excavation. Excavation assumes the cost of about $4/cu yd. Restoring the pond should include putting a clay and sand layer on the bottom to prevent seepage of phosphorus from the peat, removal of the access road and final landscaping. The above estimates are approximate.

Excavation assumes the cost of about \$4/cu yd. Restoring the pond should include putting a clay and sand layer on the bottom to prevent seepage of phosphorus from the peat, removal of the access road and final landscaping. The above estimates are approximate.

The HWG report assessed in detail sediment dredging which was apparently suggested years ago as a feasible remediation. This solution required:

	Cost \$
• Pumping all water from the pond (volume about 13,000 cu yards or 2.6 MG) *	2,000
• Building an access road for trucks and excavating machinery, estimated	20,000
• After sediment drying, excavation of about 12,000 cu yard of the sediment	60,000
• Trucking the sediment to a landfill in New Hampshire and dumping	500,000**
• Restoring the pond, adding a layer of sand and gravel on top of the peat and refilling it with water	200,000
• Labor, permits, design	?
• Final landscaping	?
Total approximately	~1 million

* (Pump, labor and electricity); ** Per HWG report

HWG also recommended, if necessary, alum treatment following dredging to further isolate remaining phosphorous in the peat layer from re-suspension in the water column. Alum is effective for permanently binding phosphorous, but phosphorus loading from the watershed needs to be controlled beforehand to avoid simply rebuilding a new pool of available phosphorous following treatment. Other concurrent measures proposed by HSG included duck and geese control and removal of all stormwater discharges.

While sediment removal may be partially effective it would not resolve the hydrology issues, i.e., inlet of fresh water and outlet of chemically enriched water from the pond. Groundwater permeating through TP containing peat and, without an outlet, would cause TP concentrations increasing due to evaporation that does not have chemical content. Hence, filtration would be needed even after sediment removal.

Recreating a pond.

As stated above, a depression in the ground filled with water is not a functioning pond. The pond restoration should create some basic hydrologic and biotic pond functions that should include:

1. A bottom seal that would significantly reduce or even eliminate phosphorus seepage from the sediments.
2. Input of clean water and outlet of chemically enriched water from the pond.
3. Replacement of polluted water in the pond.
4. Possible filtration of the water content.
5. Maintaining healthy biota and control of water fowl.
6. Pond landscape.

***Chemical bottom seal*.**

Application of alum coagulant. The bottom seal proposed by HWG after dredging the bottom muck is an application of alum salt, which is a coagulant that precipitates phosphorus and some colloidal compounds that after settling form a temporary barrier to phosphorus seepage from the sediment.

This application would have to be repeated after a few years. It is not a perfect measure, but it has been used in many lake restoration projects along with other measures. Alum only does not fully cap toxic sediments.

Pond liners.

Capping and sealing the bottom can be done by synthetic liners or by clay or bentonite. Using liners would avoid muck excavation and transporting to out of state landfill. While the main function of liners is to prevent seepage and hold water they would also prevent seepage of phosphorus and other chemicals from the muck and peat and keep cyanobacteria and other microorganisms from penetration from the muck to the water above. Hence, sediment excavation would not be needed. Pond liner longevity is very important because repairs and replacements require dewatering and refilling the pond.

However, impermeable (e.g., vinyl) liners installed over muck wherein microbial decomposing is occurring may cause the liner to float up off the bottom. Also, high organic matter soil (muck) tends to give off excess methane gas. This and an occasional high groundwater table can cause the liner to float from the bottom to the surface. Previously, the only solution would have been to cut and patch the liner which would require dewatering the pond. Using the proper pond commercial *underliner* venting will help prevent this. An underliner contains perforated tubes wrapped by non-woven geotextile for more protection and function (see Figure 3)

The lifetime of a vinyl liner is about twenty years. The liner and underliners are anchored by stones or other means on the side of the ponds to prevent lifting. Water plants could be planted in this littoral zone.

Synthetic plastic (vinyl), rubber or tarp liners are relatively cheap (less than $0.5/sq ft). A 6-inch gravel base and then soil can be laid over it. Some installing companies *(*e.g. *Reef Industries, Houston, TX)* claim that heavy equipment can be used on top of their liners to move gravel and soil without damage. Plastic vinyl liners are shipped in large sections that can be welded together during installation. Liner installation is shown on Figure 3.

Synthetic liners are not expected to last more than 10 years without a protective layer. Adding the gravel base doubles their life time. Some vinyl liners slightly decompose and may release harmful pollutants.

Clay liner is the most natural measure which consists of a 12-inch clay layer (coarse soil with at least 20 percent clay content) spread over the pond floor and walls. Sealing a pond with clay may last at least a century due to the inorganic nature of the materials that survive over the geological time. An underliner collecting methane can be installed in this layer. Clay lining, if properly installed can last several life times (Spring Creek Concepts, 2018). It is also natural.

Instead of clay, a soil additive such as bentonite has been also used, instead of clay.

What must be done to have a functioning Frog Pond

Let us summarize:

- A functioning pond must have sound hydrology that includes influent and effluent. The water level in the pond should be maintained above the surrounding groundwater table elevation to prevent seepage of pollutants from muck and floating the liner.
- Pollutant input such as polluted surface runoff must be significantly reduced.
- Seepage of phosphorus and pollutants from the bottom muck must be eliminated.

- Harmful microorganisms (cyanobacteria?) living and surviving in water and upper sediment must be eliminated or separated.

Creating an input of fresh clean water. The input of fresh water is needed to cleanse water in the pond and keeping the water level above the groundwater table. Clean water should be pumped from the sand aquifer not from the muck and peat layer. This can be best accomplished by drilling a well and installing a pump in a manhole with an outlet disguised architecturally as a spring or a waterfall. The well will provide also clean water for the fountain. In the past, using pond water has severely damaged the fountain by encrustation of algae.

The amount of flow can be calculated by balancing rainfall, infiltration and evaporation, resulting in an annual exchange of water in the pond. The pump may be operated seasonally (mid spring to early fall) a couple of hours during dry days. The cost of drilling a shallow well and installing a submerged pump is not high; most well pumps retail for between $100 and $1,200 and the cost of drilling a shallow well may be less than $3000 (about $25.foot).

Maintaining high clarity can also be helped by the existing filtration system but filtration only cannot maintain higher water level. If the pond is properly restored, swimming pool type filtration may not be needed. Furthermore, because of the pumping head difference between pumping water from a shallow well and pushing water through extremely small voids in the reverse osmosis (RO) filter there is great difference in energy cost. The pump pressure needed for a shallow well is less than 1 bar (1 bar equals approximately to one atmosphere) while high pressure pumps providing 15 to 20 bar pressure difference are needed for RO. Hence, the energy used to provide the same amount of clean water could be as much as 20 times greater for a typical RO system than for groundwater pumping. It is not known what pressure difference is used in the RO filtration systems installed for Frog Pond. RO system cost also includes frequent replacement of membrane filters and manpower to operate the system. Pumping from a well has no labor cost, except for maintenance and turning the switch on and off, which can be automated and most likely will not need filtration.

Outlet for excess water. Currently, the only way water can be discharged from the pond is pumping it into an existing storm sewer. It could be classified as stormwater because the largest water input into the pond most likely is precipitation. When the remediation is completed the outlet water quality will be such that the discharge would be permissible under the MS4 (Small Municipal Separate Stormwater Sewer Systems) permitting. A low-pressure pump (cost about $500) may be needed to pump effluent into the storm sewer or surface channel. The existing fountain pump located in the courthouse or a new pump activated by high water levels in the pond can be installed in an outside manhole.

The outlet water would be a mix of rain water with groundwater with very small content of phosphorus, much smaller than today, and other potential pollutants would be in smaller concentration than street runoff. Therefore, because of the good quality, the discharge could be used as irrigation water in the cemetery and surrounding parks as far as the Rail Trail. If city is interested in beautification of Green Street, the main entry street to the city center, and convert it in a boulevard, a raingarden type strip can be created as shown on Figure 5 .

Creating a seal between the bottom sediment and water in the pond.

Alum coagulant salt. The cheapest but not very effective measure in the long term is application of alum coagulating salts. ALUM (aluminum sulfate) is a nontoxic material commonly used in water treatment plants to clarify drinking water. In water it forms insoluble aluminum hydroxide flocks that bind with colloids and phosphorus to form an aluminum phosphate flocks. In lakes and ponds alum is used to reduce the amount of the nutrient phosphorus in the water. These flocks then settle to the bottom and can form a (imperfect) barrier to release phosphate from the sediment.

Treatment costs range from $280/acre to $700/acre ($450=approximate average) depending on the dosage requirements and costs to mobilize the equipment. This would be a temporary measure that would have to be periodically (3 to 5 years) repeated. But it would not require drawing down of the pond (Wisconsin Department of Natural Resources, 2003). It would not kill the cyanobacteria residing in the sediment.

Permanent seal. The choice is between a natural clay layer or synthetic liner. A clay layer is recommended because there is plenty of sand and gravel nearby and a source of 20% to 25% of clay (30 truckloads) can also be located nearby. The sand/gravel/clay layer should be about 1 foot thick. Because the area of the pond is about 2.3 acres the volume of the fill material is about 3 000 cu yard (2300 cu yards sand and gravel and 700 cu yards clay). The pond must be dewatered and the top muck dried before the seal is installed. Drying and sun exposure may also kill some live cyanobacteria spores residing in the sediment.

Instead of installing the sand/clay seal on top of the muck in the pond, it is recommended that 6 in (1,400 cu yards = 1,100 tons) of the muck is removed after drying. The layer may contain millions (trillions?) of dormant but live spores of cyanobacteria. Research in the Czech Republic of hypereutrophic reservoirs showed the cyanobacteria concentrations in the sediment to be thirty times greater than those in the water column. However, because the arsenic and toxic metals is a legacy contamination by road runoff and industrial activities in the watershed decades ago (leaded gasoline and arsenic herbicides were banned forty years ago) it can be speculated the top 0.5 ft of muck may not be contaminated and require special landfilling. This speculation should be proved or disproved by chemical analyses. If the muck is not toxic it could be used for landscaping.

If the top 6" of muck is toxic, instead of excavation and trucking the muck to a landfill in New Hampshire, it may be better to put a synthetic liner with the underliners to cap the toxic muck and reduce the sand/gravel/clay layer on the top of the liner to 6". Cost of synthetic liners is about $0.5/sq ft plus the cost of relatively straightforward and quick installation (see Figure 4) .

Underliner pipes should be installed below the seal. The underliner pipes will collect possible methane formed by the organic decomposition in the layers below and excess groundwater.

After the seal is installed the pond must be architecturally landscaped. The banks should be protected with rocks with soil in which aquatic macrophytes can be planted. The gas from the underliners could be vented in there. The rocks/stones will also hold the synthetic liner.

Pond water refilling may last at least a month. Hence, the well providing clean water should be installed concurrently or before the seal is installed.

Let us recapitulate the activities and approximate costs. All costs are approximate estimates. The actual designs and costs must be done by qualified and respectable pond and lake designers and restoration companies. The cost of final landscaping, vegetation planting, etc. is not included. No manufacturers or contractors are recommended in this proposal.

Alternative 1 with natural liner (Assumed muck is not be toxic)

Activity	Approximate cost $
1. Pond dewatering, water volume 13 000 cu yard, including some water in the muck – hydraulic head 30 ft, pump efficiency 70%, \$0.15/kW-hr	2,000
2. Well pump, drilling, manhole installation, connection to the fountain.	5,000
3. Excavation of 6 in (1,100 tons) of the top muck layer, \$4/cu yard	8,200
4. Transport and deposition of the dry muck* to a nearby muck deposition, \$ 15/ton transportation, \$20/ton deposition	38,000
5. Installing underliners twenty 150 ft long multiple perforated tube lines, \$400/line, labor \$50/line	9,000
7. Sand/gravel/clay seal, 1 ft seal, 3,700 yard^3, \$24/yd^3	88,800
8. Refilling with water	1,000
9. Stones for bank protection, allowance (300 cu yards)	15,000
10. Outlet manhole with a pump	5,000
11. Cost of design, laboratory analyses and surveys is not included	
12. Costs of final architectural landscaping not included	
Total	169,000

Alternative with the synthetic liner (toxic muck)

Activity	Approximate cost $
1. Pond dewatering same as in Alternative 1	2,000
2. Well pump same as Alternative 1	5,000
3. No excavation of the top muck layer	0
4. Installing underliners, twenty 150 ft long multiple perforated tube lines, \$400/line, labor \$50/line	9,000
5. Installing synthetic liner apron, 2.3 acres = 100,000 sq ft @) \$0.5/sq ft + \$ 16,000 for installation	66,000
6. Installing sand/gravel/clay seal, 6" seal, 1,850 yard^3, \$24/yard^3	44,400
7. Refilling with water	1,000
8. Stones for bank protection and holding the underliners and liner, allowance (300 cu yards)	15,000
9. Outlet manhole with a pump	5,000
10. Cost of design, laboratory analyses and surveys is not included	
11. Costs of final architectural landscaping not included	147,4f00

Refences

Henrickson, D. (2017) Frog Pond cleanup plan moves ahead, *Newburyport Daily News,* July 2017, http://www.newburyportnews.com/news/local_news/frog-pond-cleanup-plan-moves-ahead/article_cdf0feb1-3a96-5eba-b2e8-7c6da21347c4.html

Spring Creek Concepts (2018) Liners, http://www.aquahabitat.com/techfaqs.html

Wisconsin Department of Natural Resources (2003) *Alum Treatments to Control Phosphorus in Lakes, http://www.littlesaint.org/misc_documents/alum_phosphorous_control_dnr.pdf*

COMANCO Completes PVC liner installation, August 23, 2016 http://comanco.com/blog/comanco-completes-pvc-liner-installation/

Organization for Economic Cooperation and Development, (1982). Eutrophication of Waters, Monitoring, Assessment and Control. Paris, OECD.

Figure 2 The Frog Pond in Fall (Web photo credit Joe Callahan, Salisbury)

Figure 3 Pond underliner

Figure 4 Pond synthetic liner installation (COMANCO). Note anchoring the liner with stones.

Figure 5 Surface raingarden channel for clean water /stormwater and pond outlet flow during rainfall in Malmö Sweden.