Walker Pond
Lake Management

2017 Final Report

Needham, Massachusetts

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TABLE OF CONTENTS

SECTION **PAGE**

TABLES

FIGURES

APPENDICES

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1.0 INTRODUCTION

Walker Pond is a six-acre, eutrophic waterbody located in Needham, Massachusetts. The town of Needham owns approximately two-thirds of the pond and the rest is privately owned. The pond is roughly split in half by an earthen berm. Limited connectivity between the east and west sides of the pond is retained by an opening on the south side of the berm. The pond is open to recreational fishing and contains warmwater fish species (Town of Needham 2016).

Top: Walker Pond west basin, looking toward Walker-Gordon field. Bottom: East basin, looking toward outlet and Central Ave. Native duckweed and watermeal cover the surface of the pond. August 31, 2017.

The Town aims to develop a 5-year Management Plan for the pond that can be used to guide restoration and long-term management of the pond and watershed system. The following is a summary of work conducted in 2017 in support of the project:

- September 12, 2017 – Kick-off meeting
- August 31, 2017 – Aquatic plant mapping, bathymetric mapping, fish and wildlife survey, and water quality monitoring
- October 25, 2017 – Stormwater water quality monitoring

2.0 AQUATIC PLANT ASSESSMENT

On August 31, 2017, ESS scientists conducted aquatic plant mapping to assess the current condition of the pond with respect to water quality, aquatic plant, and algae growth. ESS scientists mapped the locations of all native and non-native aquatic plant species at 31 regularly spaced sampling points throughout the pond. Location data for each point was recorded using a sub-meter accurate Trimble GPS receiver.

ESS documented 12 species of aquatic macrophytes, including one invasive species, during the aquatic vegetation survey (Table 1). Plant cover (Figure 1) and biovolume (Figure 2) were categorized as dense throughout most of the pond.

Table 1. Aquatic Macrophytes Documented on August 31, 2017

Scientific Name	Common Name	Relative Abundance	Status
Ceratophyllum demersum	Coontail	High	Native
Elodea nutallii	Western Waterweed	Medium	Native
Lemna sp.	Duckweed	High	Native
Nuphar lutea variegata	Yellow Water Lily	Medium	Native
Nymphaea odorata	White Water Lily	Low	Native
Pontederia cordata	Pickerelweed	Low	Native
Wolffia sp.	Watermeal	High	Native
Algae sp.	Filamentous Algae	Medium	Native
Lythrum salicaria	**Purple loosestrife**	**Low**	**Invasive**
Polygonum sp.	Water Smartweed	Medium	Native

Scientific Name	Common Name	Relative Abundance	Status
Typha sp.	Cattail	Low	Native
Potamogeton sp.	Pondweed	Low	Native

Most of Walker Pond is covered by the small, native free-floating plants of watermeal (*Wolffia* sp.) and duckweed (*Lemna* sp.). Beneath this cover, large sections of the pond bottom are covered with native coontail (*Ceratophyllum demersum*). Native floating-leaved plants including pondweeds (*Potamogeton* sp.), white water lily (Nymphaea odorata), and yellow water lily (*Nuphar lutea variegate*) were also present in the east and west basins. Native emergent plants including water smartweed (*Polygonum sp.*), cattail (*Typha* sp.), and pickerelweed (*Pontederia cordata*) were observed along the shoreline. The exotic wetland plant purple loosestrife (*Lythrum salicaria*) was present in one location along the shoreline. ESS scientists did not observe any sub-aquatic invasive species during the survey.

3.0 BATHYMETRIC SURVEY

ESS scientists conducted a bathymetric survey of Walker Pond on August 31, 2017. Researchers used a handheld sonar depth finder to determine water depth and a soil probe to measure sediment depth at 31 locations within Walker Pond. Sediment composition (clay, muck, sand, etc.) was also recorded for each site.

Walker pond is a shallow waterbody, with an average depth of 2.4 feet and a maximum depth of 4 feet (Figure 3). The pond bed is composed almost entirely of mucky organic sediments. Throughout the pond, this muck layer was an average of 2.5 feet thick, though values ranged from a minimum of 0.5 feet to a maximum of 5.5 feet.

Outflow from the pond is controlled by a concrete box culvert fitted with flashboards composed of at least 6 wooden boards (approximately 2" x 9"). This structure is 6.8 feet in width and the removeable flashboards extend approximately 4 feet below the water surface. However, water depth is just 1.5 feet, and sediment depth is at least 2.5 feet, within the pond at the spillway. The pond water level was approximately 4 inches below the height of the spillway barrier on August 31, and the only outflow from the pond was the result of water leaking through gaps between the boards.


Top: The pond was dominated by watermeal and duckweed (water surface), and native coontail and filamentous algae (submerged). Bottom: Detail of coontail. August 31, 2017.

4.0 FISH AND WILDLIFE ASSESSMENT

ESS scientists conducted assessments of fish and wildlife on August 31, 2017, including macroinvertebrate and mollusk sampling. No mussels or clams were observed during sampling of shallow nearshore or deeper areas within the pond. Additionally, no bivalve shells or shellfish middens were located along the shore of the pond. The only mollusks present were small air-breathing snails (*Physa sp.*) found on submerged vegetation. All invertebrates found during the survey are listed in Table 2. The Walker Pond macroinvertebrate community includes insects (non-biting midges, dragonflies, damselflies, caddisflies, mayflies, and water striders), crustaceans (copepods, amphipods, ostracods, and water fleas), aquatic earth worms, water mites, and flatworms. This community is typical of lentic freshwater habitats and no rare, threatened, or endangered species were encountered.

Table 2. Aquatic Macroinvertebrates Documented on August 31, 2017

Taxonomic Group	Lowest Taxonomic Level	Common Name
Crustaceans	Harpacticoida	Copepods
	Cladocera	Water fleas
	Ostracoda	Ostracods
	Hyalella azteca	Amphipods
Annelids (segmented worms)	Glossiphonidae	Leeches
	Oligochaeta	Aquatic worms
Platyhelminthes (flatworms)	*Dugesia sp.*	Freshwater flatworms
Arachnids	Hydrachnidia	Water mites
Mollusks	Physinae	*Physa* snails
Insects	Libellulidae, Corduliidae	Dragonflies
	Coenagrionidae	Damselflies
	Gerridae	Water striders
	Mesoveliidae	Water treaders
	Leptocerus sp.	Caddisflies
	Callibaetis sp.	Mayflies
	Chironomidae	Non-biting midges

Vertebrates observed during the survey are listed in Table 3. A great blue heron (*Ardea Herodias*) and a green heron (*Butorides virescens*) were observed foraging for food along the shore of the east basin of the pond. Both pickerel frogs (*Lithobates palustris*) and bullfrogs (*L. catesbeianus*) were present in large numbers throughout the pond. Multiple painted turtles (*Chrysemys picta*) were also observed on partially submerged logs and branches along the shoreline. A single Canada goose (*Branta canadensis*) was present in the east basin and remained in this area for at least five hours during survey work.

Table 3. Vertebrate Animals Documented on August 31, 2017

Taxonomic Group	Scientific Name	Common Name
Birds	*Anas platyrhynchos*	Mallard
	Ardea herodias	Great Blue Heron
	Butorides virescens	Green Heron
	Branta canadensis	Canada goose
Reptiles	*Chrysemys picta*	Painted turtle
Amphibians	*Lithobates catesbeianus*	Bullfrog
	Lithobates palustris	Pickerel frog

Selection of animals observed during wildlife survey of Walker Pond on August 31, 2017. Left: green heron. Middle: great blue heron. Right: female bullfrog.

5.0 WATER QUALITY ASSESSMENT

Outlet of Walker Pond on August 31, 2017. The water level was approximately 4 inches below the height of the spillway boards.

Water and surficial sediment samples were collected from the deep hole in the west basin of Walker Pond on August 31, 2017. Water samples were collected from the outlet and inlet of Walker Pond during a wet weather sampling event on October 25, 2017. Water quality parameters including dissolved oxygen, temperature, turbidity, specific conductance, pH, color, and Secchi depth, were determined in the field. Water quality parameters including total phosphorus, dissolved phosphorus, nitrate nitrogen, total Kjeldahl nitrogen, and total suspended solids, were analyzed by Phoenix Environmental Laboratories in Manchester, CT (Appendix A). Sediment samples were collected using a Eckman sediment grab and analyzed by Phoenix Environmental Laboratories. The results of these analyses and field measurements are presented in Table 4.

In-lake dissolved oxygen levels were very low. This is likely due to excessive coverage of the water surface by small floating plants, which limits oxygen exchange between the water and atmosphere. The excessive growth of these floating plants may indicate increased ammonia or dissolved phosphorous levels within the pond. Ammonia was not measured, but phosphorus levels within the pond were high; values above 0.02 mg/L are considered undesirable. Total Kjeldahl nitrogen was also slightly elevated, but this is likely the result of large amounts of organic material within the water column. Secchi disk depth, a measure of water clarity, was low, and water color value was high. These conditions can indicate the presence of high levels of total suspended solids or algae within the water column. However, as TSS levels were not unusually high, and most algae was observed growing attached to submerged surfaces, these values likely reflect natural staining of the water due to contact with tannic organic material.

Sediment chemical analyses indicated that the sample collected from the deep hole of Walker pond was fairly watery (total solids at only 8.34%). Total phosphorous levels within this sediment appear to be elevated, but not yet at levels that would be classified by USEPA as polluted. Therefore, pond sediments are likely a moderate source of phosphorous in the pond water. Furthermore, the available fraction of the phosphorous is unknown, as P fractionation was beyond the scope of the current study.

Wet weather water quality samples from the inlet and outlet were taken on October 25, 2017 after a rain event of approximately 1 inch. Dissolved phosphorus levels from the inlet were high, indicating that that stormwater runoff through the inlet may be a major source of phosphorus input. Water quality samples from the inlet and outlet were used to determine the nutrient budget of Walker Pond and are discussed in greater detail in section 6.0.

Table 4. Results of Water Quality and Sediment Sampling

Parameter	Units	Deep Hole[1]		Inlet[2]	Outlet[2]
		Water	Sediment		
Total Solids	%	—	8.34	—	—
Phosphorus, Dissolved	mg/L	0.025	—	0.056	0.038
Nitrogen, Nitrate	mg/L	< 0.02	—	< 0.02	< 0.02
Nitrogen, Total Kjeldahl	mg/L	0.89	—	0.68	0.97
Phosphorus, as P	mg/L	0.042	—	0.139	0.054
Phosphorus, Total	mg/Kg	—	545	—	—
Total Suspended Solids	mg/L	< 5.0	—	6.0	< 5.0
Dissolved Oxygen	mg/L	1.89	—	4.78	3.68
	%	20.4	—	50.9	36.2
Temperature	°C	18.4	—	17.9	18.0
Specific Conductivity	S/m	441.5	—	3.4	434.4
pH	—	7.16	—	6.73	6.78
Color	Color Units	90	—	5	10
Turbidity	NTU	1.41	—	2.32	0.94
Secchi Depth	Feet	3.38	—	—	—

[1] Sampling conducted August 31, 2017 during dry weather
[2] Sampling conduction October 25, 2017 during wet weather

6.0 HYDROLOGIC BUDGET AND NUTRIENT MODELING

The results of the hydrologic budget and nutrient load modeling for Walker Pond are presented in Appendix B.

The average annual precipitation for Walker Pond is estimated to be 45.45 inches. This value was used for precipitation inputs during the hydrologic modeling for Walker Pond. Estimated average water input to Walker Pond from surface water, groundwater, and direct precipitation is 0.332, 0.002, and 0.021 cfs, respectively, for a total average annual flow of approximately 0.355 cfs. This average annual value for flow will vary appreciably among seasons and weather conditions. Surface water flow contributes significantly (93.5%) to the total pond inflow, while groundwater inflow (0.5%) and direct precipitation (6%) to the pond surface contribute the remaining. The surface water flow can be further divided into dry weather flows (16%) and wet weather flows (84%). A summary of key hydrologic parameters for Walker Pond is presented in Table 5.

Table 5. Summary of Walker Pond Hydrology

Element	Value
Watershed Area	166.2 acres
Pond Area	6.0 acres
Pond Circumference	2,850 feet
Pond Volume	622,000 cubic feet
Average Groundwater Seepage Inputs	0.002 cfs
Average Direct Precipitation	0.021 cfs
Average Surface Water Inputs	0.332 cfs

Based on total pond volume (622,000 cubic feet) and the estimated flow through the system, average detention time was calculated to be roughly 20 days (0.056 years). Since detention time represents the duration of time necessary to exchange the volume of water in the pond one time this means that the water entering Walker Pond is retained for less than a day’s time, on average. Flushing rate is the inverse of detention time and represents the number of times per year the pond volume is replaced; for Walker Pond the flushing rate is roughly 18 times per year.

A calculation of minimum nutrient load was made by multiplying the volume of the pond by its flushing rate and the average concentration of the nutrient observed during this study. The minimum phosphorus and nitrogen loads delivered to Walker Pond were determined to be 0.55 g/m^2/yr (13 kg/yr) and 11.75 g/m^2/yr (285 kg/yr), respectively, based on the in-pond nutrient concentrations observed during the study.

The actual load of phosphorus or nitrogen will exceed the estimated minimum load as a consequence of loss processes that reduce the in-pond concentration over time. A more detailed and realistic estimate of nutrient loading can be obtained by using a combination of actual field data and in-pond modeling theory (e.g., Vollenweider, 1975 and Reckhow, 1977). Nutrient loads are calculated based on nutrient values measured within the pond and hydraulic features of the system. Based on this approach, the predicted phosphorus load necessary to achieve the values found in Walker Pond ranges between 0.56 g/m2/yr (14 kg/yr) using the Vollenweider (1975) model and 1.15 g/m2/yr (28 kg/yr) using the Reckhow (1977) model. The average predicted phosphorus load for all models was 0.78 g/m2/yr (19 kg/yr). The nitrogen load necessary to achieve the observed in-pond concentrations was estimated to be 14 g/m2/yr (340 kg/yr) (Bachmann 1980) in this manner (Table 6).

Vollenweider (1968) established criteria for calculating the phosphorus load below which no productivity problems were expected (permissible load) and above which productivity problems were almost certain to persist (critical load). These loading limits are also based on the hydraulic properties of the pond which were calculated from the hydrologic budget. The modeling results indicate that the existing conditions for phosphorus in Walker Pond exceed the permissible load and critical load. The average of phosphorus loads estimated for the pond through the in-pond models (19 kg/yr) is greater than the permissible level of 9 kg/yr and the critical level of 18 kg/yr. However, the closeness of the average estimated load to the critical load indicates that a small reduction in phosphorus could result in a large improvement in water clarity.

Similar loading limits for nitrogen have not been established, owing to the less predictable relationship between nitrogen, pond hydrology, and primary productivity. Although nitrogen data are very useful in understanding in-pond conditions and processes, phosphorus is the logical target of management actions aimed at maintaining water quality conditions in Walker Pond.

Table 6. Summary of Walker Pond Nutrient Loading Models

Nutrient	Model Output	Value
Phosphorus	Minimum Load	13 kg/yr
	Model Average Load	19 kg/yr
	Permissible Load	9 kg/yr
	Critical Load	18 kg/yr
Nitrogen	Minimum Load	285 kg/yr
	Bachmann (1980) Load	340 kg/yr

The land use based model developed for the Walker Pond watershed included the area immediately surrounding Walker Pond (Table 7, Figure 4). This modeling demonstrates that the majority of phosphorus and nitrogen entering the pond originates from developed land (largely residential).

Table 7. Average Annual Nutrient Load by Land Use within the Walker Pond Watershed*

Land Use Classification	Acres	Percentage of Phosphorus Load	Percentage of Nitrogen Load
Cropland and Pasture	—	0%	0%
Currently Developed (Residential/Commercial)	82.2	93%	64%
Forest	64.6	5%	30%
Open/Cleared Land	—	0%	0%
Transportation	0.2	0%	0%
Water	6.0	0%	0%
Wetland	13.1	1%	6%

**Export coefficients based on median value predicted by Reckhow et al. (1980), Lin (2004), and Rast and Lee (1978)*

The nutrient model results guided the management recommendations to focus on watershed-wide techniques as opposed to in-pond techniques. The modeling results demonstrate that even a small reduction in phosphorus load to Walker Pond would significantly reduce water quality issues. Therefore, the construction of stormwater best management practices (BMPs) throughout the watershed, development of vegetated buffers, or the implementation other phosphorus-load reducing techniques within the watershed are likely to effective. This does not mean that pursuit of in-lake management actions is not advisable, but they are unlikely to translate into any significant changes to the in-pond conditions.

7.0 MANAGEMENT RECOMMENDATIONS

Walker Pond is impaired by poor water quality and nuisance aquatic plant growth, which limit recreational use such as boating and fishing. The following sections address management options that the Town can take to improve water quality and reduce nuisance plant growth.

7.1 Water Quality

Nutrient loading analysis indicates phosphorus is the limiting nutrient in Walker Pond. Phosphorus is the limiting nutrient in most Massachusetts freshwater systems; adding additional phosphorus directly contributes to algal growth, increased sedimentation and eventually to excessive aquatic weed growth as the pond becomes shallower. The current phosphorus load to Walker Pond is far beyond the critical level, suggesting that it will continue to eutrophy under current conditions. The sampling results indicate that high levels of phosphorus originating from the watershed are being delivered through stormwater runoff during rain events. Steps that the Town can take to reduce nutrient loading and improve water quality in Walker Pond are detailed in the subsections below.

7.1.1 Resident Education

Although not likely to make a significant improvement in water quality on its own, an education program can increase awareness of easy, low cost actions that residents can take to improve pond water quality by reducing nutrient runoff from their property. These actions include minimizing the impact of yard care (particularly fertilization), managing pet waste, developing rain gardens, and maintaining or planting buffers at the pond margins. A brochure to raise awareness among residents could be made available at the Needham Town Hall and/or distributed to watershed residents at minimal cost by mailing out with regular Town correspondence (e.g., water bills). The cost for the resident education program depends on the programs undertaken, but will likely cost less than $3,000.

7.1.2 Stormwater Infrastructure

The Town can also help maintain water quality by committing to proper maintenance of stormwater infrastructure including catch basin cleaning, street vacuuming, and installation of modern BMPs. Modern BMPs include grassed swales, bio-infiltration designs, and created wetland systems for management runoff or peak runoff. The addition of stormwater detention and infiltration facilities at key runoff locations could greatly reduce phosphorus loading.

Additionally, the Town should ensure that further development and redevelopment within the watershed incorporates low impact development (LID) stormwater techniques to prevent additional deterioration. LID features include rain gardens and detention ponds. A study to identify sites that may be superior candidates for retrofitting with LID or other infiltrative stormwater management techniques would be expected to cost roughly $15,000 to $20,000.

7.1.3 Phosphorus Binding

Nutrient inactivation involves the addition of alum (aluminum sulfate) to surface water or sediment, with the intention of binding available phosphorus, thereby effectively "inactivating" it. Alternatives to alum, such as polyaluminum chloride, various ferric compounds, and a lanthanum-based proprietary agent called Phoslock are also available on the market. During treatment, bound phosphorus precipitates out of solution and settles into sediments, where it remains unavailable for biological activity. Inactivation agent that does not immediately bind with available phosphorus settles into the sediments, helping to capture additional phosphorus that may be released from sediments over time.

An in-pond low-dose alum treatment could be applied as needed to prevent or control an incipient algae bloom. This approach is the most appropriate for addressing occasional algae blooms and, due to the low dosage applied, can be implemented with minimal risk of undesired impact. Although low-dose alum treatments carry a higher cost than algaecide treatments, they provide an added benefit of removing phosphorus from the water column and may provide control over a longer period than algaecides. Algaecides target the algae, while alum targets the cause of the excessive algae. Low-dose alum treatments should be preceded, accompanied and followed by sampling of the water body targeted for treatment. Sampling should minimally include analysis of dissolved phosphorus, aluminum, pH, and alkalinity and the locations sampled should be representative of all areas to be treated.

Costs for treatment vary significantly depending on the type of inactivation agent used, the necessary dosage of the selected agent, and commodity prices at the time. Tributary dosing stations must be resupplied with the treatment agent as supplies are exhausted and may also require additional engineering design and permitting prior to implementation.

Phosphorus binding compounds can effectively reduce plant and algal growth. However, phosphorus binding compounds will only be effective for a short period of time if watershed sources of phosphorus continue to enter the lake. Treatment is relatively expensive if the effects are only expected to last a few years. In contrast, if watershed sources of phosphorus are greatly reduced, phosphorus binding could effectively reduce algal growth for one to two decades. Phosphorus binding treatment is more cost effective if the effects are expected to last over a longer timescale.

Nutrient inactivation requires an Order of Conditions issued under the Wetlands Protection Act. Therefore, a Notice of Intent (NOI) must be filed with the Needham Conservation Commission. In addition, the applicator must possess a Commercial Applicator License.

7.1.4 Algaecides

To our knowledge, algal blooms have not been problematic at Walker Pond, although this pond provides ideal conditions to support a bloom. Algal blooms can be associated with aquatic vegetation control due to the reduced competition for light in managed areas. Registered algaecides are primarily copper-based and result in almost immediate control of a broad spectrum of planktonic and filamentous algae. Algaecide treatments can be expected to cost on the order of \$250 to \$500/acre for most formulations, although some specialty formulations may exceed this cost.

Algaecides would only be recommended if algal growth were to reach nuisance levels. Algaecide application requires an Order of Conditions issued under the Wetlands Protection Act. Therefore, a NOI must be filed with the Needham Conservation Commission. In addition, the applicator must possess a

Commercial Applicator License and obtain a water body-specific “license to apply herbicides” prior to treatment.

7.1.5 Septic System

The town of Needham has sanitary sewer lines installed within much of the watershed of Walker Pond; however, these lines do not service many of the homes along Walker Lane. The Walker Lane homes are on septic systems, many of which are located within 100 feet of the shoreline of Walker Pond. If these were well maintained and functioning systems, this would not necessarily be problematic as much of the phosphorus generated from a wastewater system is adsorbed to soil as the water moves through the ground.

Failed piece of 4-inch Orangeburg pipe removed from septic system on Walker Lane. (Photo: T. Achituv)

ESS has learned that most of these systems were installed over 50 years ago using piping known as Orangeburg pipe. Orangeburg was lightweight soft pipe made of bitumenized fiber layers of wood pulp and pitch pressed together. Orangeburg was a low cost alternative to metal for sewer lines and was later replaced by PVC or other economical plastic materials. Lack of strength causes pipes made of Orangeburg to fail more frequently than pipes made with other materials. The useful life for an Orangeburg pipe is about 50 years under ideal conditions, but has been known to fail in as little as 10 years. Orangeburg pipe is not a currently acceptable material for construction of drainage lines in Needham.

Failing septic systems and drainage lines provide a significant conduit for nutrients and other pollutants to move from the septic system through the ground and into the pond. Obviously, repairing a failing system with breakouts is critical, but the underlying problem of the use of Orangburg pipe for most of the homes along Walker Lane and the lack of a municipal sanitary sewer line along this road is likely to result in future failures and impacts to Walker Pond. Extending the sewer line beyond 67 Walker Lane to the other homes along Walker Lane would be beneficial to the water quality in Walker Pond given the anticipated future failures of Orangeburg pipe. At a cost of approximately $100 per foot to extend this sewer line, the anticipated costs would be on the order of $100,000.

7.2 Aquatic Vegetation

The surface of Walker Pond is covered with nuisance levels of native watermeal and duckweed. The bottom of Walker Pond is covered with nuisance levels of native coontail. Dense growths of coontail can outcompete native underwater vegetation, leading to loss of biodiversity. Exotic purple loosestrife was also observed along the shoreline of the pond. Options to control plant growth include the use of herbicides, macrophyte harvesting, water level control (drawdown), and dredging.

7.2.1 Herbicides

Herbicide treatment is usually the most cost-effective means by which to rapidly achieve the goal of reducing aquatic biomass over a large area. Herbicides may also be used over the long-term as part of a comprehensive management plan to treat areas of recurring infestations that are not readily controllable through other means. Over time, as control of the target species is achieved, management may be re-focused on other non-chemical methods, if desired.

The five herbicide options with potential to be useful for aquatic plant control at Walker Pond are fluridone, 2,4-D, imazamox, diquat dibromide, and flumioxazin. Each herbicide is detailed in the sections below.

Fluridone – Systemic Herbicide

Fluridone (tradename Sonar) is a systemic herbicide that reduces photosynthesis in affected plants, leading to the eventual starvation of the entire plant. Fluridone is a systemic herbicide that effective on coontail. Fluridone may be applied as a liquid formulation or as a slow-release pellet formulation.

The primary advantages of fluridone include the following:

- As a systemic herbicide that kills the plants and roots, fluridone may result in multiple seasons of control for some species of plants.
- Due to the slow action of this herbicide, plant dieback is gradual and dissolved oxygen sags and subsequent algal blooms are rarely problematic.
- Label restrictions are minimal.

The primary limitations of fluridone include the following:

- Concentrations must be maintained at treatment levels for as long as 90 days to achieve effective treatment. This can be difficult in water bodies with rapid flushing rates, although use of granular formulations or advanced liquid formulations (e.g., Sonar Genesis) may significantly improve treatment success.
- Coontail does not rely on roots and therefore there may not be a multi-year benefit to its use

Fluridone is one of the more expensive herbicides on the market and treatments typically cost $800 to more than $1,000/acre, depending on the formulation used and the need for “booster” treatments to maintain the concentration of the herbicide at an effective level over the treatment period. ESS does not recommend the use of fluridone for Walker Pond as there are other herbicide options that are superior.

2,4-D – Systemic Herbicide

2,4-D is a systemic herbicide that prevents affected plants from being able generate new tissue, resulting in eventual death of the plant. This herbicide is effective coontail, and to a lesser degree watermeal and duckweed. Various formulations of 2,4-D are approved for aquatic use under multiple tradenames (e.g., Navigate) in Massachusetts.

The primary advantages of 2,4-D include the following:

- As a systemic herbicide, 2,4-D may result in multiple seasons of control.
- 2,4-D is selective for dicots, which means that it is effective on coontail while having less impact or no impact on desirable plant species such as native pondweeds.
- The required contact time for 2,4-D is significantly less than fluridone. Therefore, it may be easier to achieve effective control of target species in waterbodies with high flushing rates.

The primary limitations of 2,4-D include the following:

- The potential for migration through soils means 2,4-D cannot be used in Interim or Zone II Wellhead Protection Areas without significant additional hydrologic or hydrogeologic assessments. Additionally, setbacks from private wells are required to minimize the potential for 2,4-D treated water to be drawn into these wells. Setbacks vary from 25 to 200 feet, depending on geology.

- The coontail, watermeal and duckweed would not be impacted for multi-year control as these are not rooted plants.

2,4-D may be potentially useful for control of coontail and the duckweed and watermeal. 2,4-D has been on the market for decades and is one of the most cost-effective systemic herbicides available. It typically costs $450 to $500/acre to apply, not inclusive of any required monitoring. Given the potential for this herbicide to impact groundwater and the expected single-season effect of a treatment, ESS does not recommend 2,4-D over other herbicide options.

<u>Flumioxazin – Contact Herbicide</u>

Flumioxazin (trade name Clipper) works by inhibiting protoporphyrinogen oxidase (PPO), an enzyme necessary for photosynthesis. Inhibition of PPO causes destruction of plant cell plasma membranes in the presence of sunlight, resulting in rapid dieback of plant tissues.

The primary advantages of flumioxazin include the following:

- Flumioxazin a contact herbicide that provides rapid control coontail and will also inhibit growth of duckweed and watermeal.
- Minimal contact time is required for flumioxazin to be effective.

The primary limitations of flumioxazin include the following:

- As a contact herbicide, flumioxazin only kills the exposed parts of the plant (leaves and stem). Long-term control requires consistent reapplication to the same beds over several years.
- Because flumioxazin requires sunlight to work, it is less effective once a significant vegetative canopy has developed in the water column, due to the shading that develops. This may be an issue with the dense coontail growth in Walker Pond which underlies the duckweed and watermeal which also have a shading effect.
- Flumioxazin degrades rapidly in water, so it may result in poor control if not precisely applied to the targeted beds.
- Application is limited to no more than one-quarter of the total lake area for waterbodies in Massachusetts. Additionally, the treatment cannot be reapplied to the same area for at least three consecutive years. This is required to protect non-target species populations and prevent the development of resistant plant populations.

The cost of flumioxazin is significantly higher than most other contact herbicides, ranging up to $1,000/acre for treatment. Treatment costs can sometimes be reduced if flumioxazin is used in combination with diquat. Given the limitations placed on this herbicide for partial pond treatments and the need to control coontail throughout the entire pond, this herbicide is not ideal for Walker Pond at this time.

Diquat Dibromide – Contact Herbicide

Diquat dibromide, also known as diquat or by its tradename Reward, works quickly by interrupting the photosynthetic process, resulting in the dieback of leaf and stem cells. It offers immediate control of coontail and has shown to be somewhat effective at controlling duckweed and watermeal at higher doses.

The primary advantages of diquat include the following:

- Provides rapid control of targeted plant.
- Minimal contact time is required for diquat to be effective.

The primary limitations of diquat include the following:

- Diquat is not effective against all species.
- As a contact herbicide, diquat only kills the exposed parts of the plant (leaves and stem). The roots and crowns typically survive and put out another flush of growth in the following year (or even later in the same season). Long-term control requires consistent reapplication over several years.
- Application should be limited to no more than one-half of total pond area per label restrictions. This is required to prevent impacts to aquatic life due to rapid dieback of treated plants, which could result in temporary reductions in dissolved oxygen levels.

Diquat may be useful for control of coontail and to a lesser degree the watermeal and duckweed. Diquat is one of the least expensive herbicides on the market on a per-treatment basis. Treatments typically cost between $200 and $250/acre, therefore an annual cost of $2,000 to $2,500 (including mobilization costs) for Walker Pond should be anticipated. ESS does recommend the use of diquat as an herbicide alternative for managing excess weed growth in Walker Pond.

Permitting

Herbicide application requires an Order of Conditions issued under the Wetlands Protection Act. Therefore, a Notice of Intent (NOI) must be filed with the Needham Conservation Commission.

The applicator must possess a Commercial Applicator License and obtain a water body-specific License to Apply Herbicides prior to treatment.

7.2.2 Macrophyte Harvesting

Macrophyte harvesting covers a wide range of techniques, including mechanical harvesting, hand harvesting (often conducted by divers), and diver assisted suction harvesting (DASH). Of these, ESS recommends hand harvesting and DASH as precision techniques that can provide effective control over small areas. Mechanical harvesting is not recommended given the shallow depths of the pond. The two recommended techniques are discussed further below.

Mechanical Harvesting

Hydroraking uses a backhoe-like machine mounted on a barge to remove plants directly from pond sediments. Depending on the attachment used, plants are scooped, scraped, or raked from the bottom and deposited on shore for disposal. Rotovation is essentially underwater rototilling of pond sediments. Rotating blades cut through roots, shoots, and tubers, dislodging and expelling them from their growing locations. Some operations are also outfitted to collect some or most of the rotovated plant materials. Both hydroraking and rotovation are most useful for local control of water lilies and other plants with large rhizomes or tubers, as these methods can physically remove or destroy the bulky portions of the plant.

Hydroraking is not recommended for control of vegetatively reproducing species such as coontail. Costs to perform hydroraking vary from $6,000 to more than $12,000 per acre, if performed by a contractor. Given the presence of coontail, lack of nuisance lilies, and high cost of implementation, ESS does not recommend hydroraking as a management technique at Walker Pond.

Hand Harvesting

The simplest form of harvesting is hand pulling of selected plants. Depending on the depth of the water at the targeted site, hand harvesting may involve wading, snorkeling, or SCUBA diving. Pulled plants and fragments are placed in a mesh bag or container that allows for transport and disposal of the vegetation. Hand harvesting of submerged vegetation aims to remove entire plants, including the roots, thereby preventing re-growth in subsequent seasons. In practice, it is difficult to achieve 100 percent removal, except where beds are isolated or represent pioneer infestations. Where hand harvesting is used to control established weed beds, some re-growth should be expected in subsequent seasons. With diligence, control may be achieved after a few consecutive seasons of hand harvesting.

At Walker Pond, hand harvesting could be used to provide precision control of coontail around key access points, fishing areas, and the outlet. Hand harvesting of submerged aquatic plants can be conducted on smaller scales (up to a few hundred square feet) by trained homeowners and volunteers. Larger scale work is a major effort that may span weeks and is usually conducted by professionals. Costs for hand harvesting vary with bed density and expertise of the staff conducting the operation, but typically range from $2,500 per acre for lighter infestations to more than $4,000 per acre for very dense beds.

Due to the dense aquatic plant growths present throughout the entirety of Walker Pond, ESS would not recommend moving forward with an aquatic vegetation hand harvesting program at this time. However, hand harvesting is recommended to control purple loosestrife along the shoreline of Walker Pond because it is currently isolated to a small area. Hand harvesting may be useful in the future if aquatic plant densities can be reduced by other means (including chemical treatment and/or DASH harvesting) to the point where hand harvesting can be efficiently employed.

DASH

DASH is similar to hand harvesting but more efficient because entire plants are fed into a suction hose and lifted to a collection vessel at the surface, thereby significantly reducing the time it takes for the diver to handle and return plants to the surface. DASH can also reduce the potential for release of plant fragments.

At Walker Pond, DASH could be used to provide precision control of coontail as a non-herbicide alternative to clear target management areas up to a few acres in size. As with hand harvesting, DASH is unlikely to result in full control after a single harvesting event.

DASH costs approximately $3,000 to $6,000 per acre. The approximate cost for implementing this technique throughout the entire pond would be approximately $18,000 to $36,000. However, DASH costs within a targeted area would be expected to decline over time, as control is achieved.

Due to the higher annual costs of DASH harvesting over chemical treatment, ESS would not recommend this technique unless the Town would prefer a non-chemical approach to aquatic plant management.

7.2.3 Water Level Control (Drawdown)

Drawdown involves lowering the water level of a pond to expose shallow bottom sediments and associated plants (both native and non-native) to drying and/or freezing. It is most effective against species that reproduce by vegetative means, including coontail.

Ponds with rapid drop-offs to great depths tend to benefit most from drawdown. Due to the shallow bathymetry of Walker Pond, drawdown is only likely to provide limited control of aquatic invasive plant growth. Although drawdown can be conducted at any time, the interaction of drying and freezing that occurs with winter drawdown is usually most effective. Environmental restrictions and recreational use also limit the appropriate window for drawdown to the winter period. In Massachusetts, winters are often variable in their intensity and the ideal winter condition of very cold weather with limited snow cover is not likely to be achieved more frequently than every other year.

Drawdown could be achieved by removing boards at the outlet to the pond. However, due to the shallow nature of the pond (maximum depth 4 feet), aquatic animals, including fish and benthic invertebrates, may not be able to successfully overwinter in the reduced water depth. Furthermore, care would have to be taken to ensure that large amounts of sediment are not released into the outlet while the water level is being lowered.

Drawdown requires an Order of Conditions issued under the Wetlands Protection Act. Therefore, a NOI must be filed with the Needham Conservation Commission. ESS does not recommend drawdown as a management technique for improving Walker Pond as the approach would be detrimental to fish and wildlife while only being minimally beneficial towards controlling nuisance weed growth.

7.2.4 Dredging

Dredging works as a plant control technique when either a light limitation is imposed through increased water depth or when enough soft sediment is removed to reveal a less hospitable substrate for plant growth (e.g. hard bottom or other nutrient-poor substrate). Light limitation through increased depth is possible in Walker Pond, particularly since water clarity is already relatively poor.

Dredging in Walker Pond could be an effective long-term control technique for some nuisance aquatic plants within the targeted management area, but will be costly. Dredging would not be entirely effective at controlling coontail, watermeal, or duckweed as these plants are not rooted. Dredging would remove the accumulated sediment and nutrients that contribute to the nuisance weed growth in the pond.

The key factor influencing the approach and costs for moving forward with a dredge program at Walker Pond will be the ability to draw down the pond to allow for dredging within the drained basin to occur using conventional excavation equipment. This is most likely an environmentally sound and feasible approach if conducted during the winter months when wetland areas associated with the pond would be dormant. This approach would allow for sediment to be dewatered within the basin itself by pulling the sediment up to the margins of the pond to allow water to drain back into the main portion of the basin.

If conventional "dry" dredging is not determined to be feasible for Walker Pond due to equipment access issues or water management concerns, hydraulic dredging would be a viable alternative. Hydraulic dredging is generally more expensive than conventional dredging for limited projects and it would require a larger and more sophisticated containment area to dewater the sediment as it is removed from the pond.

Alternatively, advanced dewatering techniques such as the use of Geotubes (geotextile fabric for dewatering) or a belt-filter press machine could be used instead but these would add additional costs over traditional dewatering containment. All of these external sediment dewatering options will require land adjacent to the pond to be made available for the dewatering process. The Town's public access lot may be adequate space for the use of a belt-filter press machine, but a larger area (such as the ball field) would be required for either the use of the Geotubes (>1.0 acres) or a standard dewatering basin (> 2 acre).

The amount of material to be removed and the type of disposal or reuse will also have a significant impact on the cost of dredging. Environmental permitting for dredging projects is moderately complex and will require up to a year before the project could receive all required approvals. Federal (U.S. Army Corps of Engineers 404), state (Massachusetts Environmental Protection Act Certificate and 401 Water Quality Certificate), and local permits (Notice of Intent filed for Order of Conditions from the Department of Natural Resources) are all required, and would necessitate considerable advance information and review time.

With an estimated soft sediment volume of approximately 25,000 cubic yards in Walker Pond, the cost of a dry or hydraulic dredging project for the entire pond would likely run between $600,000 and $1,000,000 (including permitting and design) for removal of all of the soft sediments, although not all sediments would necessarily need to be removed to achieve light limitation throughout the pond. Costs could increase if sediment cannot be reused or disposed of in the immediate vicinity of the pond.

Chemical content of the material to be dredged is an important consideration in determining the feasibility of reuse or disposal. Disposal costs could vary greatly depending on whether the material can be beneficially reused. If the material removed from the pond is clean, it is useful as a soil amendment. It is possible that the material may potentially be sold to local garden suppliers or landscape businesses which would make the project more economically feasible. However, material that is not suitable for beneficial use would need to either be amended with clean material (potentially from within the basin) to dilute the concentrations to suitable levels or trucked to a site for disposal. Either of these options would increase the cost of the project and, depending upon the level of implementation, could potentially make dredging a less cost-effective option.

If dredging is considered to be a viable long-term option, the next steps would be:

1. Assessment of specific scope and extent of dredge program including possible funding options.

2. Additional chemical and physical analysis of the sediments in areas targeted for dredging. One core will need to be collected specifically from the target dredge area for each 1,000 cubic yards of sediment proposed to be dredged.

3. Development of an engineering design for submission to permitting authorities.

4. Initiation of the permitting process including an Environmental Notification Form filing for MEPA (Massachusetts Environmental Policy Act) review, filing a local Notice of Intent under the Wetlands Protection Act, filing for a Section 401 Water Quality Certificate from MassDEP, and seeking a U.S. Army Corps of Engineers Section 404 Permit for dredging.

These four activities might be expected to cost up to $50,000 for Walker Pond, but are essential if dredging is to be pursued as a management option. Additional design costs would include final engineering design following the permitting process (incorporating any accepted changes resulting from these reviews) along with the development of a bid specification package for the project.

Assuming the estimated sediment accumulation rate of 10 to 20 cy/year and a dredge volume of 25,000 cubic yards in the targeted management area, refill could be expected to take several hundred years. Using a conservative estimate of a 100-year project lifespan, the annualized dredging cost of a conventional dredging project would be $6,000 to $10,000 per year. This estimate is based entirely on measured TSS load and could be higher or lower depending on pond circulation patterns, in-pond algae and macrophyte production, and the occurrence of catastrophic weather events.

8.0 SUMMARY OF MANAGEMENT RECOMMENDATIONS

Although Walker Pond is not a large recreational waterbody within the Town of Needham, it has the potential to support boating and fishing as well as skating in the winter months. These recreational endeavors were historically afforded by the pond, but due to nutrient and sediment loading from the pond's watershed, the waterbody has significantly deteriorated in recent years.

There are a range of options available for improving the pond. The simplest, most economical and quickest option would be to control excessive weed growth with herbicides. ESS does recommend the application of the contact herbicide diquat as one approach to alleviate the weed problems in the pond. Costs for this would be on the order of $2,500 per year and would need to occur indefinitely.

ESS also recommends improving the incoming water quality by making improvements to the stormwater management system within the watershed. Next steps in this regard would be to conduct a study of the watershed ($20,000) to identify suitable locations for infiltrating runoff efficiently. Additionally, educating watershed residents on proper land stewardship with a targeted brochure would be beneficial, to a limited degree, at a cost of about $3,000.

ESS recommends that the Town consider extending the sewer line along Walker Lane to capture sewage effluent from systems that are currently or will inevitably fail over the coming years due to failure of construction materials such as Orangeburg pipe. Costs for this are estimated to be on the order of $100,000, exclusive of design and permitting.

Finally, ESS does recommend that the Town consider dredging as a longer-term solution that can rectify the weed growth and reset the pond. Dredging alone will not improve the quality of the water entering the pond, but it will deepen the pond, remove accumulated organic sediment and nutrients, and if dredged to sufficient depth, would preclude the growth of rooted plants. Although the costs to dredge Walker Pond could approach $1 million, the project would be expected to benefit the pond for more than 100 years. Next steps in this regard would be to determine the potential for funding a project of this magnitude within Town and to undertake the necessary design and permitting for the project.

9.0 REFERENCES

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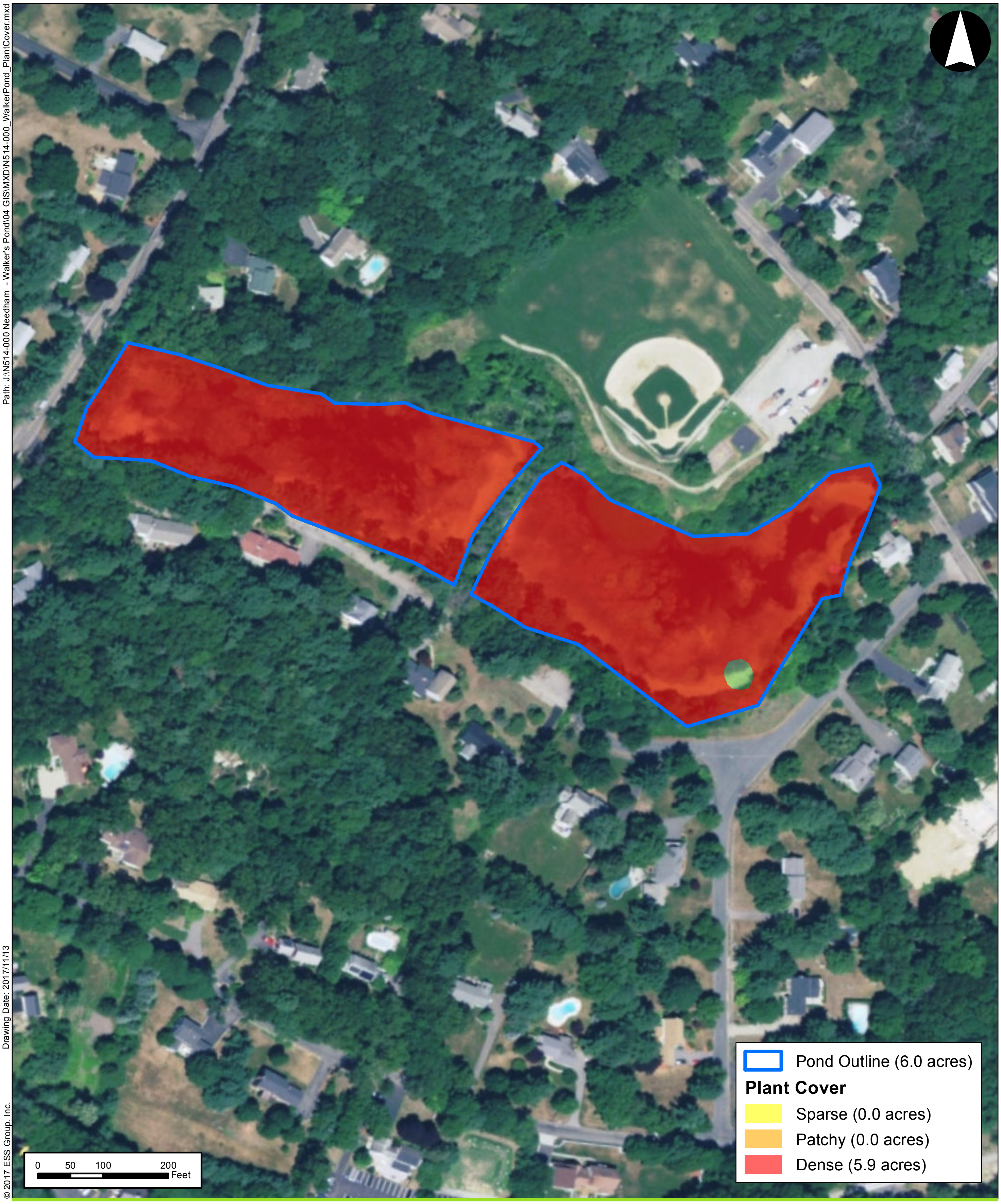
Vollenweider, R.A. 1975. Input-output models with special references to the phosphorus loading concept in limnology. Schweizerische Zeitschrift für Hydrologie 37:53-62.

Figures



Path: J:\N514-000 Needham - Walker's Pond\04 GIS\MXD\N514-000_WalkerPond_PlantCover.mxd

Drawing Date: 2017/11/13

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ESS group
environmental consulting
& engineering services

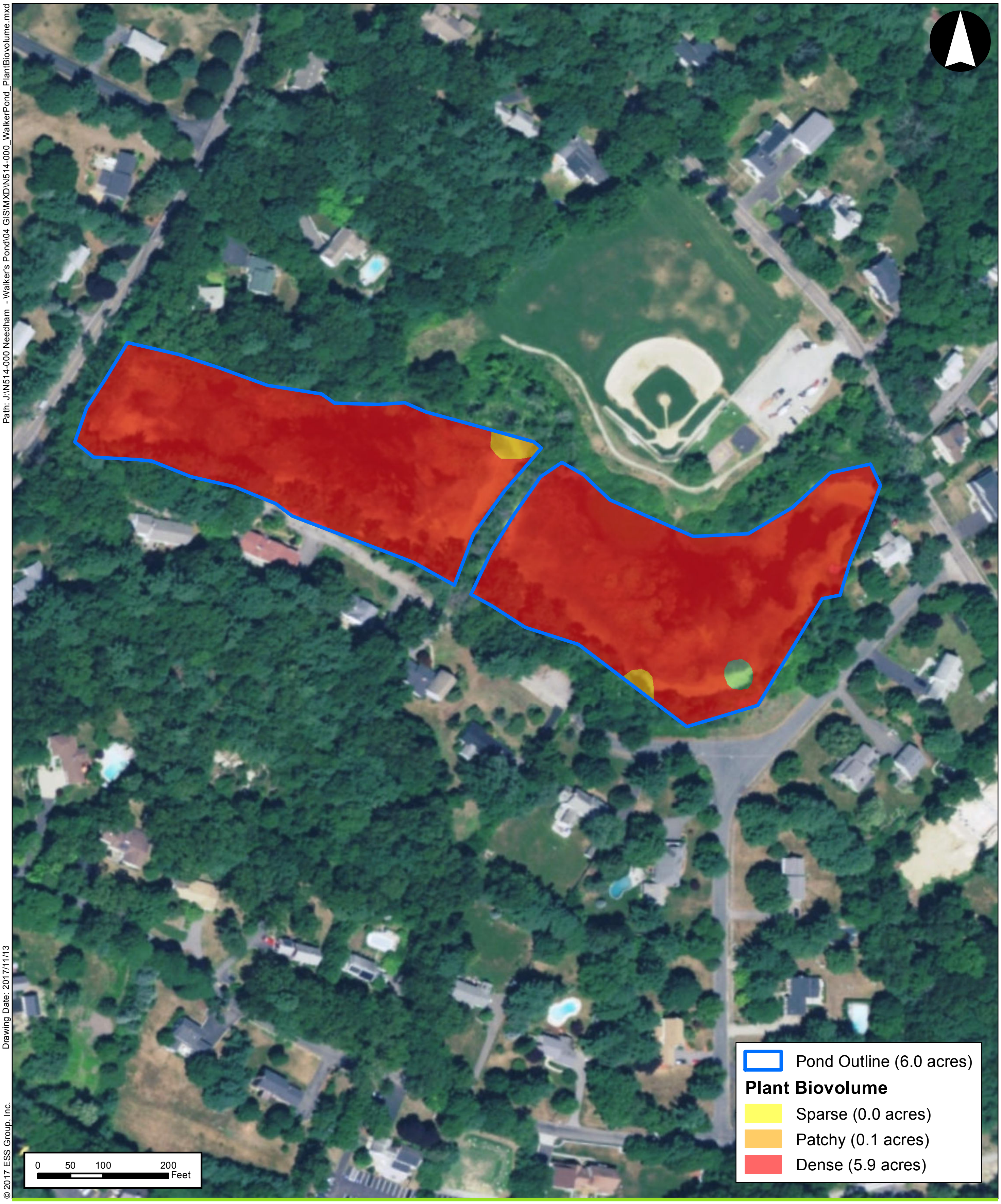
Walker Pond
Needham, Massachusetts

1 inch = 200 feet

Source: 1) MassGIS, Half-Meter Resolution, 2001
2) ESS, GPS Locations, 2017

Plant Cover

Figure 1



Path: J:\N514-000 Needham - Walker's Pond\04 GIS\MXD\N514-000_WalkerPond_PlantBiovolume.mxd

Drawing Date: 2017/11/13

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environmental consulting & engineering services

Walker Pond

Needham, Massachusetts

1 inch = 200 feet

Source: 1) MassGIS, Half-Meter Resolution, 2001
2) ESS, GPS Locations, 2017

Plant Biovolume

Figure 2

Path: J:\N514-000 Needham - Walker's Pond\04 GIS\MXD\N514-000_WalkerPond_Bathy.mxd

Drawing Date: 2017/11/13

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Walker Pond
Needham, Massachusetts

1 inch = 200 feet

Source: 1) MassGIS, Half-Meter Resolution, 2001
2) ESS, GPS Locations, 2017

Pond Outline (6.0 acres)
1ft Contours

Bathymetry

Figure 3

Path: J:\N514-000 Needham - Walker's Pond\04 GIS\MXD\N514-000_WalkerPond_LandUse.mxd

Drawing Date: 2017/11/14

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Walker Pond
Needham, Massachusetts

DRAFT

1 inch = 500 feet

Source: 1) USDA, NAIP Imagery, 2016
2) ESS, GPS Locations, 2017
3) MassGIS, Land Use, 2005

Land Use

Figure 4

Appendix A

Water Quality Laboratory Reports

www.essgroup.com

Monday, September 11, 2017

Attn: Mr Matt Ladewig
ESS Group Inc.
10 Hemingway Drive 2nd Floor
Riverside, RI 02915-2224

Project ID: WALKERS POND
Sample ID#s: BY94224 - BY94225

This laboratory is in compliance with the NELAC requirements of procedures used except where indicated.

This report contains results for the parameters tested, under the sampling conditions described on the Chain Of Custody, as received by the laboratory. This report is incomplete unless all pages indicated in the pagination at the bottom of the page are included.

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

A scanned version of the COC form accompanies the analytical report and is an exact duplicate of the original.

If you have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext. 200.

Sincerely yours,

Phyllis Shiller

Phyllis Shiller
Laboratory Director

NELAC - #NY11301
CT Lab Registration #PH-0618
MA Lab Registration #M-CT007
ME Lab Registration #CT-007
NH Lab Registration #213693-A,B
NJ Lab Registration #CT-003
NY Lab Registration #11301
PA Lab Registration #68-03530
RI Lab Registration #63
VT Lab Registration #VT11301

Environmental Laboratories, Inc.

587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 11, 2017

FOR: Attn: Mr Matt Ladewig
ESS Group Inc.
10 Hemingway Drive 2nd Floor
Riverside, RI 02915-2224

Sample Information		Custody Information		Date	Time
Matrix:	SURFACE WATER	Collected by:		08/31/17	13:05
Location Code:	ESSGRPRI	Received by:	SW	09/01/17	15:20
Rush Request:	Standard	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GBY94224
Phoenix ID: BY94224

Project ID: WALKERS POND
Client ID: DEEP HOLE

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Phosphorus, Dissolved as P Low Level	0.025	0.003	mg/L	0.5	09/07/17	JR	SM4500PE-99
Nitrate-N	< 0.02	0.02	mg/L	1	09/01/17 18:58	MI	E353.2
Nitrogen Tot Kjeldahl	0.89	0.10	mg/L	1	09/07/17	WHM	E351.1
Phosphorus, as P	0.042	0.003	mg/L	0.5	09/07/17	JR	SM4500PE-99
Total Suspended Solids	< 5.0	5.0	mg/L	1	09/06/17	KH	SM2540D-97,-11

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

Dissolved-Phosphate was not field filtered within 15 minutes of collection.

If there are any questions regarding this data, please call Phoenix Client Services.
This report must not be reproduced except in full as defined by the attached chain of custody.

Phyllis Shiller, Laboratory Director
September 11, 2017
Reviewed and Released by: Bobbi Aloisa, Vice President

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

September 11, 2017

FOR: Attn: Mr Matt Ladewig
ESS Group Inc.
10 Hemingway Drive 2nd Floor
Riverside, RI 02915-2224

Sample Information		Custody Information		Date	Time
Matrix:	SEDIMENT	Collected by:		08/31/17	14:30
Location Code:	ESSGRPRI	Received by:	SW	09/01/17	15:20
Rush Request:	Standard	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GBY94224
Phoenix ID: BY94225

Project ID: WALKERS POND
Client ID: DEEP HOLE

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Total Solids @ 104C	8.34	0.1	%	1	09/06/17	KH	SM2540B-97
Phosphorus, Total	545	6.0	mg/Kg	1	09/07/17	JR	SM4500PE-99

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

All soils, solids and sludges are reported on a dry weight basis unless otherwise noted in the sample comments.

If there are any questions regarding this data, please call Phoenix Client Services.
This report must not be reproduced except in full as defined by the attached chain of custody.

Phyllis Shiller, Laboratory Director
September 11, 2017
Reviewed and Released by: Bobbi Aloisa, Vice President

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

QA/QC Report

September 11, 2017

QA/QC Data

SDG I.D.: GBY94224

Parameter	Blank	Blk RL	Sample Result	Dup Result	Dup RPD	LCS %	LCSD %	LCS RPD	MS %	MSD %	MS RPD	% Rec Limits	% RPD Limits
QA/QC Batch 400373 (mg/L), QC Sample No: BY93735 (BY94224)													
Total Suspended Solids	BRL	5.0	<5.0	<14	NC	95.0						85 - 115	
QA/QC Batch 400510 (mg/L), QC Sample No: BY93906 (BY94224)													
Phosphorus, as P	BRL	0.01	<0.010	<0.01	NC	103			112			85 - 115	20
Comment:													
Additional: LCS acceptance range is 85-115% MS acceptance range 75-125%.													
QA/QC Batch 400122 (mg/L), QC Sample No: BY94001 (BY94224)													
Nitrate-N	BRL	0.02	<0.02	<0.02	NC	99.6			101			90 - 110	20
QA/QC Batch 400542 (mg/Kg), QC Sample No: BY94225 (BY94225)													
Phosphorus, Total as P	BRL	0.50	545	545	0	112						75 - 125	30
Comment:													
Additional: LCS acceptance range is 85-115% MS acceptance range 75-125%.													
QA/QC Batch 400216 (), QC Sample No: BY94225 (BY94225)													
Total Solids	BRL	0.1	8.34	8.51	2.00	100						75 - 125	30
Comment:													
Additional: LCS acceptance range is 85-115% MS acceptance range 75-125%.													
QA/QC Batch 400486 (mg/L), QC Sample No: BY94306 (BY94224)													
Nitrogen Tot Kjeldahl	BRL	0.10	25.8	26.4	2.30	106			108			85 - 115	20

If there are any questions regarding this data, please call Phoenix Client Services at extension 200.

RPD - Relative Percent Difference
LCS - Laboratory Control Sample
LCSD - Laboratory Control Sample Duplicate
MS - Matrix Spike
MS Dup - Matrix Spike Duplicate
NC - No Criteria
Intf - Interference

Phyllis Shiller

Phyllis Shiller, Laboratory Director
September 11, 2017

Monday, September 11, 2017

Criteria: None

State: MA

Sample Criteria Exceedances Report

GBY94224 - ESSGRPRI

SampNo	Acode	Phoenix Analyte	Criteria	Result	RL	Criteria	RL Criteria	Analysis Units

*** No Data to Display ***

Phoenix Laboratories does not assume responsibility for the data contained in this report. It is provided as an additional tool to identify requested criteria exceedences. All efforts are made to ensure the accuracy of the data (obtained from appropriate agencies). A lack of exceedence information does not necessarily suggest conformance to the criteria. It is ultimately the site professional's responsibility to determine appropriate compliance.

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

NY # 11301

Analysis Comments

September 11, 2017 SDG I.D.: GBY94224

The following analysis comments are made regarding exceptions to criteria not already noted in the Analysis Report or QA/QC Report: None.

Cooler: Yes ☒ No ☐
Coolant: IPK ☒ ICE ☐ No ☐

PHOENIX Environmental Laboratories, Inc.

CHAIN OF CUSTODY RECORD

587 East Middle Turnpike, P.O. Box 370, Manchester, CT 06040
Email: info@phoenixlabs.com Fax (860) 645-0823
Client Services (860) 645-8726

Temp 2.1 °C Pg of

Data Delivery:
☐ Fax #:
☑ Email: mlydecis@essgroup.com, mmahoney@essgroup.com

Customer: ESS Group
Address: 10 Hemingway Drive, 2nd Floor, East Providence, RI 02915

Project: Walkers Pond, Needham, MA
Report to: Matt Ladewig
Invoice to: Barbara Cabral
Phone #: (401) 330-1244
Fax #:

Project P.O:

This section MUST be completed with Bottle Quantities.

Client Sample - Information - Identification

Sampler's Signature: [signature] Date: 8/31/17

Matrix Code:
DW=Drinking Water GW=Ground Water SW=Surface Water WW=Waste Water
RW=Raw Water SE=Sediment SL=Sludge S=Soil SD=Solid W=Wipe
OIL=Oil B=Bulk L=Liquid

Analysis Request

PHOENIX USE ONLY SAMPLE #	Customer Sample Identification	Sample Matrix	Date Sampled	Time Sampled	Total phosphorus	Dissolved phosphorus	Nitrate	TKN	TSS	Soil VOA Vials [ ] methanol [ ] H2O	GL Soil container ( ) oz ( ) oz	40 ml VOA Vial [ ] As is [ ] HCl	GL Amber 1000ml [ ] As is [ ] H2SO4	PL As is [✓] 250ml [ ] 500ml [ ] 1000ml	PL H2SO4 [X] 250ml [ ] 500ml	PL HNO3 250ml	PL NaOH 250ml	Bacteria (as is)	Bacteria (w/thio)
94224	Deep Hole	SW	8/31/17	1305	X	X	X	X	X					2	1				
94225	Deep Hole	SE	8/31/17	1430	X									1					

Relinquished by:	Accepted by:	Date:	Time:
[signature]	[signature]	9-1-17	9:35
[signature]	Krystal Bunce	9.1.17	16:20

Comments, Special Requirements or Regulations:
Note low detect on phosphorus - 0.01 mg/L or better. (surface water)

Turnaround:
☐ 1 Day*
☐ 2 Days*
☐ 3 Days*
☑ Standard
☐ Other
* SURCHARGE APPLIES

RI
☐ Direct Exposure (Residential)
☐ GW
☐ Other

CT
☐ RCP Cert
☐ GW Protection
☐ SW Protection
☐ GA Mobility
☐ GB Mobility
☐ Residential DEC
☐ I/C DEC
☐ Other

MA
☐ MCP Certification
☐ GW-1
☐ GW-2
☐ GW-3
☐ S-1
☐ S-2
☐ S-3
☐ MWRA eSMART
☐ Other

Data Format
☑ Excel
☑ PDF
☐ GIS/Key
☐ EQuIS
☐ Other

Data Package
☐ Tier II Checklist
☐ Full Data Package*
☐ Phoenix Std Report
☐ Other
* SURCHARGE APPLIES

State where samples were collected: MA

Monday, November 06, 2017

Attn: Mr Matt Ladewig
ESS Group Inc.
10 Hemingway Drive 2nd Floor
Riverside, RI 02915-2224

Project ID: NS14-000.01
Sample ID#s: BZ27251 - BZ27252

This laboratory is in compliance with the NELAC requirements of procedures used except where indicated.

This report contains results for the parameters tested, under the sampling conditions described on the Chain Of Custody, as received by the laboratory. This report is incomplete unless all pages indicated in the pagination at the bottom of the page are included.

A scanned version of the COC form accompanies the analytical report and is an exact duplicate of the original.

If you have any questions concerning this testing, please do not hesitate to contact Phoenix Client Services at ext. 200.

Sincerely yours,

Phyllis Shiller
Laboratory Director

NELAC - #NY11301
CT Lab Registration #PH-0618
MA Lab Registration #M-CT007
ME Lab Registration #CT-007
NH Lab Registration #213693-A,B
NJ Lab Registration #CT-003
NY Lab Registration #11301
PA Lab Registration #68-03530
RI Lab Registration #63
VT Lab Registration #VT11301

587 East Middle Turnpike, P.O. Box 370, Manchester, CT 06040
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Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

Analysis Report

November 06, 2017

FOR: Attn: Mr Matt Ladewig
ESS Group Inc.
10 Hemingway Drive 2nd Floor
Riverside, RI 02915-2224

Sample Information		Custody Information		Date	Time
Matrix:	SURFACE WATER	Collected by:	ML	10/25/17	9:45
Location Code:	ESSGRPRI	Received by:	B	10/25/17	17:00
Rush Request:	Standard	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GBZ27251
Phoenix ID: BZ27251

Project ID: NS14-000.01
Client ID: INLET

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Phosphorus, Dissolved as P Low Level	0.056	0.003	mg/L	0.5	11/01/17	JR	SM4500PE-99
Nitrate-N	< 0.02	0.02	mg/L	1	10/25/17 22:28	MI	E353.2
Nitrogen Tot Kjeldahl	0.68	0.10	mg/L	1	11/02/17	WHM	E351.1
Phosphorus, as P	0.139	0.003	mg/L	0.5	11/01/17	JR	SM4500PE-99
Total Suspended Solids	6.0	5.0	mg/L	1	10/27/17	KH	SM2540D-97,-11

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

Dissolved-Phosphate was not field filtered within 15 minutes of collection.

If there are any questions regarding this data, please call Phoenix Client Services.
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Phyllis Shiller, Laboratory Director
November 06, 2017
Reviewed and Released by: Bobbi Aloisa, Vice President

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Location Code:	ESSGRPRI	Received by:	B	10/25/17	17:00
Rush Request:	Standard	Analyzed by:	see "By" below		
P.O.#:					

Laboratory Data

SDG ID: GBZ27251
Phoenix ID: BZ27252

Project ID: NS14-000.01
Client ID: OUTLET

Parameter	Result	RL/ PQL	Units	Dilution	Date/Time	By	Reference
Phosphorus, Dissolved as P Low Level	0.038	0.003	mg/L	0.5	11/02/17	JR	SM4500PE-99
Nitrate-N	< 0.02	0.02	mg/L	1	10/25/17 22:29	MI	E353.2
Nitrogen Tot Kjeldahl	0.97	0.10	mg/L	1	11/03/17	WHM	E351.1
Phosphorus, as P	0.054	0.003	mg/L	0.5	11/02/17	JR	SM4500PE-99
Total Suspended Solids	< 5.0	5.0	mg/L	1	10/27/17	KH	SM2540D-97,-11

RL/PQL=Reporting/Practical Quantitation Level ND=Not Detected BRL=Below Reporting Level

Comments:

Dissolved-Phosphate was not field filtered within 15 minutes of collection.

If there are any questions regarding this data, please call Phoenix Client Services.
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Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 06, 2017
Reviewed and Released by: Bobbi Aloisa, Vice President

PHOENIX

Environmental Laboratories, Inc.
587 East Middle Turnpike, P.O.Box 370, Manchester, CT 06045
Tel. (860) 645-1102 Fax (860) 645-0823

QA/QC Report

November 06, 2017

QA/QC Data

SDG I.D.: GBZ27251

Parameter	Blank	Blk RL	Sample Result	Dup Result	Dup RPD	LCS %	LCSD %	LCS RPD	MS %	MSD %	MS RPD	% Rec Limits	% RPD Limits
QA/QC Batch 407352 (mg/L), QC Sample No: BZ26815 (BZ27251)													
Total Suspended Solids	BRL	5.0	62	63	1.60	98.0						85 - 115	
QA/QC Batch 407080 (mg/L), QC Sample No: BZ26824 (BZ27251, BZ27252)													
Nitrate-N	BRL	0.02	<0.02	<0.02	NC	102			97.5			90 - 110	20
QA/QC Batch 407995 (mg/L), QC Sample No: BZ27037 (BZ27251)													
Nitrogen Tot Kjeldahl	BRL	0.10	0.77	0.74	4.00	99.8			101			85 - 115	20
QA/QC Batch 407353 (mg/L), QC Sample No: BZ27037 (BZ27252)													
Total Suspended Solids	BRL	5.0	8.0	8.0	NC	94.0						85 - 115	
QA/QC Batch 407897 (mg/L), QC Sample No: BZ27038 (BZ27251)													
Phosphorus, as P	BRL	0.01	0.218	0.22	0.90	104			109			85 - 115	20
Comment:													
Additional: LCS acceptance range is 85-115% MS acceptance range 75-125%.													
QA/QC Batch 408030 (mg/L), QC Sample No: BZ27257 (BZ27252)													
Phosphorus, as P	BRL	0.01	2.50	2.48	0.80	98.3			96.6			85 - 115	20
Comment:													
Additional: LCS acceptance range is 85-115% MS acceptance range 75-125%.													
QA/QC Batch 408196 (mg/L), QC Sample No: BZ27287 (BZ27252)													
Nitrogen Tot Kjeldahl	BRL	0.10	0.63	0.63	0	109			104			85 - 115	20

If there are any questions regarding this data, please call Phoenix Client Services at extension 200.

RPD - Relative Percent Difference
LCS - Laboratory Control Sample
LCSD - Laboratory Control Sample Duplicate
MS - Matrix Spike
MS Dup - Matrix Spike Duplicate
NC - No Criteria
Intf - Interference

Phyllis Shiller

Phyllis Shiller, Laboratory Director
November 06, 2017

Sample Criteria Exceedances Report

GBZ27251 - ESSGRPRI

Criteria: None

State: MA

SampNo	Acode	Phoenix Analyte	Criteria	Result	RL	Criteria	RL Criteria	Analysis Units

*** No Data to Display ***

Phoenix Laboratories does not assume responsibility for the data contained in this report. It is provided as an additional tool to identify requested criteria exceedences. All efforts are made to ensure the accuracy of the data (obtained from appropriate agencies). A lack of exceedence information does not necessarily suggest conformance to the criteria. It is ultimately the site professional's responsibility to determine appropriate compliance.

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ACCREDITED IN ACCORDANCE WITH nelac NY # 11301

Analysis Comments

November 06, 2017 SDG I.D.: GBZ27251

The following analysis comments are made regarding exceptions to criteria not already noted in the Analysis Report or QA/QC Report: None.

Cooler: Yes [X] No [ ]
Coolant: IPK [/] ICE [X] No [ ]

CHAIN OF COUSTODY RECORD

PHOENIX
Environmental Laboratories, Inc.

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Email: info@phoenixlabs.com Fax (860) 645-0823
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Temp 3.2 C Pg of

Contact Options:
[ ] Fax:
[ ] Phone:
[X] Email: MLADEWIG@ESSGROUP.COM

Customer: ESS Group
Address: 10 Hemingway Drive, 2nd Floor
East Providence, RI 02915

Project: NS14-000.01
Report to: Matt Ladewig
Invoice to: Barbara Cabral

Project P.O:

This section MUST be completed with Bottle Quantities.

Client Sample - Information - Identification

Sampler's Signature: Melissa Lenker Date: 10/25/2017

Matrix Code:
DW=Drinking Water **GW**=Ground Water **SW**=Surface Water **WW**=Waste Water
RW=Raw Water **SE**=Sediment **SL**=Sludge **S**=Soil **SD**=Solid **W**=Wipe
OIL=Oil **B**=Bulk **L**=Liquid

Analysis Request

PHOENIX USE ONLY SAMPLE #	Customer Sample Identification	Sample Matrix	Date Sampled	Time Sampled	Total Phosphorus	Dissolved Phosporus	Nitrate Nitrogen	Total Kjeldahl Nitrogen	Total Suspended Solids	Soil VOA Vials [ ] methanol [ ] H2O	GL Soil container ( )oz	GL Soil container ( )oz	40 ml VOA Vial [ ] As is [ ] HCl	GL Amber 1000ml [ ] As is [ ] H2SO4	PL As is [X] 250ml [ ] 500ml [ ] 1000ml	PL H2SO4 [X] 250ml [ ] 500ml	PL HNO3 250ml	PL NaOH 250ml	Bacteria Bottle
27251	Inlet	SW	10/25/17	9:45	X	X	X	X	X						2	1			
27252	Outlet	SW	10/25/17	9:00	X	X	X	X	X						2	1			

Relinquished by:	Accepted by:	Date:	Time:
Melissa Lenker	[signature]	10-25-17	15:45
[signature]	Krystal Bruce	10.25.17	17:00

Comments, Special Requirements or Regulations:
Low detect on phosphorus - 0.01 mg/L or better

Turnaround:
[ ] 1 Day*
[ ] 2 Days*
[ ] 3 Days*
[X] Standard
[ ] Other
* SURCHARGE APPLIES

RI
[ ] Direct Exposure (Residential)
[ ] GW
[ ] Other

CT
[ ] RCP Cert
[ ] GW Protection
[ ] SW Protection
[ ] GA Mobility
[ ] GB Mobility
[ ] Residential DEC
[ ] I/C DEC
[ ] Other

MA
[ ] MCP Certification
[ ] GW-1
[ ] GW-2
[ ] GW-3
[ ] S-1
[ ] S-2
[ ] S-3
[ ] MWRA eSMART
[ ] Other

Data Format
[X] Excel
[X] PDF
[ ] GIS/Key
[ ] EQuIS
[ ] Other

Data Package
[ ] Tier II Checklist
[ ] Full Data Package*
[ ] Phoenix Std Report
[ ] Other
* SURCHARGE APPLIES

State where samples were collected: MA

Appendix B

Hydrologic Budget and Nutrient Modeling Spreadsheets

Walker Pond - HYDROLOGIC ASSESSMENT

						Source:
Watershed for Walker Pond =		166.2 acres		7,239,672 SF	0.260 mi2	ESS delineation based on MassGIS USGS topos
Pond Area		6.0 acres		261,360 SF	24,281 meters2	ESS, 2011, calculation in GIS
Area of Watershed - Pond Area		160.2 acres		6,978,312 SF		
Lake Circumference		2,850.0 feet				ESS, 2011, calculation in GIS
Lake Volume		622,036.8 cubic feet			17,614.1 meters3	ESS, 2011, calculation based on GIS and field data
Area influenced by seepage		14,250.0 ft2	=	1,324 m2		ESS estimate derived from pond circumference
Groundwater (data)		4 l/m2/day	=	0.141 cf/m2/day		ESS estimate based on unpublished data
			=	186.9 cf/day		Calculation
			=	0.002 cfs		Calculation
Annual PPT/yr		45.45 inches				Natick Weather station, 7.08 miles from Needham, from www.idcide.com
Annual PPT - ET	30.45	2.54 ft/yr		0.02 cfs		Precip on pond minus regional ET
Runoff (watershed)	15.00	1.25 ft/yr		0.28 cfs		Calculation
Base Flow (Streams) as measured during dry weather - Average =				0.06 cfs		No flow during dry weather, field data

	Ground	**PPT**	**Surfacewater**	**Total**
Dry	0.002	0.000	0.055	**0.057**
Wet	0.000	0.021	0.277	**0.298**
Total	**0.002**	**0.021**	**0.332**	**0.355** cfs

Estimated range of total annual input into lake:
(1.5 to 2 cfs/sq mi of watershed) =
0.39 to 0.52 cfs

Walker Pond, Needham, Massachusetts - Existing Conditions

IN-LAKE MODELS FOR PREDICTING PHOSPHORUS LOADS AND CONCENTRATIONS

THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE		
TP	Lake Total Phosphorus Conc.	ppb	From data or model	42	Enter Value	
L	Phosphorus Load to Lake	g P/m2/yr	From hydro & sub-watershed model	0.55	Enter Value	Assumes 100%
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	139	Enter Value	
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	54	Enter Value	
I	Inflow	m3/yr	From data	317,089	Enter Value	
A	Lake Area	m2	From data	24281	Enter Value	
V	Lake Volume	m3	From data	17614	Enter Value	
Z	Mean Depth	m	Volume/area	0.725423		
F	Flushing Rate	flushings/yr	Inflow/volume	18.0021		
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.388489		
Qs	Areal Water Load	m/yr	Z(F)	13.05914		
Vs	Settling Velocity	m	Z(S)	0.281819		
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.611511		
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.340449		
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.190735		

THE MODELS

NAME	FORMULA	PREDICTION CONC. (ppb)	PREDICTION LOAD (g/m2/yr)
Mass Balance	TP=L/(Z(F))*1000	42	
(minimum load)	L=TP(Z)(F)/1000		0.55
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	28	
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.83
Vollenweider 1975	TP=L/(Z(S+F))*1000	41	
(V)	L=TP(Z)(S+F)/1000		0.56
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	16	
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		1.15
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	34	
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.68
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	34	
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.68
Average of Model Values		31	
(without mass balance)			0.78
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	37	
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		0.62
From Vollenweider 1968			
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.36
Critical Load	Lc=2(Lp)		0.72

LOAD ANALYSIS

MODEL	ESTIMATED LOAD (kg/yr)	ESTIMATED LOAD (mg/L)	
Phosphorus			
Mass Balance (no loss)	13		
Kirchner-Dillon 1975	20		
Vollenweider 1975	14		
Reckhow 1977 (General)	28		
Larsen-Mercier 1976	16		
Jones-Bachmann 1976	16		
Model Average			
(without mass balance)	19	0.0596	
Reckhow 1977 (Anoxic)	15		
Permissible Load	9	0.0277	Permissible Conc.
Critical Load	18	0.0553	Critical Conc.

PREDICTED WATER CLARITY

PREDICTED CHL AND WATER CLARITY

MODEL	Value
Mean Chlorophyll (ug/L)	
Dillon and Rigler 1974	10.4
Jones and Bachmann 1976	12.0
Oglesby and Schaffner 1978	14.7
Modified Vollenweider 1982	15.0
"Maximum" Chlorophyll (ug/L)	
Modified Vollenweider (TP) 1982	46.5
Vollenweider (CHL) 1982	39.5
Mod. Jones, Rast and Lee 1979	44.5
Secchi Transparency (M)	
Oglesby and Schaffner 1978 **(Avg)**	1.7
Modified Vollenweider 1982 **(Max)**	3.7

ADDENDUM FOR NITROGEN

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE		
TN	Lake Total Nitrogen Conc.	ppb	From data or model	900	Enter Value	
L	Nitrogen Load to Lake	g N/m2/yr	From data or model	11.75	Enter Value	Assumes 100%
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	3.437099		

NAME	FORMULA	PREDICTION CONC. (ppb)	PREDICTION LOAD (g/m2/yr)
Mass Balance	TN=L/(Z(F))*1000	900	
(minimum load)	L=TN(Z)(F)/1000		11.75
Bachmann 1980	TN=L/(Z(C+F))*1000	756	
	L=TN(Z)(C+F)/1000		14.00

MODEL	ESTIMATED LOAD (kg/yr)	ESTIMATED LOAD (mg/L)	
Nitrogen			
Mass Balance (no loss)	285		
Bachmann 1980	340	1.07	(check - av in pond nitrogen concentration - mg/L)

Average Annual Nutrient Load by Land Use within the Walker Pond Watershed

Land Use Classification	Acres	P load rate (kg/ha/yr)	P Load rate (kg/acre/yr)	Phosphorus Load (kg/yr)	Percentage of Phosphorus Load	N load rate (kg/ha/yr)	N Load rate (kg/acre/yr)	Nitrogen Load (kg/yr)	Percentage of Nitrogen Load
Cropland and Pasture	0.0	0.50	1.24	0.0	0%	5.0	12.35	0.0	0%
Currently Developed (Residential/Commercial)	82.2	1.00	2.47	203.1	93%	5.0	12.35	1015.6	64%
Forest	64.6	0.08	0.19	12.0	5%	3.0	7.41	478.9	30%
Open/Cleared Land	0.0	0.10	0.25	0.0	0%	3.0	7.41	0.0	0%
Transportation	0.2	1.00	2.47	0.5	0%	5.0	12.35	2.5	0%
Water	6.0	0.00	0.00	0.0	0%	0.0	0.00	0.0	0%
Wetland	13.1	0.10	0.25	3.2	1%	3.0	7.41	97.1	6%
Preliminary Total Annual Nutrient Load				218.8				1594.0	
Attenuation Coefficient (% of load reaching lake)				9%				22%	
Adjusted Total Annual Nutrient Load				**19.7**				**350.7**	

Notes: Phosphorus export coefficients based on median value predicted by Reckhow et al. (1980), Lin (2004), and Rast and Lee (1978)