Project Report
October 29, 2013

Hickory Hills Lake
2013 Aquatic Vegetation and Water Quality Survey

Prepared For:

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SECTION 1: INTRODUCTION

Geosyntec Consultants (Geosyntec) was contracted by the Hickory Hills Landowners, Inc. (HHL) to conduct water quality monitoring and a macrophyte (vascular aquatic plant) survey of Hickory Hills Lake in Lunenburg, Massachusetts during the summer of 2013. The primary purposes of these investigations were to:

1. Provide updated water quality data for use in assessing the general ecological health and trophic status of Hickory Hills Lake;
2. Provide an update on the composition and distribution of Hickory Hills Lake's macrophyte community, allowing the HHL to track changes in the Lake's plant community over time and in response to vegetation management efforts; and
3. Provide the HHL with recommendations for aquatic vegetation plant management.

Hickory Hills Lake (314 acres)
Lunenburg, MA

SECTION 2: AQUATIC VEGETATION SURVEY

2.1 Methodology

Geosyntec conducted a macrophyte survey of the 314-acre Hickory Hills Lake over the course of three days on September 4, 6 and 11, 2013. Plant species were identified at 44 sampling locations (see Figure 2), with 41 stations located within Hickory Hills Lake and 3 stations within Little Hickory Lake. Each sampling station was field-located with a mapping-grade Trimble Global Positioning System unit with sub-meter accuracy. Plants were identified by visual inspection and by using an aquatic vegetation grappling hook to sample submerged vegetation. At each station, the dominant plant(s) were recorded, as well as estimates of plant growth density and biomass. As categorized in Table 1, plant density is an estimate of aerial coverage when looking down to the lake bottom from the water surface. Biomass estimates the amount of plant matter within the water column. For example, a sampling station with dense growth of low-growing plants may have a high density estimate but a relatively low plant biomass estimate. A station with dense growth of a long, ropey plant such as fanwort, with stems reaching the surface, would have both high plant density and high biomass estimates.

In addition to recording information from the 44 sampling stations, a running documentation of plant growth densities was estimated throughout the lakewide survey. Geosyntec's estimate of lakewide plant growth density (see Figure 2) is intended as a generalized representation of major plant growth zones. Localized growth within the depicted growth zones can vary significantly.

2.2 Aquatic Vegetation Survey Results

A listing of plant species present at each of the 44 sampling stations is provided in Table 3, including information on vegetation density, plant biomass, and dominant plants at each station. A summary of the major findings of the 2013 vegetation survey is as follows:

fanwort

- 27 macrophyte species were identified during the survey, including 26 native species and 1 non-native (*Cabomba caroliniana*, known as fanwort).

- Fanwort was observed at one sampling station and one additional location in the Mulpus Brook inlet cove. Walt Parquet of the HHL was notified of both fanwort locations. The two observed fanwort locations are not indicative of all locations where fanwort is growing in the lake. These locations are in addition to the locations previously mapped by HHL.

eastern purple bladderwort

- The most dominant and well-distributed plant in the lake was eastern purple bladderwort (*Utricularia purpurea*). This plant was identified at 38 out of the 44 sampling stations (86%) and was the dominant plant at 16 stations (36%). Bladderworts are carnivorous plants that capture and digest zooplankton (microscopic animals) in clusters of underwater "bladders" for which they are named. Eastern purple bladderwort is easily recognized in late summer by its purple-magenta flowers that extend above the water surface. Two other species of bladderwort were also observed during the 2013 survey, common bladderwort (*Utricularia vulgaris*) and little floating bladderwort (*Utricularia radiata*). Both of these species have yellow flowers.

tapegrass

- Other plants that were well-distributed around the lake included tapegrass (*Vallisneria americana*), Robbins' pondweed (*Potamogeton robbinsii*), watershield (*Brasenia schreberi*), spike rush (*Eleocharis sp.*), white water lily (*Nymphaea odorata*), Ribbonleaf pondweed (*Potamogeton epihydrus*) and bur-reed (*Sparganium americanum*). All other species were observed at less than 20% of the sampling stations.

- The species richness index (average number of species per sampling station) for Hickory Hills Lake is 5.3. Species richness and total observed species are measures of biological diversity within the plant community that can be useful when looking at trends over a period of time. As a snapshot, both of these metrics indicate a diverse population of predominantly native aquatic plants.

- With an average depth of approximately 10.5 feet, Hickory Hills Lake has a significant area that is suitable for growth of aquatic plants. Although most of the deeper areas of the lake can be characterized as having sparse (0-25% density) plant growth, areas of dense to very dense growth were common along the lake's near-shore areas and in its numerous shallow coves. Dense plant growth was particularly notable in the following areas:

  - Mulpus Brook inlet cove (vicinity of sampling stations 18-22): This area was dominated by dense growth of eastern purple bladderwort, tapegrass white water lily and watershield. Due to very dense growth of floating-leaf plants, the shallow northwestern portion of this cove is nearly inaccessible to most boats.

  - Coves and shoreline areas along the western side of the lake (vicinity of sampling stations 4-5, 11-17): Eastern purple bladderwort, watershield and tapegrass were abundant in these areas.

  - Proctors Cove (vicinity of station #11) was heavily dominated by dense growth of mermaid weed (*Proserpinaca palustris*). Station #19, at the northwestern tip of the lake, was the only other location where mermaid weed was observed. This plant has finely divided, feather-like submersed leaves that look similar to those of milfoil species. Mermaid weed can be distinguished from milfoils by its alternate leaf arrangement and forked leaflets.

  - Along the shoreline in the lake's northeastern section (vicinity of sampling stations 37-41): Eastern purple bladderwort was abundant throughout this area, with watershield, largeleaf pondweed (*Potamogeton amplifolius*), watershield, tapegrass, and ribbonleaf pondweed (*Potamogeton epihydrus*) also common.

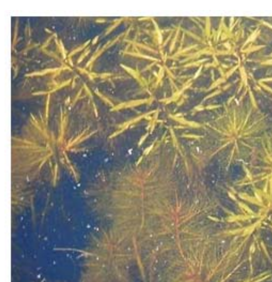
Data summary tables, a vegetation density map, and a species tally sheet from the 2012 vegetation survey are provided on the following pages.

Robbins' pondweed

watershield

ribbonleaf pondweed

white water lily



mermaid weed

Figure 1: Distribution and Dominance of Aquatic Plant Species, Hickory Hills Lake, September 4-11, 2013

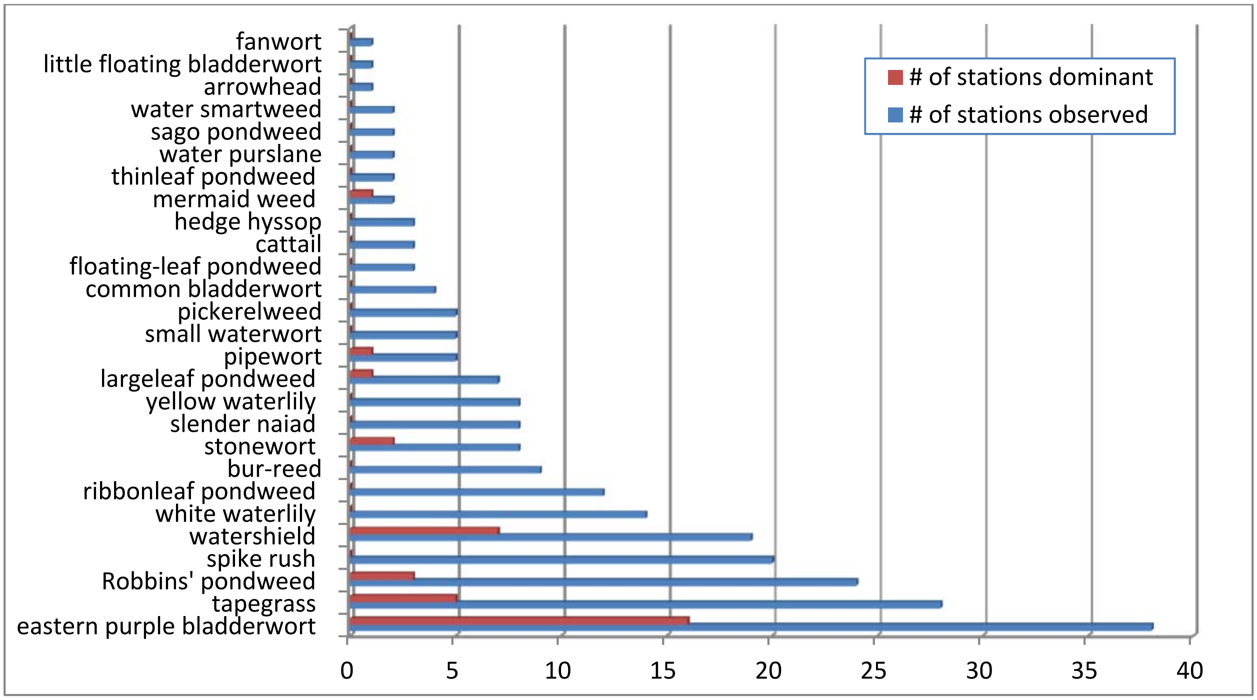


Table 1: 2013 Plant Growth Density

Density Rating	# of stations[1]	% of stations[1]
1: Sparse 0-25%	21	48%
2: Moderate 26-50%	7	16%
3: Dense 51-75%	9	20%
4: Very Dense 76-100%	7	16%
Density Index: 2.05		

Table 2: 2013 Plant Biomass

Biomass Rating	# of stations[1]	% of stations[1]
1: Scattered plant growth; or primarily at lake bottom	24	55%
2: Less abundant growth, or in less than half of water column	9	20%
3: Substantial growth through majority of water column	9	20%
4: Abundant growth throughout water column to surface	2	5%
Biomass Index: 1.75		

Density Index and **Biomass Index** are averages of the density ratings biomass ratings for the vegetation survey. The numeric rating (1 to 4) for each station is summed and divided by the number of sampling stations, resulting in the index value.

These indices allow for a comparison of relative changes in plant growth density and biomass over time.

1. Based on the 44 sampling stations included in the 2013 vegetation survey, as shown in Figure 2.

Table 3: Aquatic Vegetation Survey Tally Sheet

Location: Hickory Hills Lake (Lunenburg, MA)
Date: September 4, 6 and 11, 2013 **Surveyed by:** R. Hartzel

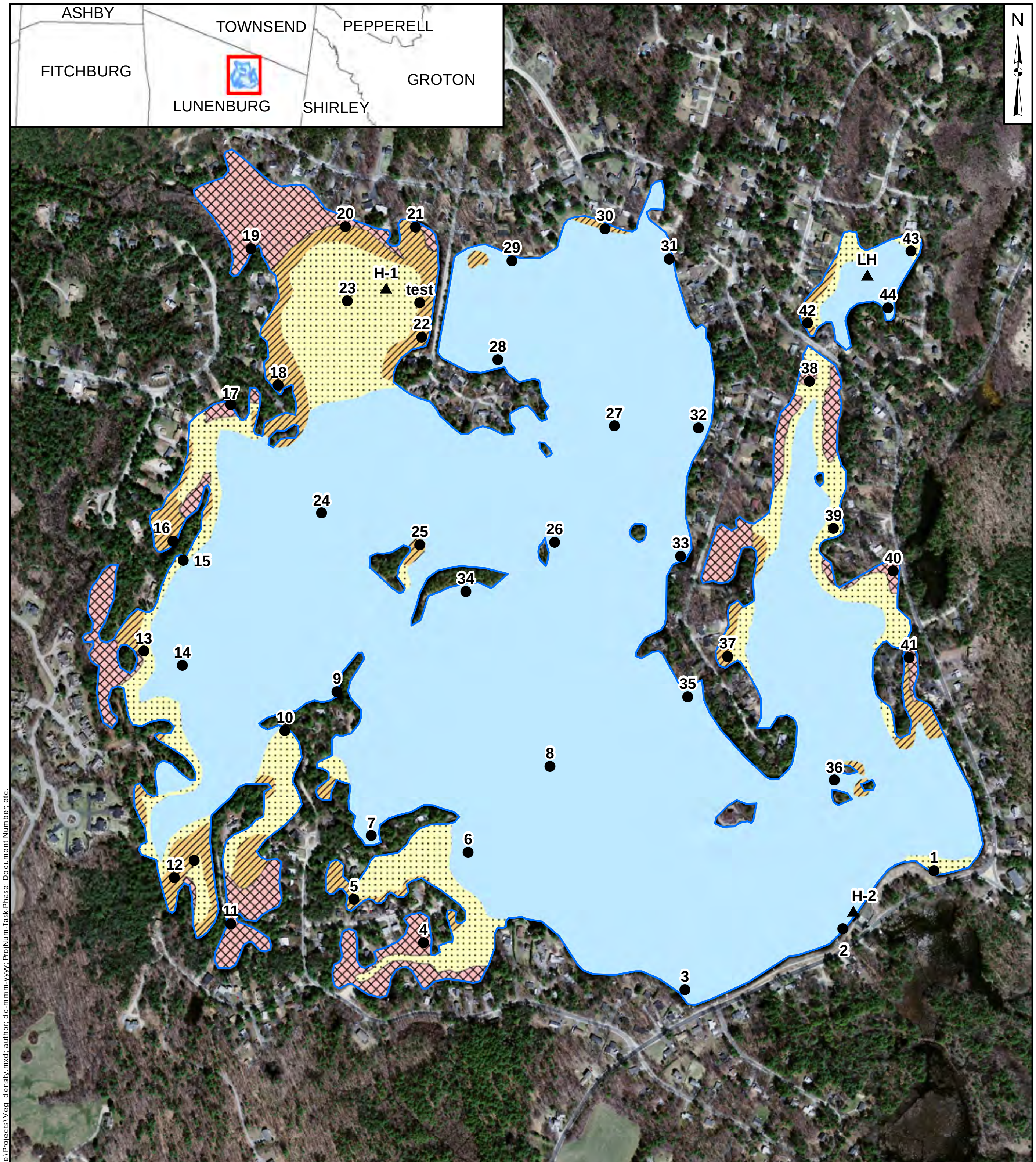
● species present at monitoring station
● species dominant at monitoring station

Geosyntec consultants

Plant Species				Monitoring Locations																																											
Common name	Scientific Name	# stations present	# stations dominant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42*	43*	44*
eastern purple bladderwort	*Utricularia purpurea*	38	16	●	●	●	**●**	●		●		●	**●**	●	**●**	**●**	**●**	**●**	**●**	●	●	**●**	●	**●**	●	**●**	●	**●**	**●**		**●**	●	●	●	**●**	●		●	●	**●**	●	**●**	**●**	●	●		
tapegrass	*Vallinsneria americana*	28	5	●	●		●			●					●	●					●		●	●	**●**	**●**		●	●	●	●	●		●	●	**●**	●	●	●			●	●	●			
Robbins' pondweed	*Potamogeton robbinsii*	24	3	●	●		●		●			**●**	●	●	●	●	**●**	●			**●**				●		●		●				●	●	●	●		●		●		●	●	●	**●**	**●**	●
watershield	*Brasenia schreberi*	19	7	●		●	●	**●**					●	●	●	**●**		●	**●**	**●**		**●**		●	●				**●**											**●**	**●**		●	●			
spike rush	*Eleocharis sp.*	20	0							●		●				●		●		●		●	●			●		●	●			●	●		●		●	●	●	●		●			●		●
white waterlily	*Nypmphaea odorata*	14	0				●	●					●	●				●	●			●	●	●	●																●	●	●	●			
ribbonleaf pondweed	*Potamogeton epihydrus*	12	0	●				●					●	●						●	●	●	●			●								●						●				●			
bur-reed	*Sparganium americanum*	9	0				●	●					●					●				●	●		●											●			●								
stonewort	*Nitella sp.*	8	2						●	●	**●**						●												●	●							**●**					●					
slender naiad	*Najas flexilis*	8	0	●			●									●					●										●									●	●		●				
yellow waterlily	*Nuphar variegatum*	8	0				●							●					●	●	●		●		●															●							
largeleaf pondweed	*Potamogeton amplifolius*	7	1				●			●									●								●												●	●				**●**			
pipewort	*Eriocaulon septangulare*	5	1					●					●					●														**●**							●								
common bladderwort	*Utricularia vulgaris*	4	0																			●		●				●																●			
small waterwort	*Elatine minima*	5	0		●								●																			●		●											●		
pickerelweed	*Pontederia cordata*	5	0					●					●												●																					●	
floating-leaf pondweed	*Potamogeton natans*	3	0																	●		●																						●			
mermaid weed	*Proserpinaca palustris*	2	1											**●**								●																									
thinleaf pondweed	*Potamogeton pusillus*	2	0			●	●																																								
water purslane	*Ludwidgia palustris*	2	0				●						●																																		
sago pondweed	*Stuckenia pectinata*	2	0											●																														●			
cattail	*Typha sp.*	3	0																															●		●										●	
arrowhead	*Sagittaria americana*	1	0																																	●											
little floating bladderwort	*Utricularia radiata*	1	0																			●																									
hedge hyssop	*Gratiola sp.*	3	0																	●																							●		●
water smartweed	*Polygonum sp.*	2	0																																							●		●	
fanwort	*Cabomba caroliniana*	1	0																													●													
Plant Density Rating				2	1	1	4	3	1	1	1	1	2	4	3	2	1	2	3	4	3	4	3	4	3	2	1	3	1	1	1	1	1	1	1	1	1	1	1	3	4	2	3	4	2	1	1
Plant Biomass Rating				2	1	1	4	3	1	1	1	1	2	3	1	2	1	2	2	4	2	3	2	3	1	2	1	3	1	1	1	1	1	1	1	1	1	1	1	3	3	1	3	3	2	1	1
# of species present				6	4	3	11	7	2	5	1	3	10	8	4	6	4	7	5	7	6	9	7	6	8	4	3	5	5	2	3	5	3	6	4	6	3	4	6	8	4	6	6	11	5	4	3

* Sampling locations 42, 43 and 44 located on Little Hickory Lake

Key to Density and Biomass Ratings



Legend

● Vegetation Survey Location

▲ Water Quality Sampling Location

Vegetation Density

Sparse: 0-25%

Moderate: 26-50%

Dense: 51-75%

Very Dense: 76-100%

800 400 0 800 Feet

Hickory Hills Lake Vegetation Density Survey Date: September 4-11, 2013

Lunenburg, MA

Geosyntec consultants

Acton, MA

OCTOBER 2013

Figure 2

(Q:\ = \\boston-01\GIS$\) Q:\GISProjects\BW0237_HickoryHillsLake\Projects\Veg_density.mxd; author; dd-mmm-yyyy; ProjNum-Task-Phase; Document Number; etc.

2.3 Aquatic Vegetation Management Recommendations

When evaluating an aquatic plant management strategy for Hickory Hills Lake, it is important to consider the current condition of the lake and the goals of the HHL with regard to maintenance of the lake's ecological and recreational values. Based on Geosyntec's field investigations and discussions with members of the HHL, the primary goals for Hickory Hills Lake include:

1. Continued efforts to prevent the further spread and proliferation of non-native fanwort, which was first observed in Hickory Hills Lake in 2011;

2. Restoration and preservation of conditions suitable for sustainable in-lake recreational uses, including boating, swimming, and fishing; and

3. Preservation and improvement of the overall water quality and ecological values of Hickory Hills Lake.

As discussed in Section 2.2, a majority of Hickory Hills Lake exhibits relatively sparse growth of an aquatic plant community that is predominantly comprised of beneficial native species. However, a significant portion of the lake's shoreline and shallow cove areas exhibit dense to very dense growth. This is not surprising, given the shallow depths and suitable organic substrate that exist over much of the lake. A diverse native plant community plays an important role in maintaining a healthy lake ecosystem and its recreational values. For example, the role of macrophytes in maintaining lake water clarity has been well documented, and native plant beds are critical as forage and protective cover for fish.

Based on the results of the 2013 vegetation survey, it appears that the HHL has been quite effective in its efforts to contain and control the growth of invasive fanwort. These efforts have included routine volunteer monitoring to document new areas of infestation and both diver hand-harvesting and diver-assisted suction harvesting (DASH). Although fanwort has continued to spread to new locations since 2011, the HHL has been largely successful in (1) rapidly identifying and harvesting newly infested areas, and (2) controlling the overall biomass of fanwort in well-established areas.

The relatively new infestation of fanwort and its continued spread in Hickory Hills Lake creates challenges that will require an adaptive and flexible approach to plant management. The optimal approach, or combination of approaches, is likely to change over time. The best approach for one area of the lake is likely to be inappropriate for another area, depending on plant growth density, species composition, and depth. It will be important to continually re-assess the effectiveness of fanwort control efforts and the overall condition of the lake's ecological and recreational values. As the HHL is well aware, fanwort is capable of spreading rapidly in shallow water, outcompeting native species and impairing recreation by growing in dense beds that can extend to the water surface. In the absence of active management, recreational uses can also be impaired by dense growth of native species in some sections of Hickory Hills Lake. The challenge lies in implementing a plant management strategy that properly balances the three goals listed above.

If no steps are taken to actively manage growth within some of the densely vegetated cove and shoreline areas of Hickory Hills Lake, it is expected that the densely vegetated zones will continue to extend further into the open water areas over time. A discussion of aquatic vegetation techniques that could be used as part of a long-term strategy for Hickory Hills Lake is provided below.

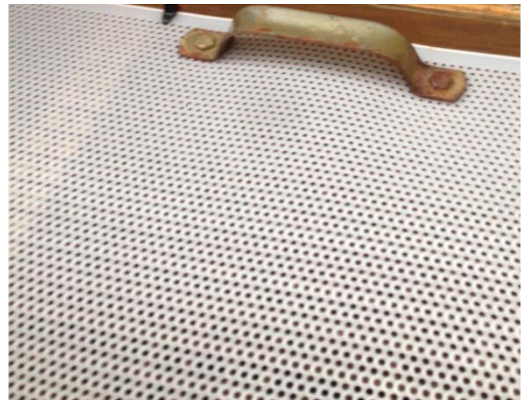
Diver Hand–Harvesting / Diver Assisted Suction Harvesting (DASH)

As stated above, the HHL's ongoing program of volunteer fanwort monitoring and hand harvesting /DASH has been effective and should continue. For new and relatively small areas of infestation, diver hand harvesting can be an effective and low-cost control technique. DASH has proven to be an effective technique for somewhat larger areas. The risk of plant fragmentation associated with DASH boat operation can be reduced by incorporating the following controls:

1. Water and plants pumped to the collection boat should be filtered through a mesh with a maximum opening size no greater than 0.125 inches (1/8 inch) to separate plant material from

water discharged off the boat. The screen should be cleared regularly as needed to prevent clogging and allow return water flow. No plant fragments should be discharged back to the lake.

2. A moveable silt/fragment curtain (i.e., Brockton Equipment Type 2 SILTDAM turbidity barrier or equivalent) suspended in the water column from the surface to the lake bottom could be used to prevent plant fragments from spreading beyond the locus of active plant removal areas. The silt/fragment curtain would be placed to either surround the DASH work area or in a horseshoe shape around the downstream side of the work area.


A 1/8-inch polyethylene mesh screen installed in a DASH boat to filter plant fragments.

In addition to focusing DASH efforts on areas of fanwort growth, DASH is also recommended as a part of a strategy to control the nuisance growth of mermaid weed in Proctors Cove. Ideally, this approach would be used in combination with lake-level drawdown (discussed below). Drawdown could provide control within nearshore areas, allowing DASH efforts to focus on boat access channels in the deeper middle sections that are not exposed to drawdown.

Lake-level Drawdown

Lake-level drawdown should be considered by the HHL as part of long-term, sustainable plant management strategy. Lake–level drawdown is conducted during the winter months to control plant growth by exposing plant seeds and over-wintering structures to freezing conditions and desiccation. As presented in the 2012 Aquatic Weed Survey and Water Quality Analysis of Hickory Hills Lake (ACT, Inc.), a 3-foot vertical drawdown would expose 32.4 acres (10.3%) of the lake bottom, and a 6-foot drawdown would expose 76.8 acres (24.4%). A few considerations regarding drawdown include:

- Although a 3-foot drawdown would not provide the maximum achievable sediment exposure for plant control, it would expose many of the near-shore areas where plant growth is most dense. A total of 37.2 acres (11.8%) of the lake were determined to have "dense" or "very dense" plant growth during the 2013 survey. A drawdown of up to 3-feet would present the easiest permitting route, and could potentially be permitted as a minor project addendum to the existing Order of Conditions for the 18-inch drawdown (currently conducted for shoreline maintenance). A 3-foot drawdown would yield modest results at best, but would require very limited additional resources from the HHL as compared to the current 18-inch drawdown. This approach is recommended, either as a long-term management technique or until further investigation determines that deeper drawdown is feasible from a technical and permitting perspective.

- Drawdown is most effective for control of species that use vegetative propagules for overwintering and expansion, such as fanwort and mermaid weed (dominant in shallow Proctors Cove). Drawdown can also provide effective control of floating-leaf species, such as watershield and water lilies, which grow densely and inhibit boat access in some cove and shoreline areas. However, drawdown is not considered an effective method for the control of bladderwort species.

- The optimal drawdown depth for Hickory Hills Lake, when considering both plant control goals and permitting constraints, is likely be between 3 and 6 feet. Determining the optimal drawdown depth and permitting feasibility will require assessment of the following:
  - *Public and/or Private Water Supplies:* Identify wells or water supply intakes which could dry up during a drawdown, and mitigation for unavoidable impacts.
  - *Rare Species:* Demonstrate the absence of rare wildlife habitat, or that drawdown will not adversely affect any rare wildlife habitat that is present.

- *Fisheries:* Estimate area/depth zones of the drawdown area and verify that the drawdown will maintain sufficient deep-water refuge to prevent fish kills. Provide drawdown/refill dates, estimate of refill time, and estimated downstream flow rates during refill.
- *Alternative Analysis:* Consider all reasonable alternatives for controlling target plants and explain why drawdown (or drawdown used with other methods) was chosen.
- *Control of Target Species*: Provide a map showing the distribution/density of target and non-target plants, a list of target species to be reduced, verification that target species would be reduced, and verification that target species would be dewatered.
- *Dam/Outlet Control Structures*: Evaluate the dam's structural integrity to verify that it can withstand the proposed drawdown, and provide a contingency plan if the structure is stuck in an open position.

Mechanical Harvesting

Prior to 2011, the HHL used its own mechanical harvester to control shoreline plant growth on a regular basis. The HHL has not used the harvester since the discovery of fanwort. This was a prudent response to the new infestation, with a goal of preventing unintended fanwort fragmentation and spread.

As reported by the HHL, some areas that had been previously managed on a routine basis with the mechanical harvester have become more densely vegetated since 2011, to the point where recreational impairments (e.g., accessibility of boats from cove areas to deeper open water) are evident. This observation is supported by the results of Geosyntec's 2013 vegetation survey.

Any practical discussion about future use of mechanical harvesting in Hickory Hills Lake has to acknowledge the fact that the HHL owns a harvester. This is significant because:

1. Mechanical harvesting provides immediate but often very short-term results. Compared to commercially-contracted harvesting or short-term equipment leasing, owning a harvester makes it much more affordable to conduct repeat "maintenance cuttings" in high density growth areas.

2. By using the harvester only at Hickory Hills Lake, there is no risk of having a new non-native species introduced by the equipment.

3. By owning the harvester, the HHL can carefully control any protocols for its use. This could include:
    a. Harvesting only in limited areas (e.g., designated coves or shoreline zones) that have no known, recent, or nearby fanwort growth;
    b. Requiring a pre-harvesting survey to confirm that fanwort has not been identified in the designated area;
    c. Requiring a post–harvesting survey to confirm if fanwort is identified in any newly harvested area or nearby shoreline areas collecting windblown fragments; and
    d. Immediate cessation of harvesting in any area where fanwort is identified.

As the HHL is well aware, the biggest drawback to mechanical harvesting in Hickory Hills Lake is the potential to fragment and spread fanwort. However, now that HHL has a well-established fanwort monitoring and control program, it is reasonable to reconsider all available options based on current conditions.

In densely vegetated areas frequented by motorized boat traffic, some amount of plant fragmentation is unavoidable. In these areas, the limited risk associated with a very carefully controlled harvesting program may be balanced by the recreational impairment associated with the "no-action alternative" and plant fragmentation by boat propellers. With appropriate protocols in place, Geosyntec recommends that mechanical harvesting could be used in a limited manner in designated areas to open shoreline access and boating channels. Although mechanical harvesters cut all plants in their path and therefore are not selective, they do allow areas to be selectively cut or avoided. This allows the HHL to focus efforts where homeowner needs are greatest and avoid areas where access is not an issue and the native plant assemblage is providing ecological benefit.

For the same reason that mechanical harvesting is not recommended in areas of fanwort growth, mechanical harvesting is also not recommended for control of mermaid weed in Proctors Cove. Mermaid weed has the ability to re-vegetate and spread readily by fragments. Use of the mechanical harvester in Proctors Cove could increase the risk of spreading this plant to new areas in Hickory Hills Lake.

Herbicide Treatment

The use of herbicides can be an appropriate and effective technique for aquatic vegetation control in some settings. Although Geosyntec does not recommend the use of herbicides in the main body of Hickory Hills Lake at this time, the HHL should consider the following:

- For fanwort, Sonar (fluridone) is the only herbicide currently registered in Massachusetts that provides effective short-term control. Unfortunately, this broad-spectrum systemic herbicide requires a long exposure time (>60 days). Given the current locations of fanwort in Hickory Hills Lake, treating with Sonar is not practical or recommended because it would require treating virtually the entire lake. However, another broad-spectrum herbicide (Clipper, active ingredient flumioxazin) has been proven effective for short–term fanwort control. Clipper is pending registration based on a June 2013 recommendation from the Massachusetts Department of Environmental Protection (MassDEP). Because this "contact" herbicide requires a very short exposure time, it can be used for spot treatments. As such, Clipper may provide a useful option for the relatively small infestation areas of Hickory Hills Lake. It is worth noting that the use restrictions for Clipper recommended by MassDEP include the following:

  > *"Treated areas may not be retreated with flumioxazin or any herbicide with a similar mode of action (i.e., light dependent peroxidizing herbicide) in consecutive years in order to prevent the development of herbicide resistance in treated plants.*

  Based on this recommended restriction, a strategy for Clipper use could involve herbicide application in one year to reduce plant abundance, followed by DASH harvesting in the following year.

- The continued use of Sonar in Little Hickory Lake should be considered on an as-needed basis. Because of its relatively small size and separation from mixing with the main body of Hickory Hills Lake, Little Hickory has the ideal features for successful use of this systemic herbicide.

- Herbicide treatments using broad-spectrum herbicides to target native plants are generally not recommended at this time. However, it is reasonable to consider such herbicides as a tool for control in very limited areas where recreational access is impaired and the other recommended methods either do not provide relief or are impractical. In such cases, the correct herbicide will depend on target species (e.g., diquat for bladderwort control, glyphosate for floating leaf plants including water lilies and watershield).

SECTION 3: WATER QUALITY MONITORING

3.1 Methodology

Water quality monitoring was conducted on September 6, 2013 at three sampling stations. As shown in Figure 2, the H1 sampling station is located in the Mulpus Brook inlet cove, H2 is near the lake outlet at the dam, and LH is near the center of Little Hickory Lake.

Geosyntec conducted sampling for the following parameters:

- Total Phosphorus (lab)
- Nitrate Nitrogen (lab)
- Ammonia Nitrogen (lab)
- Chlorophyll-*a* (lab)
- Alkalinity (lab)
- Color/True Color (lab)
- Specific Conductance (in-situ)
- pH (in-situ)
- Dissolved Oxygen & Temperature (in-situ)
- Turbidity (in-situ)
- Secchi disk transparency

In-situ measurements were taken throughout the water column at 0.5-meter intervals with an In-Situ TROLL 9500 multi-parameter sampler. Surface grab samples taken for laboratory analysis were sent to Alpha Analytical Laboratory in Westborough, MA.

3.2 Water Quality Monitoring Results

The water quality data collected on September 6, 2013 is presented in Table 5 and key findings are summarized below.

Dissolved Oxygen (DO) levels have an important impact on fish and other aquatic biota within a pond. Low DO concentrations (below 5 mg/L) can impair the health and spawning of fish and other organisms. DO enters the water column from physical mixing (e.g., waves, turbulence) or by photosynthesis of rooted plants and algae within the water column. DO is depleted by the respiration of organisms and decomposition of organic matter within the water column and sediments. Anoxic (oxygen depleted) conditions at the sediment/water interface are also associated with the release of phosphorus from lake sediments back into the water column, fueling summer algae and plant growth.

The average observed DO concentrations in Hickory Hills Lake on the sampling date ranged from 7.1 to 8.2 mg/L, indicating suitable conditions for warm water fishery habitat. DO concentrations at the Little Hickory sampling stations ranged from 5.0 to 5.3 mg/L, just slightly above the threshold for warm water fisheries.

pH is a measure of acidity based on the presence of hydrogen ions. A pH of 7.0 is neutral, while values below 7.0 indicate acidic conditions and values above 7.0 indicate basic conditions. Lower pH values found at depth are due to biological decomposition that leads to anoxic (oxygen-depleted) conditions and other chemical reactions that reduce pH. Most fish cannot tolerate a pH below 4 or above 11, and their growth and health is affected by long-term exposure to a pH less than 6.0 and over 9.5. The observed pH values indicated slightly acidic to neutral waters, ranging from 6.8 to 6.9 in Hickory Hills Lake and from 6.5 to 6.6 in Little Hickory.

Alkalinity is a measure of a water body's natural capacity to neutralize acids, also known as "buffering capacity". Alkalinity in surface waters can come from a variety of sources, but is often strongly determined by the geology of the area. For example, lakes in areas with large quantities of limestone tend to have higher buffering capacity (more alkaline) and areas dominated by granite bedrock tend to have lower buffering capacity. Lakes with low buffering capacity are more sensitive to acid inputs from sources such as atmospheric deposition. Table 4 shows how the U.S. Environmental Protection Agency (EPA) classifies the alkalinity of lakes and ponds. As the concentration of calcium carbonate ($CaCO_3$) increases, alkalinity increases and risk of acidification decreases.

The average alkalinity in Hickory Hills Lake was 16.65 mg/L $CaCO_3$, in the middle of the “Sensitive” category according to the EPA classification system. Little Hickory was 20.1 mg/L $CaCO_3$, just barely above the threshold of the “Not Sensitive” category.

Table 4: EPA Classification of Alkalinity of Lakes and Ponds

U.S. EPA Category	Alkalinity (mg/L $CaCO_3$)
Acidified	<1 and pH<5
Critical	<2
Endangered	2 – 5
Highly Sensitive	5 – 10
Sensitive	10 – 20
Not Sensitive	>20

Specific conductance is a measure of the water’s ability of water to conduct electricity, as indicated by the presence of ions in solution. Chloride is typically the predominant ion found in surface waters, including man-made sources of chloride ions such as wastewater and road salt. The primary natural sources of chloride ions in surface waters include the weathering of soils and rocks, precipitation, and from dust or particulate matter. Regional variations in watershed geology can result in a wide range of “normal” conductance levels in freshwater, from 0 to 1,300 µs/cm. However, abnormally high conductance levels can be an indicator of pollutants sources such as road salting, wastewater discharges, and runoff from developed areas. The specific conductance measurements ranged from 140 to 143 µs/cm in Hickory Hills Lake and from 233 to 236 µs/cm in Little Hickory. These measurements are within the normal range for freshwater in Massachusetts, although the higher results at Little Hickory may indicate an anthropogenic source requiring further field investigation.

Total phosphorus (TP) is a measure of all organic and inorganic phosphorus forms, including soluble phosphorus and the phosphorus in plant and animal fragments suspended in lake water. In freshwater lakes, phosphorus is usually the most important nutrient determining the growth of algae and aquatic plants. Since phosphorus is typically less abundant than nitrogen, it is considered the “limiting nutrient” for biological productivity. In-lake TP concentrations greater than 25 ug/L are considered an indicator of eutrophic (nutrient-rich) conditions, as further discussed in Section 4 (Trophic Status Assessment).

Total phosphorus measurements in Hickory Hills Lake averaged 10.5 µg/L for stations H1 and H2. As further described under Section 4, these results are indicative of upper oligotrophic conditions according to the Carlson Trophic Index. The TP concentration in Little Hickory was 16 µg/L, indicative of mid-mesotrophic conditions.

Nitrogen (N), along with phosphorus, is a nutrient required for plant growth. The general ratio of nitrogen to phosphorus in algae is 16:1 (referred to as the “Redfield Ratio”). In most freshwater lakes and ponds, the N:P ratio is typically much higher, which means that there is a relative excess of nitrogen and that any additional input of nitrogen will not stimulate plant growth.

Two forms of nitrogen were sampled: Nitrate-N and Ammonia-N. Nitrate-N accounts for the oxidized forms of bioavailable nitrogen. This form of nitrogen can be a useful indicator of watershed pollutant sources, particularly in waters that are well-oxygenated. Nitrate-N was not detected at levels above the laboratory reporting limit (0.10 mg/L) at any of the sampling stations.

Ammonia-N is a reduced form of nitrogen that is the preferred form for growth of algae and plants. For in-lake sampling, ammonia sampling can be useful because waters with nitrogen-rich organic matter can exhibit low nitrate levels, as decomposition of organic matter lowers dissolved oxygen levels, which then slows the rate at which ammonia is oxidized to nitrite (NO_2) and then to nitrate (NO_3). Ammonia-N was not detected at levels above the laboratory reporting limit (0.075 mg/L) at stations H1 and H2, and was measured at 0.21 mg/L at LH. The higher Ammonia-N results at the LH station, combined with the higher specific conductance levels at this station, indicate potential pollutant sources (e.g., fertilizers, wastewater, animal wastes) that are affecting Little Hickory more than the main body of the lake.

Chlorophyll-a provides an indirect measure of algal biomass and can be used as a metric to estimate a lake's trophic status. Chlorophyll-a is a green pigment used by plants, phytoplankton and cyanobacteria to convert sunlight into the chemical energy needed to convert carbon dioxide into carbohydrates. The average chlorophyll-a concentration in Hickory Hills Lake (stations H1 and H2) was 3.82 mg/m^3, which indicates mesotrophic conditions as discussed in Section 4. Despite having a higher TP measurement than stations H1 and H2 on the sampling date, station LH had a lower chlorophyll-a measurement of 2.44 mg/m^3. Since phosphorus is the limiting nutrient that allows for algal growth, TP concentrations and chlorophyll-a are often strongly correlated.

The **Secchi disk** is a weighted black and white disk that is lowered into the water by a calibrated chain until it is no longer visible. This method provides a measure of water clarity (light penetration), which is primarily a function of algal abundance, water color, and turbidity caused by suspended particulate matter. Water clarity influences the growth of rooted aquatic plants by determining the depth to which sunlight can penetrate to the lake sediments. At sampling station H2, the Secchi disk was visible to a depth of 2.5 meters, indicating mid-mesotrophic conditions. At the other sampling locations (H1 and LH) the Secchi disk was visible to the lake bottom (approximately 2.0m and 1.5m, respectively). As such, the H1 and LH measurements do not provide a valid measure of water clarity and only the H2 measurement was used for the trophic status assessment in Section 4.

Turbidity is another common measure of water clarity. Turbidity is measured in nephlometric turbidity units (NTU) with an electronic turbidimeter. Turbidity in NTU describes the degree to which a sample of water interferes with the perpendicular transmission of a beam of monochromatic light. Turbidity is often used for regulatory purposes (e.g., to measure the quality of runoff from an active construction site or regulated industrial discharge pipe in comparison to permitted discharge limits). Turbidity levels measured at all sampling stations were generally low, ranging from 0.5 to 1.5 NTU.

True and Apparent Color are two metrics commonly used to define the color of a waterbody. Apparent color is the color of the water as influenced by both dissolved and suspended substances. True color is measured after filtering a water sample, leaving only dissolved substances to influence color. Dissolved substances that contribute to water color include humic acids and tannins from decomposed organic matter (e.g., leaves, aquatic vegetation) and metallic ions (e.g., iron, manganese) from the surrounding watershed. Suspended substances that contribute to color include algae and suspended sediment carried into the lake with stormwater or re-suspended from the lake bottom by wind, boat activity, or other disturbances. Both true and apparent color are typically measured in Apparent Platinum Cobalt Units (A.P.C.U.).

Station H1, located in the densely vegetated Mulpus Brook inlet, had the highest color measurements of the three stations (34 A.P.C.U. apparent color and 22 A.P.C.U. true color), although the results from Little Hickory were similar. The results from the deeper and less densely vegetated H2 station were somewhat lower (17 A.P.C.U. apparent color and 28 A.P.C.U. true color).

SECTION 4: TROPHIC STATUS ASSESSMENT

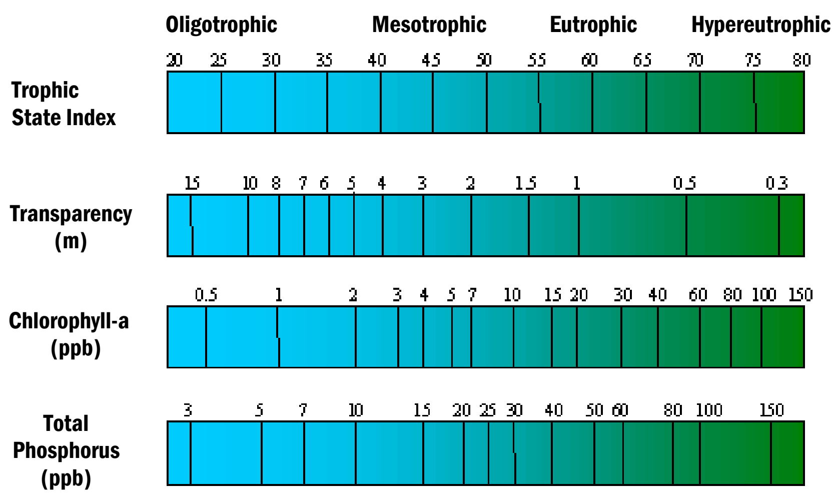
Lakes and ponds are typically categorized according to trophic state as follows:

- **Oligotrophic:** Low biological productivity. Oligotrophic lakes are very low in nutrients and algae, and typically have high water clarity and a nutrient-poor inorganic substrate. Oligotrophic water bodies are capable of producing and supporting relatively small populations of living organisms (plants, fish, and wildlife). If the water body is thermally stratified, hypolimnetic (deep water) oxygen is usually abundant.
- **Mesotrophic:** Moderate biological productivity and moderate water clarity. A mesotrophic water body is capable of producing and supporting moderate populations of living organisms (plant, fish, and wildlife). Mesotrophic water bodies may begin to exhibit periodic algae blooms and other symptoms of increased nutrient enrichment and biological productivity.
- **Eutrophic:** High biologically productivity due to relatively high rates of nutrient input and nutrient-rich organic sediments. Eutrophic lakes typically exhibit periods of oxygen deficiency and reduced water clarity. Nuisance levels of macrophytes and algae may result in recreational impairments.
- **Hypereutrophic:** Dense growth of algae throughout summer. Dense macrophyte beds, but extent of growth may be light-limited due to dense algae and low water clarity. Summer fish kills are possible.

Geosyntec calculated the trophic status for Hickory Hills Pond using the Carlson Trophic Status Index (TSI). The Carlson TSI is one of the most commonly used means of characterizing a lake's trophic state. As illustrated in Figure 3, the TSI assigns values based upon logarithmic scales which describe the relationship between three parameters (total phosphorus, chlorophyll-a, and Secchi disk clarity) and the lake's overall biological productivity. TSI scores below 40 are considered oligotrophic, scores between 40 and 50 are mesotrophic, scores between 50 and 70 are eutrophic, and scores from 70 to 100 are hypereutrophic.

Figure 3: Carlson Trophic State Index

(Figure adapted from 1988 Lake and Reservoir Restoration Guidance Manual. USEPA. EPA 440/5-88-002.)



TROPHIC STATUS	TSI	TP[1] (ppb)	Secchi Disk (m)	Chl-*a*[2] (ppb)
Oligotrophic	<40	<12	>4	<2.6
Mesotrophic	40-50	12-24	4-2	2.6-7.3
Eutrophic	51-70	25-96	2-0.5	7.4-56
Hypereutrophic	>70	>96	<0.5	>56

Notes:
1. For TP, parts per billion (ppb)=μg/L
2. For Chl-*a*, ppb=mg/m3

Transparency: *Note: The Secchi disk was visible to the lake bottom (approximately 2m) on the sampling date at station H1. Only the H2 measurement was used for the TSI calculation.*

Secchi disk at station H2 = 2.5m
TSI = 60 - 14.41*ln (Secchi Disk)
TSI = 46.8

Chlorophyll-a: Mean chlorophyll-a (stations H1 and H2) = 3.82 mg/m3;
TSI = (9.81)* ln (Chlorophyll-a) + 30.6
TSI = 43.7

Total Phosphorus: Mean epilimnetic total phosphorus (stations H1 and H2) = 10.5 µg/L;
TSI = (14.42)* ln (TP) + 4.15
TSI = 38.1

The TSI results indicate that Hickory Hills Lake falls into the mid-mesotrophic range for transparency and chlorophyll-a and in the upper oligotrophic range for total phosphorus. It is important to keep in mind that this TSI analysis reflects the results from a single sampling date (9/6/2013). Incorporating a larger data set to represent average conditions over the summer months will allow for greater confidence in the TSI assessment.

Table 5: Water Quality Sampling Results - September 6, 2013

Date	Site ID	Depth (m)	Temp. (C)	DO (mg/L)	pH	Spec. Cond. (µs/cm)	Turb. (NTU)	Total Phos. (µg/L)	True Color (A.P.C.U.)	Apparent Color (A.P.C.U.)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Alkalinity (mg/L CaCO3)	Chlor-*a* (mg/m3)	Secchi Disk (m)
09/06/13	H1	0.0	23.0	7.3	6.9	143	0.5	10	22	34	ND	ND	16.7	2.90	visible to bottom (approx. 2.0m)
		0.5	22.8	7.4	6.9	143	0.5								
		1.0	22.6	7.9	6.9	143	1.5								
		1.5	22.4	8.2	6.9	143	0.7								
	H2	0.0	24.2	7.3	6.9	141	1.1	11	17	28	ND	ND	16.60	4.74	2.5
		0.5	24.2	7.3	6.9	141	1.0								
		1.0	23.8	7.5	6.9	140	1.3								
		1.5	23.1	7.3	6.9	141	1.3								
		2.0	22.9	7.2	6.9	140	1.5								
		2.5	22.9	7.2	6.8	140	1.2								
		3.0	22.9	7.1	6.8	140	1.4								
		3.5	22.9	7.1	6.8	140	1.4								
		4.0	22.9	7.1	6.8	140	1.5								
	LH	0.0	22.3	5.3	6.6	236	0.5	16	21	32	0.21	ND	20.10	2.44	visible to bottom (approx. 1.5m)
		0.5	21.7	5.1	6.6	235	0.7								
		1.0	21.6	5.0	6.6	235	0.7								
		1.5	21.5	5.0	6.5	233	0.7								

ND = Not detected at the laboratory reporting limit for the sample.

H1: Mulpus Brook inlet cove

H2: Near the lake outlet at the dam

LH: Little Hickory Lake