

**Annual Report**  
2021 Management Program  
Westford Ponds  
Westford, MA

Prepared by: SÖLitude Lake Management  
590 Lake Street  
Shrewsbury, MA 01545

Prepared for: Town of Westford  
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55 Main Street  
Westford, MA 01886

Submitted on: November 17, 2021

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### **Introduction**

In accordance with the aquatic management program contract between SÖLitude Lake Management and the Town of Westford for the Westford Ponds (Nabnasset Lake, Long Sought for Pond, Keyes Pond, Burges Pond, Old Mill/Graniteville Pond, Kennedy Pond and Forge Pond) the following document serves to provide this year's treatment and monitoring results, as well as recommendations for the 2022 management season. As proposed, ESS Group, Inc. (ESS) conducted all monitoring work.

All management activities were conducted in compliance with the current Orders of Conditions issued by the Westford Conservation Commission and the Licenses to Apply Chemicals (# WM04-000619 – Long Sought For Pond, WM04-000618 - Nabnasset Lake) issued by the MA DEP Office of Watershed Management.

This year's program was delayed due to staffing and contract issues, therefore pre-treatment surveys and active management was limited to Long Sought for Pond and Nabnasset Lake. Post-treatment/late season monitoring was conducted on all of the waterbodies and this year's contract also included development of a 5-year management plan for each waterbody as well as an educational seminar. Active management consisted of treating nuisance pondweeds at Long Sought for Pond and treatment of milfoil and nuisance algae at Nabnasset Lake.

### **Pre-Treatment Surveys**

The pre-treatment surveys for Nabnasset Lake and Long Sought For Pond were conducted by ESS Group on July 16th. Curlyleaf pondweed (*Potamogeton crispus*) and flat-stem pondweed (*Potamogeton zosteriformis*) were noted at nuisance levels and recommended for treatment. In Nabnasset Lake, a significant amount of curlyleaf pondweed was observed and recommended for treatment. Water celery (*Vallisneria americana*) was also mapped and noted as a dominant species in the lake but was not slated for treatment. Prior to treatment at Nabnasset Lake, residents noted growth of variable watermifoil (*Myriophyllum heterophyllum*), mostly along the northern, eastern and western shoreline and provided a sketch map for use in directing the treatment to also target this species. The complete pre-treatment report from ESS Group is attached.



### **Herbicide Treatments**

Treatment of Long Sought For Pond and Nabnasset Lake were performed on August 25th to control respective aquatic invasive species growth around select areas of the shoreline. Prior to both treatment events, notification was posted on the Town's website and Facebook page, as well as water-use restriction signs that were posted along the shoreline of each pond.

Both ponds were treated utilizing diquat herbicide; approximately 50 acres in Long Sought For, and 39 acres in Nabnasset were treated. An early season copper sulfate treatment was performed at Nabnasset Lake on June 30th to address an algae bloom prior to the initiation of this year's contract with the Town.

### **Post-Treatment Assessment**

The final post-treatment plant mapping and WQ sampling at all seven waterbodies was conducted by ESS in September.

Overall, the herbicide treatments at Long Sought for Pond and Nabnasset Lake worked well to control the target species. Nabnasset Lake did not have any curlyleaf pondweed growth present at the time of the survey and only a small amount of variable milfoil in Shipley Swamp and one other location along a nearby shoreline of the main lake. No curlyleaf pondweed or viable flat-stem pondweed was observed in Long Sought For Pond. The detailed results of the sampling and late season mapping work are included in the attached report by ESS.

### **Ongoing Management Recommendations**

Consistent with prior years, we recommend continuing annual monitoring and treatment, if warranted, at each pond in 2022. We strongly recommend initiating monitoring and management of all ponds in early spring to sufficiently allow for scheduling and appropriate treatment timing for the various target species. More information on the recommendations from ESS (with input from SOLitude) is included in their attached report and will be forthcoming as the 5-Year Management Plan is discussed and finalized.



August 13, 2021

Dominic Meringolo  
SOLitude Lake Management  
590 Lake Street  
Shrewsbury, Massachusetts 01545

**Re: Aquatic Plant and Water Quality Monitoring and Reporting, Pre-treatment – 2021  
Westford, Massachusetts  
ESS Project No. S469-006**

Dear Mr. Meringolo,

ESS Group, Inc. (ESS) was contracted by SOLitude Lake Management (SOLitude) to complete a pre-treatment monitoring program at Long Sought-for Pond and Nabnasset Lake located within the Town of Westford (Town).

### **Pre-treatment Monitoring**

Pre-treatment monitoring consisted of aquatic vegetation mapping and water quality sampling and was completed at on July 16, 2021.

### **Aquatic Vegetation Monitoring**

Aquatic plants were surveyed using comparable methods to 2020. Plant rakes were used to help assess aquatic invasive plant densities. Data was collected using a combination of field notes and a Trimble Geo7x DGPS receiver capable of sub-meter accuracy. Aquatic plants observed during the pre-treatment monitoring are presented in Table 1.

Additional details on the results of the aquatic plant surveys are presented, by pond, in the following sections.

### **Long Sought-for Pond**

Seven species of aquatic plant and one species of macroalgae were observed at Long Sought-for Pond during the pre-treatment survey (Table 1).

Aquatic invasive curly-leaf pondweed covered approximately 14 acres during the 2021 pre-treatment survey (Figure 1). Beds were generally of low density in all areas where observed.

Additionally, a native thinleaf pondweed species (*Potamogeton spp.*) covered approximately 36 acres of the pond in light to moderate growth, with a few small areas of denser beds along the western shoreline (Figure 2). The observed plants were still immature, but may represent regrowth of flatstem pondweed (*P. zosteriformis*) which was first identified by SOLitude in the pond in 2019.

Eurasian milfoil (*Myriophyllum spicatum*), which has been observed in the recent past, was not observed at Long Sought-for Pond during 2021 pre-treatment monitoring.



*Area of dense phytoplankton and filamentous algal growth at Long Sought-for Pond.*



Of note, some areas of dense phytoplankton growth were noted at Long Sought-for Pond in 2021, often mixed with filamentous algae. The bloom appeared to be concentrated in sheltered coves and was not readily visible elsewhere. Based on a qualitative analysis of a single grab sample taken from the eastern shoreline, the phytoplankton in this area appeared to be dominated by cyanobacteria (*Microcystis* sp.).

#### Nabnasset Lake

Nine species of aquatic plants and one species of macroalgae were observed at Nabnasset Lake during the pre-treatment survey (Table 1).

Most notably, water chestnut (*Trapa natans*) was documented at Nabnasset Lake during the 2021 survey. Although it was confined to a single location (Figure 3), this species is capable of rapid spread and should be monitored for and managed while the infestation is still in its pioneer stage.

Water chestnut is a highly impactful aquatic invasive species that produces a dense crop of floating-leaved rosettes. These rosettes shade the water column and restrict diffusive and physical exchange with the atmosphere. This can lead to the development of hypoxic or anoxic (low dissolved oxygen) zones in the lake, even in shallow waters. As an annual species, water chestnut spreads by seeds, which drop in late summer through early fall. Once the seeds ripen, they may remain viable for many years. Therefore, the goal in water chestnut management is to prevent a seed bank from developing. Otherwise, a decade or more of persistent management efforts may be required to bring the infestation back under substantial control.

During the pioneer infestation stage, water chestnut may be easily controlled through hand harvesting. Individual plants are easy to pull from a small watercraft. However, regular monitoring during the growing season is necessary to prevent any seed drop from occurring.

Additionally, aquatic invasive curly-leaf pondweed covered approximately 37 acres during the 2021 pre-treatment survey (Figure 4). This species was widespread but only found at low to moderate densities within most of the mapped area.

Water celery (*Vallisneria americana*), although not an exotic species, was also widespread at Nabnasset Lake, covering approximately 32 acres (Figure 5). As with curly-leaf pondweed, water celery was generally present at low to moderate densities with only a limited area of higher density beds.

Variable-leaf milfoil was not observed in Nabnasset Lake during 2021 pre-treatment monitoring, although it was observed adjacent to the lake in the outlet of Shipley Swamp.

**Table 1. Aquatic Plants Observed at Westford Ponds during 2021 Pre-treatment Surveys.**

Common Name	Scientific Name	Native or Exotic	Long Sought-for Pond	Nabnasset Lake
Aquatic Moss	<i>Fontinalis spp.</i>	Native		X
Bigleaf Pondweed	<i>Potamogeton amplifolius</i>	Native		X
Common Bladderwort	<i>Utricularia macrorhiza</i>	Native	X	
<b>Curly-leaf Pondweed</b>	<b><i>Potamogeton crispus</i></b>	<b>Exotic</b>	<b>X</b>	<b>X</b>
Floating-leaf Pondweed	<i>Potamogeton epihydrus</i>	Native	X	X
Golden Hedge-hyssop	<i>Gratiola aurea</i>	Native		X
Robbins' Pondweed	<i>Potamogeton robbinsii</i>	Native	X	
Spikerush	<i>Eleocharis sp.</i>	Native	X	X
Stonewort	<i>Nitella sp.</i>	Native	X	X
Thinleaf Pondweed	<i>Potamogeton spp.</i>	Native	X	
<b>Variable-leaf Milfoil</b>	<b><i>Myriophyllum heterophyllum</i></b>	<b>Exotic</b>		*
Water Celery (Tapegrass)	<i>Vallisneria americana</i>	Native	X	X
<b>Water Chestnut</b>	<b><i>Trapa natans</i></b>	<b>Exotic</b>		<b>X</b>
Yellow Water Lily	<i>Nuphar lutea variegata</i>	Native		X
<b>Total</b>			<b>8</b>	<b>10</b>

\* = Only in Shipley Swamp

### Water Quality Monitoring

ESS conducted water quality sampling at three stations within each waterbody, including one location in the deepest portion of each waterbody. ESS measured the following parameters in the field: dissolved oxygen, temperature, turbidity, pH, and water clarity (Secchi disk).

ESS collected water samples for laboratory analysis of the following analytes: hardness, nitrate nitrogen, alkalinity, total phosphorus, total Kjeldahl nitrogen, and ammonia nitrogen. Water samples were analyzed by a Massachusetts-certified analytical laboratory. Notable water quality results are summarized in the following sections.

#### Dissolved Oxygen

Each pond exhibited dissolved oxygen concentrations suitable for aquatic life near the surface. However, water quality results indicate low dissolved oxygen levels (hypoxia and anoxia) developed in the cool, deeper waters of Nabnasset Lake (Tables 1 and 2). Long Sought-for Pond contained sufficient dissolved oxygen to the bottom of the water column. However, Long Sought-for also demonstrated supersaturated (i.e., >100%) dissolved oxygen in near-surface waters. This could potentially be associated with bloom conditions, in which photosynthesis by phytoplankton removes carbonic acid (carbon dioxide) from the water and produces oxygen.

#### Turbidity

Turbidity was higher in Long Sought-for Pond than Nabnasset Lake (Table 4) but did not appear to be elevated in any of the locations sampled. Some variability was observed among sampling locations within a pond, with turbidity readings ranging twice as high at some locations as others.

### Secchi Depth (Transparency)

Secchi depth is a measure of water transparency and may be reduced by suspended sediments, algal growth, or the presence of other organic matter in the water column. Reduced Secchi depths are typically associated with nutrient-enriched ponds.

In this study, Secchi depth was similar for both water bodies (Table 4). Although transparency was not excellent, it also did not appear to be severely limited.

### pH, Hardness, and Alkalinity

The pH of both water bodies was circumneutral (i.e., pH near 7.0).

Hardness was higher at Nabnasset Lake but alkalinity was similar between the two ponds. These results are consistent with the results of pre-treatment water quality sampling conducted in prior years.

Greater hardness suggest higher levels of dissolved metals. Increased alkalinity suggests greater buffering capacity of the water (i.e., resistance to pH change). Ponds with low buffering capacity may be susceptible to more abrupt swings in pH than those with higher alkalinity.

### Phosphorus and Nitrogen

Phosphorus and nitrogen are both major nutrients fueling plant and algal growth. Of the two, phosphorus tends to be limiting nutrient in most New England freshwater systems. However, nitrogen levels can also impact the overall productivity of the system and type of algal growth favored, and may even influence the production of toxins in some cyanobacteria. In general, high water column nutrient levels can contribute to algal blooms and excessive aquatic plant growth, especially floating plants.

Total phosphorus concentrations were modest in the open waters of both Long-Sought-for Pond and Nabnasset Lake. However, they were somewhat higher in surface waters of Long Sought-for Pond than bottom waters, possibly reflecting the presence of phytoplankton near the surface of the pond and mobilization of phosphorus in runoff from recent rains. Concentrations in excess of 0.020 mg/L were recorded only from the inlet site at Long-Sought-For Pond. Algal blooms may occur even where total phosphorus levels are very low. However, as a rule of thumb, they tend to be more frequent and are more likely to become problematic where concentrations remain elevated for extended periods of time.

Overall nitrogen levels were highest Nabnasset Lake, where nitrate contributed similar concentrations of nitrogen as total Kjeldahl nitrogen (TKN). This is consistent with prior years, which indicate elevated concentrations of nitrate nitrogen in Nabnasset Lake. Ammonia nitrogen, which is a component of TKN, was low at all locations.

**Table 2. Dissolved Oxygen Profiles at Deep Hole Locations During 2021 Pre-treatment Monitoring**

Depth	Long-Sought-for Pond		Nabnasset Lake	
	m	%	mg/L	%
0.5	108	8.5	98	8.0
1.0	111	9.0	102	8.5
1.5	110	9.1	99	8.4
2.0	112	9.4	98	8.4
2.5	111	9.4	96	8.2
3.0	100	8.5	94	8.1
3.5	87	7.4	87	7.5
4.0	81	6.9	63	5.5
4.5	80	6.9	49	4.3
5.0	76	6.7	14	1.3
5.5	74	6.7	4	0.4
6.0	72	6.5	2	0.2
6.5	-	-	3	0.3
7.0	-	-	3	0.3
7.5	-	-	2	0.2
8.0	-	-	2	0.2
8.5	-	-	3	0.3

**Table 3. Temperature (°C) Profiles at Deep Hole Locations During 2021 Pre-treatment Monitoring**

Depth (m)	Long-Sought-for Pond	Nabnasset Lake
0.5	27.1	24.8
1.0	25.5	24.4
1.5	24.3	23.6
2.0	23.8	23.3
2.5	23.4	23.1
3.0	23.1	22.7
3.5	22.8	22.6
4.0	22.7	22.1
4.5	22.2	21.8
5.0	21.5	19.8
5.5	20.5	18.7
6.0	20.0	17.7
6.5	-	16.6
7.0	-	16.2
7.5	-	16.0
8.0	-	15.8
8.5	-	15.7

**Table 4. Water Quality Parameters Collected During 2021 Pre-treatment Monitoring**

Parameter	Units	Long Sought-for Pond			Nabnasset Lake		
		LSF-A	LSF-B	LSF-C	NAB-A	NAB-B	NAB-C
		Deep Hole		Inlet	Deep Hole		Outlet
		Surface	Bottom		Surface	Bottom	
Total depth	m	6.0		0.5	8.5		2.0
Sample depth	m	surface	5	surface	surface	7	surface
Temperature	C	27.1	20.0	28.6	24.8	15.7	25.9
Dissolved oxygen	%	107.7	72.0	110.6	97.9	2.9	97.9
	mg/L	8.5	6.5	8.5	8.0	0.3	7.9
Turbidity	NTU	1.89	1.16	2.25	0.21	0.52	0.78
pH	SU	7.3	7.3	7.2	7.2	7.2	7.1
Secchi Depth	m	3.5		0.5 (bottom)	3.5		2 (bottom)
Hardness	mg/L	37.8	37.7	37.1	49.6	49.7	50.6
Alkalinity	mg/L	24.6	24.6	21.5	24.7	25.9	22.5
Total phosphorus	mg/L	0.015	0.010	0.028	0.006	0.013	0.006
Nitrate nitrogen	mg/L	<0.02	<0.02	0.03	0.41	0.40	0.39
Total Kjeldahl nitrogen	mg/L	0.48	0.40	0.52	0.47	0.44	0.43
Ammonia nitrogen	mg/L	<0.05	<0.05	<0.05	0.06	<0.05	<0.05

**Monitoring**

Fall season/post-treatment water quality and aquatic vegetation monitoring is recommended for Nabnasset Lake and Long Sought-for Pond, as well as the other five ponds that are typically monitored on a biannual basis (Keyes Pond, Old Mill/Graniteville Pond, . This will allow for the development of the next five-year management plan using data that are up-to-date and accurately reflect the current condition of each water body. For consistency, post-treatment monitoring protocols should be the same as the pre-treatment monitoring conducted as part of this study. ESS recommends completing the monitoring program in September or early October to maximize comparability of the results to prior years.

We appreciate the opportunity to work with you on this project. Please contact Matt Ladewig at (401) 330-1204 if you have any questions.

Sincerely,

**ESS GROUP, INC.**

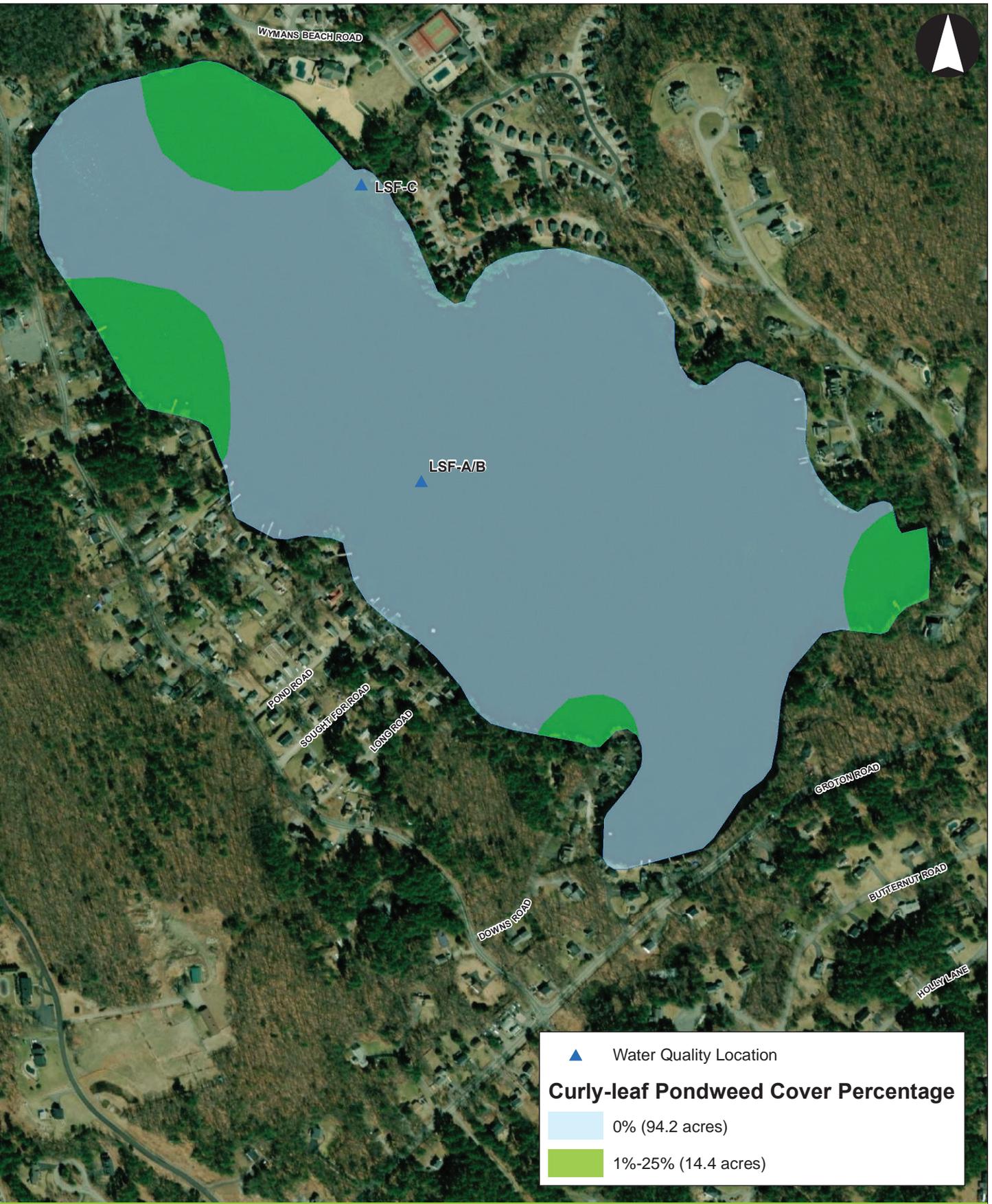


Matt Ladewig, CLM  
Senior Scientist

Attachments: Figures



Path: J:\S\469-006 Solitude Lake Management LLC-2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\MXD\S469\_006\_PlantMaps\_FigD\_X\_LSF\_Prispus202107.mxd  
Drawing Date: 2021/08/02  
© 2014 ESS Group, Inc.



▲ Water Quality Location

**Curly-leaf Pondweed Cover Percentage**

Light Blue	0% (94.2 acres)
Green	1%-25% (14.4 acres)



**Solitude Lake Management LLC**  
Westford, Massachusetts

**Long Sought For Pond  
Curly-leaf Pondweed (July 2021)**

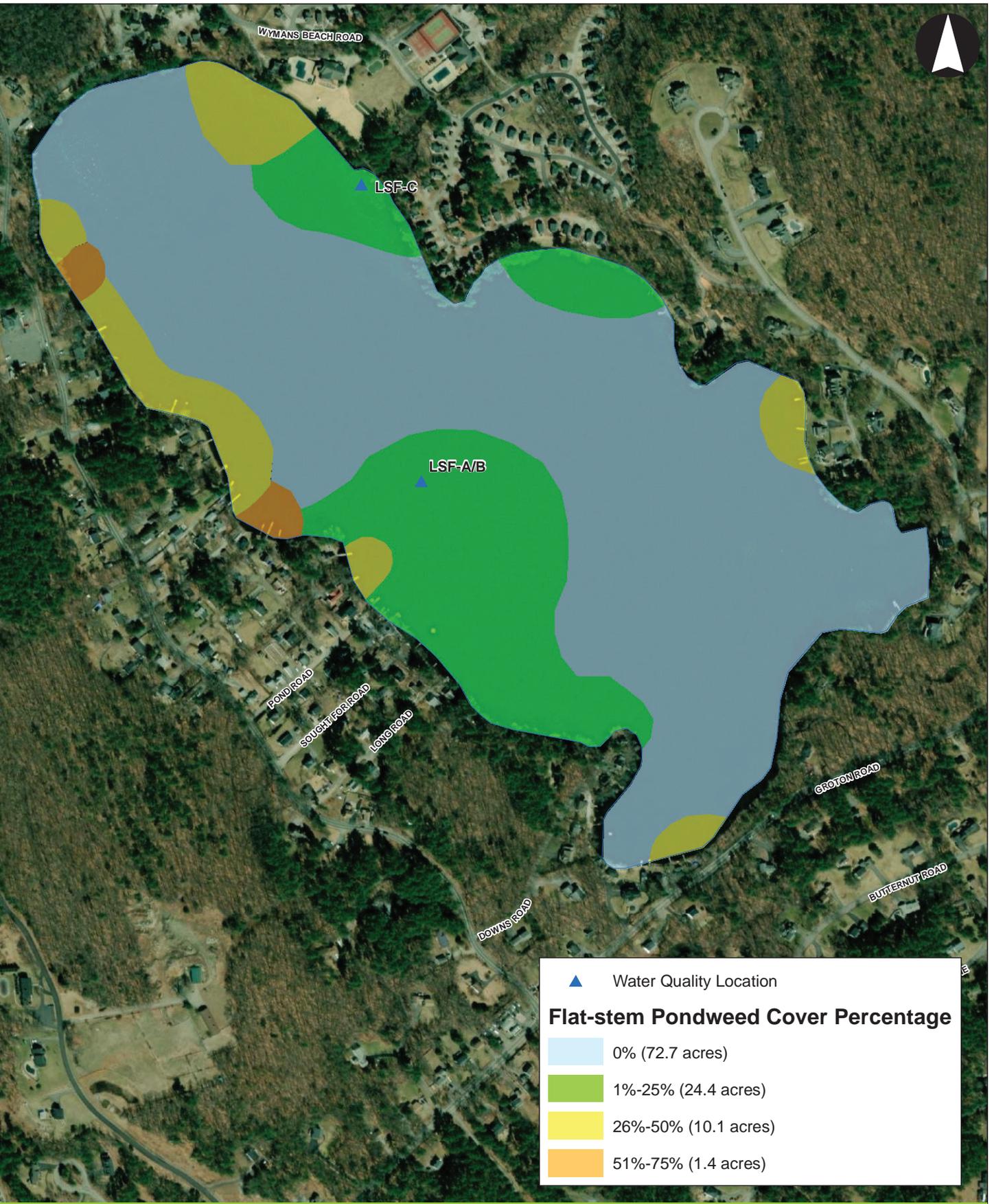
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2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, July 2021



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Drawing Date: 2021/08/02

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▲ Water Quality Location

**Flat-stem Pondweed Cover Percentage**

Light Blue	0% (72.7 acres)
Green	1%-25% (24.4 acres)
Yellow	26%-50% (10.1 acres)
Orange	51%-75% (1.4 acres)



**Solitude Lake Management LLC**  
Westford, Massachusetts

**Long Sought For Pond**  
**Flat-stem Pondweed (July 2021)**

Source: 1) ESRI, World Imagery, 2019  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, July 2021





*Nabnasset Pond*



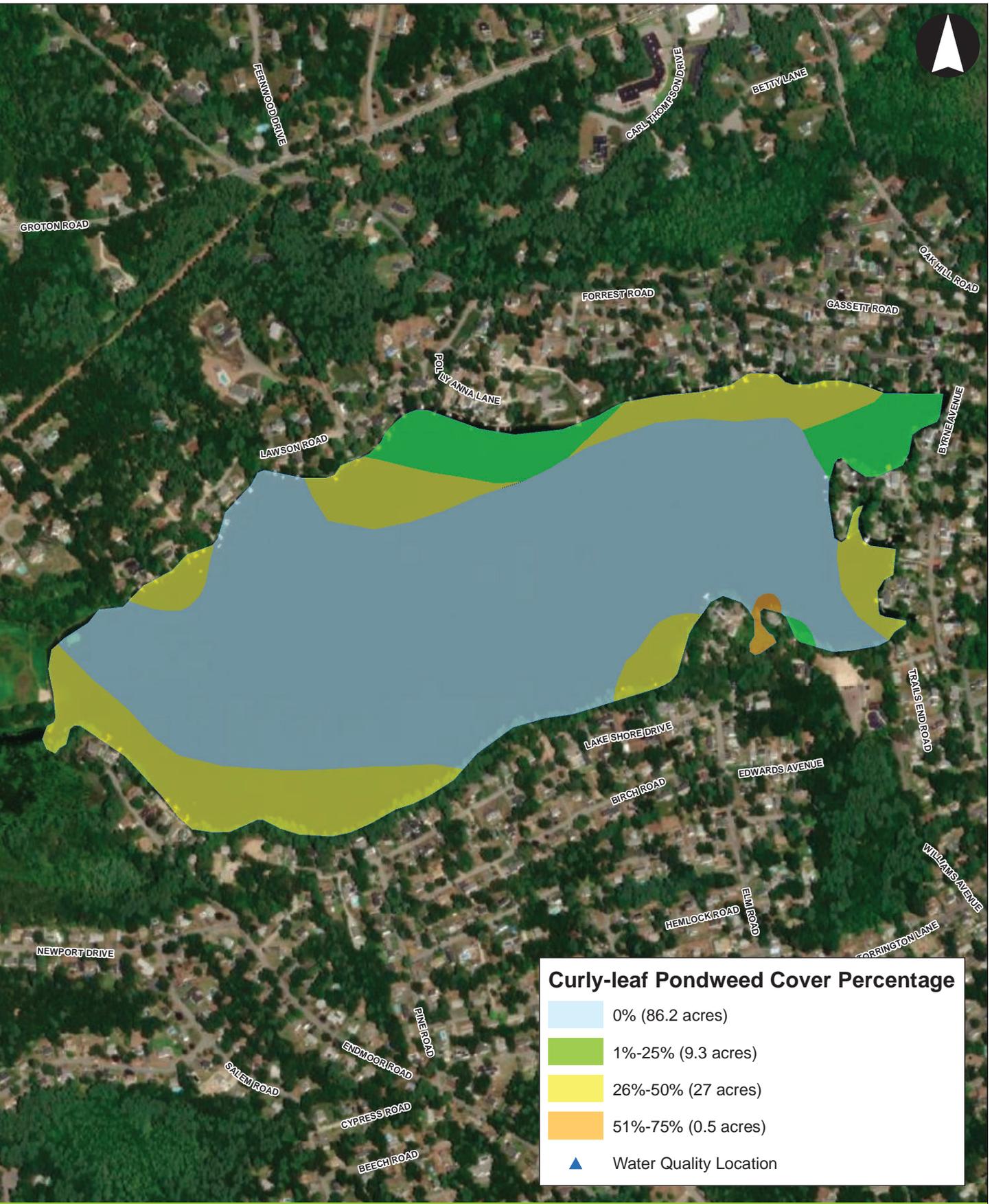
**SOLitude Lake Management, LLC**  
 Town of Westford, MA

**Nabnasset Pond**  
**Water Chestnut (July 2021)**

Source: 1) ESRI, World Imagery, 2020  
 2) ESS GPS, 7/16/2021

 Water Chestnut





**Curly-leaf Pondweed Cover Percentage**

Light Blue	0% (86.2 acres)
Green	1%-25% (9.3 acres)
Yellow	26%-50% (27 acres)
Orange	51%-75% (0.5 acres)
Blue Triangle	Water Quality Location

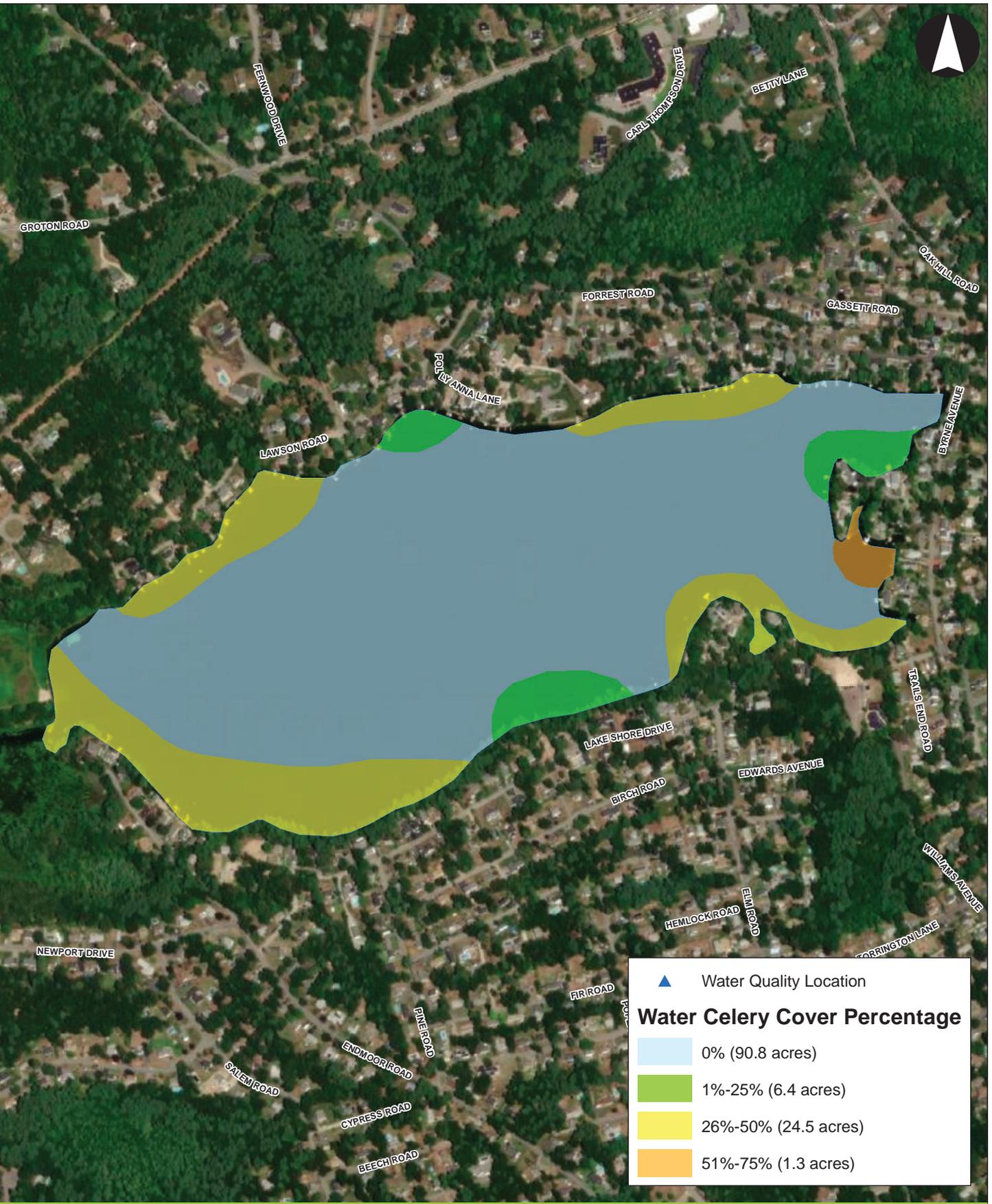


**Solitude Lake Management LLC**  
Westford, Massachusetts

**Nabnasset Pond**  
**Curly-leaf Pondweed (July 2021)**

Source: 1) ESRI, World Imagery, 2019  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, July 2021





▲ Water Quality Location

**Water Celery Cover Percentage**

Light Blue	0% (90.8 acres)
Green	1%-25% (6.4 acres)
Yellow	26%-50% (24.5 acres)
Orange	51%-75% (1.3 acres)



**Solitude Lake Management LLC**  
Westford, Massachusetts

**Nabnasset Pond**  
**Water Celery (July 2021)**

Source: 1) ESRI, World Imagery, 2019  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, July 2021





November 12, 2021

Dominic Meringolo  
SOLitude Lake Management  
590 Lake Street  
Shrewsbury, Massachusetts 01545

**Re: Aquatic Plant and Water Quality Monitoring and Reporting, Post-treatment – 2021  
Westford, Massachusetts  
ESS Project No. S469-006**

Dear Mr. Meringolo,

ESS Group, Inc. (ESS) was contracted by SOLitude Lake Management (SOLitude) to complete a post-treatment monitoring program at two lakes and ponds located within the Town of Westford (Town), as follows: Long Sought-for Pond and Nabnasset Lake. In addition, a late season monitoring event was completed at five additional ponds, as follows: Keyes Pond, Old Mill/Graniteville Ponds, Burge's Pond, Kennedy Pond, and Forge Pond. The post-treatment/late season monitoring program was completed to complement pre-treatment monitoring at Long Sought-for Pond and Nabnasset Lake, conducted by ESS in early summer 2021.

This report provides the findings of the monitoring program, builds on the findings of prior monitoring efforts, and makes recommendations for management of these water bodies in 2022.

## **POST-TREATMENT AND LATE-SEASON MONITORING 2021**

The 2021 post-treatment/late season monitoring program consisted of aquatic vegetation mapping and water quality sampling and was completed at each of the seven ponds on the following dates:

- September 14 – Forge Pond (including both the Westford and Littleton sides) and Old Mill/Graniteville Ponds
- September 16 – Burge's Pond and Kennedy Pond
- September 17 – Long Sought-For Pond and Keyes Pond
- September 22 – Nabnasset Lake

### **Aquatic Vegetation Monitoring**

Aquatic plants were surveyed using comparable methods to recent monitoring events, including the 2021 pre-treatment monitoring effort. Plant rakes were used to help assess aquatic invasive plant densities. Data were collected using a combination of field notes and a Trimble Geo7x DGPS receiver capable of sub-meter accuracy. Aquatic plants observed during the post-treatment/late season monitoring are presented in Table 1.

Additional details on the results of the aquatic plant surveys are presented, by pond, on subsequent pages.



**Table 1. Aquatic Plants Observed during 2021 Post-treatment/ Late Season Surveys**

Common Name	Scientific Name	Native or Exotic	Keyes Pond	Long Sought-for Pond	Nabnasset Lake	Old Mill/Graniteville Ponds	Burge' s Pond	Kennedy Pond	Forge Pond
Aquatic Moss	<i>Fontinalis sp.</i>	Native	X		X		X		
Bigleaf Pondweed	<i>Potamogeton amplifolius</i>	Native							X
<b>Brittle Naiad</b>	<b><i>Najas minor</i></b>	<b>Exotic</b>							<b>X</b>
Bushy Naiad	<i>Najas flexilis</i>	Native		X	X			X	
Canadian Waterweed	<i>Elodea canadensis</i>	Native				X			
Clasping-leaf Pondweed	<i>Potamogeton perfoliatus</i>	Native						X	
Common Bladderwort	<i>Utricularia macrorhiza</i>	Native	X	X	X	X	X		X
Coontail	<i>Ceratophyllum demersum</i>	Native				X			X
<b>Eurasian Milfoil</b>	<b><i>Myriophyllum spicatum</i></b>	<b>Exotic</b>				<b>X</b>			<b>X</b>
<b>Fanwort</b>	<b><i>Cabomba caroliniana</i></b>	<b>Exotic</b>				<b>X</b>			<b>X</b>
Flat-leaf Bladderwort	<i>Utricularia intermedia</i>	Native	X						
Floating-leaf Pondweed	<i>Potamogeton epihydrus</i>	Native			X				
Golden Hedge-hyssop	<i>Gratiola aurea</i>	Native						X	
Humped Bladderwort	<i>Utricularia gibba</i>	Native		X	X				
Little Floating Bladderwort	<i>Utricularia radiata</i>	Native					X		
Low Milfoil	<i>Myriophyllum humile</i>	Native	X				X	X	
Marsh Seedbox	<i>Ludwigia palustris</i>	Native				X		X	
Purple Bladderwort	<i>Utricularia purpurea</i>	Native			X				
Quillwort	<i>Isoetes spp.</i>	Native		X				X	
Robbins' Pondweed	<i>Potamogeton robbinsii</i>	Native		X					X
Slender Naiad	<i>Najas gracillima</i>	Native			X				
Spikerush	<i>Eleocharis sp.</i>	Native		X	X	X	X	X	
Stonewort	<i>Nitella sp.</i>	Native		X	X				X
Southern Naiad	<i>Najas guadalupensis</i>	Native		X					
Thinleaf Pondweed	<i>Potamogeton pusillus</i>	Native			X			X	X
<b>Variable-leaf Milfoil</b>	<b><i>Myriophyllum heterophyllum</i></b>	<b>Exotic</b>			<b>X</b>	<b>X</b>			<b>X</b>
Water Celery (Tapegrass)	<i>Vallisneria americana</i>	Native		X	X	X			X
Watershield	<i>Brasenia schreberi</i>	Native	X		X	X	X	X	

Common Name	Scientific Name	Native or Exotic	Keyes Pond	Long Sought-for Pond	Nabnasset Lake	Old Mill/Graniteville Ponds	Burge' s Pond	Kennedy Pond	Forge Pond
Waterwort	<i>Elatine sp.</i>	Native						X	
White Water Lily	<i>Nymphaea odorata</i>	Native	X	X	X	X	X		X
Yellow Water Lily	<i>Nuphar lutea variegata</i>	Native	X		X		X	X	X
<b>Total</b>			<b>7</b>	<b>10</b>	<b>15</b>	<b>11</b>	<b>8</b>	<b>11</b>	<b>13</b>

#### Keyes Pond

Seven species of native plants were observed in Keyes pond during the 2021 post-treatment survey. No aquatic invasive plants were observed (Figure 1). Of note, invasive variable-leaf milfoil (*Myriophyllum heterophyllum*) has not been observed during ESS's surveys at Keyes Pond since pre-treatment mapping in 2017.

#### Long Sought-for Pond

Eleven species of aquatic plants were observed in Long Sought-for Pond during the 2021 post-treatment survey. However, no aquatic invasive plants were observed (Figure 2).

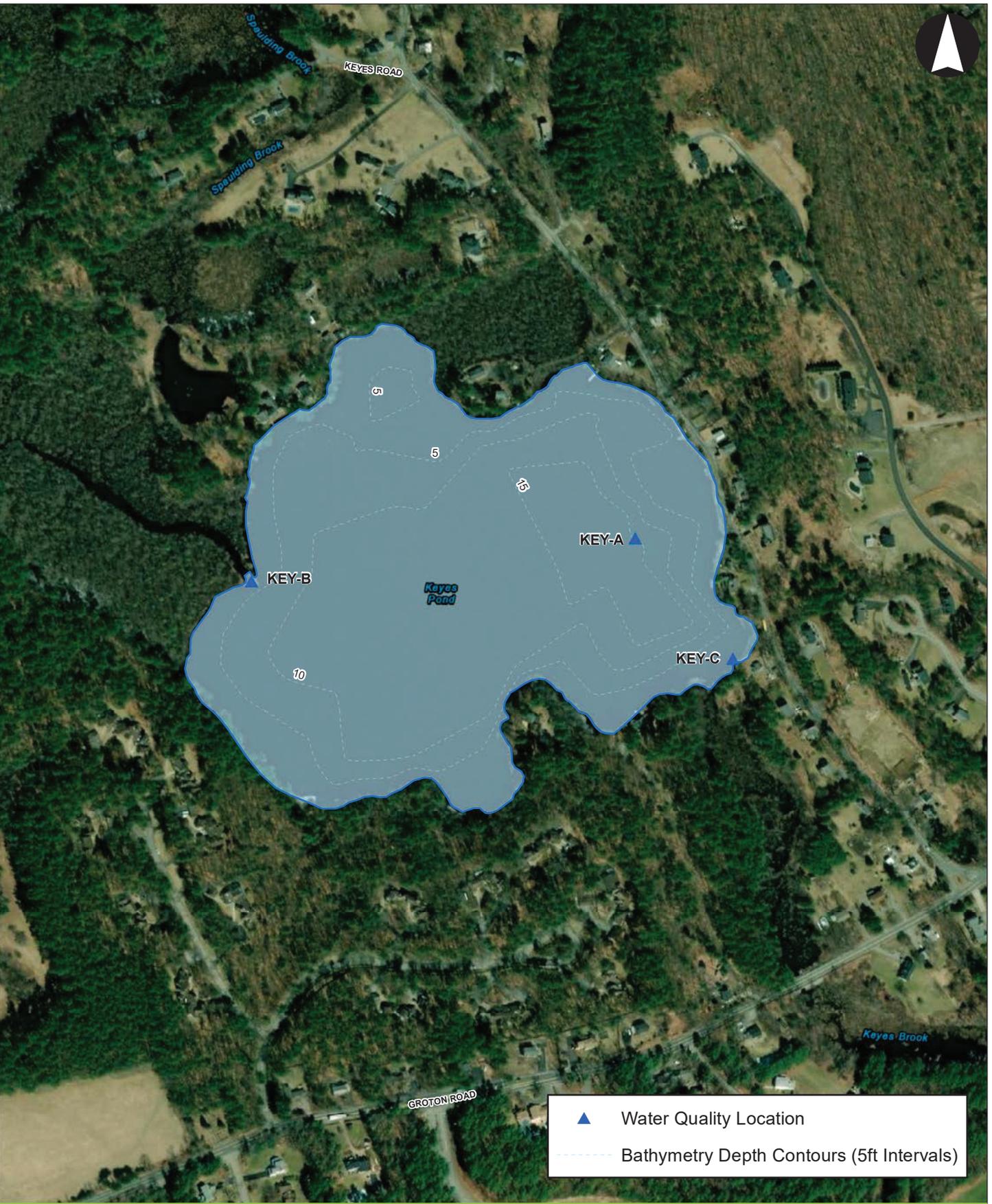
Flat-stem pondweed (*Potamogeton zosteriformis*), a management target at Long Sought-for Pond, was also not observed during the 2021 post-treatment survey. However, this species was observed as expired biomass, presumably having succumbed to treatments applied earlier in the season.

#### Nabnasset Lake

Fifteen species of aquatic plants were observed at Nabnasset Lake during the 2021 post-treatment survey, including one exotic invasive species. Invasive variable-leaf milfoil was confined to sparse beds in Shipley Swamp and in a nearby shoreline location on the northwestern shoreline of Nabnasset Lake (Figure 3). Other aquatic invasive plants observed during the pre-treatment survey, including curly-leaf pondweed (*Potamogeton crispus*) and water chestnut (*Trapa natans*) were not encountered during the post-treatment survey.

Native water celery (*Vallisneria americana*) was observed growing in sparse to patchy beds along much of the shoreline of Nabnasset Lake during the 2021 post-treatment survey (Figure 4). This species covered approximately 12 acres, which is less than half the total area covered during recent surveys in July 2021 and autumn 2020.

Path: J:\S469-006 Solitude Lake Management LLC-2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\MXD\S469\_006\_PlantMaps\_Fig0X\_Keyes\_2021PostTreatment\_WO.mxd  
Drawing Date: 2021/11/03  
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	Water Quality Location
	Bathymetry Depth Contours (5ft Intervals)



**Solitude Lake Management LLC**  
Westford, Massachusetts

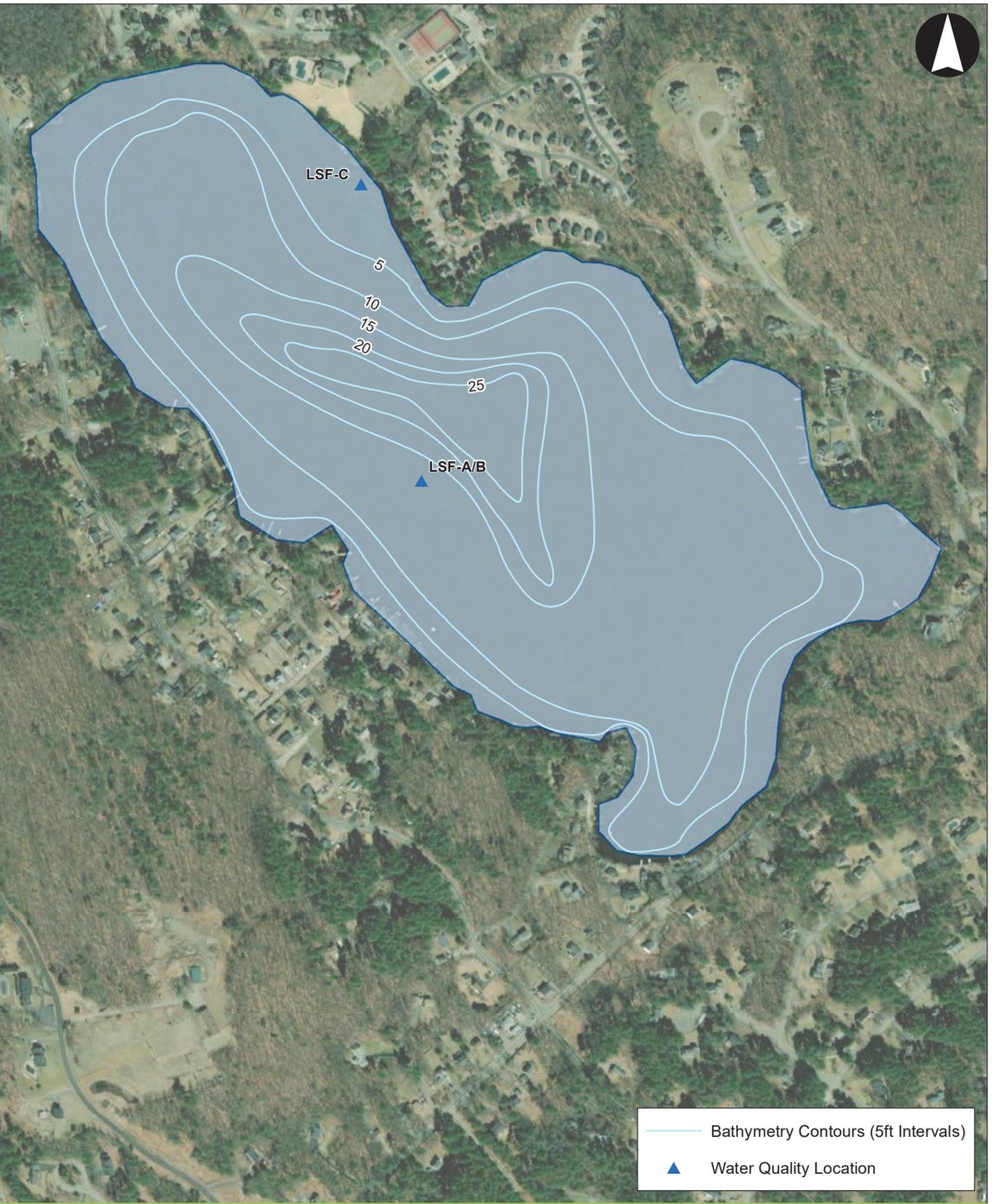
Source: 1) ESRI, Maxar Imagery, 2019  
2) MassGIS, Major Roads, 2003  
3) ESS, Bathymetry, 2015  
4) ESS, GPS Data, 2021

**Keyes Pond**  
**Water Quality Sampling Locations**  
**Post-Treatment (September 2021)**



Figure 1

Path: J:\S469-006 Solitude Lake Management LLC- 2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\MXD\S469\_006\_PlantMaps\_Fig0X\_LSF\_2021PostTreatments.mxd  
Drawing Date: 2021/11/12  
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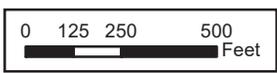
— Bathymetry Contours (5ft Intervals)  
▲ Water Quality Location



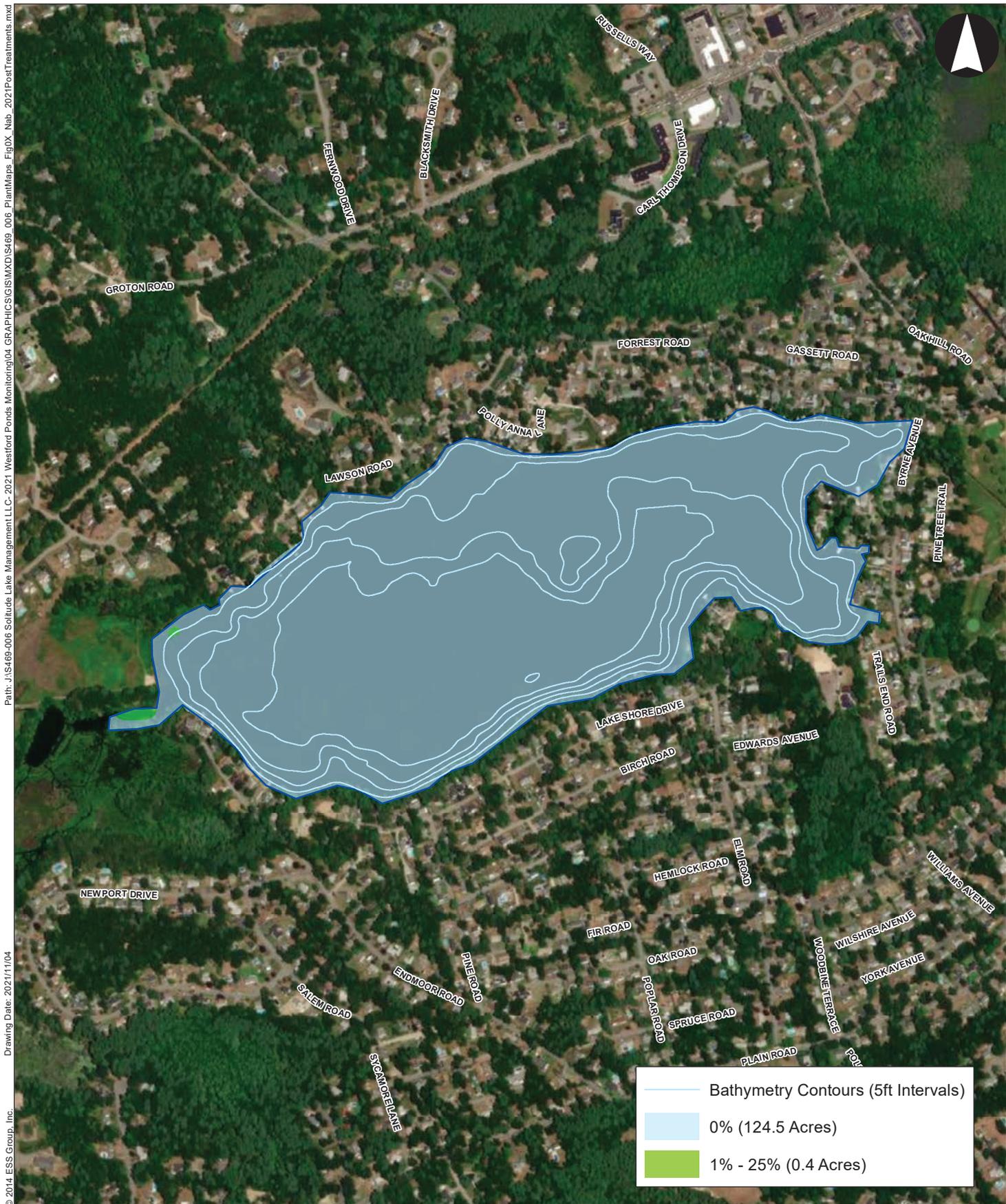
**Solitude Lake Management LLC**  
Westford, Massachusetts

Source: 1) ESRI, World Imagery, 2021  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, 2021

**Long Sought-For Pond  
Water Quality Sampling Locations  
Post-Treatment (September 2021)**



**Figure 2**

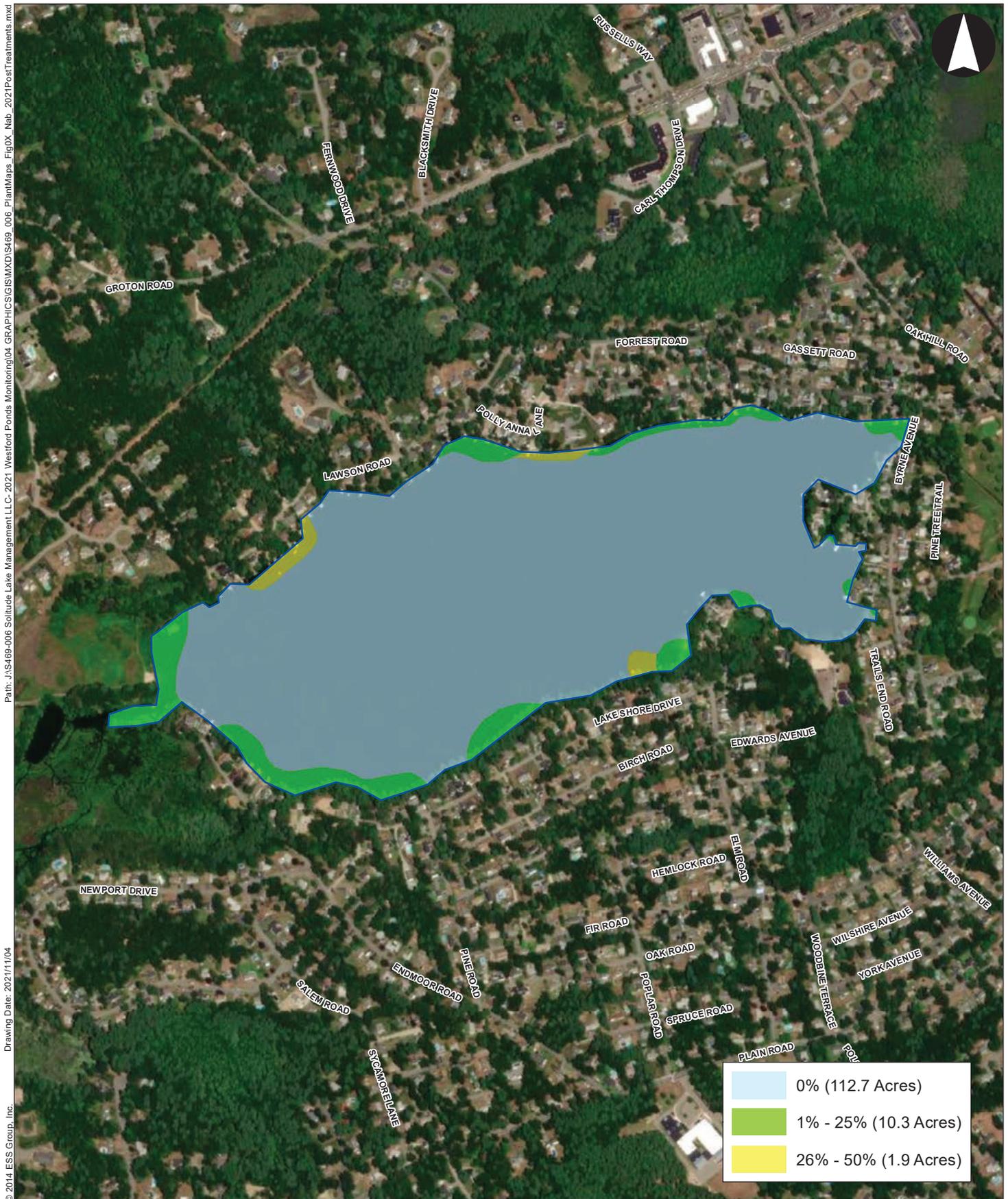


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Westford, Massachusetts

**Nabnasset Pond**  
**Variable-Leaf Milfoil Cover**  
**Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2020  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, September 2021





Path: J:\S469-006 Solitude Lake Management LLC-2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\IMXD\S469\_006\_Plan\Maps\_Fig0X\_Nab\_2021PostTreatments.mxd  
 Drawing Date: 2021/11/04  
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**Solitude Lake Management LLC**  
 Westford, Massachusetts

**Nabnasset Pond  
 Water Celery Cover  
 Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2020  
 2) MassGIS, Major Roads, 2003  
 3) ESS, GPS Data, September 2021



**Figure 4**

Old Mill/Graniteville Ponds

Eleven species of aquatic plants were observed at the Old Mill/Graniteville Ponds during the 2021 late season survey, including three exotic invasive species. Aquatic invasive fanwort (*Cabomba caroliniana*), Eurasian milfoil (*Myriophyllum spicatum*), and variable-leaf milfoil were observed during the late season mapping. Of these, Eurasian milfoil has not previously been observed at this location.

Eurasian milfoil was only observed in the upper basin (Figure 5). Although the total area covered was nearly 5 acres, the sparse nature of the beds suggests that the actual area covered by this plant is only a fraction of this.

Fanwort was found growing in patchy to very dense stands covering 8.8 acres in both basins of the pond during the 2021 late season survey (Figure 6). This represents an increase in overall fanwort extent, compared to the 6.1 acres of growth reported during the 2020 late season survey.

Variable-leaf milfoil was observed growing in sparse beds in both basins of the Old Mill/ Graniteville Ponds during the 2021 late season survey (Figure 7). Cover of this species was approximately 3.5 acres, which is higher than observed during the 2021 late season survey.



*Very dense bed of fanwort reaching the surface in lower basin of Old Mill/Graniteville Ponds.*



*The open waters of Burge's Pond provide for excellent recreational opportunities while providing ample habitat for aquatic life.*

Burge's Pond

Eight species of aquatic plants were found in Burge's Pond during the 2021 late season survey. No aquatic invasive plant species were observed in 2021 (Figure 8), which is consistent with prior mapping of Burge's Pond dating back to post-treatment mapping completed in 2016. Based on these survey results, the control of variable-leaf milfoil previously achieved appears to persist.

Kennedy Pond

Eleven species of aquatic plants were observed in Kennedy Pond during the late season survey. No aquatic invasive plant species were found (Figure 9). However, as in prior years, the exotic invasive common reed (*Phragmites australis*) was observed growing along portions of the shoreline.

Forge Pond

Thirteen species of aquatic plants were observed during the 2021 late season survey of Forge Pond, including four exotic invasive species. The following exotic invasive species were observed: brittle naiad (*Najas minor*), Eurasian milfoil, fanwort, and variable-leaf milfoil. Of these, ESS has not previously observed brittle naiad at Forge Pond.

Path: J:\S469-006 Solitude Lake Management LLC-2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\MXD\S469\_006 PlantMaps\_Fig0X\_OMG\_2021PostTreatments.mxd  
 Drawing Date: 2021/11/04  
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-----	Bathymetry Contours (5ft Intervals)
▲	Water Quality Locations
Light Blue	0% (8.8 Acres)
Green	1% - 25% (4.8 Acres)



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 Westford, Massachusetts  
 1 inch = 334 feet

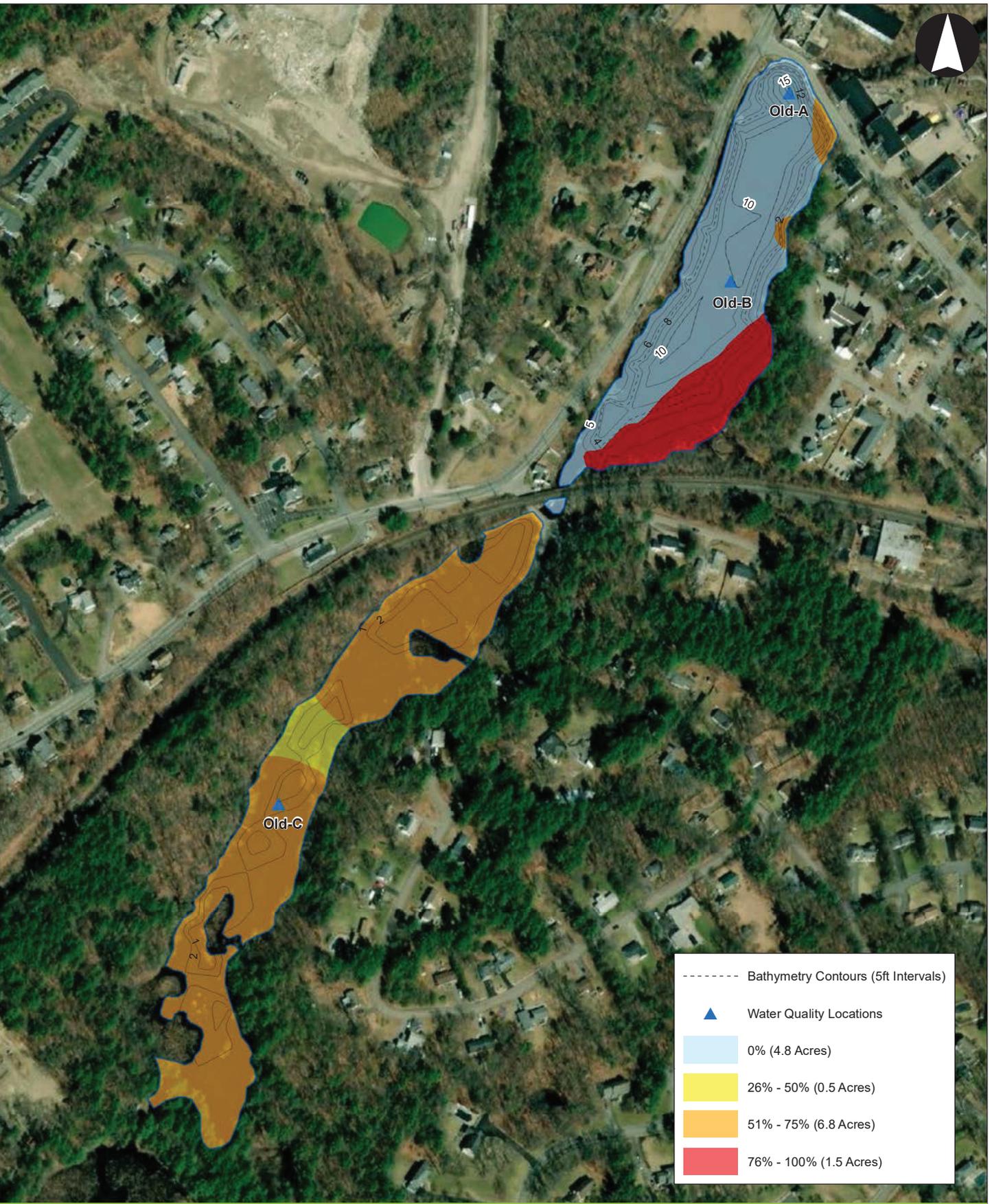
**Old Mill / Graniteville Ponds**  
**Eurasian Milfoil Cover**  
**Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2019  
 2) MassGIS, Major Roads, 2003  
 3) ESS, Bathymetry, 2015  
 4) ESS, GPS Data, 2021



**Figure 5**

Path: J:\S469-006 Solitude Lake Management LLC-2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\MXD\S469\_006 PlantMaps\_Fig0X\_OMG\_2021PostTreatments.mxd  
 Drawing Date: 2021/11/04  
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-----	Bathymetry Contours (5ft Intervals)
▲	Water Quality Locations
Light Blue	0% (4.8 Acres)
Yellow	26% - 50% (0.5 Acres)
Orange	51% - 75% (6.8 Acres)
Red	76% - 100% (1.5 Acres)



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**Old Mill / Graniteville Ponds**  
**Fanwort Cover**  
**Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2019  
 2) MassGIS, Major Roads, 2003  
 3) ESS, Bathymetry, 2015  
 4) ESS, GPS Data, 2021



**Figure 6**

Path: J:\S469-006 Solitude Lake Management LLC-2021 Westford Ponds Monitoring\04 GRAPHICS\GIS\MXD\S469\_006 PlantMaps\_Fig0X\_OMG\_2021PostTreatments.mxd  
 Drawing Date: 2021/11/04  
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-----	Bathymetry Contours (5ft Intervals)
▲	Water Quality Locations
Light Blue	0% (10.1 Acres)
Green	1% - 25% (3.5 Acres)



**Solitude Lake Management LLC**  
 Westford, Massachusetts

1 inch = 334 feet

Source: 1) ESRI, World Imagery, 2019  
 2) MassGIS, Major Roads, 2003  
 3) ESS, Bathymetry, 2015  
 4) ESS, GPS Data, 2021



**Old Mill / Graniteville Ponds  
 Variable-Leaf Milfoil Cover  
 Post-Treatment (September 2021)**

**Figure 7**

Path: J:\S468-006 Solitude Lake Management LLC- 2021 Westford Ponds Monitoring\04 GRAPHICS\GISMXD\S469\_006\_PlantMaps\_Fig0X\_Burges\_2021PostTreatment\_WQ.mxd  
Drawing Date: 2021/11/03  
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▲ Water Quality Location  
----- Bathymetry Contours (5ft Interval)



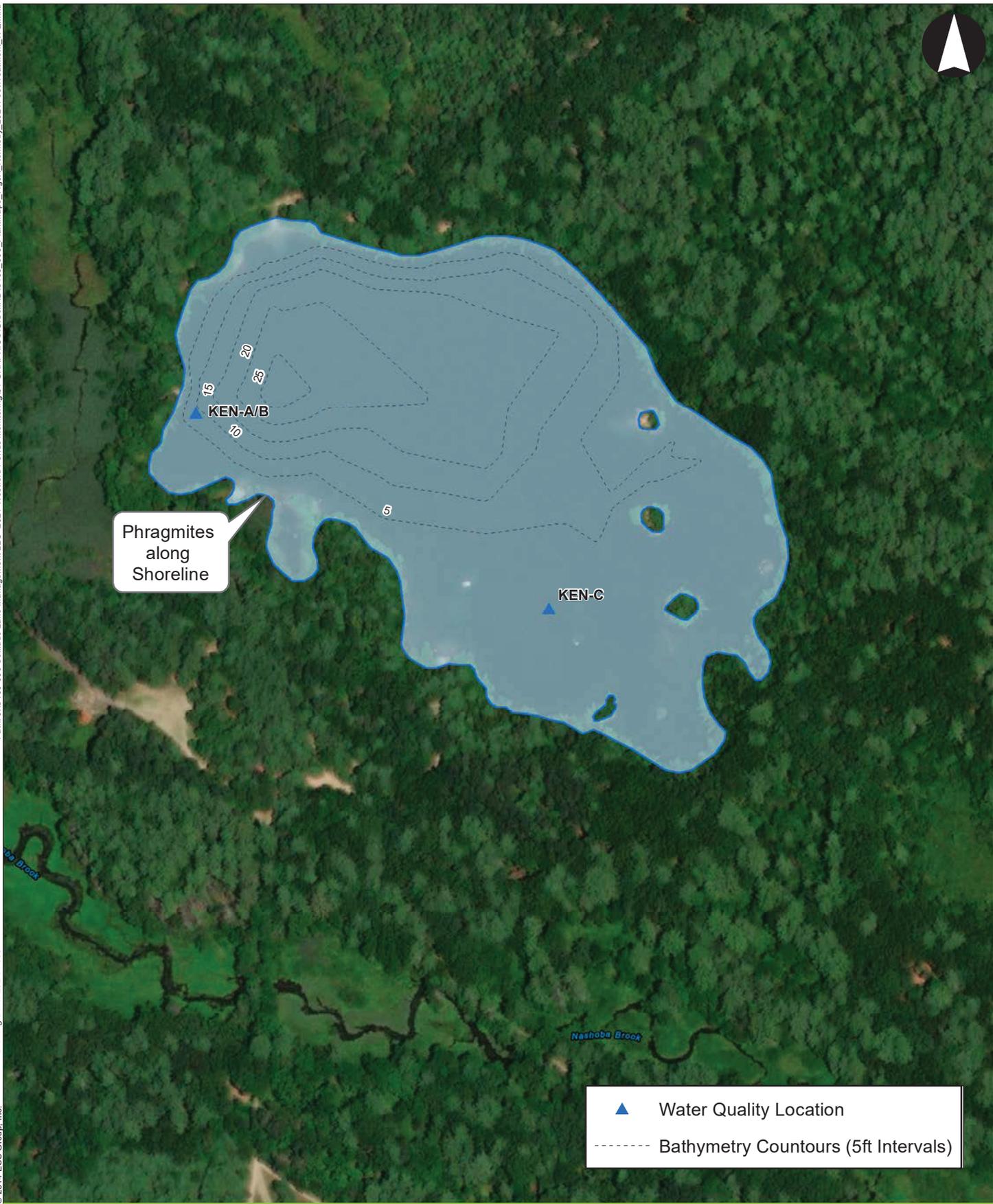
**Solitude Lake Management LLC**  
Westford, Massachusetts

Source: 1) ESRI, Maxar Imagery, 2019  
2) MassGIS, Major Roads, 2003  
3) ESS, Bathymetry, 2015  
4) ESS, GPS Data, 2021



**Burge's Pond**  
**Water Quality Sampling Locations**  
**Post-Treatment (September 2021)**

**Figure 8**



Phragmites along Shoreline

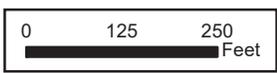
-  Water Quality Location
-  Bathymetry Countours (5ft Intervals)



**Solitude Lake Management LLC**  
Westford, Massachusetts

Source: 1) ESRI, Maxar Imagery, 2019  
2) MassGIS, Major Roads, 2003  
3) ESS, Bathymetry, 2015  
4) ESS, GPS Data, 2021

**Kennedy Pond**  
**Water Quality Sampling Locations**  
**Post-Treatment (September 2021)**



**Figure 9**

Curly-leaf pondweed was not observed, although this species typically completes its life cycle in early summer. Therefore, it is likely to persist in Forge Pond and is expected to return to active growth in spring 2022.

Brittle naiad cover in Forge Pond was observed to be just over an acre in extent, occurring primarily as sparse to patchy growth (Figure 10). Growth was confined to shoreline areas on the eastern side of the pond inside the Westford town line.

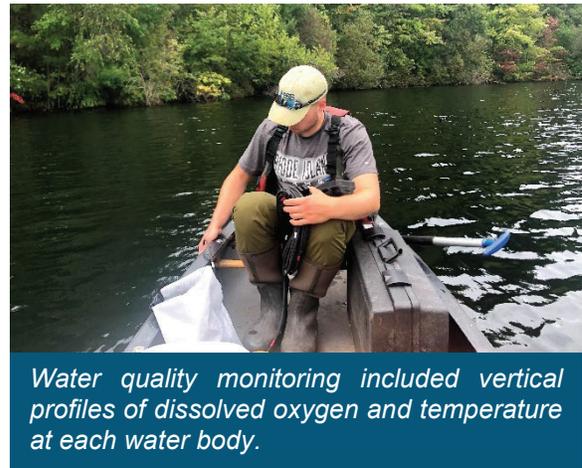
Eurasian milfoil was observed in mostly sparse to patchy beds covering approximately 12 acres of Forge Pond during the 2021 late season survey (Figure 11). This includes some beds on the Littleton side of the pond that would not have been mapped in prior years.

Fanwort was observed in extensive beds covering approximately 41 acres (Figure 12). Most beds were dense, with a few areas of sparse to patchy growth. Fanwort was the dominant aquatic plant species on the Littleton side of the pond.

Variable-leaf milfoil covered approximately 8 acres in sparse beds along shoreline areas of Forge Pond during the 2021 late season survey (Figure 13). Although this is a slight increase in areal extent from 2020, it also includes portions of beds on the Littleton side of the pond that would not have been previously mapped.

### Water Quality Monitoring

As in prior years, ESS conducted water quality sampling at three stations within each water body, including at least one location in a deep spot. During the water quality monitoring event, ESS measured the following parameters in the field: dissolved oxygen, temperature, turbidity, pH, and water clarity (Secchi disk). ESS also collected water samples for laboratory analysis of the following analytes: hardness, nitrate nitrogen, alkalinity, total phosphorus, total Kjeldahl nitrogen, and ammonia nitrogen. Notable water quality results are summarized in the following sections.



#### Dissolved Oxygen

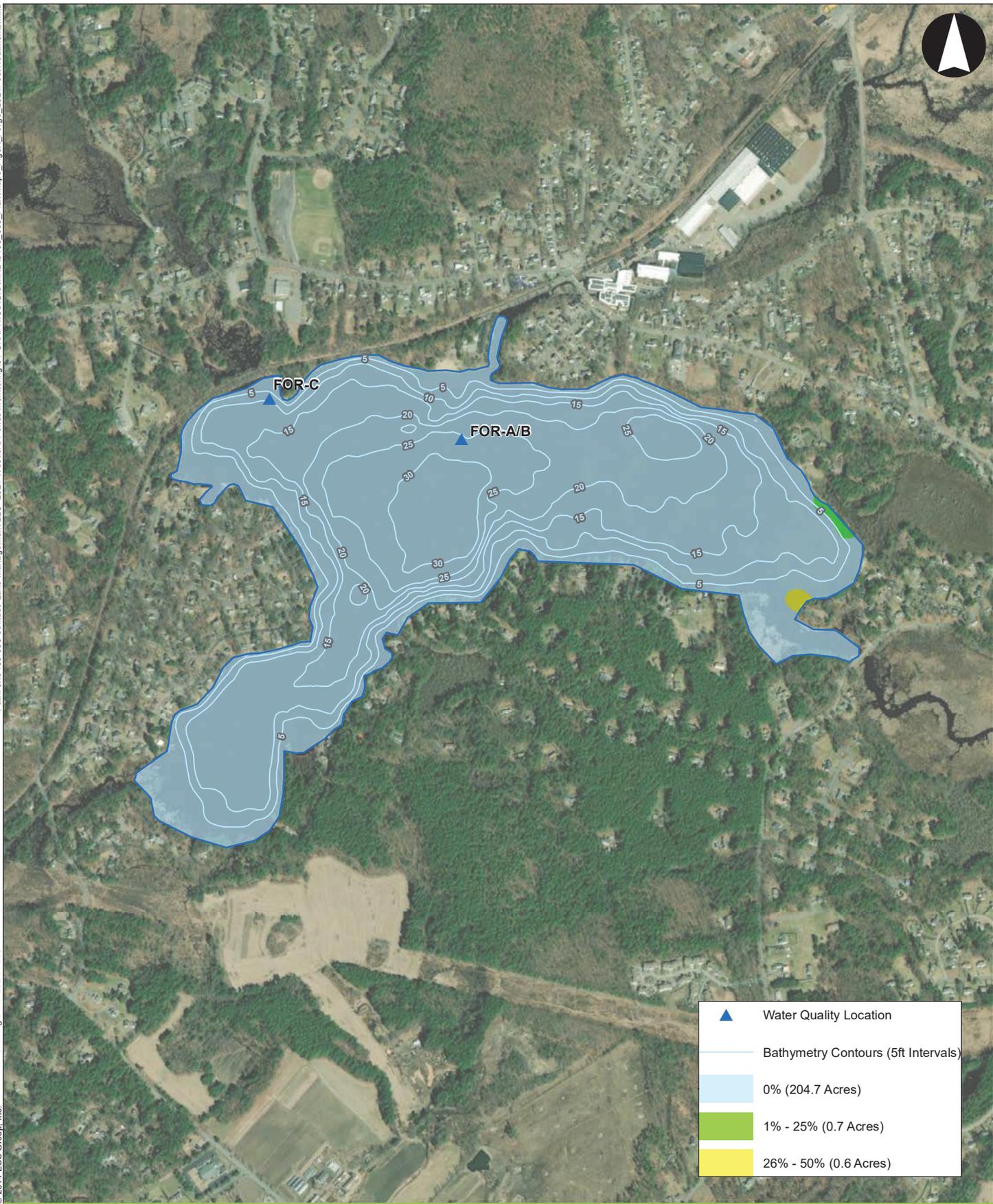
Each water body exhibited dissolved oxygen concentrations suitable for aquatic life near the surface, except for Keyes Pond and Old Mill/Graniteville Ponds. Dissolved oxygen conditions at both of these water bodies were below the state numerical criterion of 5.0 mg/L for warmwater fisheries.

Post-treatment/late season water quality results also indicate low (hypoxia) to very low (anoxia) dissolved oxygen levels in the deeper waters of all the ponds sampled. This pattern was most extensive in Old Mill/Graniteville Ponds, Keyes Pond, and Forge Pond. Extensive areas of persistently low dissolved oxygen concentrations are typically considered unsupportive of most aquatic life. Additionally, they may increase the likelihood of internal phosphorus release from pond sediments, which can compound management issues associated with eutrophication (nutrient enrichment).

#### Turbidity

Turbidity varied somewhat within each of the water bodies. Surface turbidity was highest in Keyes Pond although the highest overall turbidity observed was measured in bottom waters of Long Sought-for Pond.

Path: J:\S468-006 Solitude Lake Management LLC- 2021 Westford Ponds Monitoring\04\_GRAPHICS\GIS\MXD\S469\_006\_PlantMaps\_Fig0X\_Forge\_2021PostTreatments.mxd  
 Drawing Date: 2021/11/03  
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	Water Quality Location
	Bathymetry Contours (5ft Intervals)
	0% (204.7 Acres)
	1% - 25% (0.7 Acres)
	26% - 50% (0.6 Acres)



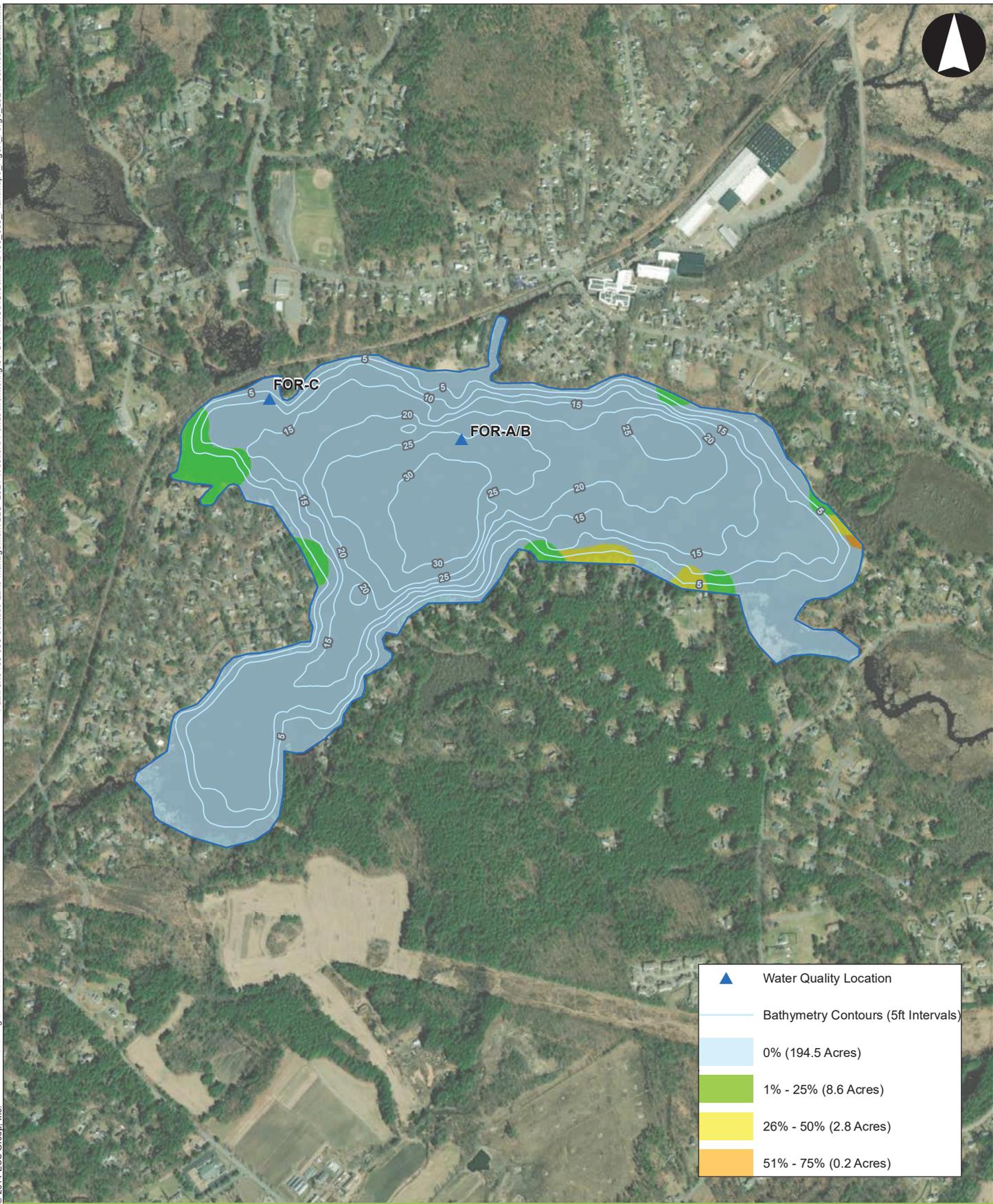
**Solitude Lake Management LLC**  
 Westford, Massachusetts

**Forge Pond  
 Brittle Naiad  
 Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2020  
 2) MassGIS, Major Roads, 2003  
 3) ESS, GPS Data, 2021  
 4) Contours based on MA DFW  
 "Forge Pond", 2019



**Figure 10**



	Water Quality Location
	Bathymetry Contours (5ft Intervals)
	0% (194.5 Acres)
	1% - 25% (8.6 Acres)
	26% - 50% (2.8 Acres)
	51% - 75% (0.2 Acres)



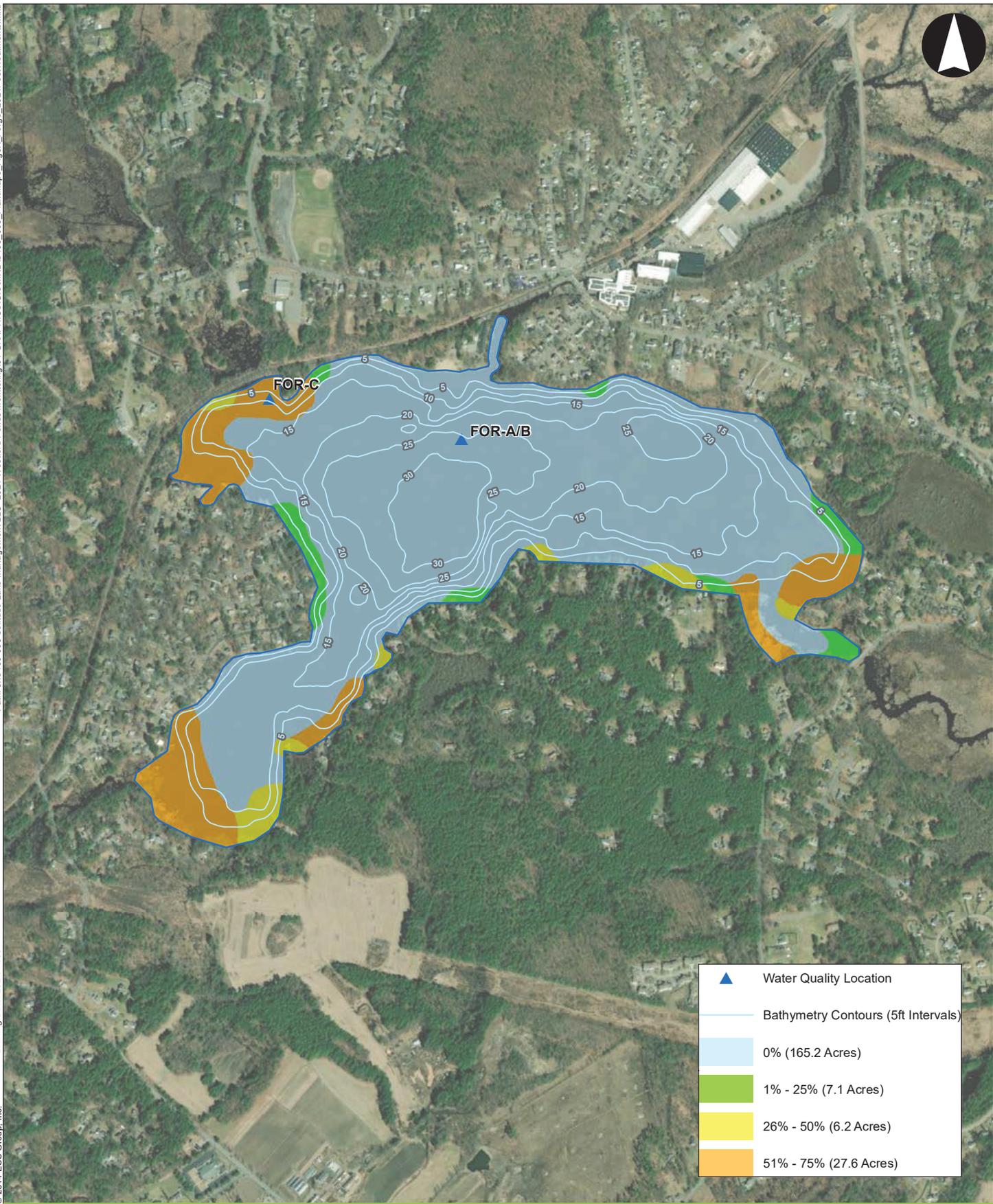
**Solitude Lake Management LLC**  
Westford, Massachusetts

**Forge Pond**  
**Eurasian Milfoil**  
**Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2020  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, 2021  
4) Contours based on MA DFW "Forge Pond", 2019



**Figure 11**



	Water Quality Location
	Bathymetry Contours (5ft Intervals)
	0% (165.2 Acres)
	1% - 25% (7.1 Acres)
	26% - 50% (6.2 Acres)
	51% - 75% (27.6 Acres)



**Solitude Lake Management LLC**  
Westford, Massachusetts

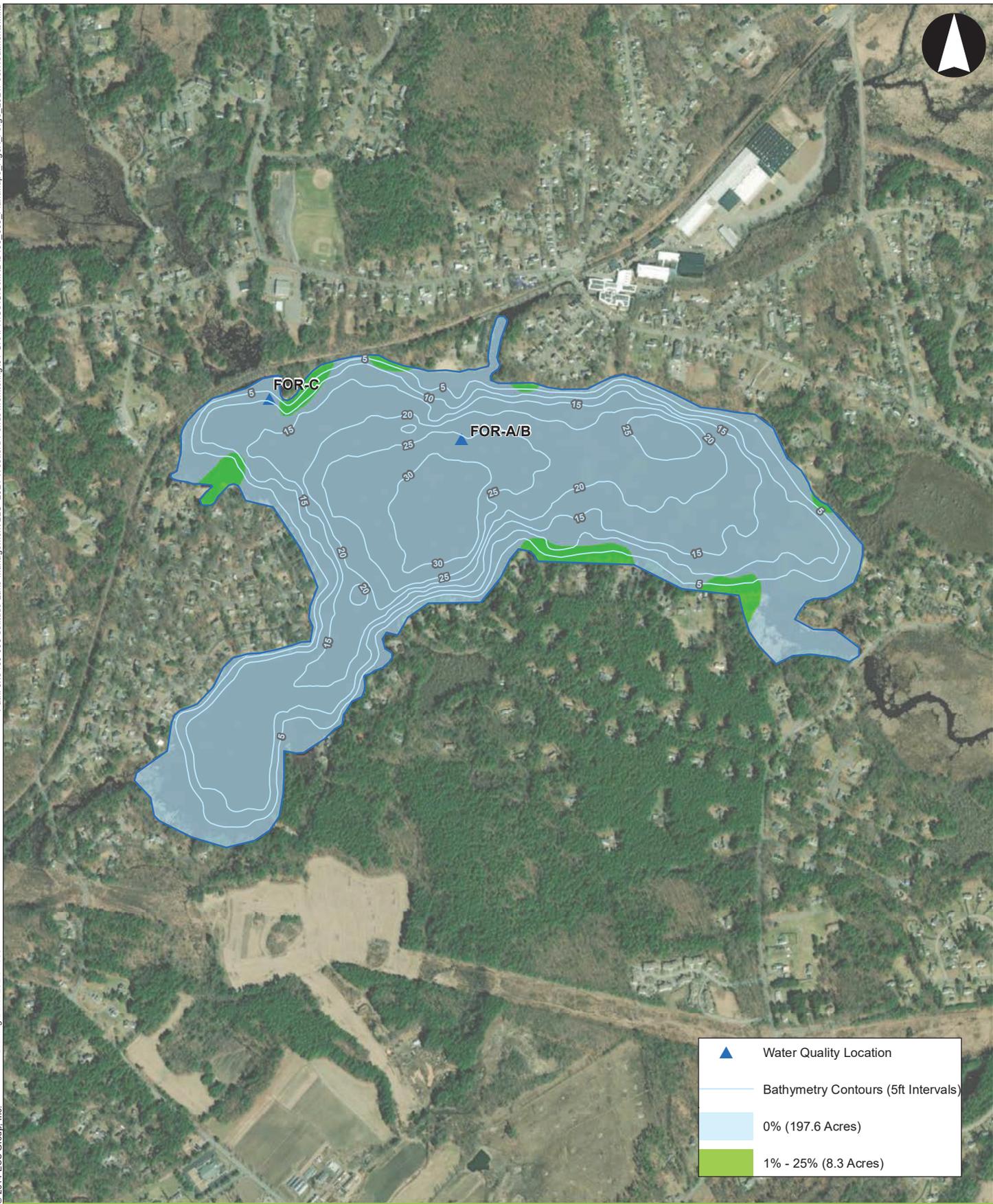
**Forge Pond**  
**Fanwort**  
**Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2020  
2) MassGIS, Major Roads, 2003  
3) ESS, GPS Data, 2021  
4) Contours based on MA DFW  
"Forge Pond", 2019



**Figure 12**

Path: J:\S468-006 Solitude Lake Management LLC- 2021 Westford Ponds Monitoring\04\_GRAPHICS\GIS\MXD\S469\_006\_PlantMaps\_Fig0X\_Forge\_2021PostTreatments.mxd  
 Drawing Date: 2021/11/03  
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	Water Quality Location
	Bathymetry Contours (5ft Intervals)
	0% (197.6 Acres)
	1% - 25% (8.3 Acres)

0 225 450 900  
 Feet

**Solitude Lake Management LLC**  
 Westford, Massachusetts

**Forge Pond**  
**Variable-Leaf Milfoil**  
**Post-Treatment (September 2021)**

Source: 1) ESRI, World Imagery, 2020  
 2) MassGIS, Major Roads, 2003  
 3) ESS, GPS Data, 2021  
 4) Contours based on MA DFW  
 "Forge Pond", 2019

**Figure 13**

However, turbidity did not appear to be abnormally elevated in any of the locations sampled during post-treatment/late season monitoring.

#### Secchi Depth (Transparency)

Secchi depth is a measure of water transparency and may be reduced by suspended sediments, algal growth, or the presence of other organic matter in the water column. Reduced Secchi depths are typically associated with nutrient-enriched ponds, although this condition can also be caused by influx of turbid storm flows or wind events. During post-treatment/late season monitoring, the shallowest Secchi depths were measured at Keyes Pond, Old Mill/Graniteville Ponds, and Forge Pond, where water transparency was 2.5 m or less. The deepest Secchi depths (i.e., clearest water) were measured at Long Sought-for Pond, where transparency extended to 5.0 meters.

#### pH, Hardness, and Alkalinity

Similar to previous sampling events, most of the locations sampled during post-treatment/late season monitoring were circumneutral (i.e., pH near 7.0). The most acidic pH was measured in Keyes Pond and Burge's Pond, while the most basic pH measurements were collected in Old Mill/Graniteville Ponds.

Hardness and alkalinity tend to be naturally higher in the Merrimack River valley than adjacent parts of eastern Massachusetts, although they can also be influenced by human activity in the watershed as well as atmospheric acid deposition. These parameters varied substantially between ponds, but generally demonstrated similar patterns in variation with lower hardness values corresponding to lower alkalinity. This is not unexpected, as harder waters tend to have a higher alkalinity (also known as acid neutralizing capacity). Increased alkalinity suggests greater buffering capacity of the water (i.e., resistance to pH change). Ponds with low buffering capacity, such as Burge's Pond, may be susceptible to more abrupt swings in pH than those with higher alkalinity, such as Forge Pond.

#### Phosphorus and Nitrogen

Phosphorus and nitrogen are both major nutrients fueling plant and algal growth. Of the two, phosphorus tends to be limiting nutrient in most New England freshwater systems. However, nitrogen levels can also impact the overall productivity of the system and type of algal growth favored, and may even influence the production of toxins in some cyanobacteria. In general, high nutrient levels in the water column can contribute to algal blooms and excessive floating plant growth. High availability of nutrients in the sediments can contribute to excessive rooted plant growth.

During post-treatment/late season monitoring, total phosphorus concentrations were generally highest at Keyes Pond and Forge Pond. Algal blooms may occur even where total phosphorus levels are very low. However, they tend to be more frequent and are more likely to become problematic where concentrations regularly exceed 0.020 mg/L. Sediment release of phosphorus is apparent when bottom (hypolimnetic) concentrations are much higher than surface (epilimnetic) concentrations during the time of the year when the water body is stratified (warm surface water overlaying cold bottom water). This pattern is most apparent at Burge's Pond, Kennedy Pond, Nabnasset Lake, and Forge Pond. As indicated previously, release of sediment phosphorus may be aggravated by low dissolved oxygen concentrations at depth.

Overall nitrogen levels were highest at Forge Pond and nitrate nitrogen levels were greatest at Nabnasset Lake. High levels of nitrate nitrogen may be an indication of septic loading or stormwater runoff. Post-treatment/late season samples from Forge Pond and Nabnasset Lake contained the highest levels of ammonia nitrogen, which may be associated with direct septic loading or persistent anoxic or hypoxic conditions.



Table 2. Dissolved Oxygen Profiles at Deep Hole Locations during 2021 Post-treatment/Late Season Monitoring

Depth m	Keyes Pond		Old Mill/Graniteville Ponds		Burge's Pond		Kennedy Pond		Long Sought-for Pond		Nabnasset Lake		Forge Pond	
	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L
0.5	35.0	3.20	54.4	4.68	67.9	5.81	90.9	7.71	83.0	7.24	104.2	9.02	81.0	6.98
1.0	8.4	0.77	49.3	4.35	67.1	5.75	89.9	7.60	77.3	6.69	102.5	8.99	79.0	6.88
2.0	1.9	0.18	45.7	4.09	55.6	4.79	90.5	7.68	77.8	6.69	94.8	8.24	52.8	4.55
3.0	1.7	0.17	44.3	3.94	47.2	4.10	85.4	7.29	78.9	6.80	89.5	7.90	35.0	3.12
4.0	1.5	0.15	38.6	3.51	23.1	2.02	92.0	7.93	75.9	6.56	74.5	6.54	7.2	0.65
5.0	1.3	0.14	0.7	0.07	0.8	0.07	31.7	2.82	60.6	5.27	42.5	3.75	0.9	0.09
6.0	1.3	0.15					5.2	0.51	1.6	0.14	1.30	0.11	0.8	0.08
7.0							0.9	0.09	1.2	0.11	0.80	0.08	0.7	0.07
8.0									1.0	0.10	0.70	0.07	0.6	0.07
9.0									0.9	0.09				
Total depth (m)	6.0		5.0		6.0		8.0		9.0		8.0		8.0	

**Table 3. Temperature Profiles at Deep Hole Locations during 2021 Post-treatment/Late Season Monitoring**

Depth (m)	Keyes Pond	Old Mill/Graniteville Ponds	Burge's Pond	Kennedy Pond	Long-Sought-for Pond	Nabnasset Lake	Forge Pond
0.5	20.7	22.6	23.4	22.9	22.9	22.7	22.5
1.0	20.2	21.9	23.3	23.9	22.9	22.5	22.1
2.0	18.2	21.1	23.0	23.9	22.9	22.3	22.7
3.0	15.5	20.6	22.6	23.5	22.9	22.2	21.9
4.0	13.0	20.1	22.3	23.0	22.9	21.9	20.0
5.0	11.1	19.2	20.5	21.4	22.6	21.6	17.6
6.0	10.4			17.9	21.2	19.5	15.3
7.0				14.6	17.7	16.4	14.1
8.0					15.3	15.1	12.6
9.0					14.4		
<b>Total depth (m)</b>	<b>6.0</b>	<b>5.0</b>	<b>6.0</b>	<b>8.0</b>	<b>9.0</b>	<b>8.0</b>	<b>8.0</b>

**Table 4. Water Quality Parameters Collected During 2021 Post-treatment/Late Season Monitoring**

Parameter	Station ID	Units	Keyes Pond			Old Mill/Graniteville Ponds			Burge's Pond			Kennedy Pond			Long Sought-for Pond			Nabnasset Lake			Forge Pond		
			KEY-A	KEY-B	KEY-C	OLD-A	OLD-B	OLD-C	BUR-A	BUR-B	BUR-C	KEN-A	KEN-B	KEN-C	LSF-A	LSF-B	LSF-C	NAB-A	NAB-B	NAB-C	FOR-A	FOR-B	FOR-C
Location			Deep hole		Outlet	Deep Hole		Deep Hole		In-pond	Deep Hole		Deep Hole		Deep Hole		Deep Hole		Deep Hole		Inlet		
			mid-depth	Inlet		Surface	Bottom	Surface	Bottom		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface
Total depth		m	6.0	1.0	0.5	5.0	5.0	6.0	2.0	2.0	8.0	1.0	9.0	9.0	0.5	8.0	2.0	8.0	8.0	8.0	8.0	2.3	
Sample depth		m	3.0	0.5	0.5	0.5	5.0	0.5	0.5	0.5	7.0	0.5	8.0	8.0	0.5	7.0	0.5	7.0	7.0	0.5	7.0	0.5	
Temperature		C	15.5	19.0	20.8	22.6	19.2	23.4	20.5	23.5	22.9	24.2	22.9	15.3	22.0	22.7	16.4	22.4	22.5	22.5	14.1	21.8	
Dissolved oxygen		%	1.7	29.4	48.5	54.4	0.7	63.2	0.8	70.0	0.9	90.5	83.0	1.0	71.0	104.2	0.8	92.4	81.0	81.0	0.7	71.9	
		mg/L	0.17	2.73	4.36	4.68	0.07	5.48	0.07	5.95	0.09	7.60	7.24	0.10	6.35	9.02	0.08	8.04	6.98	6.98	0.07	6.30	
Turbidity		NTU	3.23	1.66	2.41	2.20	3.41	2.13	2.95	1.91	1.88	3.26	2.17	6.98	1.94	2.92	3.77	1.40	2.65	2.65	1.87	1.65	
pH		SU	6.5	6.8	6.8	7.6	7.2	6.6	6.1	6.2	6.4	7.1	7.4	7.2	7.3	7.4	7.0	6.8	7.4	7.4	7.2	7.2	
Secchi Depth		m	1.5	bottom (1.0)	bottom (0.5)	2.5	bottom (1.5)	3.0	2.0	4.5	bottom (1.0)	5.0	bottom (0.5)	2.75	bottom (2.0)	1.8	bottom (2.0)	1.8	bottom (2.3)	1.8	bottom (2.3)	bottom (2.3)	
Hardness		mg/L	31.5	23.0	24.4	58.7	59.0	1.6	1.6	1.5	39.7	77.9	39.1	45.4	38.1	49.2	58.8	49.5	58.4	58.4	77.9	59.0	
Alkalinity		mg/L	21.6	14.3	13.5	41.1	40.6	<5.00	<5.00	<5.00	36.2	13.0	26.6	40.4	24.4	28.6	45.2	26.7	39.0	39.0	64.6	38.9	
Total phosphorus		mg/L	0.039	0.046	0.031	0.022	0.020	0.013	0.032	0.006	0.046	0.021	0.005	0.019	0.006	0.017	0.053	0.023	0.031	0.031	0.079	0.020	
Nitrate nitrogen		mg/L	0.03	<0.02	<0.02	0.06	0.05	<0.02	0.03	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	0.14	0.04	0.14	<0.02	<0.02	<0.02	<0.02	
Total Kjeldahl nitrogen		mg/L	0.57	0.51	0.65	0.47	0.47	0.52	0.72	0.48	0.67	0.38	0.42	1.00	0.63	0.54	1.16	0.74	0.52	0.52	11.2	0.88	
Ammonia nitrogen		mg/L	0.05	0.08	<0.10	0.06	0.06	0.07	0.06	0.06	0.09	<0.05	0.07	0.54	0.26	<0.05	0.63	0.07	<0.05	<0.05	0.92	<0.05	

## MANAGEMENT RECOMMENDATIONS FOR 2022

The vegetation management program at Keyes Pond and Long Sought-for Pond continues to be successful in controlling most of the targeted perennial exotic species (including exotic milfoils). In fact, ESS has not observed any exotic milfoils in Keyes or Long Sought-for Pond for multiple seasons.

Variable-leaf milfoil made a resurgence at Nabnasset Lake in 2021 but the extent of beds observed there remains low. However, variable-leaf milfoil should be closely monitored for continued regrowth or expansion in Nabnasset Lake and managed as needed to prevent re-establishment of this species.

Curly-leaf pondweed, which has an annual life cycle, continues to be a challenge at Long Sought-for Pond and Nabnasset Lake. This plant is typically problematic from spring through early summer and management efforts are usually targeted for this period to prevent plant maturation and the release of seeds and turions. However, curly-leaf pondweed occasionally reaches nuisance levels later in the year and can persist locally into late summer. Therefore, ESS continues to recommend that the timing of management actions for curly-leaf pondweed remain flexible, where possible, to account for this possibility.

Water chestnut, which also has an annual life cycle, may also need to be managed in 2022 at Nabnasset Lake, should it return. This species is one of the most negatively impactful aquatic invasive plants. Therefore, every effort should be made to prevent it from invading Westford's lakes and ponds.

Old Mill/ Graniteville Ponds and Forge Pond were not treated in 2021. As such, both ponds continue to host large beds of exotic milfoils and fanwort, some of which are dense. The reduction in shallow-water beds of milfoils and fanwort observed following winter drawdown in 2020 at Forge Pond is less pronounced. Curly-leaf pondweed likely continues to infest these ponds as well. Additionally, brittle naiad was documented at Forge Pond in 2021.

No aquatic invasive species were observed by ESS in Keyes, Burge's, or Kennedy Ponds in 2021. This is the first year that Keyes Pond has remained free of aquatic invasive species.

Recommendations for the 2022 management program at the Westford Ponds are presented in the following sections.

### Chemical Controls

The Order of Conditions issued by the Westford Conservation Commission for Keyes Pond, Old Mill/Graniteville Ponds, and Burge's Pond allows herbicide treatment with fluridone (trade name Sonar) and diquat dibromide (also known as Reward, Tribune, or simply Diquat). Similarly, Long Sought-for Pond's Order of Conditions allows for treatment of aquatic vegetation with fluridone and diquat dibromide. Nabnasset Lake's Order of Conditions permits treatment of aquatic vegetation with diquat dibromide.

ESS is not aware of other herbicides currently authorized for use in any of the seven ponds included in this study. However, in addition to the herbicides noted above, ESS recommends that the Town consider adding **florpyrauxifen-benzyl** (trade name ProcellaCOR EC) as a chemical control for water bodies infested with exotic milfoils. ProcellaCOR is a fast-acting systemic herbicide that may achieve control of target species for two or more seasons. When applied at very low concentrations, it is highly selective for exotic milfoils.

**Diquat dibromide (diquat)** is recommended for the control of curly-leaf pondweed at Keyes Pond (should it return), Long Sought-for Pond, and Nabnasset Lake. It would also be useful for control of this species at Forge Pond and Old Mill/Graniteville Ponds, should the Town decide to pursue chemical treatments of those water bodies. If possible, the timing of this treatment should be prior to the plants topping out in the water column (i.e., late May or early June) to avoid seed and turion maturation, which would otherwise

perpetuate curly-leaf pondweed growth into future years. The Town may also wish to consider the option for a second round of spot treatments, should curly-leaf pondweed regrow later in the season, as was observed at Long Sought-for Pond and Nabnasset Lake in 2019.

Although diquat may also be used for the treatment of exotic milfoils, ESS recommends using ProcellaCOR instead where these species are the primary target, as control is likely to be more sustained.

Finally, diquat may be used as a spot control for nuisance beds of native thinleaf pondweeds, should they return to Long Sought-for Pond at problematic levels in 2022.

**Fluridone** (trade name *Sonar*) is only recommended for use in 2022 at Long Sought-for Pond, where it could be used to control curly-leaf pondweed and regrowth (if any) of Eurasian milfoil, while also suppressing nuisance growths of native pondweeds. It could also be used should the Town desire to seek more widespread control of fanwort and exotic milfoils at Forge and Old Mill/Graniteville Ponds. Fluridone requires a long contact time to be effective on most target species and should therefore ideally be applied starting in spring if summerlong control is desired. Sonar is the only systemic herbicide approved for use in Massachusetts that is likely to be effective on mixed beds of fanwort and exotic milfoils.

Old Mill/ Graniteville Ponds proved to be a challenge to treat with fluridone in the past, due to the high rate of flushing through the system, particularly in the upper basin. Therefore, any treatment there would likely require the use of a pelleted slow release formulation and/or booster treatments. Additionally, or alternatively, the Town could consider use of an effective contact herbicide (e.g., **flumioxazin** [trade name Clipper]), which could be highly effective despite the rapid flushing rate. However, should the Town decide to proceed with such a treatment, flumioxazin may need to be added to the Order of Conditions. Alternatively, the Town could elect to focus just on the lower basin, as this area offers the greater potential recreational value and flushes less frequently than the upper basin (thereby making it easier to achieve the longer contact time for fluridone).

ESS is not aware of fluridone being approved for use under a valid Order of Conditions at Forge Pond. Therefore, additional permitting may be required before moving forward with a fluridone treatment at Forge Pond, if there is interest in this approach.

**Nautique** (copper ethylenediamine and triethanolamine complexes) was not applied in 2021, to ESS's knowledge. However, it may offer potential for spot control of nuisance beds of water celery at Nabnasset Lake. These beds continued to grow at nuisance levels in 2021 and are likely to return at similar levels in 2022, unless otherwise controlled.

**Other copper-based algaecide formulations** (selected by contractor for effectiveness on the species present) may also be helpful for the control of nuisance algal growths or blooms in any of the ponds, should they develop in 2022. Copper-based algaecides have also occasionally been used to control excessive algal growth at Keyes Pond and Nabnasset Lake in prior years.

Depending on the actual development of plant beds and algal blooms in 2022, more than one treatment may be needed to effectively address the seasonality of different target species. The specific chemical controls currently recommended for consideration in 2022 are summarized in Table 5.

**Table 5. Recommended Herbicides for Aquatic Invasive Vegetation Treatment in 2022**

Herbicide	Keyes Pond	Long Sought-for Pond	Nabnasset Lake
Fluridone (Sonar)		X <sup>c</sup>	
Diquat dibromide (Reward/Diquat)		X	X
Copper Ethylenediamine and Triethanolamine Complexes (Nautique)			X <sup>a</sup>
Florpyrauxifen-benzyl (ProcellaCOR)			X <sup>b</sup>

<sup>a</sup>Recommended for use with diquat in controlling nuisance beds of water celery (*Vallisneria sp.*)

<sup>b</sup>For control of variable-leaf milfoil, where not adequately controlled through drawdown. Order of Conditions would likely need to be amended.

<sup>c</sup>For control of curly-leaf pondweed and suppression of nuisance native pondweeds. Diquat can remain an option for spots where full control of nuisance pondweeds is desired.

### Winter Drawdown

Winter drawdown has been an effective management option for the control of variable-leaf milfoil at Nabnasset Lake in the past, although a full six-foot drawdown has not been implemented in several years. However, given the fact that this species was observed at multiple in-lake locations in 2021, a deeper drawdown may be warranted for winter 2021-2022. Even if a deeper drawdown achieves in-lake control of variable-leaf milfoil, it is unlikely to provide substantial control of this species in Shipley Swamp based on prior observations by ESS dating back to initiation of the drawdown program in the early 2000s. Therefore, the Town may still wish to consider use of chemical controls in 2022 to manage source populations of variable-leaf milfoil in Shipley Swamp. Otherwise, this species is likely to return to in-lake areas of Nabnasset Lake in the near future. The availability of ProcellaCOR as a fast-acting but selective systemic herbicide may make this a more palatable option than it was in prior years, when broader spectrum diquat was the primary chemical control in use.

At Forge Pond, drawdown impacts to exotic milfoils and fanwort were not apparent during the 2021 late season survey. However, it is not unusual for winter drawdown programs to achieve uneven results from year to year depending on weather conditions over the course of the drawdown period. The success of winter drawdown as an aquatic vegetation control method typically requires repeated use over a series of winters to achieve the desired outcome over the longer term. Therefore, ESS recommends another drawdown in winter 2021-2022 for the purpose of controlling shallow growths of exotic milfoils and fanwort, especially if chemical controls are not planned for use at Forge Pond. Drawdown is unlikely to have an impact on brittle naiad but this species produces less biomass and tends to be less predictable in distribution and extent than the other aquatic invasive plants known to inhabit Forge Pond.

### Hand Harvesting

If water chestnut reappears at Nabnasset Lake in 2022, hand harvesting will be the most prudent means of managing this species. ESS recommends that hand harvesting of water chestnut occur on an as-needed basis. However, harvesting should be completed no later than early August to ensure that seeds are not

allowed to mature and drop to lake sediments. Once mature, water chestnut seeds can remain viable for years. Therefore, prevention of all seed drop is the only way to ensure that this plant will not become established in Nabnasset Lake.

### **Low-dose Alum**

A low-dose alum treatment was approved under the original Order of Conditions for Burge's, Keyes, and Old Mill/Graniteville Ponds (DEP File # 334-1635) and may be an option for implementation in 2022, if needed. Of these water bodies, Keyes Pond would be the most likely to benefit from such a treatment, given the low transparency and community reports of algae blooms and turbidity-related events in 2021.

Prior nutrient budgets developed by ESS in 2017 suggest that low-dose alum could be effective at stripping phosphorus, algae, and particulates from incoming flows and the pond water column while also gradually reducing internal recycling of phosphorus from the sediments. Alum is more expensive to apply than copper for the control of algae. However, it also targets one of the root causes of excessive algal growth and, therefore, may provide greater overall benefit.

These nutrient budgets also suggested the potential for benefits from a higher dose alum treatment at water bodies with relatively low flushing rates and higher potential for internal recycling of phosphorus from the sediments, such as Nabnasset Lake. The potential benefit of such a treatment is also becoming more evident in the water quality data collected under this monitoring program, which suggest internal loading of phosphorus from sediments continues to be a significant source. Should the Town desire to explore the feasibility of such a treatment, additional study would need to be completed to identify the appropriate dosing, address logistical issues, and identify appropriate mitigation measures.

### **Monitoring**

The 2021 early season/pre-treatment monitoring program was delayed and only implemented at Long Sought-for Pond and Nabnasset Lake. However, even in this limited form it did provide water quality and aquatic plant data that were useful for guiding management efforts. This included documentation of a new and high-priority aquatic invasive species at Nabnasset Lake (water chestnut).

The delay in the initiation of monitoring probably resulted in an underestimate of curly-leaf pondweed populations this year. However, the impact of this will probably not be understood until pre-treatment mapping in 2022.

ESS recommends pre-treatment/early season and post-treatment/late season water quality and aquatic vegetation monitoring at each pond in 2022, with a priority on water bodies where active management has recently been undertaken or is likely to be advanced in 2022. By our current understanding, this includes Long Sought-for Pond, Nabnasset Lake, and Forge Pond, although there are also opportunities to undertake vegetation management at Old Mill/Graniteville Ponds and water quality improvements at Keyes Pond.

As always, continuing to monitor each of the ponds will allow for the detection of pioneer infestations of invasive species before they spread, thereby allow the Town the opportunity to respond quickly and avoid or minimize more costly large-scale management activities in the future. It also permits the Town to document and track management successes, the most substantial of which include the following:

1. Interception and potential prevention of a water chestnut infestation at Nabnasset Lake
2. Sustained control of Eurasian milfoil at Long Sought-for Pond
3. Sustained control or potential eradication of variable-leaf milfoil at Keyes Pond



Dominic Meringolo  
November 12, 2021

4. Sustained control or potential eradication of variable-leaf milfoil at Burge's Pond
5. Sustained control of in-lake variable-leaf milfoil at Nabnasset Lake for several years until reemergence in 2021

We appreciate the opportunity to work with you on this project. Please contact Matt Ladewig at (401) 330-1204 if you have any questions.

Sincerely,

**ESS GROUP, INC.**

A handwritten signature in black ink, appearing to read "Matt Ladewig".

Matt Ladewig, CLM  
Senior Scientist

