Report For:

Town of Palmer
4417 Main Street
Palmer, MA 01069

Forest Lake Assessment and Watershed Based Plan

Prepared by:

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Table of Contents

Tables

Figures

Preface

This Forest Lake Assessment and Watershed Based Plan was prepared in partnership between the Town of Palmer and Aquatic Restoration Consulting, LLC (ARC). Funding for the plan was partially provided by the Massachusetts Department of Environmental Protection (MassDEP) under the Environmental Protection Agency (EPA) Section 604(b) of the Clean Water Act. The contents do not necessarily reflect the views and policies of EPA or MassDEP, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

INTRODUCTION

Forest Lake is a 45-acre freshwater Great Pond located entirely within the Town of Palmer (Town), Massachusetts. The watershed lies within the drainage basin of the Chicopee River. The outflow from Forest Lake flows to the Ware River approximately 4.4 miles upstream of its confluence with the Swift River and 5.2 miles upstream of its confluence with the Quaboag River, which together form the headwaters of the Chicopee River. The Chicopee River reaches the Connecticut River in Springfield, flowing eventually to Long Island Sound.

Forest Lake and its one perennial unnamed tributary maintain a Massachusetts Class B, "fishable/swimmable" ranking. Forest Lake, however, is included on 2022 Massachusetts Integrated Lists of Waters, also known as EPA's 303(d) List of Impaired Waters, for noxious aquatic weeds. This extensive weed growth, coupled with nutrient loading, shoreline and watershed development and stormwater discharges have accelerated the natural succession of Forest Lake, resulting in increased eutrophication. Unmanaged nuisance aquatic plant growth and degrading water quality decrease the availability of high-quality fish and wildlife habitat, decreases aesthetics, and reduces recreational appeal of the pond.

Available historical information about the uses of Forest Lake dates back to the early 1600's. According to a local historian, Nipmuc Indians encamped near the lake during the warm summer months for fishing in the Ware River. In the 1700's a grist mill and sawmill were erected on the shore. In the late 1800's, some of the local landowners formed the Forest Lake Company and created a resort on the northwesterly shore of the Lake. The resort, used principally for picnics and family gatherings, was first opened to the public in 1885. Forest Lake Resort became one of the most popular resorts in the area, offering a pavilion, a roller-skating arena, ballroom, bowling alleys, and an amusement park with a merry-go-round, picnic area and slides. Swimming in Forest Lake increased and became the primary summer use of the Lake during the 1900's. Reports dating back to 1901 described problems of excessive aquatic plant growth and the historic town records document several annual fish kills, which were explained at that time as the result of limited dissolved oxygen in the water.

Public access to Forest Lake was formalized in 1958, through special legislation documented in Ch. 418, Acts of 1958. Public access is provided along approximately 1,600 linear feet of River Street at the northerly end of the lake, including a small, unsupervised beach area. Recently, the Department of Fish and Game (DFG) acquired land and constructed a boat launch and parking area on the northeastern edge of the lake. There is also a 220-unit seasonal cottage resort proposed for the south and west sections of the lake. Proposed development and increased access to the lake are threats to water and habitat quality. It is imperative to assess conditions and develop a plan to improve current conditions and protect the future of the lake and its watershed.

Forest Lake is the only public swimming area located in the Town of Palmer, and the continuation of Forest Lake's present condition and further degradation will adversely affect all residents of the Town, especially those who reside near or periodically use the lake for recreational purposes. Several downstream waterways of Forest Lake are listed on the 303(d) List of Impaired Waters (Ware, Quaboag, Chicopee & Connecticut Rivers) and improvements in Forest Lake water quality will only enhance the water quality downstream.

APPROACH TO THE PROBLEM

The overall project purpose is to assess existing conditions and develop and implement a Watershed Based Plan (WBP). This WBP provides recommendations to improve water quality and prevent further degradation. Improvements are accomplished primarily through structural and non-structural Best Management Practices (BMPs). Implementation of BMPs mitigate existing pollutant sources, such as the sedimentation, nutrient and bacteria loading, risk of harmful algal blooms, excessive non-native aquatic macrophyte growth and oxygen loss in the lake. Education and outreach activities increase community awareness of pollutant sources with the intent for volunteers and residents to take actions to protect and improve the environment.

The December 1981 Feasibility Study for the Rehabilitation of Forest Lake prepared by Cullinan Engineering, Inc. (Cullinan Report) was a comprehensive evaluation of the lake and its watershed. Data and analysis included general lake physical characteristics, watershed description, bathymetric data, water quality data, and sediment quality data. This WBP, prepared by Town and ARC, was designed to make use of these data to the extent practicable, but also to provided updated information supplementing these data where appropriate and as the budget permits. This WBP was also developed using the Massachusetts Department of Environmental Protection's (MassDEP's) Watershed-Based Plan Tool as a guide.

FOREST LAKE AND WATERSHED CHARACTERISTICS

The 45-acre Forest Lake has a large watershed, 3.5 square miles (2,221 acres)[1] (Figure 1), with a maximum and mean depth of 26 and 10 feet, respectively (Figure 2). The soft sediment depth of the lake is extensive and supports dense rooted plant growth. The Cullinan Report documented sediment depth during their investigation and reported over twenty feet of soft sediment in multiple locations (Figure 3). The shoreline is primarily undeveloped with residential homes located on the northwest shoreline. There is one unnamed perennial tributary which drains the southern part of the watershed with headwaters at Thompson Lake. Several smaller tributaries drain into this unnamed tributary before reaching the Roger Reed Fish Hatchery (Hatchery) located just north of Route 32 and Gates Street. The Hatchery was contacted by the Town to request water quality monitoring data, but the contact at the Hatchery stated that they do not perform water quality monitoring because their facility does not require National Pollutant Discharge Elimination System (NPDES) discharge sampling. According to an invitation to bid on engineering services at fish culture facilities in Massachusetts, "water from the Roger Reed Fish Hatchery is discharged into a holding pond/Gates Brook, which flows through a series of remnant rearing ponds and raceways on hatchery property before discharging into Forest Lake."[2] The holding ponds are likely the lagoons located downstream of Route 32. The hatchery is one of five hatcheries in Massachusetts operated by Massachusetts Division of Fish and Wildlife (MassWildlife) that raises and stocks over 500,000 trout and landlocked salmon during the calendar year.

Based on the Massachusetts Geographic Information System 2016 Land Cover/Land Use mapping from aerial imagery, 5% of the watershed is impervious surface. Impervious surface occurs when development (e.g., pavement, roofs, compaction of soils) prevents water from infiltrating into the ground. This results in a higher volume of stormwater runoff increasing flooding probability and carrying pollutants to waterbodies. Soils serve as a natural filter and attenuate transport of pollutants (petroleum products, fertilizers, wildlife and pet bacteria, etc.).

[1] Watershed delineation from MassGIS Data Drainage Sub-basins published 2007. Slight adjustments were made based on field observations during precipitation events. Drainage area proximal to the Massachusetts Turnpike was inaccessible and could not be field verified.

[2] Source: https://www.mass.gov/doc/dsblist181301-aquaculture-bioengineering-study-and-design-of-massachusetts-freshwater-fish/download

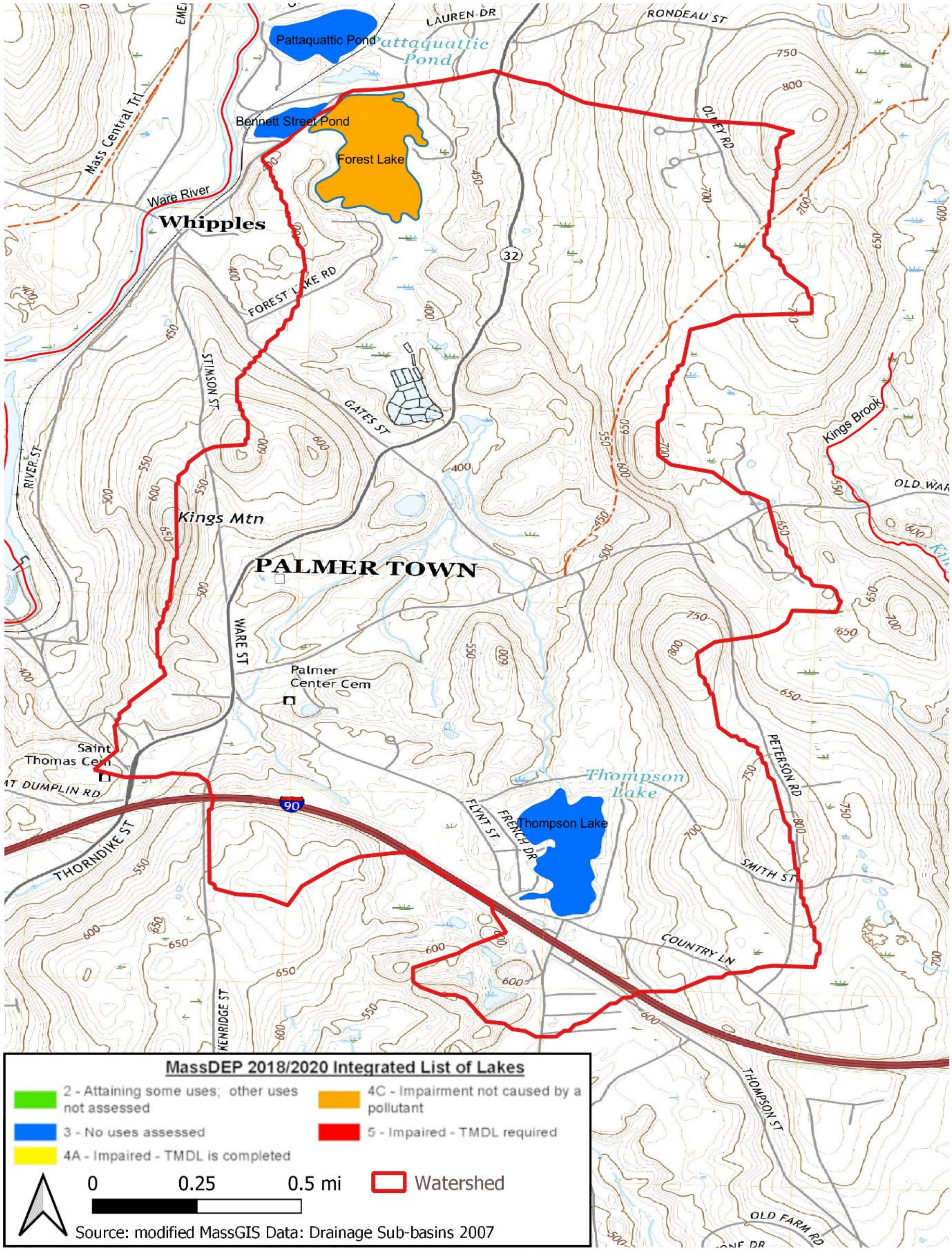

Figure 1. Forest Lake Watershed

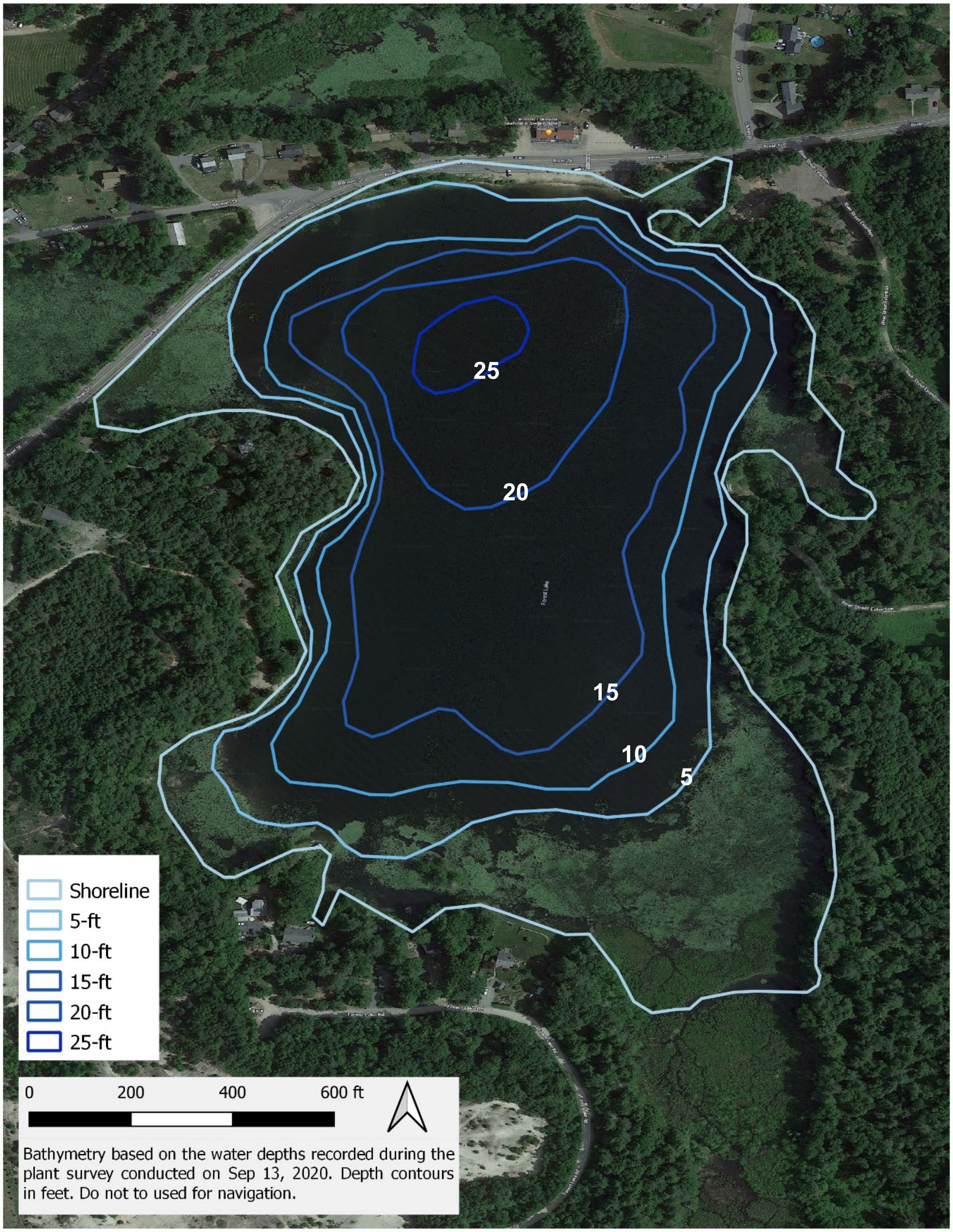

Figure 2. Forest Lake Bathymetry

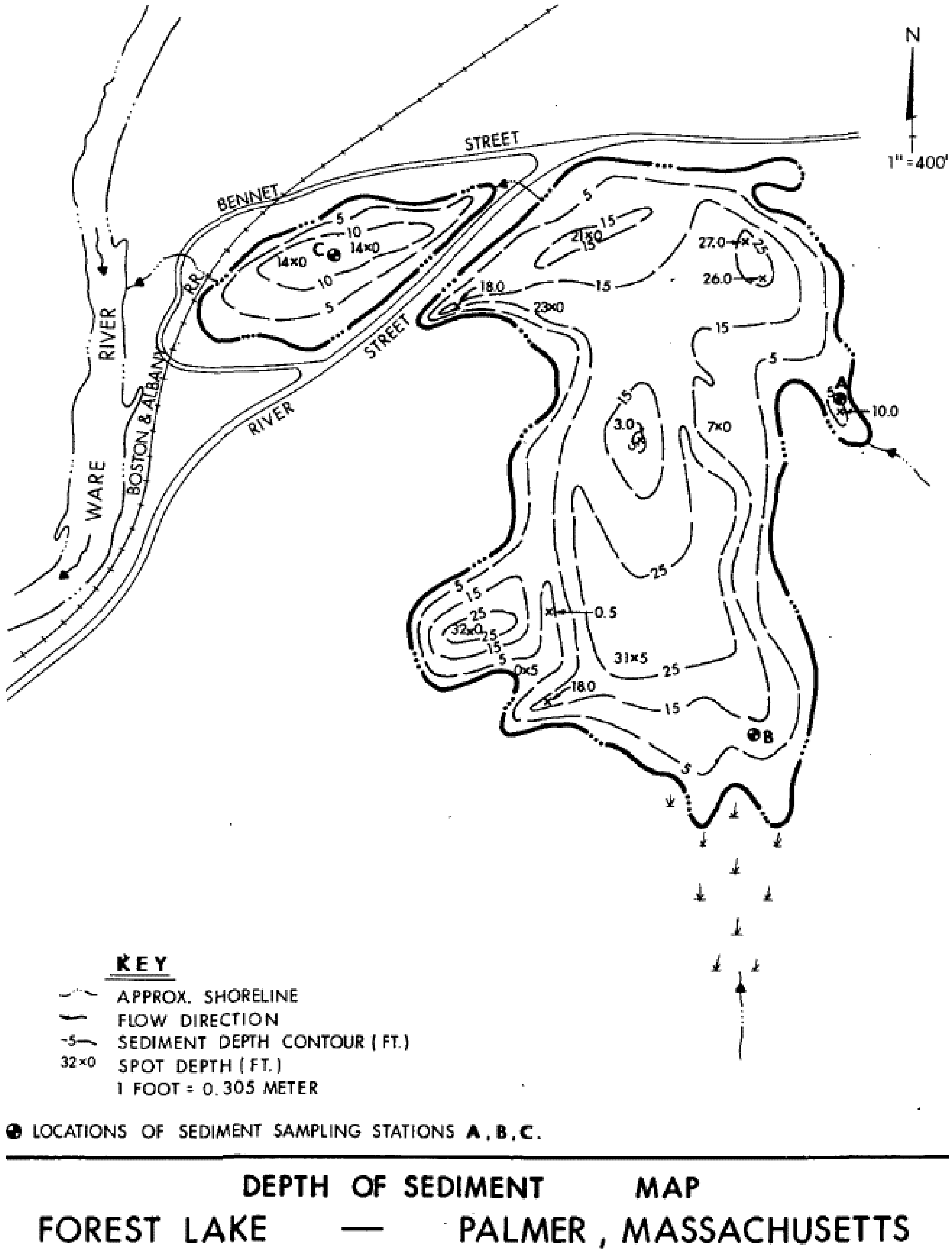

Figure 3. Forest Lake Sediment Depth (Cullinan 1981).

Impervious surfaces also increase water temperature and lowers water tables and baseflow in streams. Waterbodies can be negatively impacted from watersheds with as little as 5-10% of impervious surface (Figure 4). Impacts become severe with impervious rates exceed 20 percent. Just over half (53.5%) of Forest Lake's watershed is considered developed. Forty-four percent is residential, four percent is commercial and industrial land and six percent right-of-way (major roads) (Table 1; Figure 5).

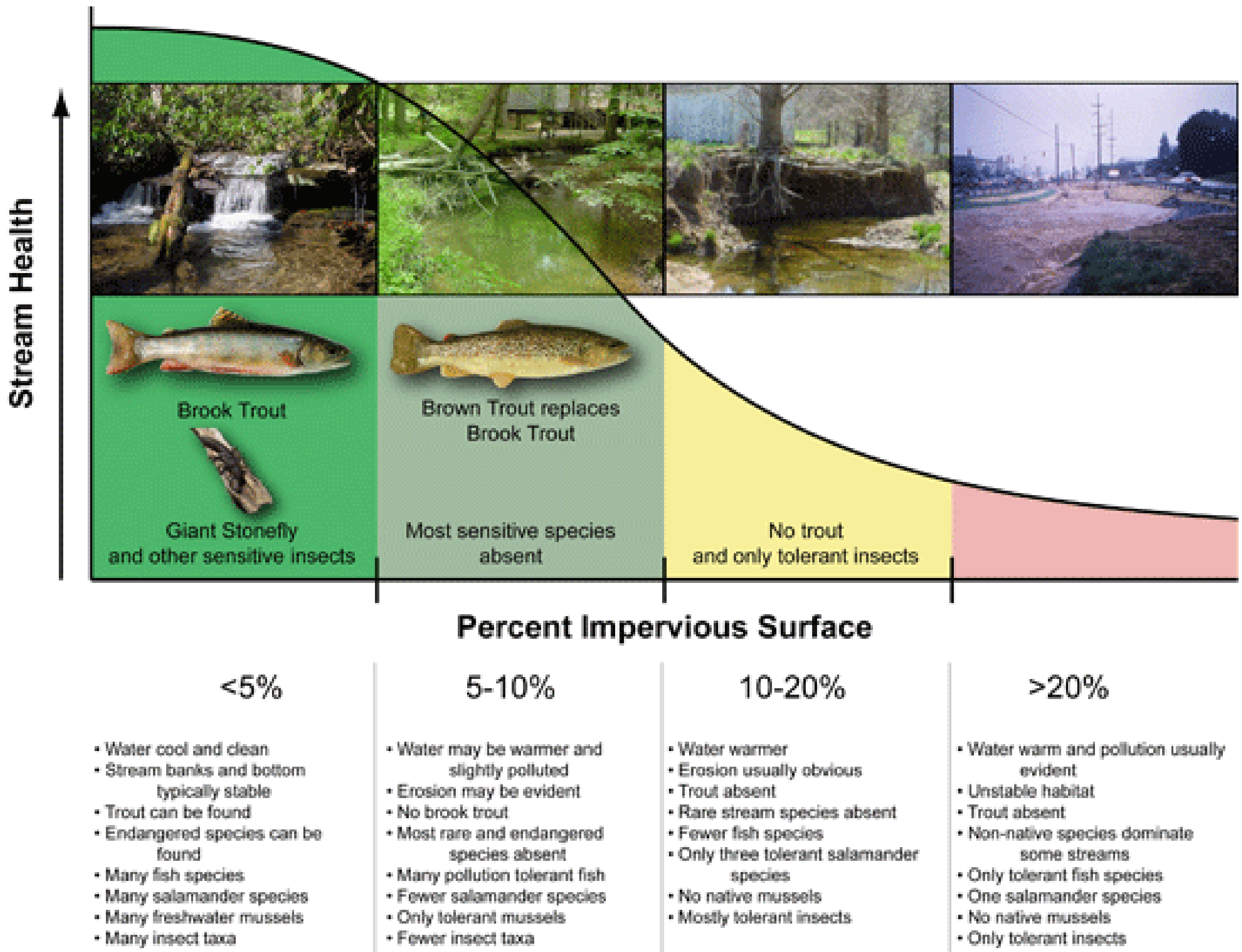

Figure 4. Illustration of Stream Health vs Percent Impervious Surface[3]

[3] From Maryland Department of Natural Resources Stream Health https://dnr.maryland.gov/streams/Pages/streamhealth/How-Impervious-Surface-Impacts-Stream-Health.aspx

Table 1. Forest Lake Watershed Land Use

Land Use and Land Cover	Area (Acres)	Percent Total
Residential - single family	**884.7**	**39.8%**
Bare Land	0.6	
Deciduous Forest	341.3	
Developed Open Space	117.2	
Evergreen Forest	282.5	
Grassland	33.0	
Impervious	46.1	
Palustrine Aquatic Bed	0.2	
Palustrine Emergent Wetland	7.2	
Palustrine Forested Wetland	27.6	
Palustrine Scrub/Shrub Wetland	0.7	
Pasture/Hay	7.6	
Scrub/Shrub	20.0	
Water	0.7	
Tax exempt (State/Town Owned)	**521.5**	**23.5%**
Bare Land	0.4	
Deciduous Forest	131.1	
Developed Open Space	20.5	
Evergreen Forest	298.2	
Grassland	22.1	
Impervious	3.7	
Palustrine Aquatic Bed	0.6	
Palustrine Emergent Wetland	4.4	
Palustrine Forested Wetland	28.6	
Palustrine Scrub/Shrub Wetland	0.3	
Scrub/Shrub	7.8	
Water	3.9	
Open land	**493.4**	**22.2%**
Bare Land	4.2	
Deciduous Forest	197.8	
Developed Open Space	11.4	
Evergreen Forest	204.5	
Grassland	5.8	
Impervious	1.8	
Palustrine Emergent Wetland	2.3	
Palustrine Forested Wetland	22.9	
Palustrine Scrub/Shrub Wetland	0.7	
Pasture/Hay	1.9	
Scrub/Shrub	5.0	
Water	35.0	

Land Use and Land Cover	Area (Acres)	Percent Total
Right-of-way	**134.0**	**6.0%**
Deciduous Forest	30.5	
Developed Open Space	17.6	
Evergreen Forest	21.2	
Grassland	0.5	
Impervious	62.0	
Palustrine Aquatic Bed	0.1	
Palustrine Emergent Wetland	0.2	
Palustrine Forested Wetland	1.8	
Scrub/Shrub	0.1	
Residential - multi-family	**83.5**	**3.8%**
Deciduous Forest	22.2	
Developed Open Space	6.4	
Evergreen Forest	45.1	
Grassland	1.8	
Impervious	2.7	
Palustrine Aquatic Bed	0.1	
Palustrine Emergent Wetland	0.6	
Palustrine Forested Wetland	4.6	
Water	0.1	
Commercial	**46.3**	**2.1%**
Bare Land	9.2	
Deciduous Forest	6.5	
Developed Open Space	0.8	
Evergreen Forest	15.9	
Grassland	7.1	
Impervious	1.4	
Palustrine Aquatic Bed	0.1	
Palustrine Emergent Wetland	1.7	
Palustrine Forested Wetland	0.5	
Palustrine Scrub/Shrub Wetland	0.5	
Scrub/Shrub	2.7	
Industrial	**39.5**	**1.8%**
Bare Land	2.4	
Deciduous Forest	15.1	
Developed Open Space	1.1	
Evergreen Forest	9.8	
Grassland	6.7	
Impervious	2.1	
Palustrine Forested Wetland	1.5	
Scrub/Shrub	0.8	

Land Use and Land Cover	Area (Acres)	Percent Total
Water	**13.4**	**0.6%**
Deciduous Forest	0.3	
Evergreen Forest	0.8	
Grassland	0.1	
Palustrine Aquatic Bed	10.3	
Palustrine Emergent Wetland	0.3	
Palustrine Forested Wetland	0.8	
Water	0.7	
Forest	**4.8**	**0.2%**
Deciduous Forest	2.9	
Evergreen Forest	0.6	
Grassland	0.6	
Scrub/Shrub	0.7	
Watershed Total	**2221.2**	**100.0%**

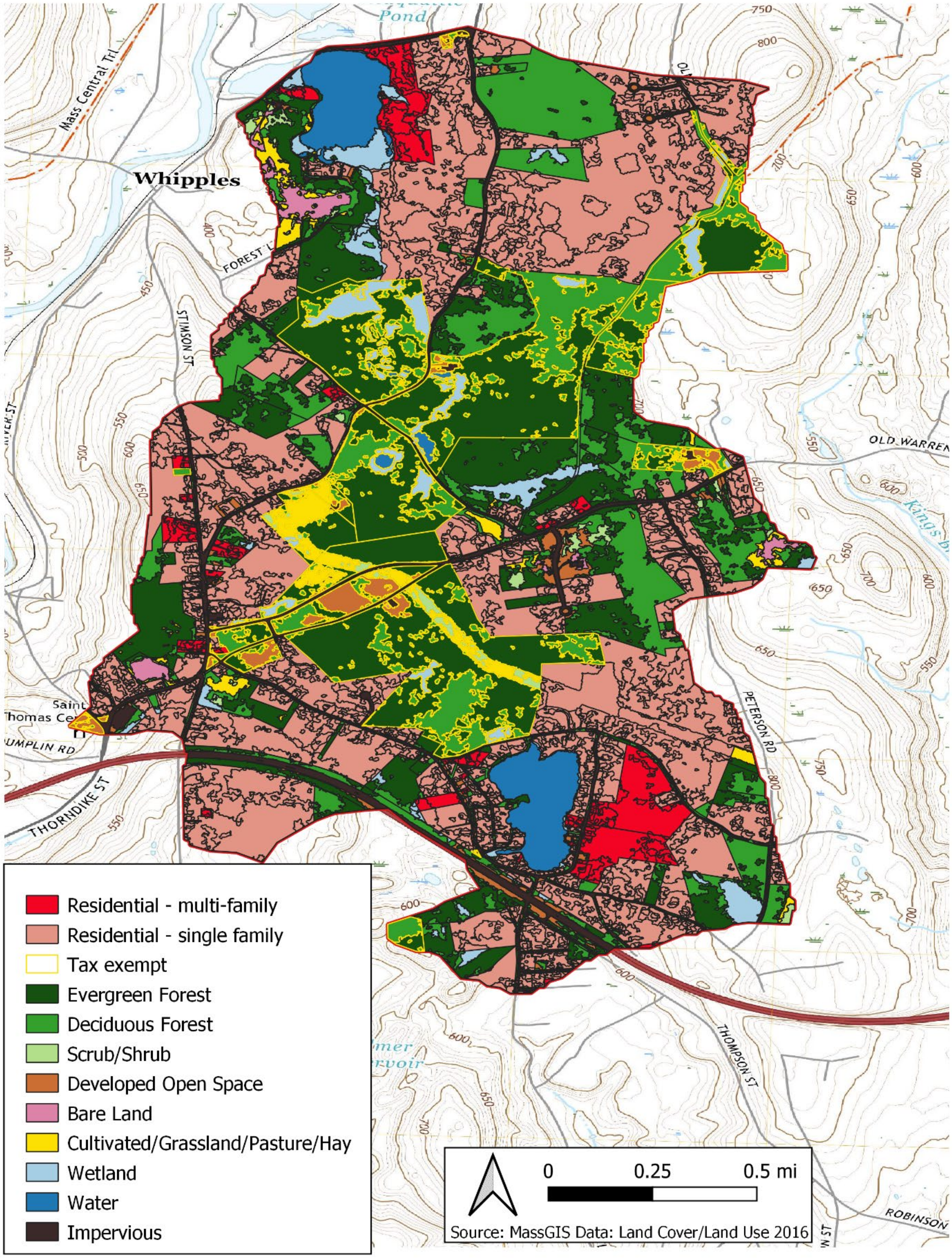

Figure 5. Forest Lake Watershed Land Cover/Land Use

WATER QUALITY

The last known water quality sampling of Forest Lake and its watershed was conducted as part of the Feasibility Study for Rehabilitation of Forest Lake by Cullinan Engineering Company prepared in 1981 (Cullinan Report). Since these data are dated, in-lake water quality and the immediate surrounding watershed were evaluated as part of this assessment. Water quality samples were collected on four occasions: twice during dry weather and twice during precipitation events. Dry weather sampling occurred on June 17, 2020 and on September 13, 2020. Wet weather sampling occurred on August 19, 2021 and on November 12, 2021. ARC conducted the sampling in accordance with the project specific Quality Assurance Project Plan (QAPP). The QAPP was approved by MassDEP and the Environmental Protection Agency (EPA) Region 1.

During dry weather, ARC scientists evaluated water quality at three locations. Scientists recorded in-situ measurements of temperature, dissolved oxygen (DO), pH, conductivity, and turbidity at all locations and collected surface water grab samples for laboratory analysis. At the in-lake station, deep location (FL-01), in-situ measurements were recorded at multiple depths. The other two dry weather sample locations included the unnamed tributary approximately 200 feet upstream of the lake (FL-02) and downstream of Route 32 proximal to the MassWildlife Roger Reed Fish Hatchery (DwnsFWS) (Table 2; Figure 6). Wet weather sampling, targeting the first flush of a precipitation event after three days of no measurable precipitation, consisted of in-situ measurement and grab sampling at four locations: at the beach (Beach), sheet flow runoff at the former boat ramp (Boat Ramp), sheet flow runoff from Forest Lake Road (Dirt Road) and the unnamed tributary (FL-02).

All grab samples were delivered to Massachusetts State Certified analytical laboratories. The laboratory analyzed samples for several forms of nutrients: Total phosphorus (TP), dissolved phosphorus (DP), nitrite and nitrate nitrogen (NO_2+NO_3), total Kjeldahl nitrogen (TKN) and ammonia (NH3-N). Other water quality analytes included total suspended solids (TSS) and bacteria [total coliform and *Escherichia coli* (*E. coli*)]. Grab samples were placed in laboratory provided pre-preserved bottles and stored on ice before delivery to the laboratory.

Table 2. Water Quality Sample Locations

Station ID	Description
DRY WEATHER	
FL-01	In-lake deep location
FL-02	Main unnamed tributary originating from Thompson Lake outlet; Sampled in flowing water along western side of the wetland off Forest Lake Road approximately 400 feet south of Forest Lake
DwnsFWS*	Downstream of Roger Reed Fish Hatchery. *Not in initial Scope of Work but sampled without charge to assess select water quality variables
WET WEATHER	
FL-02	Main unnamed tributary originating from Thompson Lake outlet; Sampled in flowing water along western side of the wetland off Forest Lake Road approximately 400 feet south of Forest Lake
Beach	At beach at the north end of the lake in about three feet of water
Boat Ramp	Sheet flow runoff from River Street collected along the former paved boat ramp next to the beach
Dirt Road	Runoff from Forest Lake Road draining toward the western portion of the lake

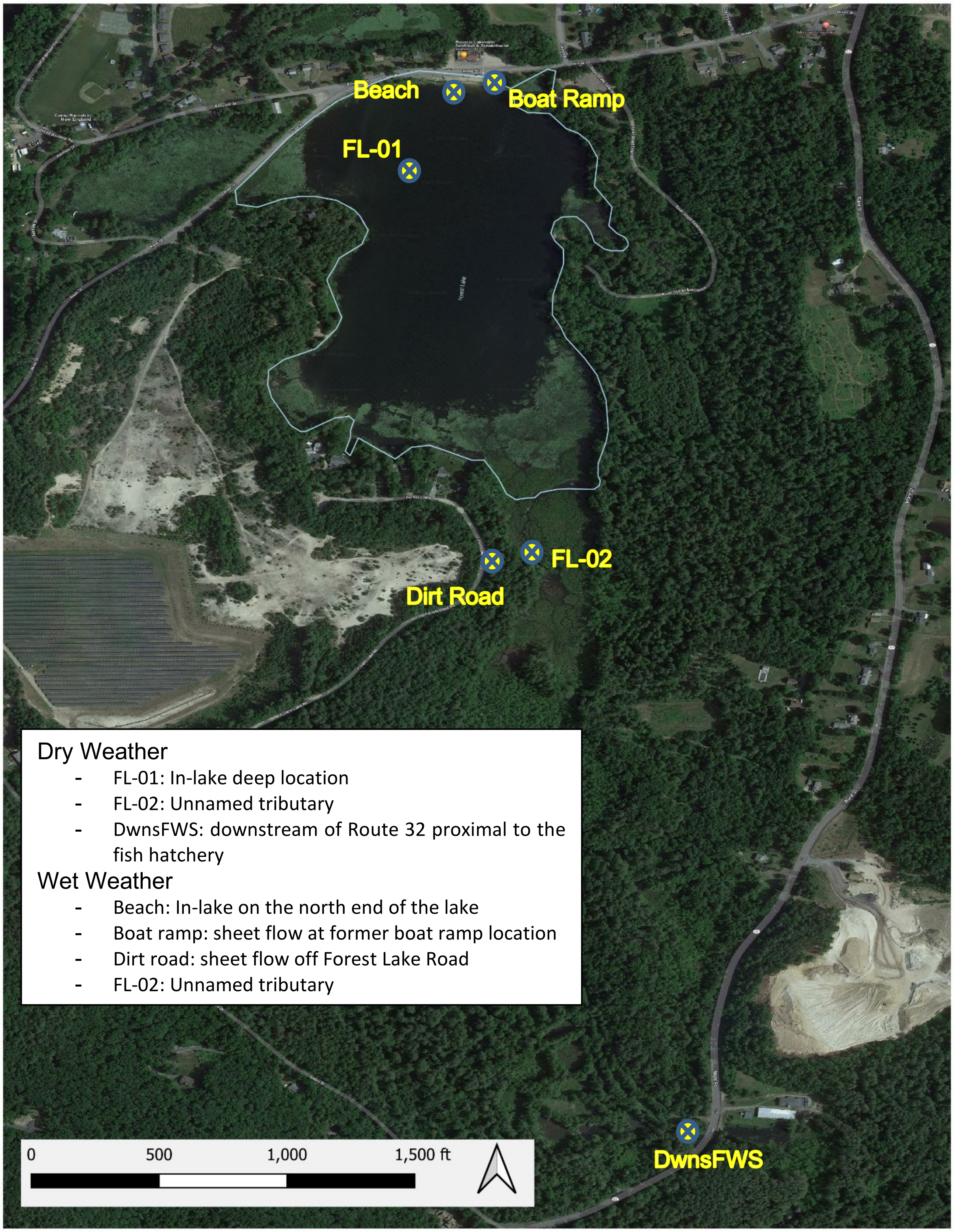

Figure 6. Lake and Watershed Sample Locations

In-situ Measurements

Forest Lake began to thermally stratify in June, although neither June nor September indicated strong stratification in 2020. The thermocline (boundary between upper, warmer layer and lower, colder, layer) was present at approximately six feet (ft) in June and ten feet in September (Figure 7). Waters containing DO above 5.0 milligrams per liter (mg/L) are considered supportive for aquatic life, in accordance with Massachusetts State Water Quality Standards for Class B warm water fisheries (WQS). In the absence of oxygen, certain undesirable chemical compounds will accumulate in the bottom water layer (hypolimnion), most notably dissolved and particulate phosphorus, iron, manganese, ammonia, and possibly hydrogen sulfide. Oxygen concentrations were desirable at the surface but were depressed below the thermocline and anoxic conditions (defined as concentrations less than 2.0 mg/L) were present at water depths greater than 18 feet during June and 10 feet in September. The marked increase in DO during June in the 10-14 water depth zone could be the result of circulation or algal and rooted plant photosynthesis.

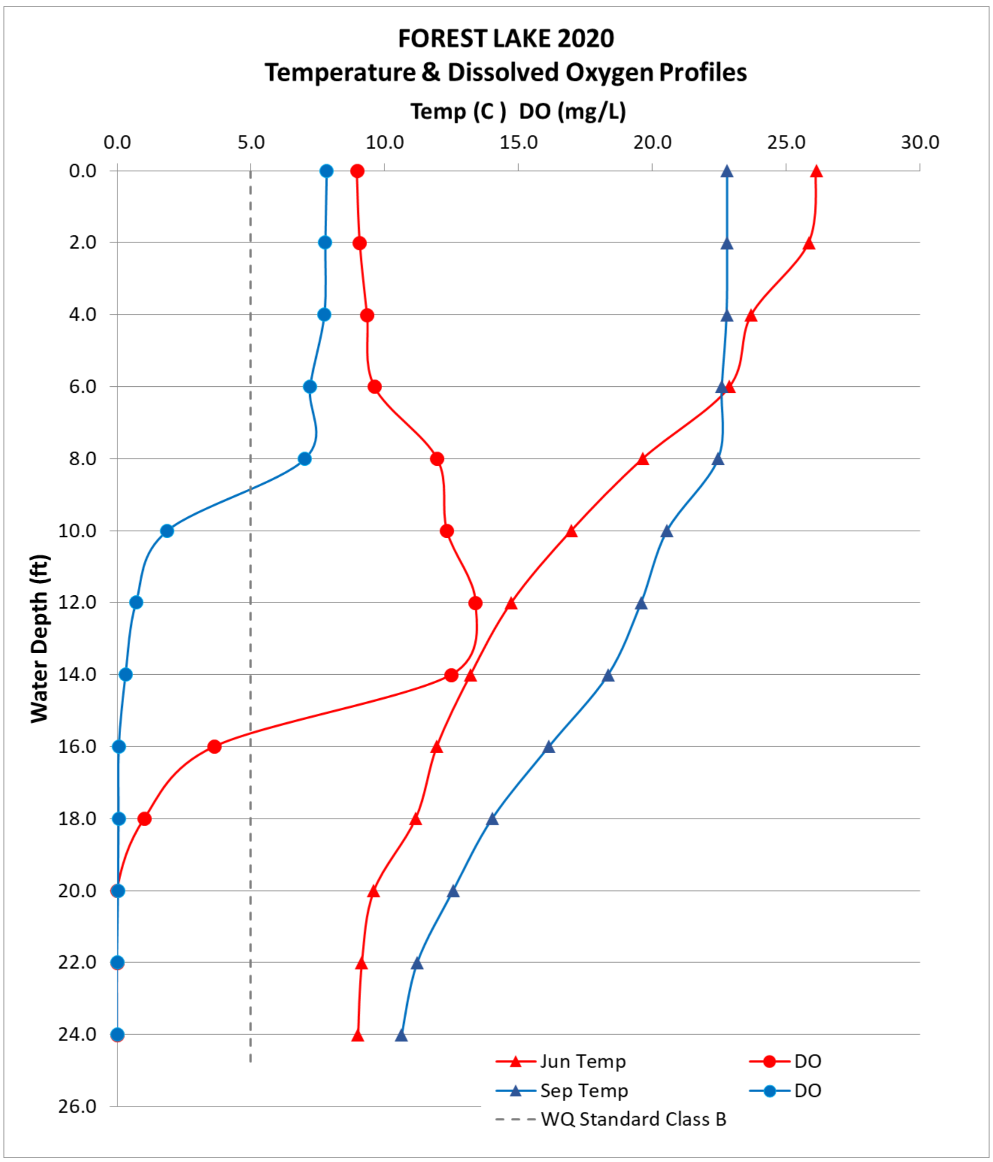

Figure 7. Temperature and Dissolved Oxygen Profiles

In comparison with the Cullinan Report, DO deficit is much greater today than in 1980-1981. Anoxic conditions were only observed at the very bottom (at 24 feet) in the early 80's, verses 10-feet in 2020. Depressed oxygen was recorded at 18 feet in the Cullinan Report, but generally DO concentrations were about the 5.0 mg/L threshold at most depths. This suggests that the chemical and biological oxygen demand of the sediments and overlying water is much greater today. This is likely due to increased eutrophication (nutrient enrichment) and overabundance of rooted plant growth.

Like temperature and DO, in-lake water depth profiles for pH, specific conductivity and turbidity were recorded twice during dry weather. Surface water values at the unnamed tributary (FL-02) and stormwater runoff location were also recorded during dry and wet weather. These data are summarized in Table 3. DO was desirable at all locations except the tributary (FL-02) in August when DO was below 5.0 mg/L.

pH is a measure of hydrogen ion concentration and provides an indication of whether the water is acidic [pH <7 standard units (SU)] or basic (pH>7 SU)]. Values in Forest Lake were nearly neutral but did achieve a high of 8.2 SU in September; this is likely the result of high photosynthetic activity. During photosynthesis carbon dioxide is removed from the water raising pH. During plant respiration, plants release carbon dioxide into the water lowering pH. This is why it is common to see very low pH just before sunrise and higher pH mid-afternoon. In-lake and watershed pH ranged from 6.5 to 8.5 SU during dry weather. The sample location in the unnamed tributary immediately downstream of Route 32 and the Hatchery (DwnsFWS) had the elevated pH. During wet weather, pH ranged from 5.9 to 8.1 SU, with the Boat Ramp exhibiting the lowest pH and the Dirt Road exhibiting the highest. The WQS range for pH is 6.5 to 8.3 SU and no more than 0.5 SU outside the background range. On occasion, in-lake pH is beyond the high end of the range and the watershed pH is less than the low end.

Conductivity measures the quantity of dissolved solids in water. It is a rough indicator of overall fertility, or potential productivity. Specific conductivity is the measure of conductance corrected for temperature at 25°C. This allows for comparisons when temperatures vary. Specific conductance in Forest Lake was 212 and 254 microsiemens per centimeter (µS/cm) in June and September 2020, respectively (Table 3). Conductivity in the watershed during dry weather was similar with an average of 264 µS/cm at the unnamed tributary (FL-02) and 247 µS/cm downstream of Route 32/Hatchery (DwnsFWS). Conductivity during wet weather was lower, with sheet flow runoff being very low. The Beach and FL-02 results were somewhat lower during wet weather than under dry conditions. Values below 100 µS/cm are considered low. Values above this level usually indicate human disturbance from road salts, fertilizers, wastewater, and/or stormwater runoff from developed and agricultural areas. Values above 500 µS/cm are excessive. The Cullinan Report indicates that in-lake conductivity was lower (126 µS/cm) as well as downstream of Route 32/Hatchery (112 µS/cm). Conductivity values appear to be increasing with time indicating the human influence is having a stronger impact on water quality conditions.

Turbidity measures the volume of suspended solids in the water column, including algae and suspended sediment. Turbidity values in Forest Lake was variable and ranged from 0 to 217 Nephelometric Turbidity Units (NTU) in 2020. The high values were nearest the bottom. This could be the result of suspended sediments or algae. Surface turbidity was <1 NTU. Turbidity in the tributary during dry weather was also low, <2 NTU. As expected, wet weather turbidity was excessive with values in runoff from the Dirt Road runoff averaging 1,733 NTU and Boat Ramp averaging 127 NTU. The tributary (FL-02) was also high with an average of 71 NTU. The Beach turbidity was 4.5 NTU.

Table 3. In-lake and Watershed Water Quality

		Dry Weather					
		June 17, 2020			September 13, 2020		
Variable	**Unit**	**FL-01**	**FL-02**	**DwnsFWS***	**FL-01**	**FL-02**	**DwnsFWS***
Temperature	**°C**	26.1	18.5	18.7	22.9	17.5	17.3
Dissolved Oxygen	**mg/L**	9.0	7.4	10.6	7.8	8.6	10.5
pH	**SU**	7.8	6.9	8.5	7.1	6.5	7.1
Specific Conductivity	**µs/cm**	212	239	216	254	290	279
Turbidity	**NTU**	0.4	1.7	0.1	0.4	1.0	0.0
Ammonia as N	**mg/L**	<0.10	0.11	NA	0.13	<0.10	NA
Nitrate-Nitrite as N	**mg/L**	<0.02	0.354	NA	<0.02	0.189	NA
Total Kjeldahl Nitrogen as N	**mg/L**	0.23	0.25	NA	0.29	0.08	NA
Total Nitrogen	**mg/L**	0.25	0.604	0.584	0.31	0.269	0.335
Total Phosphorus as P	**mg/L**	0.036	0.022	0.047	0.026	0.048	0.048
Dissolved Phosphorus as P	**mg/L**	0.025	0.012	NA	<0.01	0.021	NA
Total Suspended Solids	**mg/L**	<5	12	NA	<5	7	NA
Total Coliform	**MPN/100 mL**	290	770	NA	1000	1200	NA
E. coli	**MPN/100 mL**	<1	250	NA	1	30	NA
Secchi Disk Transparency	**ft**	12.9			10.4		

		Wet Weather							
		August 19, 2021				November 12, 2021			
Variable	**Unit**	**Beach**	**Boat Ramp**	**Dirt Road**	**FL-02**	**Beach**	**Boat Ramp**	**Dirt Road**	**FL-02**
Temperature	**°C**	23.9	22.8	21.9	17.9	10.8	16.0	13.2	10.6
Dissolved Oxygen	**mg/L**	7.9	8.4	8.7	2.9	8.6	9.6	10.5	9.6
pH	**SU**	6.5	5.9	6.8	6.5	7.2	6.5	8.1	7.5
Specific Conductivity	**µs/cm**	146	3	8	117	162	26	4	167
Turbidity	**NTU**	2.3	240.3	2916.0	67.2	6.6	12.9	549.9	75.2
Ammonia as N	**mg/L**	<0.10	<0.10	<0.10	<0.10	0.25	0.2	0.1	0.12
Nitrate-Nitrite as N	**mg/L**	0.009	0.033	0.055	0.083	0.013	0.028	0.01	0.075
Total Kjeldahl Nitrogen as N	**mg/L**	0.26	0.57	0.57	0.5	0.46	0.56	0.63	0.18
Total Nitrogen	**mg/L**	0.269	0.603	0.625	0.583	0.473	0.588	0.64	0.255
Total Phosphorus as P	**mg/L**	0.019	0.126	0.179	0.054	0.038	0.131	0.045	0.031
Dissolved Phosphorus as P	**mg/L**	0.014	0.035	0.046	0.024	0.019	0.092	0.037	0.016
Total Suspended Solids	**mg/L**	<5	20	136	11	26	23	150	19
Total Coliform	**MPN/100 mL**	>2420	>2420	>2420	>2420	>2420	>2420	>2420	>2420
E. coli	**MPN/100 mL**	1400	1200	4400	>2420	37	14	13000	2400
Secchi Disk Transparency	**ft**								

MPN = most probable number
NA = not analyzed

Turbidity affects water clarity. Field measurement of in-lake water clarity are made using a Secchi disk. Secchi disk transparency (SDT) in Forest Lake was 12.9 feet in June and 10.4 feet in September 2020 (Table 3). The Cullinan Report SDT averaged 8.9 feet with a maximum of 12 feet in April 1981, comparable to data collected in 2020.

Nutrients and Bacteria

Phosphorus is usually the growth-limiting nutrient for freshwater photosynthetic organisms, including algae. Total phosphorus (TP) includes all forms of phosphorus in the water column, from readily absorbable dissolved orthophosphates to refractory particulate phosphorus. TP, along with other variables, is often used as a measure of a lake trophic state. Surface TP concentrations below 0.010 mg/L are usually associated with clear water and lack appreciable phytoplankton density (algae). The EPA "Gold Book"[4] recommends that TP remain below 0.025 mg/L to prevent accelerated eutrophication and avoid nuisance conditions like harmful algal blooms. However, nuisance conditions are observed in lakes with concentrations less than this guidance level. Values as low as 0.020 mg/L have supported recurring blooms and the scientific evidence suggest that some species of algae can take up phosphorus at the sediment-water interface thus, not requiring higher water column concentrations to grow. These algae regulate their buoyancy and migrate to the surface once TP is consumed where their numbers rapidly multiply resulting in a bloom. In these situations, lake surface TP remain low but still experience recurring blooms.

Grab in-lake water samples from Forest Lake suggest that nutrients are present in excessive concentrations, well above the Gold Book threshold (Table 3). Surface water TP was 0.036 mg/L in June and 0.026 mg/L in September of 2020, suggesting that there is ample phosphorus to cause severe and recurring algal blooms. Sources of phosphorus are both internal (from sediment and plant decomposition) and the watershed. The unnamed tributary concentrations (FL-02) averaged 0.035 mg/L and further upstream at Route 32/Hatchery TP averaged 0.048 mg/L. Average in-lake TP reporting in the Cullinan Report was 0.032 mg/L, similar to 2020 values. The unnamed tributary TP averaged 0.039 mg/L, similar to FL-02 and the sample collected just downstream of Route 32/Hatchery was 0.048 mg/L, again similar to 2020. These data indicate that while conditions haven't worsened, they also have not improved in 40 years.

Much of the phosphorus in Forest Lake (19-69%) is in the dissolved form and readily available for algal uptake. During wet weather, nine to 82% of the phosphorus was dissolved. Dissolved phosphorus (DP) refers to the soluble portion of TP (inorganic and organic). DP may be cycled so rapidly as to suggest that the presence of measurable DP is a negative sign.

Nitrogen is a nutrient that also may be limiting for aquatic organisms such as algae and plants. Nitrogen exists in lakes in many forms. The most important forms of readily absorbable nitrogen are nitrate (NO_{3^-}) and ammonium (NH_{4^+}) (Wetzel 1983)[5]. Nitrite is also adsorbable but is rarely found in quantities above detection levels in lakes because it is rapidly converted to nitrate during the nitrification process. Limnologists typically measure the both nitrite and nitrate together (NO_2^- + NO_3^-). Both forms are unlikely to cause water quality problems such as algal blooms at concentrations below 0.3 mg/L, but problems may occur at concentrations above 1 mg/L. Nitrate+nitrite nitrogen in Forest Lake was low, less than the laboratory detection limit (<0.02 mg/L) on both sample dates in 2020. Nitrate+nitrite nitrogen in the unnamed tributary (FL-02) was elevated (0.354 mg/L in June) during dry weather and low during wet weather (average 0.079 mg/L). This difference suggests there is a constant load of nitrogen that is diluted under wet conditions. Samples collected as part of the Cullinan Report were comparable. Nitrate+nitrite ranged from 0.01 to 0.39 mg/L at the unnamed tributary.

Total Kjeldahl nitrogen (TKN) is a measure of ammonium-N and organic nitrogen forms present in the water column. Low (<0.5 mg/L) TKN concentrations are usually indicative of desirable water quality, with problems such as algal blooms unlikely to occur. Concentrations higher than 2 mg/L are indicative of undesirable water quality, with a substantial transition range in between those thresholds. Both in-lake and tributary (FL-02) TKN were low on both sampling dates in 2020 (in-

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[4] US EPA, 1986. Quality Criteria for Water. US-EPA 440/5-86-001. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, District of Columbia

[5] Wetzel R. G., 1983. *Limnology*, 2nd edition. Saunders College Publishing, Philadelphia, PA.

lake average 0.260 mg/L; FL-02 average 0.165 mg/L; Table 3). Wet weather TKN values were higher but were only slightly above the 0.5 mg/L threshold. The Boat Ramp and Dirt Road runoff contained the highest values.

Total nitrogen concentrations [(the sum of total Kjeldahl nitrogen (TKN) and nitrate+nitrite nitrogen)] less than 0.3 mg/L in lakes is considered low, values between 0.3 and 1.0 mg/L are moderate and values exceeding 1.0 mg/L are high. In-lake TN was low, with an average of 0.280 mg/L in 2020. The unnamed tributary (FL-02) was in the moderate range with an average of 0.437 mg/L and the upstream location within the tributary (DwnsFWS) was slightly higher with an average of 0.460 mg/L. Wet weather TN was higher but remained in the moderate range for all locations and dates (Table 3).

While phosphorus usually determines phytoplankton biomass (quantity of suspended algae), the N:P (by weight) ratio often determines phytoplankton species composition. Generally, when nitrogen concentrations are low, cyanobacteria (blue-green algae) are favored. Many species of cyanobacteria can fix atmospheric nitrogen and are more efficient at phosphorus uptake (Lee 1989)[6]. When N:P is higher than 15:1, green algae (Chlorophyta) are typically favored. When nutrient levels are high overall, nuisance cyanobacteria blooms are more likely to occur. N:P ratios in Forest Lake average below 10:1. This condition would favor cyanobacteria. High phosphorus concentrations coupled with warm temperatures also favor cyanobacteria.

Bacteria, measured as *Escherichia coli* (*E. coli*), at bathing beaches should not exceed the geometric mean of 126 colonies per 100 ml from the five most recent samples and no single sample should exceed 235 colonies per 100 ml during the bathing seasons, according to the Massachusetts Department of Public Health (105 CMR 445.010). *E. coli* was below the single sample standard during dry weather in the lake but exceeded this standard at the unnamed tributary in June (250 colonies per 100 ml). All wet weather samples collected on August 19, 2021 and samples at the unnamed tributary and Dirt Road in November 2021 greatly exceeded this standard. Samples at the Beach and the Boat Ramp during wet weather in November were below the single sample standard.

[6] Lee R. E., 1989. *Phycology*, 2nd edition. Cambridge University Press, Cambridge, GB.

AQUATIC HABITAT

Shoreline aquatic habitat is generally desirable with most of the shoreline undeveloped. The lake is used heavily for recreation (swimming, boating, fishing) but only small, motorized boats are allowed (<10 horsepower). This restriction likely limits the vessel congestion on the lake, minimizing soil disturbance and keeping banks stable. Because the shoreline and immediate riparian area is well vegetated, the existing shoreland habitat is excellent. However, the improved boat launch and expanded parking may result in an increase in boating traffic and shoreline erosion should be monitored. There is ample overhanging vegetation keeping shallow areas cool and out of direct sunshine. Insects that drop from overhanging trees are a significant source of food for fish. Trees and limbs that fall in the lake become structure habitat for multiple classes of animals. The emergent vegetation provides aquatic insects like dragonflies and damselflies structure to crawl out of the water and undergo metamorphosis into flying insects. The aquatic stages of these insects are important food source for other aquatic life.

The lake is heavily fished, and historic reports suggest that the fishing pressure was great enough to impair the population to warrant stocking. Historically the lake was fished for pickerel, perch and horned pout. MassWildlife has a long history of stocking the lake with many different fish species, including three species of trout (rainbow, brook and brown). Trout are cold water species and are not expected to survive and reproduce in the warm temperatures observed in Forest Lake. The more favorable cooler deep waters (>10 feet) undergo anoxic conditions and are not desirable for fish. Over 24 acres of the lake is greater than 10 feet deep, over half of the 45 surface acres. This severely limits the habitat availability for fish. Also, the excessive plant density can restrict movement and feeding success in shallow areas. The lake has also experienced fish kills that were attributed to oxygen loss associated with overly dense plants.

The lake supports a wide variety of other wildlife. During the 2020-2021 surveys, multiple beavers were observed along with several species of waterfowl and wading birds (cormorant, great blue herons, ducks and geese) as well as reptiles (water snakes, turtles), amphibians (frogs) and mammals. Although not directly observed, the habitat is likely to support muskrat, weasels, and otters.

Forest Lake is mapped by the Massachusetts Natural Heritage Endangered Species Program (NHESP) Priority Habitats of Rare Species and Estimated Habitats of Rare Wildlife as of August 1, 2021 (Figure 8). The Priority Habitat represent the geographical extent of state-listed rare species and as such, any activities that have the potential to impact these species are held to higher standard of review and permit approval process. The Estimated Habitat is a subset of the Priority Habitat based on documentation of observations over the last 25 years. It is not known, as of the writing of this document which species occur in Forest Lake, but the habitat characteristic of the lake and riparian area are likely to support multiple species documented in the Town of Palmer listed on Table 4.

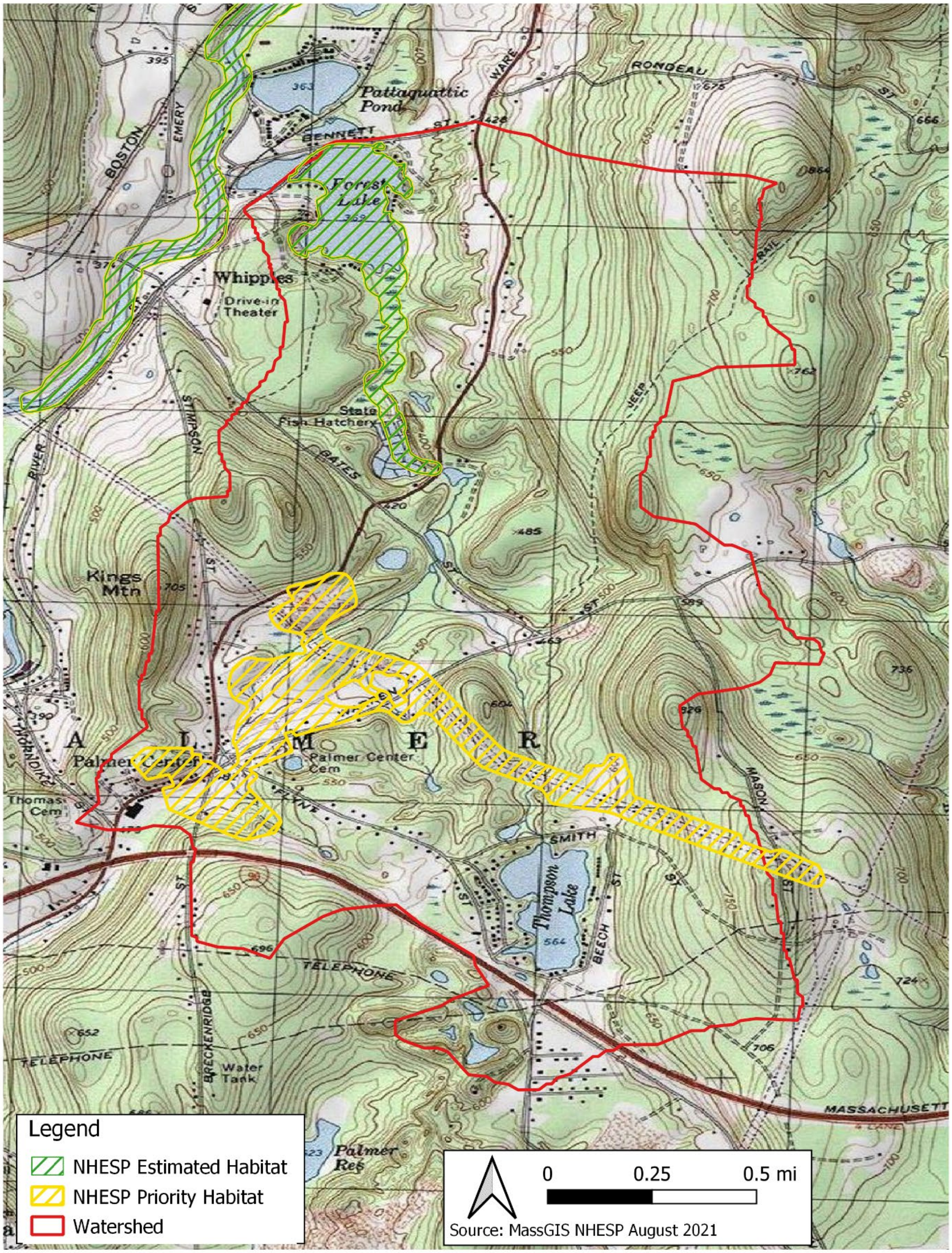

Figure 8. NHESP Priority and Estimated Rare Species Habitat

Table 4. NHESP Documented State Listed Species in Palmer

Common Name	Scientific Name	Taxonomic Group	Status	Most Recent Obs.
Jefferson Salamander (complex)	*Ambystoma jeffersonianum*	Amphibian	Special Concern	2016
Purple Tiger Beetle	*Cicindela purpurea*	Beetle	Special Concern	2015
Grasshopper Sparrow	*Ammodramus savannarum*	Bird	Threatened	2013
Frosted Elfin	*Callophrys irus*	Butterfly/Moth	Special Concern	2019
New Jersey Tea Inchworm	*Apodrepanulatrix liberaria*	Butterfly/Moth	Endangered	2016
Orange Sallow Moth	*Pyrrhia aurantiago*	Butterfly/Moth	Special Concern	2020
Slender Clearwing Sphinx	*Hemaris gracilis*	Butterfly/Moth	Special Concern	2016
Brook Snaketail	*Ophiogomphus aspersus*	Dragonfly/ Damselfly	Special Concern	2004
Spine-crowned Clubtail	*Hylogomphus abbreviatus*	Dragonfly/ Damselfly	Special Concern	2004
Bridle Shiner	*Notropis bifrenatus*	Fish	Special Concern	2016
Creeper	*Strophitus undulatus*	Mussel	Special Concern	2014
Eastern Box Turtle	*Terrapene carolina*	Reptile	Special Concern	2004
Wood Turtle	*Glyptemys insculpta*	Reptile	Special Concern	2019
American Waterwort	*Elatine americana*	Vascular Plant	Endangered	1925
Climbing Fumitory	*Adlumia fungosa*	Vascular Plant	Special Concern	2016
Eastern Dwarf Mistletoe	*Arceuthobium pusillum*	Vascular Plant	Special Concern	2009
Green Rock-cress	*Boechera missouriensis*	Vascular Plant	Threatened	2018
Lion's Foot	*Nabalus serpentarius*	Vascular Plant	Endangered	2016
Small-flowered Buttercup	*Ranunculus micranthus*	Vascular Plant	Endangered	2017

Macrophytes

Forest Lake has been plagued with excessive rooted aquatic plant growth for decades. As part of this investigation, ARC conducted a plant survey on September 13, 2020. ARC scientists observed submerged aquatic plants using an Aqua-Vu® underwater camera using a modified semi-quantitative systematic design point interception method (Madsen and Wersal, 2017)[7]. This systematic design establishes predefined observation points based on a grid system. This methodology is best to provide an overall assessment of the lake community as the observer is more likely to encounter most of the species that exist within the lake. We established a grid with approximately 150-foot spacing between points. The point grid resulted in 85 observation points (Figure 9), each marked with Global Position System (GPS) coordinates. By employing this method, observation points can be revisited in subsequent years to assess changes over time. At each point, we recorded:

[7] Madsen, JD and RM Wersal. 2017. A review of aquatic plant monitoring and assessment methods. *Journal of Aquatic Plant Management*. 55:1–5

- water depth using a graduated metal conduit for depths <10 feet (using the conduit reduces the depth interference by plants) and sonar in waters >10 ft; These data were also used to generate the bathymetric map.
- estimated percent cover of all plants as measured by the areal extent of plants within an approximate two square meter visual area.
- estimated percent biovolume as measured by the amount of the water column filled with plants within the two square-meter area.
- both cover and biovolume are estimated using a semi-quantitative (0-4) ranking system as follows:

0 = 0%	1 = to 1 - 25%,
2 = 26 - 50%,	3 = 51 - 75%, and
4 = 76 – 100%	

- plant identification to the species level and to genus level for those that are not readily identifiable in the field. We utilized a rake toss to verify the visual identification of plants, and
- the relative abundance of each species observed with the Aqua-Vu® and rake toss.

Table 5 provides a listing of data collected at each observation point. Plants were observed at 51% of the observation points (43 out of 85). Plant cover in these locations was greater than 50% of the lake bottom (cover ranks 3 & 4) at 35 observation points, representing 41% of the observation points. Biovolume, a representation of the portion of the water column taken up by plants, was moderate – with 32% of the locations containing plants occupying over half of the water column. In summary, most of the lake bottom supports plant growth, with plants observed at all locations with water depth less than 13 feet with the exception of the sandy beach area. Biovolume is high in shallow locations and where non-native species were observed.

There were 17 submerged or floating-leaved species encountered, three of which are non-native invasive species: fanwort (*Cabomba caroliniana*), variable milfoil (*Myriophyllum heterophyllum*), and Eurasian watermilfoil (*Myriophyllum spicatum*). One non-native emergent wetland species was observed: purple loosestrife (*Lythrum salicaria*). Fanwort dominated the plant community and was observed at 47% of the observation locations and 93% of the locations which contained plants. Fanwort was not reported in the Cullinan Report, but Cullinan did document the presence of milfoil, however, the species of milfoil was not provided. Watershield (*Brasenia schreberi*) was the next most frequently encountered species (25%). Watershield is very common floating leaved plant and native to Massachusetts. It is capable of spreading and taking over large shallow areas in lakes impeding recreation but provides desirable habitat for fish.

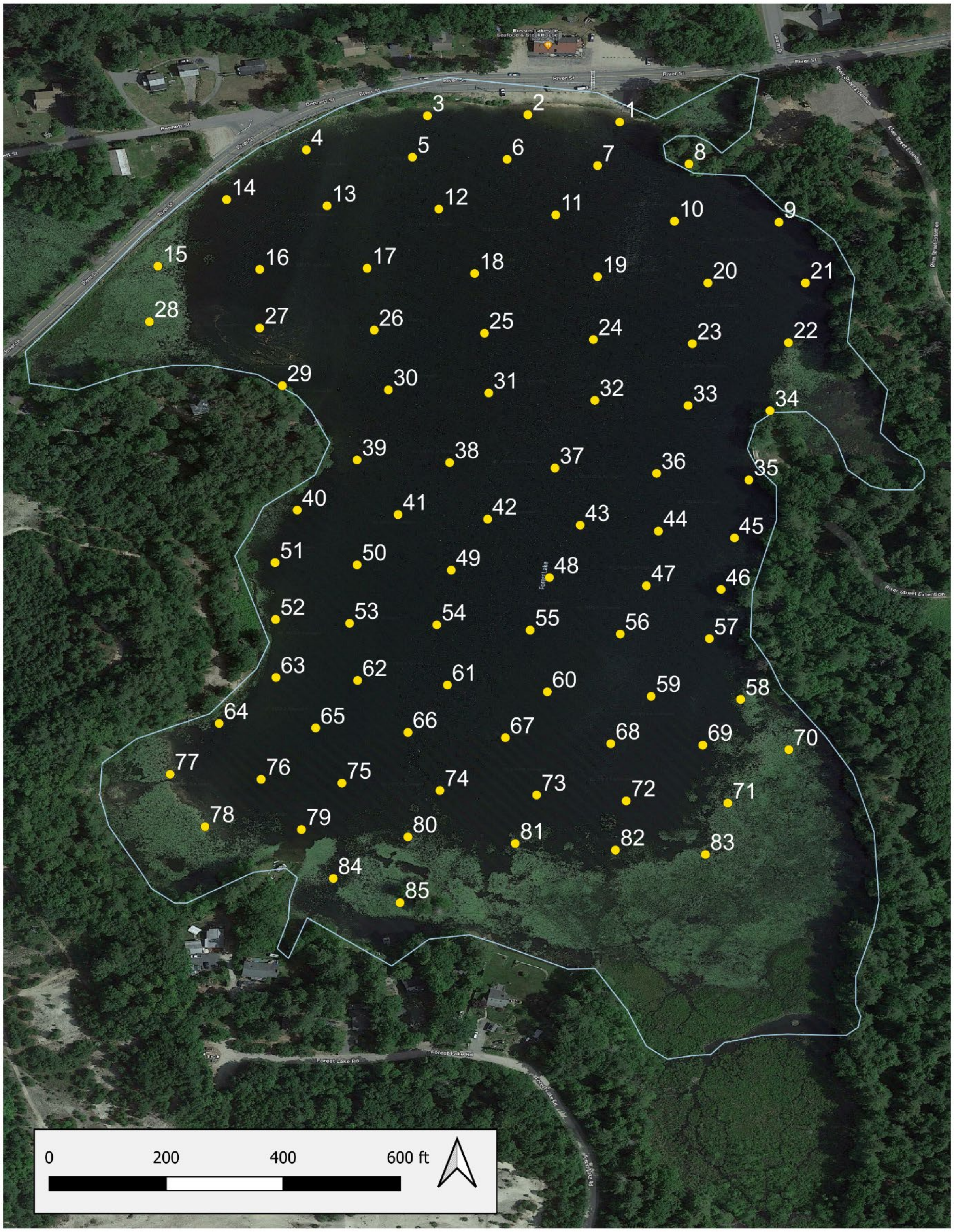

Figure 9. Plant Survey Observation Locations.

Table 5. Forest Lake Aquatic Plant Observations

Obs Pt	Depth (ft)	Cover	Bio-volume	Bs	Cc	Cd	Lm	Mh	Ms	Ng	No	Nv	Pamp	Pcor	Pe	Prob	Pv	Sag	Usp	Va	Shoreline emergents
1	4.7	4	2		5	20							10		5	20				40	
2	4	0	0																		
3	7	4	2	10	10					60	10								10		x
4	7.5	4	3	10	20				5	30	10					20			5		
5	9.2	4	4		60	10			30												
6	9.7	4	3		60	10			30												
7	16.5	0	0																		
8	3.6	4	1		10	20				20				5		40	5				
9	8	4	1		20					60						20					
10	18.4	0	0																		
11	21.5	0	0																		
12	19.4	0	0																		
13	10.5	2	2		70				30												
14	7	2	1							60						40					
15	4.5	4	4	20	20						20	20		5		10			5		
16	15.6	0	0																		
17	24.1	0	0																		
18	25.1	0	0																		
19	21	0	0																		
20	17.9	0	0																		
21	6	4	3	5	5	10				30						50					
22	5	4	4	10	20	10	5		5	5	20		5		10				10		
23	15.5	0	0																		
24	21.3	0	0																		
25	24.4	0	0																		
26	24.8	0	0																		
27	14	0	0																		

Obs Pt	Depth (ft)	Cover	Bio-volume	Bs	Cc	Cd	Lm	Mh	Ms	Ng	No	Nv	Pamp	Pcor	Pe	Prob	Pv	Sag	Usp	Va	Shoreline emergents
28	4.1	4	4	10	15						40	5		20					10		
29	3.7	4	4	10	65	20											5				
30	23.5	0	0																		
31	22.8	0	0																		
32	19.4	0	0																		
33	16	0	0																		
34	3.8	4	4	5	10		5	5				10		20		20	10	10	5		X - loosestrife
35	8.9	4	4		100																
36	15.6	0	0																		
37	19	0	0																		
38	20.3	0	0																		
39	16	0	0																		
40	9.5	4	4		70					30											
41	19.2	0	0																		
42	18.1	0	0																		
43	18.5	0	0																		
44	11.5	1	1						100												
45	4.7	4	3	10	10	5			10	30						30			5		
46	4.2	4	3	15	10				10		30					30		5			
47	15	0	0																		
48	18	0	0																		
49	18	0	0																		
50	17.2	0	0																		
51	9.5	4	4		90				10												
52	6	4	1		10					60	20			10							
53	17.2	0	0																		
54	18.2	0	0																		
55	18	0	0																		

Aquatic Restoration Consulting, LLC

Obs Pt	Depth (ft)	Cover	Bio-volume	Bs	Cc	Cd	Lm	Mh	Ms	Ng	No	Nv	Pamp	Pcor	Pe	Prob	Pv	Sag	Usp	Va	Shoreline emergents
56	17	0	0																		
57	7	4	3	5	20					40	30		5								
58	4	4	2								60		5	10					25		x
59	14.2	0	0																		
60	17.5	0	0																		
61	17.2	0	0																		
62	17	0	0																		
63	11.3	1	1		100																
64	7.4	4	3	5	70						10	5		5		5					
65	15	0	0																		
66	12.5	0	0																		
67	17	0	0																		
68	13.3	0	0																		
69	7.3	3	3		95														5		
70	2.8	4	4	5	30						20	20		10		5			10		x
71	3.8	4	4		15						10	30				40			5		
72	7.4	4	2		80											20					
73	10.7	2	2		100																
74	10.7	2	2		100																
75	11.3	2	2		10				90												
76	11.3	2	1		50				40										10		
77	6.5	4	4	10	40	5			10		15	20									
78	5.6	4	4	10	40						20	20							10		
79	6.6	3	1		40				30		30										
80	6	4	4	20	30	10				5	15	10							10		
81	4.8	4	4	20	30	10					10	5				15			10		
82	4	4	3	10	20	5					60		5								
83	3.5	4	3	10	20						50	10		5		10					
84	5.1	4	4	20	40	15					20					5					

Obs Pt	Depth (ft)	Cover	Bio-volume	Bs	Cc	Cd	Lm	Mh	Ms	Ng	No	Nv	Pamp	Pcor	Pe	Prob	Pv	Sag	Usp	Va	Shoreline emergents
85	3	4	4	10	30	25					25		5						5		
mean	12.3	1.8	1.4																		
	Frequency of occurrence			21	40	14	2	1	13	12	21	11	6	9	2	17	3	2	16	1	
	% frequency of all points			25%	**47%**	16%	2%	1%	15%	14%	25%	13%	7%	11%	2%	20%	4%	2%	19%	1%	

Key to plant identification

Id	Common Name	Scientific Name
Bs	Watershield	*Brasenia schreberi*
Cc	Fanwort	*Cabomba caroliniana*
Cd	Coontail	*Ceratophyllum demersum*
Lm	Duckweed	*Lemna minor*
Mh	Variable milfoil	*Myriophyllum heterophyllum*
Ms	Eurasian watermilfoil	*Myriophyllum spicatum*
Ng	Slender waternymph	*Najas gracillima*
No	White waterlily	*Nymphaea odorata*
Nv	Yellow water lily	*Nuphar variegata*

Id	Common Name	Scientific Name
Pamp	Large-leaf pondweed	*Potamogeton amplifolius*
Pcord	Pickerelweed	*Pontederia cordata*
Pe	Ribbon-leaved pondweed	*Potamogeton epihydrus*
Prob	Robbins' pondweed	*Potamogeton robbinsii*
Pv	Arrow-arum	*Peltandra virginica*
Sag	Arrowhead	*Sagittaria* sp
Usp	Bladderwort	*Utricularia* spp.
Va	Tapegrass	*Vallisneria americana*

Shoreline emergents	
Common Name	**Scientific Name**
Cat-tail	*Typha* sp.
Purple loosestrife	*Lythrum salicaria*
Rush	*Juncus* sp.
Bur-reed	*Sparganium* sp.

Red text indicates non-native invasive species.

Rooted Plant Management

Excessive rooted plant densities not only impact recreation but they also impair habitat for other aquatic life. Decomposition of plants can strip the water column of oxygen and the decaying biomass contributes phosphorus to the system resulting in accelerated eutrophication. There are several aquatic plant management techniques available to control rooted plant growth. A description of each technique's efficacy, based on case studies and which factors to consider when employing a technique, is presented in detail in the Eutrophication and Aquatic Plant Management in Massachusetts Final Generic Environmental Impact Report (GEIR)[8]. A brief description of some of the most frequently employed and effective techniques are provided in the discussion below, with some text presented herein taken directly from the GEIR. The applicability of each technique to Forest Lake is also discussed briefly below. If the Town wishes to actively manage aquatic plants, a lake-specific Aquatic Plant Management Plan should be prepared to fully evaluate and compare management alternatives.

Winter Water Level Drawdown

Winter water level drawdown involves lowering the surface water elevation by gravity and/or pumping or siphoning. The water elevation is lowered to expose the littoral area over the winter months allowing the sediments, plants and roots to freeze. This technique kills the plant and prevents or slows regrowth in the summer. The movement of ice can rip plants from the sediment also reducing plant density come spring. This technique is only effective within the drawdown zone and does not control plant growth in areas not exposed to freezing. Winter water level drawdown is not applicable in Forest Lake because there is no apparent water level control structure that would facilitate a drawdown without significant capital investments.

Mechanical Removal

Mechanical removal is the physical removal of plants or portions thereof. Mechanical removal includes harvesting, cutting without collection, rototilling and hydroraking. Each of these types of mechanical removal are discussed in the GEIR. Hand pulling and suction harvesting are too labor intensive to handle the extent of vegetation in Forest Lake. Cutting without collection is not recommended because many of the undesirable species in the lake propagate vegetatively, meaning that plant fragments are able to root and produce a new colony. Cutting can exacerbate the problem. Rototilling and hydroraking are non-selective and will remove all plants within the target area. These techniques also generate a lot of fragments and turbidity and are typically used along the shoreline for problematic emergent species like cat-tails and common reed (*Phragmites*). Hydroraking was recommended in the Cullinan Report. The Town can read more about hydroraking in the GEIR to gain a better understanding of their effectiveness, impacts, and other considerations. There is additional permitting scrutiny placed on hydroraking due to the amount of sediment disturbance.

Benthic Barriers

Benthic barriers are essentially lake sediment covers. Cover material can be natural substances like clay, sand, gravel or manufactured sheets made from nylon, plastic, fiberglass, or other non-toxic materials. Natural materials change the composition of sediment to prevent plant growth whereas manufactured sheets prevent root access to underlying sediment. Both techniques can be applied over existing plant materials, but efficacy is reduced. It is recommended, if possible, that areas be cleared or partially cleared of plants prior to implementation. Over time, natural processes will deposit silts and organics allowing plants to take root once again.

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[8] Available at https://www.mass.gov/files/documents/2016/08/sd/eutrophication-and-aquatic-plant-management-in-massachusetts-final-generic-environmental-impact-report-mattson.pdf (GEIR 2004)

This technique is usually applied to small areas like beaches and around docks and access ramps. Manufactured barriers were successful in controlling milfoil in Lake George in three acres for about three years. Recolonization of the area with native species was rapid, but milfoil returned within two years. Given the fact that the beach area would be the most logical use of this technique but is relatively sandy and void of plants, it is not warranted at this time. Individual homeowners to the south may have interest in this technique near docks or to provide a weed free wading area.

Biological Control

Biological control is the introduction of another species to control plant growth. Herbivorous fish (such as grass carp) and invertebrates (such as weevils and beetles) are common biota used for biological control. They have variable success and often had more undesirable effects than anticipated in many cases. Grass carp are not approved for introduction in the State of Massachusetts. For these reasons biological controls are not recommended for Forest Lake.

Herbicides

For large areas, aside from winter water level drawdowns, herbicides are the most economical choice. A very extensive discussion on herbicides is included in the GEIR. A short discussion on herbicides is provided herein, however, the Town should contact a license herbicide applicator to discuss available options. There are new herbicides approved for use in Massachusetts since the GEIR's publication that may work very well on the plant assemblage at Forest Lake.

> Herbicides are typically classified as contact or systemic herbicides based on the action mode of the active ingredient. Contact herbicides are toxic to plants by uptake in the immediate vicinity of external contact, while systemic herbicides are taken up by the plant and are translocated throughout the plant. In general, contact herbicides are more effective against annuals than perennials because they may not kill the roots, allowing perennials to grow back. Seeds are also not likely to be affected, but with proper timing and perhaps several treatments, growths can be eliminated much the same way harvesting can eliminate annual plants. Systemic herbicides tend to work more slowly than contact herbicides because they take time to be translocated throughout the plant. Systemic herbicides generally provide more effective control of perennial plants than contact herbicides, as they kill the entire plant under favorable application circumstances. Systemic herbicides will also kill susceptible annual species, but regrowth from seeds will require additional treatments as with contact herbicides. GEIR 2004

There are several active ingredients in herbicides that are known to control fanwort and milfoil. Diquat is a non-selective contact herbicide and will impact all photosynthetic plants at the recommended dose. Diquat is fast acting and will reduce plant densities within a few weeks of application. It is nonselective and will kill or impair any plant it encounters. Since it is fast acting it can kill off substantial biomass that can deplete water oxygen upon decay and release phosphorus encouraging algal blooms. If desired, silt curtains could be deployed around the treatment area to restrict the herbicide's movement and lessen impacts to non-target plants, but this will increase costs. There is temporary water use restriction (3 days no cooking/drinking; 5 days no irrigation; 1 day no watering livestock). There are no restrictions on contact recreation (swimming, boating or fishing). Diquat costs about $250-$500 per acre plus additional permitting and monitoring costs ($3,000-$5,000).

Flumioxazin is a contact herbicide recently registered for use in Massachusetts and its use carries several restrictions which may limit its use potential. Until flumioxazin is more widely used in the

State and more data are collected it is unlikely that these restrictions will change. Its use would likely be reserved for small spot-treatments within the waterbody. It provides quick and effective control of target plant species. Like diquat, treatments must be planned to ensure oxygen depletion does not occur. Even though it has not shown systemic activity, one or more years of reasonable control have been observed at other similar lakes in New England. Flumioxazin is extremely fast-acting and has a very short half-life, so it is perfect for spot/site specific treatments. The cost of flumioxazin is slightly more expensive (about $50 more per acre) than diquat.

Fluridone is a systemic herbicide. Lethal effects take much longer (30-90 days) than diquat since the plants must uptake the chemical through its shoots and roots. It is best used on young rapidly growing plants. It is often used in whole lake treatments since the target concentration must be maintained for six to nine weeks. Since it is slower acting, the oxygen depletion commonly associated with contact herbicides is not as concerning. It is not atypical for it to take two seasons to achieve control. Fluridone can be somewhat selective at low dosages, but it is unclear if low-dose applications would be successful for both fanwort and milfoil control. Fluridone is more expensive than diquat and flumioxazin, with an estimated cost range of $500-$1,000/acre plus permitting and monitoring ($3,000-$5,000). This doesn't include any bump treatments necessary to maintain target concentrations. However, fluridone is very effective and biomass is often reduced for more than one growing season.

Herbicides will not eradicate these aggressive non-native species, they will only temporarily reduce biomass, some longer than others. Annual monitoring and retreatments will likely be required. Herbicides could be used initially to knock down the density to make suction harvesting and/or hand harvesting more efficacious and less expensive.

Dredging

While dredging is the most effective way to rehabilitate lakes and reduce plant biomass as it physically removes the plant and the underlying substrate, it is permit intensive and extremely expensive. The sediment volume in Forest Lake is substantial. The Cullinan Report estimated that dry dredging 350,000 cubic yards with local upland disposal would cost $2.1 million in the early 1980's. Assuming similar sediment quality, quantity and disposal location, the price in today's dollars would be about $7 million. A dredging feasibility study would be required to test sediments to determine disposal locations, acquire permits and optimize the volume of material to remove.

PHOSPHORUS LOADING

While Forest Lake is not currently listed as impaired on the 2022 Massachusetts 303(d) Integrated List Waters for nutrients (e.g., phosphorus), excessive loading is a threat to the lake. Reducing the current loading is expected to protect the lake from declining conditions, and perhaps even improve the current condition. Annual phosphorus loading was estimated using the Lake Loading Response Model (LLRM). LLRM is a Microsoft Excel-based model that uses scientific literature derived nutrient export coefficients together with watershed land use/landcover data to generate groundwater and surface flow nutrient loading. The model also allows for calculation of atmospheric inputs, septic systems, internal loading and point sources, if known. Using the estimated loading values, together with morphometric characteristics of the lake and accepted limnological empirical equations, the model predicts in-lake TP concentrations, chlorophyll concentrations, SDT, and algal bloom probability. Once the model is calibrated based on data collected in the field (in this case, data are limited to two sampling events), the model can be used to predict in-lake response to best management practices, such as infiltration, phosphorus inactivation and treatment ponds.

The watershed was subdivided into four basins based on topography and observed drainage during precipitation events (Figure 10). The Northeast subbasin primarily drains River Street. The East subbasin drains areas to the east of the lake and includes a small unnamed intermittent tributary. The Unnamed Tributary subbasin drains the largest portion of the watershed and includes Thompson Lake and the Roger Reed Fish Hatchery. The Northwest subbasin is mostly direct drainage with no observable tributaries. This basin includes drainage from Forest Lake Road, the dirt road and the highest density of septic systems within 10 feet of the lake.

Eighty-eight percent of the phosphorus loading to the lake comes from the main Unnamed Tributary. This is not surprising given its size in comparison to the other subbasins. While the contribution from the Northeast subbasin is small (smallest area of all delineated basin), this basin consists primarily of water runoff from River Street which contains the highest concentrations of phosphorus (see Boat Ramp results in Table 3).

The Town performed a survey of the septic systems surrounding the lake. The survey was voluntary information gathering from the homeowners. Of the 24 systems identified, half of them were located between 100 and 300 feet from the lake. Thirty three percent were within 100 feet of the lake. Septic system loading was based on average 2.5 people per house and a loading rate of 0.5 kg/person/year. The loading was attenuated based on the estimated distance from the lake, assuming that the systems are fully functional, although the survey revealed several non-code compliant systems, and several systems hadn't been serviced in more than 10 years. Given this information, the septic system loading estimate may be underestimated.

This loading estimate is based on limited data. The model was calibrated using data collected in 2020 & 2021 (four rounds of sampling) and consulting the Cullinan Report. Given that the Unnamed Tributary subbasin is the largest phosphorus contribution to the lake, this basin should be further subdivided and sampled during dry and wet weather conditions to increase precision in this loading estimate. Further, inputs specifically from the Roger Reed Fish Hatchery should be investigated. The nutrient export from fish hatcheries can be excessive even when the volume of discharge is less than the NPDES permit requirement. Water leaving the hatchery is likely to contain high ammonia, biological oxygen demand, nitrogen and phosphorus. This input could be quantified and potentially mitigated with minimal effort.

LLRM predicts that Forest Lake's average TP concentrations would range between 29 and 42 microgram per liter (µg/L) annually with an average of 35 µg/L (0.035 mg/L). Measured concentrations in 2020 averaged 31 µg/L, and represents a close agreement between measured concentration and predicted average TP. SDT was predicted to average five feet with predicted maximum of 11.8 ft. Measured SDT was 10.4 and 12.9 ft. Algal blooms haven't been a concern, but the TP concentrations are high enough to support frequent blooms. Based on the empirical response equations, a bloom occurrence has about a 43% chance of occurring. It could be possible that the lake flushes more frequently than expected or there is a healthy population of zooplankton that is reducing algal biomass through grazing, preventing blooms.

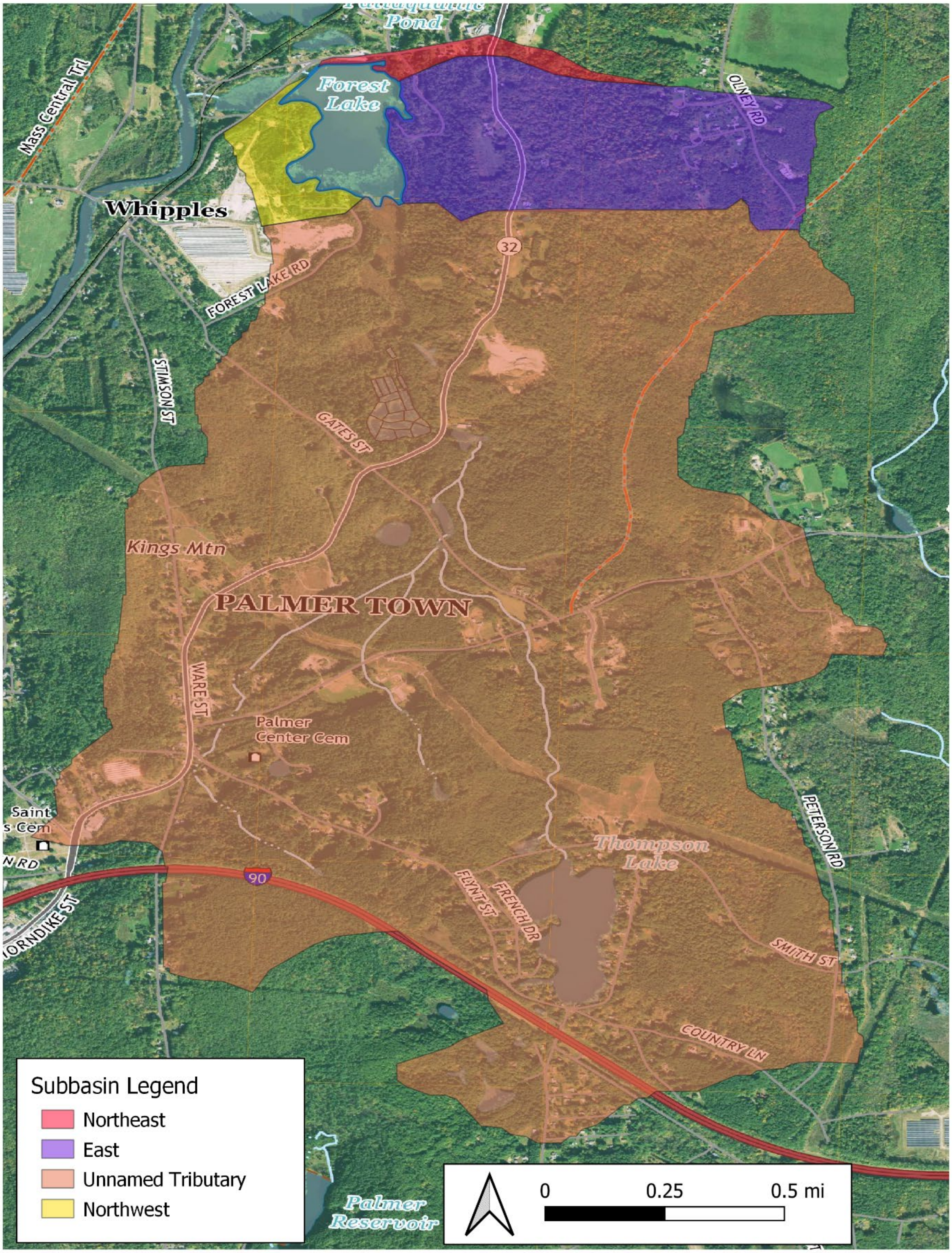
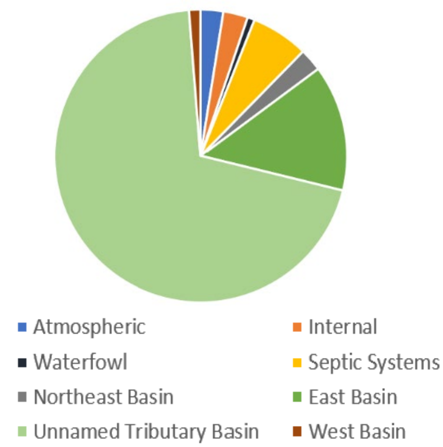


Figure 10. Forest Lake Watershed Subbasins

Table 6. Annual Total Phosphorus Loading

Loading	TP (kg/yr)	% Total
Atmospheric	6.4	3%
Internal	6.9	3%
Waterfowl	2.0	1%
Septic Systems	16.1	6%
Watershed		
Northeast Basin	6.4	3%
East Basin	35.6	14%
Unnamed Tributary Basin	178.1	70%
West Basin	3.2	1%
Total Watershed	**223.4**	**88%**
Total Load to the Lake	**254.8**	



Load Reduction Goal

By changing all development land use/landcover in the model to forested lands, the model can predict what the lake conditions would be like absent human occupation. The LLRM predicts annual TP loading of 97 kg/yr, with an estimated in-lake TP concentration of 12.6 µg/L (0.0126 mg/L). Average chlorophyll concentration is predicted at 4.2 µg/L and a SDT maximum value of 15.7 feet. The probability of algal blooms is reduced to <2% of the year. While this condition is no longer achievable, there are best management practices that the Town and residents can implement to improve and protect the lake against eutrophication going forward.

Using a target TP threshold of 0.025 mg/L, EPA's "Gold Book" standard, a reduction of 77 kg/yr is needed (30% reduction of existing loading estimate). This is an achievable target. This would be achieved through implementation of BMPs such as infiltration, source controls, street sweeping, dirt road maintenance, education and outreach encouraging behavior modifications of homeowners to implement measures such as rain gardens, phosphorus-free lawn maintenance, creation of shoreland buffers, and routine septic system maintenance. Most of the reduction (Table 7), by percentage, is expected from the Northeast basin through infiltration (described in the next report section) and dispersed BMP throughout the Unnamed Tributary watershed. Additional investigation of this subbasin is required, with emphasis on the potential Hatchery and Thompson Lake phosphorus loading and potential removal opportunities.

A more protective lake concentration of 0.020 mg/L would require a 110 kg/yr reduction, or 43%; more difficult to achieve but still possible. Load reductions are achieved by implementing the measures described above to a more aggressive level while adding internal load reductions through phosphorus inactivation or sediment removal.

Table 7. LLRM Existing and Predicted TP Load

	Existing Conditions	Pre development Conditions	Target 25 µg/L TP	% Target Reduction	Protective Target 20 µg/L	% Target Reduction
Watershed load	223.3	91.4	150.2	33%	119.9	46%
Northeast	6.4	0.6	1.3	80%	1.3	80%
East	35.6	8.6	32.0	10%	32.0	10%
Unnamed Tributary	178.1	81	114.0	36%	83.7	53%
West	3.2	1.2	2.9	10%	2.9	10%
Atmospheric	6.4	3.6	6.4	0%	6.4	0%
Internal load*	6.9	0	6.9	0%	3.5	50%
Waterfowl	2	2	2.0	0%	2.0	0%
Septic	16.1	0	12.9	20%	12.9	20%
Total Load	**254.7**	**97**	**178.4**	**30%**	**144.6**	**43%**
Predicted In-Lake TP µg/L	35.4	12.9	25.0		20.0	

*Literature values used; need to measure sediment phosphorus and anoxia duration to obtain site specific estimates

MANAGEMENT MEASURES FOR LOAD REDUCTIONS

The recommended measures discussed in this section are based on site visits performed by ARC and the Town. This does not include all possible management opportunities in the watershed, but rather focuses on the achievable near-term improvements and retrofits to capture and attenuate phosphorus. While we focus here specifically on phosphorus, these measures also attenuate solids and nitrogen.

Structural Stormwater Management Measures

Photo 1. Example of roadside ditch where vegetation would provide additional pollutant attenuation.

There are number stormwater management measure opportunities throughout the watershed. Since this effort was a limited scope, the Town should continue to look for opportunities in the watershed. Thompson Lake watershed is a good place to start. The Roger Reed Fish Hatchery area is another high priority area for investigation, followed by high-density development and roadways. General Best Management Practices (BMPs) that could be applied include, creation of detention ponds, infiltration basins, porous pavement, catch basin inserts, vegetated swales and ditches. Ensuring that all new development implements Green Infrastructure and Low Impact Development (LID) practices to encourage water table recharge, minimization of impervious surfaces, improving pollutant mitigation, and controlling runoff are high priorities. Keeping tree lined roadways are also important, not only to control erosion but the shade keep roadways and soil temperature down. Table 8 provides a summary of measured nutrient, total suspended solids and bacteria removal efficiencies for the most frequently used watershed BMPs. Data presented in this table are derived from the National Pollutant Removal Performance Data Base Version 3 (September 2007) prepared by the Center for Watershed Protection (http://www.cwp.org/). The selection of BMPs must be based on removal capabilities, feasibility of construction, implementation costs, and responsibility of long-term operation and maintenance (O&M). Specific recommendations for locations identified during field visits are discussed below, but need further evaluation (e.g., design, permitting).

Table 8. Watershed BMP Percent Removal Efficiency[9]

Pollutant	Statistic	Infiltration	Wet Pond	Wetlands	Filtering	Open Channel	Bio-retention	Dry Pond
TP	Median	65	52	48	59	24	5	20
	Minimum	0	12	-55	-79	-100	-100	0
	Maximum	100	91	100	88	99	65	48
	75th Percentile	96	76	76	66	46	30	25
	n	8	45	37	17	16	10	10
TN	Median	42	31	24	32	56	46	24
	Minimum	0	-12	-49	17	8	-2	-19
	Maximum	85	76	76	71	99	61	43
	75th Percentile	65	41	55	47	76	55	31
	n	7	22	24	9	9	8	7
TSS	Median	89	80	72	86	81	59	49
	Minimum	0	-33	-100	8	18	-100	-1
	Maximum	97	99	100	98	99	98	90
	75th Percentile	96	88	86	92	87	74	71
	n	4	44	37	18	17	4	10
Bacteria	Median	NA	70	78	37	-25	NA	88
	Minimum	NA	-6	55	-85	-100	NA	78
	Maximum	NA	99	97	83	-25	NA	97
	75th Percentile	NA	94	88	70	-25	NA	92
	n	0	11	3	6	3	0	2

NA = no data available
75th Percentile - design target removal
n = number of studies analyzed

[9] Fraley-McNeal, L., Schueler, T., Winer, R. 2007. National Pollutant Removal Performance Database- Version 3. Center for Watershed Protection, Ellicott City, MD. Pages 1-10

Capture and Infiltrate River Street Runoff

During rain events, significant sheet flow, with substantial velocity enters Forest Lake at the former boat launch location. This creates erosion, carrying excessive concentrations of TP, nitrogen, solids and bacteria. There is an opportunity to redirect this sheet flow and capture it in the newly constructed bioretention basin constructed by DFG. This basin was designed and constructed as part of the new state owned and operated public boat lunch. The location of the former launch was adjacent to the swimming beach and the new launch isn't much further away, less than 250 feet. As mentioned in the Water Quality section, stormwater from this drainage area contained excessive TP (average 0.129 mg/L), high suspended soilds (average 22 mg/L), turbidity (127 NTU) and excessive bacteria (total coliform >2420 mpn/100 mL and average E. coli 607 mpn/100 mL). Rerouting this runoff into the bioretention basin would essentially be significant reduction in pollutants by trapping and infiltrating the water. The capture of the high velocity water flowing down River Street would also reduce erosion at the beach.

Photo 2. Sheet flow runoff from River Street along the former boat launch into Forest Lake

The bioretention basis appears to be large enough to capture a majority of the first flush (generally the worst water quality during a storm event), however this would need to be reviewed by the design engineers. Two options exist to redirect the water. The first is creation of a vegetated drainage swale along the southern side of River Street to direct flow into the retention basin (Figure 11). A culvert may be required underneath the ramp access road before discharging into the basin. The second method could rely on catch basins along River Street and piping the water to the retention basin. The catch basins used should maximize settling, infiltration and filtration if possible. The basin could be retrofitted with an elevated outflow pipe directing water into Lily Pond if water accumulates in the basin faster than infiltrated.

This redirection of sheet flow off River Street to the existing bioretention basin and routing overflow to Lily Pond has the potential to reduce the existing TP load by 6.4 kilograms per year (kg/yr) if all sheet flow was captured and infiltrated in the bioretention basin. Realistically, not all stormwater would be captured, so 80% or about 5 kg/yr reduction could be expected. This would also greatly reduce the bacteria entering the lake right next to the swimming beach. The capital cost to implement is estimated at $15,000 if implemented under Town labor verses a contractor. The Town would be responsible for O&M of the swale along River Street but the State may be willing to assume O&M of the retention basin.

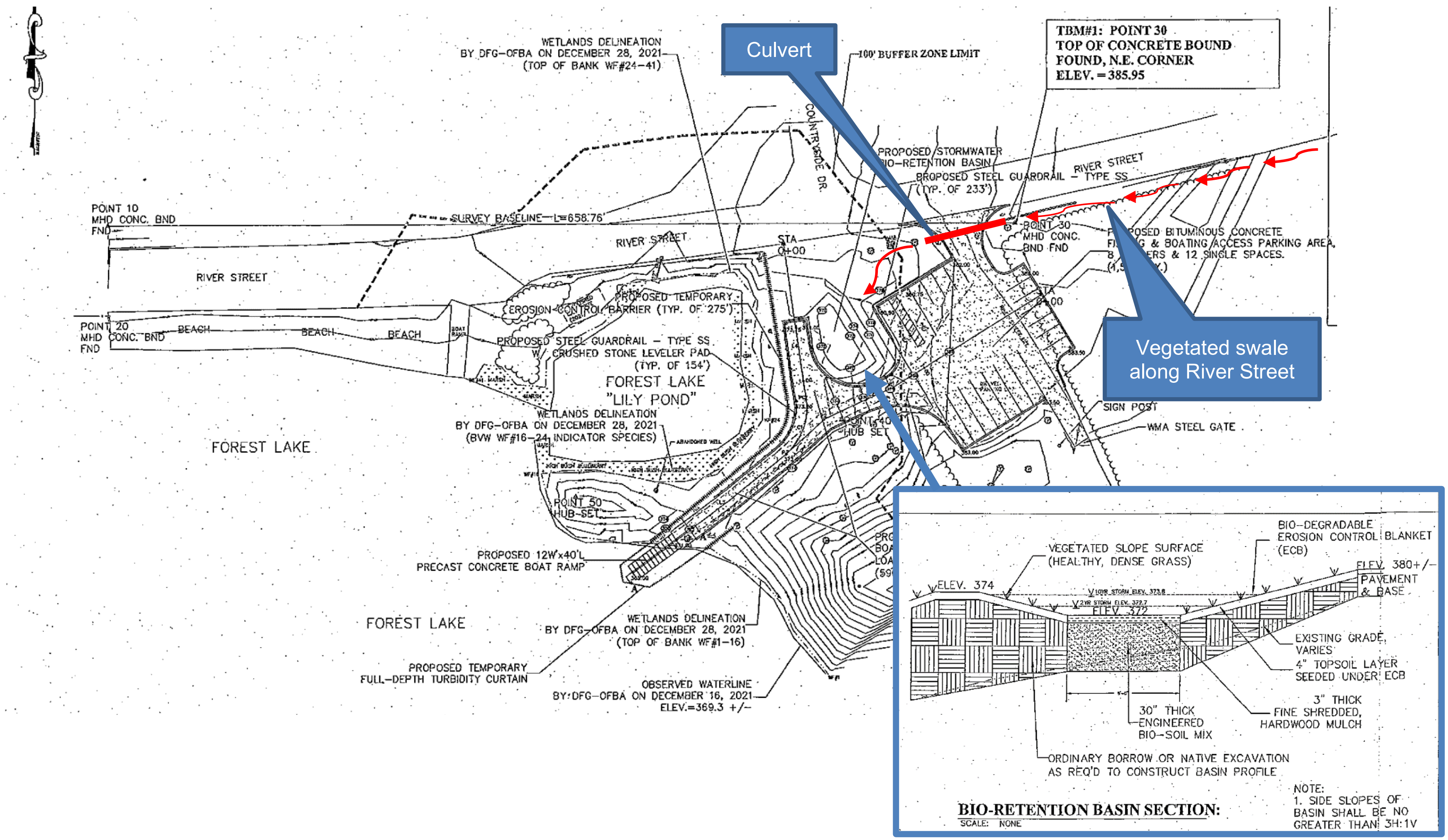


Figure 11. DFG Bioretention and Boat Ramp Design with Sheet Flow Capture and Redirection Measures

Redirect River Street Runoff Downstream of Forest Lake

Another location of River Street runoff to Forest Lake that is a potential risk is about 340 feet to the west where road runoff cuts through a small depression draining the lake (Figure 12). While the volume of this runoff is likely less than that flowing down the slope to the east, this runoff is problematic given its proximity to the beach (exposure to swimmers) and the velocity which can erode the bank and potentially cause road stability issues at River Street. There is very little space to work with between River Street and the bank of the lake, so infiltration and treatment options are limited. A catch basin (or trench drain) may fit in this location and piped to the pond, a small cutoff portion of Forest Lake between River Street and Bennett Street to the northwest. The lake already drains into the pond prior to discharging to the Ware River to the west so there isn't an increased pollutant risk to receiving water. This measure will likely be expensive and therefore less of a priority, unless work to River Street is proposed in the future (repaving, grading, etc.).

Photo 3. Sheet flow from River Street discharging to Forest Lake west of the beach

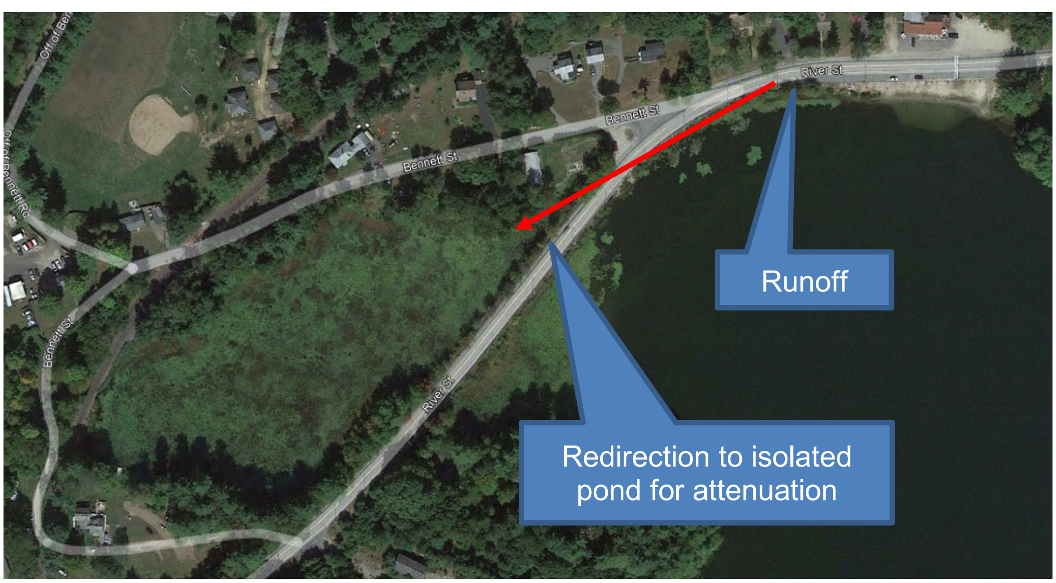


Figure 12. River Street Flow Redirection

Forest Lake Road Runoff

Forest Lake Road is a private dirt road allowing access to homes built along the southwestern portion of the lake. This road is steep in areas and there is no defined stormwater management. When the road is maintained or regraded, material is pushed to the side creating berms limiting water dissipation causing runnels within the roadway. The road could be redesigned to minimize runoff and maximize capture, infiltration and treatment. Runoff from the road contained high phosphorus (average 0.112 mg/L), excessive suspended solids and turbidity (average 143 mg/L and 1733 NTU, respectively) and extremely high bacteria (average total coliform >2420 MPN/mL and *E. coli* 8700 MPN/100 mL. Water runoff drains through a wooded area into the lake or directly to the unnamed tributary. There is very little infiltration and much of the water volume enters untreated.

Photo 4. Sheet flow from Forest Lake Road
Left photo: along road no defined stormwater ditch. Right photo: untreated sheet flow through wooded area discharging directly into Forest Lake or unnamed tributary.

The road should be designed, constructed and managed to minimize impacts to the environment with roadside ditches capable of handing the water volume generated during storm events. Some options include:

- reconstruction of road sections with permeable fills,
- reshaping of the road surface (crowned, insloped, outsloped and raising where necessary) to work with the existing topography,
- create grade beaks preventing water from flowing continuously uninterrupted gaining velocity and worsening erosion,
- create roadside ditches that are designed to infiltrate and disperse the flow rather than concentrating it. Vegetate ditches whenever possible. Ditches should not drain directly to the lake or tributary, rather an infiltration basin or trench should be constructed to hold the water and allow for infiltration.
- Broad based dips to carry water across the road to areas that can be designed to infiltrate water.
- Removing unnecessary berms or false shoulders. These exist in many areas along the road where road material is pushed aside during grading activities and general road use.
- Develop a road maintenance assessment, monitoring and maintenance plan to evaluate conditions to ensure the road is not generating and delivering pollutants to the lake.

The improvement of stormwater management and general maintenance practices of this dirt road has the potential to significantly reduce TP and solids loading to the Lake and unnamed tributary, but the predicted load is difficult to quantify since the loading only occurs during precipitation events. Assuming 10% of the load from the unnamed tributary subbasin is attributable to this area, the annual load expected is about 18 kg/yr. Infiltrating 50% of the stormwater would reduce the load to 9 kg/yr. The capital cost to implement is variable depending on which specific measures are combined (e.g., road reconstruction, infiltration basin(s) and trenches). Minor adjustments could be as little as $15,000 or upwards of $75,000 for regrading and resurfacing sections of the road. It is understood that land ownership is a constraint, but the Town should work to educate the homeowners on the importance of maintaining the road to minimize impacts to Forest Lake. The lack of proper stormwater controls impacts the value of their waterfront property and enjoyment of the lake. Perhaps there are grants or other services in which the Town can partner to implement change.

The United States Department of Agriculture, Forest Service developed a useful manual to help manage unpaved roads. The document, Environmentally Sensitive Road Maintenance Practices for Dirt and Gravel Roads, can be found at the following link:
https://dirtandgravel.psu.edu/wp-content/uploads/ESM_Field_Guide.pdf

Homeowner Pollutant Management

Pollutant reduction is not just a Town obligation, every homeowner has a responsibility to ensure water leaving their property does not adversely affect other properties or our natural resources. The load reductions required to improve and protect Forest Lake and surrounding habitat cannot be accomplished without individual landowner stewardship. Shoreland property owners are in a unique position where their property can provide some of the most critical features to reduce the impact of nutrients, sediments, moderate soil and water temperatures, and maintain habitat to support native wildlife.

Some strategies implementable by individual homeowners include:

- For shoreland or wetland abutting properties, create and maintain substantial buffers along the shoreline (25 feet or greater depending on slope). This provides habitat, infiltration of stormwater and attenuation of pollutants. Encourage old growth trees and overhanging vegetation at the shoreline. This also makes properties less attractive to geese and other waterfowl that contribute TP and bacteria to the lake.
- Capture and infiltrate water around your home using rain gardens, dry wells, impervious pavers, and other techniques. A flow chart showing which techniques could apply to specific situations is provided in Figure 13.

Photo 5. Shoreland Property with Stormwater Management Opportunities

- Store, intercept and/or divert stormwater to places where pollutants can be reduced. Some examples include vegetated swales, rain barrels and water bars.
- Inspect and pump septic systems regularly. Do not use additives, do not flush bulky items and do not pour toxic materials down your drain. Substitute baking soda and borax for cleaners containing chlorine.
- Ensuring lawn care companies are using non-phosphate fertilizers and minimizing use of pesticides.

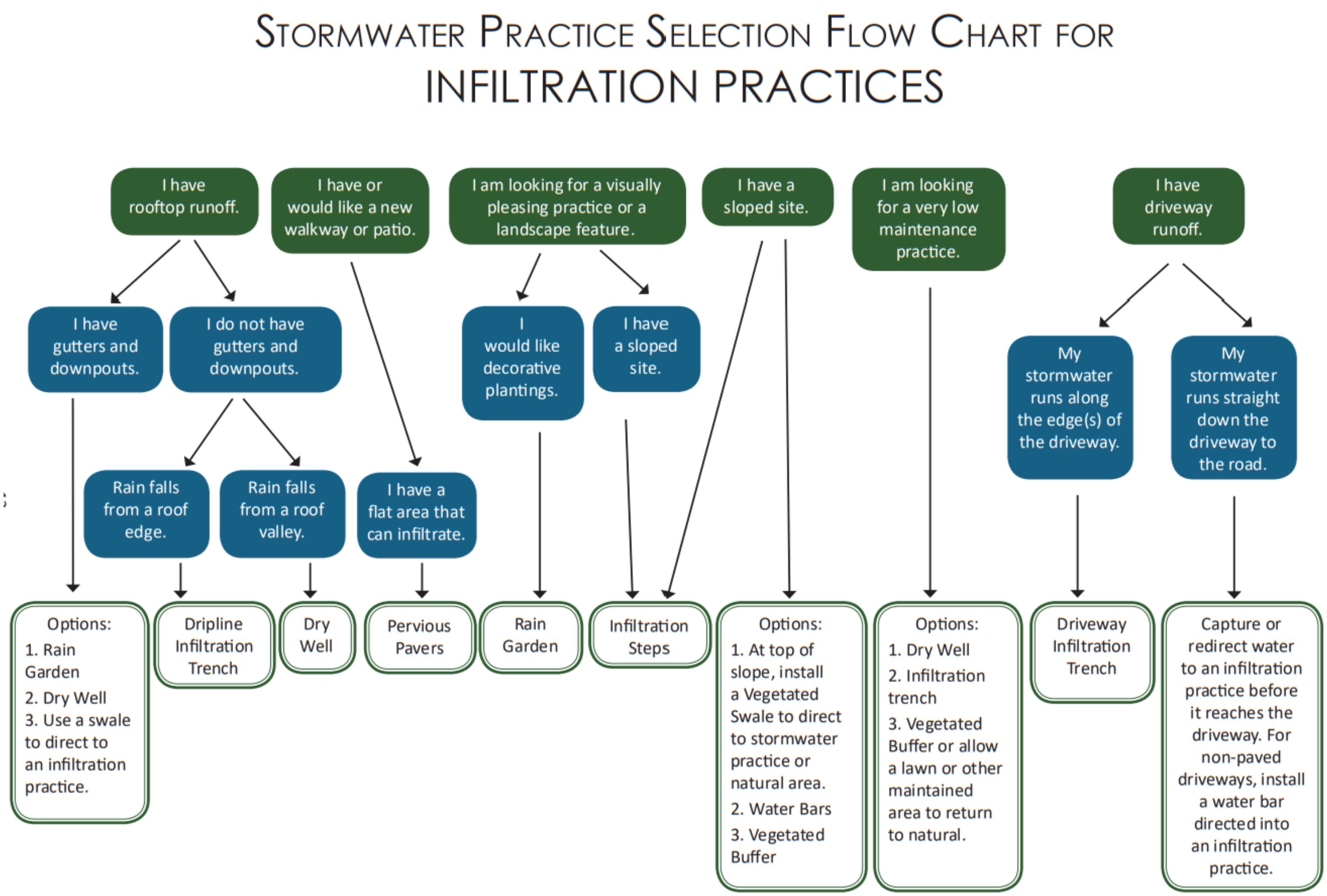


Figure 13. Flow Chart for Infiltration Options on Private Residents[10]

[10] Source New Hampshire Homeowner's Guide to Stormwater Management Nov. 2019. Available at: https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/homeowner-guide-stormwater.pdf

Education and Outreach

Watershed outreach campaigns are intended to increase resident's understanding of activities in the watershed that have the potential to harm the lake. They are also used to inform people on steps they can take to improve conditions and prevent impacts. Activities could include:

- Establishing a webpage specifically for Forest Lake Protection
- Invite speakers to present topics via webinars or in person events (e.g., invasive species, responsible lake front living, controlling stormwater, septic system maintenance, etc.)
- Produce handouts and flyers to include with tax bill or other Town-wide mailings
- Establish a Lake Association, possibly covering both Forest Lake and Thompson Lake
- Request that the DFG post educational materials on their kiosk at the boat ramp. Insist that they place signage to educated boaters on the importance of preventing transport of plants and fauna to and/or from other lakes.

Zoning and Land Use Protection Regulations

A large amount of land in the watershed is owned by the State and is in forested, undeveloped condition. It is important to preserve this space as any development will increase the nutrient loading the lake, even low impact development will have some affect. If these properties come up for sale, the Town should consider purchasing the property to reduce the risk of the land being developed and generating pollutants. Also, putting lands under conservation easements is a recommended protective measure. A strong relationship exists between land use type and pollutant generation, with developed impervious lands being the most destructive. Preserving undeveloped lands is the highest priority to ensure long-term protection and resilience against climate changes.

The Town should review their existing zoning and by-laws and determine if there are stronger ordinances that could be added or if existing policies can be more aggressively enforced. Appropriate Town-wide ordinances could include tree or vegetation cutting limitations, requirements to establish buffer zones, increase set back requirements, septic system ordinances for maintenance and inspections. Vermont's Shoreland Protection Act is a very good example[11].

Municipal Good Housekeeping

Municipal good housekeeping practices include a variety of activities that help reduce nutrient and solids entering waterbodies. These include routine practices such as street sweeping, catch basin cleaning, proper collection and removal of litter, avoid plowing snow into drainage areas and wetlands, maintenance of inlet/outlet structures and minimizing fertilizers and pesticide use on park and landscaped areas. Ensure that all landscape vendors do not apply phosphorus to landscaped and lawn areas. The Town could offer leaf litter pick up for residents, if not already offered, to ensure they do not blow leaf and landscape waste into the lake, wetlands or tributaries.

MONITORING

The purpose of monitoring is to assess existing conditions and evaluate data over time for early detection of changes or trends. Monitoring data are necessary to identify specific problems and develop mitigation measures. Having a baseline assessment also allows for measurement of success associated with implemented management measures. The Town should establish a monitoring program to understand the health of the system, detect problems and measure success of management. Several options for in-lake monitoring are shown in Table 9.

[11] https://dec.vermont.gov/sites/dec/files/wsm/lakes/docs/Shoreland/lp_ShorelandHandbook.pdf

Table 9. Suggested In-Lake Monitoring Programs

In-Lake Monitoring Program	Minimum	Good	Better	Best
Secchi Depth	1x per year - Mid-Late Aug	3x per year - Jun, Jul & Aug	4x per year - Apr, May, Jun, Jul & Aug	5x per year - Apr, May, Jun, Jul, Aug & Sep
Vertical Profile				
Temperature				
Dissolved Oxygen (DO)				
pH				
Conductivity				
Turbidity				
Analytical Chemistry				
Total Phoshorus (TP)				
Total Nitrogen (TN)				
Dissolved (DP) or Orthophosphorus (OP				
- Optional in priority order				
Total Suspended Solids (TSS)				
Total Kjeldahl Nitrogen (TKN)				
Nitrite-N+Nitrate-N (NO_2+NO_3-N)				
Ammonium-N* (NH_4-N)				
Other		2x per year - Jul & Aug	3x per year - Jun, Jul & Aug	4x per year - Jun, Jul, Aug & Sep
Chlorophyll-*a*				
Phytoplankton				
Zooplankton				
Biological Surveys	1x every 5 years - Late Aug	1x every other year - Late Aug	1x every year - Late Aug	1x every year - Late Aug
Macrophytes (plants)				
- Optional in priority order				
Macroinvertebrates				
Fish				
Target Surveys	As needed	As needed	As needed	As needed
Beach bacteria monitoring				
ex. Pre-post treatment				
ex. Illicit drainage				

* if analyzing for TKN, $N0_2$+NO_3 & NH_4-N you don't need to analyze for TN
Swimming beach monitoring should occur according to the local Board of Health and MA Dept. of Public Health regulations when applicable
If management measures are implemented, increase the frequency of monitoring to capture before and after data for comparison

In addition to the in-lake monitoring, the Town should develop a plan to assess other areas in the watershed to evaluate management opportunities. The monitoring program should be based on the specific problems and opportunities identified during site visits.

FUNDING, TECHNICAL ASSISTANCE, & IMPLEMENTATION

Assessing conditions and implementing BMPs will require financial and technical assistance. Watershed management is viewed favorably in funding circles, especially if it involves non-point source controls. Some funding sources include:

- Section 319 Non-Point Source Control Program for prevention, control, and abatement of nonpoint source pollution https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality
- Section 604(b) Water Quality Management Planning Program for water quality assessment and management planning https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality

- Stormwater MS4 Municipal Assistance Grant Program to expand municipal efforts to meet MS4 permit requirements https://www.mass.gov/info-details/grants-financial-assistance-watersheds-water-quality
- Culvert Replacement Municipal Assistance Grant Program offers assistance to replace undersized, degraded or poorly placed culverts for ecological improvements https://www.mass.gov/how-to/culvert-replacement-municipal-assistance-grant-program
- Massachusetts Environmental Trust Grants offers funding for protection and conservation projects https://www.mass.gov/met-projects-and-grant-awards
- Surface Transportation Program under the Interstate Transportation Efficiency Act offered for roadway improvements, including environmental enhancements. https://www.mass.gov/service-details/funding-considerations
- US Department of Agriculture Programs such as the Resource Conservation and Development Program and the Wildlife Habitat Incentives Program https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives
- Community Septic Management Program offer financial assistance and incentives to communities and system owners. https://www.mass.gov/info-details/water-resources-grants-financial-assistance#the-community-septic-management-program-

Each of these programs have eligibility criteria and need to be investigated further.

There are multiple sources for technical assistance. These include State Divisions and Departments such as the MassDEP Wetland and Waterways, Department of Conservation and Recreation Lakes and Ponds, Federal partners like Environmental Protection Agency, non-profit organizations like the North American Lake Management Society, Chicopee River Watershed Council and MA Congress of Lake and Pond Associations and numerous private firms offering Certified Lake Managers, Professional Engineers and Landscape Designers to help assist in the process.

The proposed schedule is to ensure steps to advance lake water quality and habitat improvement and protection measures are implemented. The implementation schedule is presented in Table 10.

Table 10. Implementation Schedule

	Year
River Street Redirection to Bioretention Basin	
Design consideration & coordination with DFG	2024
Obtain funding	2025
Construction	2026
Redirecting River Street Runoff to Pond downstream of River Street (to be implemented along with other planned road improvements)	Undetermined
Forest Lake Road - Dirt Road Management	
Educate homeowners on impact	2024
Work with owners on Management & Improvement Plan	2025-2026
Education and Outreach	
Create webpage for Lake & Watershed Education	2024
Periodically post WBP updates and monitoring data	Annually
Create and populate site with educational materials	Annually
Offer webinars and trainings to the community	Annually
Monitoring	See Table 8
Develop Aquatic Plant Management Plan	2025
Adaptive Management	
Establish working group to include municipal employees and community volunteers	2024
Monitor WBP progress	Annually
Re-evaluate and update the plan	Every 3 years

PROGRESS EVALUATION CRITERIA

To determine whether the planned nutrient reductions are achieved, and progress is being made, monitoring of conditions as described above is required. Numerical concentration data such as differences between inlet and outlet TP concentrations are one of the easiest quantifiable measures to calculate reductions and whether target goals are met. These data can be used to update the LLRM and estimate overall annual load reductions. Direct measurement of changes observed at the sample sites also inform progress. For smaller and non-structural efforts, the number and size of volunteer constructed rain gardens and buffers can be used to estimate pollutant reductions based on published literature estimates. In direct measures for non-structural solutions could include the number of catch basins cleaned, miles of streets swept, and number of outreach events.

As these data are collected, the LLRM should be updated, and this plan should be reviewed and revised every three years. Successes, failures, and lessons learned should be documented to track what works well and what led to positive results. Similarly, what did not work well should be documented to avoid expending efforts on measures that were not efficacious. The target load may need adjustment once new data (e.g., measured internal loading, loading associated with Hatchery or Thompson Pond, changes in land use, etc.) are acquired. The intent of this plan is to serve as a working document with adaptive management a necessary part in the overall success of nutrient reduction and protecting the resource well into the future.