MASSACHUSETTS
watershed·based plans

WATERSHED-BASED PLAN

Farm Pond (AU ID# MA72039)

Updated July 30, 2026

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Town of Sherborn, MA

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Prepared For:

MassDEP
Commonwealth of Massachusetts
Department of Environmental Protection

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Executive Summary

Farm Pond has had a long history of excellent water quality. The Town of Sherborn and resident volunteers, through the Farm Pond Advisory Committee (FPAC), have monitored seasonal water clarity and related water quality parameters since 1998. Farm Pond is affectionately called the "Pond," but it is a moderately deep waterbody (58 ft maximum depth) and is primarily an oligotrophic lake with low overall productivity and low aquatic plant biovolume. The Pond is prized for excellent swimming conditions. Motor use is prohibited, and the Pond is often used for open-water swimming, paddling, rowing, fishing, and dinghy sailing. Historically, clarity has been excellent, and no surface water quality issues were reported before 2020.

At that time, however, residents began to notice periodic prominent surface accumulations of cyanobacteria along the shore at the Town beach, the Town boat ramp, and the Sherborn Yacht Club. Scums have also been documented along other shores and even in open water. Residents have also noticed an increase in green filamentous algae clouds in high-use areas, and report a dramatic increase in the bottom cover of Charophyte macroalgae compared to the last decade. These changes, particularly the presence of several dramatic lake wide phytoplankton and cyanobacteria blooms in 2022, alarmed the community.

This Watershed-Based Plan has been produced alongside a comprehensive reassessment of the Farm Pond water quality. Additional monitoring data collected by Applied Watershed Sciences LLC (AWS) in 2023-2025 were synthesized into the 2025 Farm Pond Lake Management Assessment (AWS, 2025). The assessment provides new insights into the complex nature of overall phosphorus loading, nutrient internal recycling, and the impact of climate change and temperature on cyanobacteria blooms at Farm Pond. The 2025 assessment used the MA WBP tool's predictions of land-use watershed nutrient loading, reevaluated the 2015 Lake Loading Response Modeling (LLRM) watershed phosphorus load estimate (FST, 2015), and revised additional estimates of external and internal phosphorus loads based on updated information and more recent water quality data.

Farm Pond has a small watershed-to-lake area ratio (3.2:1) and a low flushing rate (<0.45 water volume flushes per year). For a considerable period of the summer, there is little to no surface water outflow. Thus, in-lake nutrient recycling dynamics generally have a more dramatic impact on cyanobacteria blooms than watershed runoff in an average year. However, external nutrient sources still impact the Pond, even from the small coverage of impervious surface in the watershed. Volunteer-collected runoff samples contained nutrient concentrations many times higher than in-lake surface phosphorus and nitrogen. Any erosion from the watershed will negatively impact water clarity at Farm Pond, as fine silts and clays do not settle out of the water column except under ice cover, threatening the historically excellent water clarity. Farm Pond is vulnerable to even small periodic erosion events in the watershed. Continued community vigilance and oversight by the Sherborn Conservation Commission are critical to preventing future erosion on public and private property, particularly during residential construction projects within the watershed.

While a significant fraction of the Farm Pond watershed nutrient load is from background conditions and cannot be reasonably improved, the watershed soil-based onsite wastewater systems (septic systems and cesspools), the resident Canada geese population, and the small amount of impervious surface runoff will need ongoing attention, inspections, and management to preserve long-term excellent water quality. In-lake phosphorus treatments can enhance sediment's ability to permanently bind phosphorus, thereby improving current water quality and reducing the incidence of cyanobacteria blooms in ways that watershed management alone cannot. Yet, watershed management is essential for the long-term preservation of Farm Pond.

Introduction

What is a Watershed-Based Plan?

Purpose & Need

The purpose of a Massachusetts Watershed-Based Plan (WBP) is to organize information about Massachusetts' watersheds and present the information in a format that will enhance the development and implementation of projects that will restore water quality and beneficial uses in the Commonwealth. The Massachusetts WBP follows the United States Environmental Protection Agency's (EPA's) recommended format for "nine-element" watershed plans.

The primary purpose of this Farm Pond WBP is to address and manage the nutrients that have fueled recent cyanobacteria blooms and to preserve long term water quality. The increased incidence of harmful cyanobacteria blooms (HCBs) has negatively impacted recreation and presents a threat to public health. While some of the identified causes of these blooms are related to climate, nutrients from external sources impact lake oxygen dynamics, affecting phosphorus cycling within the Pond and influencing cyanobacteria blooms. Photos from substantial blooms in 2020 through 2022 are included below.

July 18, 2020 (photo by D. Kingsley)

July 15, 2021 (photos by T. Trainor)

Northern side of Pond   Grab sample, northern side of Pond   Boat Ramp

September 10, 2022 (photos by Sherborn Yacht Club)

All states are required to develop WBPs, but not all states have taken the same approach. Most states develop WBPs only for selected watersheds. Massachusetts Department of Environmental Protection's (MassDEP's) approach has been to develop a tool to support statewide development of WBPs so **that good projects in all areas of the state may be eligible for federal watershed implementation grant funds** under Section 319 of the Clean Water Act.

EPA guidelines promote the use of Section 319 funding for developing and implementing WBPs. WBPs are required for all projects implemented with Section 319 funds and are recommended for all watershed projects, whether they are designed to protect unimpaired waters, restore impaired waters, or both.

Watershed-Based Plan Outline

This WBP includes nine elements (a through i) in accordance with EPA Guidelines:

a) An **identification of the causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this WBP and to achieve any other watershed goals identified in the WBP, as discussed in item (b) immediately below.

b) An **estimate of the load reductions** expected for the management measures described under paragraph (c) below, recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time.

c) A **description of the nonpoint source (NPS) management measures** needed to achieve the load reductions estimated under paragraph (b) above as well as to achieve other watershed goals identified in this WBP and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

d) An **estimate of the amounts of technical and financial assistance needed**, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, United States Department of Agriculture's (USDA's) Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant federal, state, local, and private funds that may be available to assist in implementing this plan.

e) An **information/education component** that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

f) A **schedule for implementing the NPS management measures** identified in this plan that is reasonably expeditious.

g) A description of **interim, measurable milestones** for determining whether NPS management measures or other control actions are being implemented.

h) A set of **criteria to determine if loading reductions are being achieved** over time and substantial progress is being made toward attaining water quality standards and, if not, the criteria for determining whether this WBP needs to be revised or, if a NPS total maximum daily load (TMDL) has been established, whether the TMDL needs to be revised.

i) A **monitoring component** to evaluate the effectiveness of the implementation efforts over time measured against the criteria established under item (h) immediately above.

Project Partners and Stakeholder Input

The Town of Sherborn and the Farm Pond Advisory Committee (FPAC, with volunteer members appointed by the Town Select Board) are the two primary entities responsible for the management of Farm Pond. The Town of Sherborn maintains a public swimming beach and recreation area on the southwest corner of the lake. FPAC represents the interests of residents and local property owners, organizing public communications and advising the Town Select Board on matters regarding Farm Pond and the watershed. FPAC also has an active volunteer water quality monitoring program that contributed data for the assessment of pond status and development of this plan. In developing this plan, three public webinar presentations were held for the community during 2023-2025. The Sherborn residents actively engaged in dialogue and shared observations, questions, and concerns about the management of Farm Pond and its watershed. The Watershed Based Plan (WBP) was presented for public comment, and all comments and proposed changes from residents have been reviewed and incorporated into the final version.

Data Sources

This WBP was developed using the framework and data sources provided by MassDEP's WBP Tool.
The core water quality analysis used to develop sections of the phosphorus control strategies for both in-lake and watershed management was based on water quality monitoring conducted by Applied Watershed Sciences LLC in 2023 and 2024, under a MA-DEP-approved Quality Assurance Project Plan (QAPP).

The following additional data sources were also reviewed and used in creating this plan.

1. FPAC volunteer water quality monitoring raw data, photos, observations, and reports (1998-2025).
2. Farm Pond depth map, A. Seering (2003)
3. Farm Pond Management Plan Report (FST, 2015)
4. Farm Pond Assessment (AWS, 2026)

Summary of Completed Work & Current Conditions

At present, the Town of Sherborn has implemented various nonpoint source pollution control measures to minimize stormwater runoff from Town property and the impact of Canada geese waste on the lake.

The Town of Sherborn has an existing trench drain that captures a large portion of the runoff from the boat ramp zone, funneling water to a series of small containment and infiltration sumps. The Town is also aware of runoff from the footpath and steps that lead from the parking area to the Town beach; seasonal coir logs have been placed in multiple areas that route runoff from these areas into the woods, where infiltration of smaller rain events has been successful. The Town has installed pervious materials to reduce runoff from the stairs and foot path, and has also used erosion control methods along the beach area, minimizing beach sand erosion from the most frequent smaller storms. Larger storms still cause erosion, depending on activities and active construction project timelines, as evidenced by volunteer-collected runoff samples on Town property. The mechanisms currently in place have largely succeeded in minimizing erosion from small to moderate storms. The beach erosion that occurs is a combination of groundwater eruption from the hillside and surface runoff from larger storms. Several photos of existing conditions are provided here.

The Town has ongoing plans for stormwater improvements to the parking lot and boat ramp area.

Temporary erosion control in place on the Town stairs from the parking lot in 2024.

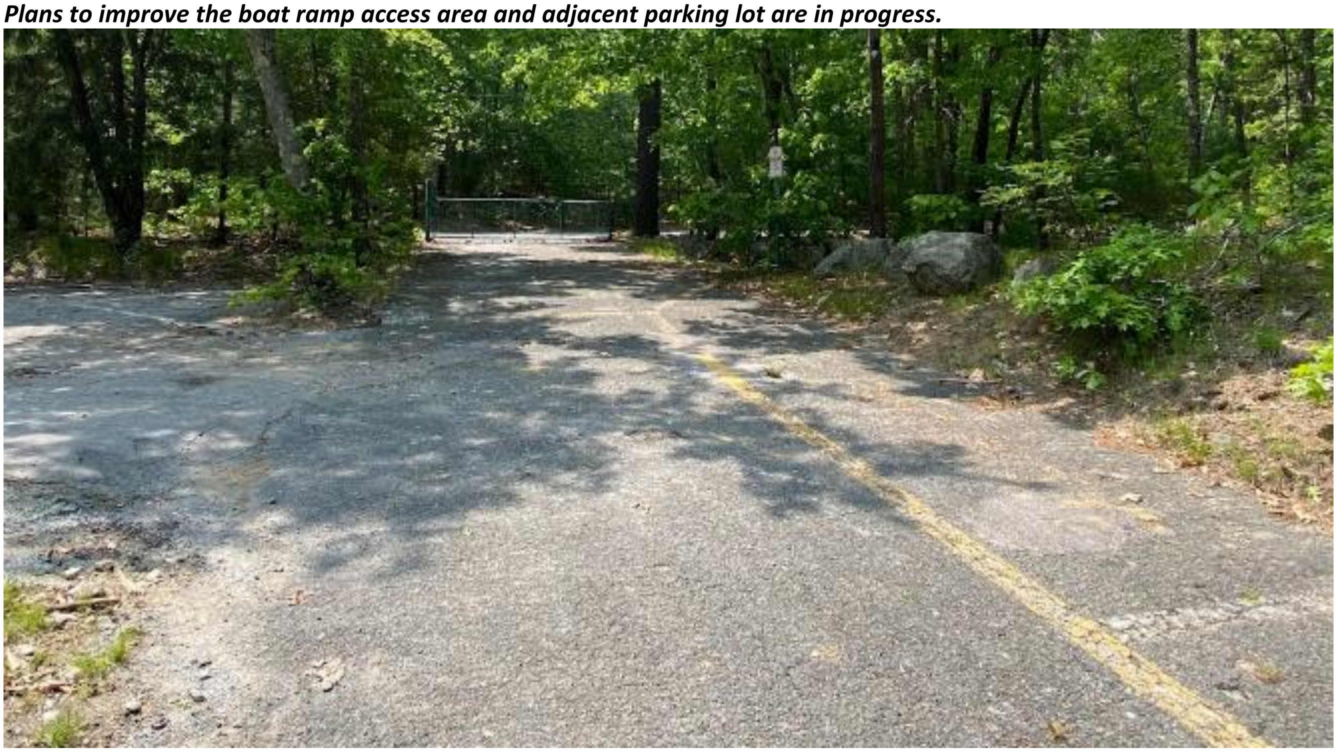
Town-installed pervious stairs to reduce runoff, with additional erosion control and water routing coir logs.

Existing trench drain and repairs to infiltration basin

Corrective actions for Sherborn Yacht Club erosion control during boat-house project in 2023

The Town's foot path from the boat ramp to the beach is sloped slightly away from the lake to minimize direct runoff and erosion. Emergency vehicles only. Naturally vegetated hillside. No major erosion issues present at this time.

Plans to improve the boat ramp access area and adjacent parking lot are in progress.



Geese management activities over various years have involved using dogs, lifeguards, motion-activated sprinklers, and Town police with blank shots to scare away waterfowl from the Town beach and boat ramp areas in the early morning hours. Still, Town officials have reported that geese return to the area if the daily dog-scaring tactics are not sustained. Scare tactics have temporarily removed geese from the Town beach area, but they typically relocate to the other side of the lake or to the central island areas. Geese generally are not present along some of the resident shorelines because local dogs and residents put in consistent effort to scare them away, and there are few locations along the shore where geese can walk up onto the land without encountering a buffer area of dense vegetation. When geese are out on the water, the use of dogs for scaring geese has limited effectiveness.

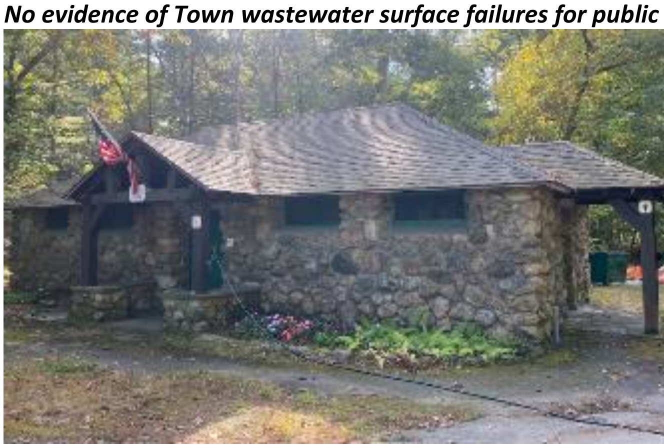
FPAC volunteers have checked for goose eggs in key areas in the past, but not within the past five years. The Town currently employs a dock-netting technique to prevent geese and other waterfowl from resting on the public beach docks overnight or when the beach is closed, but this typically pushes them to rest on boats and paddleboards moored at the nearby Yacht Club. Town lifeguards have also been trained to collect goose poop in buckets and to throw it into the woods, where there is less chance of nutrients harming the lake.

Town Beach with small number of Canada geese present.

Geese poop management is ongoing, but additional methods are needed.

Sherborn Conservation Commission took action to enforce runoff issues from 2023 and 2024 residential construction projects, as they were reported throughout the lake assessment process.

No evidence of Town wastewater surface failures for public restrooms – need updated tank inspection and pumping



Relatively low-sloped boat ramp staging area minimizes erosion by design.
Further improvements anticipated.

Element A: Identify Causes of Impairment & Pollution Sources

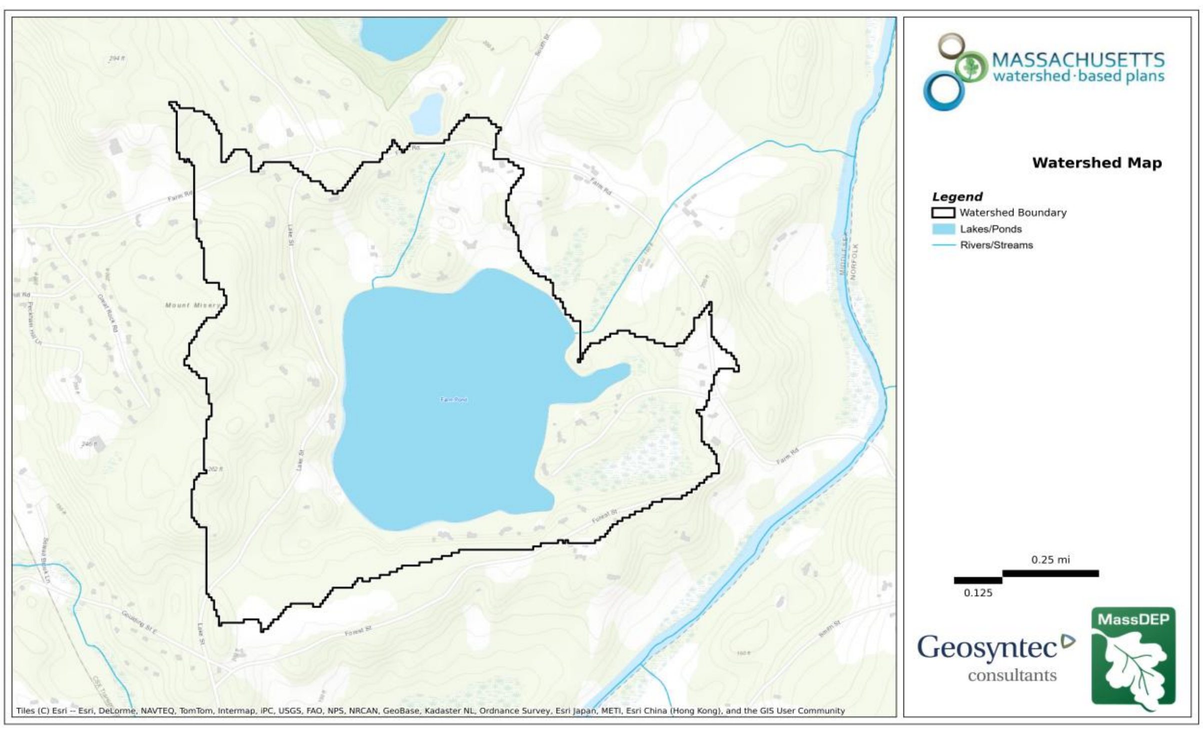
Element A: Identify the causes and sources or groups of similar sources that need to be controlled to achieve the necessary pollutant load reductions estimated in the watershed based plan (WBP).

General Watershed & Waterbody Information

Table A-1: General Watershed Information

Watershed Name (Assessment Unit ID):	Farm Pond (MA72039)
Major Basin:	CHARLES
Watershed Area (within MA):	435.5 (ac)
Water Body Size:	125 (ac)

Map 1 Watershed Boundary (MassGIS, 2007; MassGIS, 1999, MassGIS, 2001; USGS, 2016)



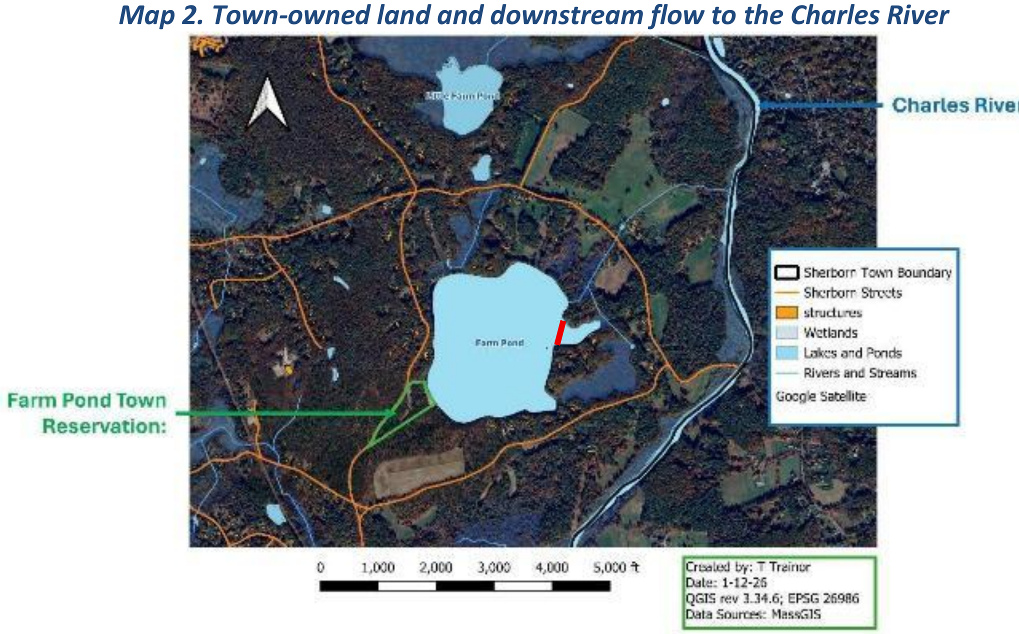
General watershed and waterbody information:

Farm Pond is a kettle lake, formed by retreating glaciers that melted at the end of the last Ice Age. The lake covers an estimated 125 acres and receives drainage from a watershed of approximately 435.5 acres within the larger Charles River basin (MADEP 2013). It has one minor tributary entering the lake from the northwest via wetlands, but the entry is not obvious at the lake shore. Instead, the flow from this minor tributary appears to enter the lake as groundwater. There is a second minor spring tributary northwest of the lake that stems from a privately-owned wetland, but the channelized wetland flow runs dry by summertime. There was some question as to whether the small pond to the north of Farm Pond was in the watershed via an under-road culvert. It may have been at one time, but two separate inspections of this area could not locate remnants of an old under-road connection. If water flows at all, it would be via seepage through the earthen materials on which the road is built.

The lake is surrounded by a largely undeveloped watershed and ample natural forestland. There is an earthen berm outlet, separating Farm Pond from a smaller and more eutrophic pond at the wetland outlet zone (marked in red in Map 2). The majority of the Farm Pond watershed is zoned residential, with 3-acre minimum lot sizes (Town of Sherborn, 2002; FST, 2015). Watershed soils are predominantly Hinckley loamy sand, Merrimack fine sandy loam, and Canton fine sandy loam - well-drained soils with Hydrologic Soil Group rating "A". There are also several wetland areas, but no surface water flows were observed in 2023-2024 at the lake shoreline. Soil maps from the NRCS Web Soil Survey were included in the FST 2015 report.

The Town owns a parcel along the western side of the lake, shown in Map 2. The lakeshore area of that parcel is the Town boat ramp and beach. MA GIS stream data shows flow apparently leaving Farm Pond via a wetland on the northeastern side of the pond, but that stream’s origin may be primarily groundwater or diffuse, unobservable wetland flow, as AWS was unable to locate surface flows at the area marked as a stream on most surface-water maps (Map 2 & 3).

Map 2. Town-owned land and downstream flow to the Charles River



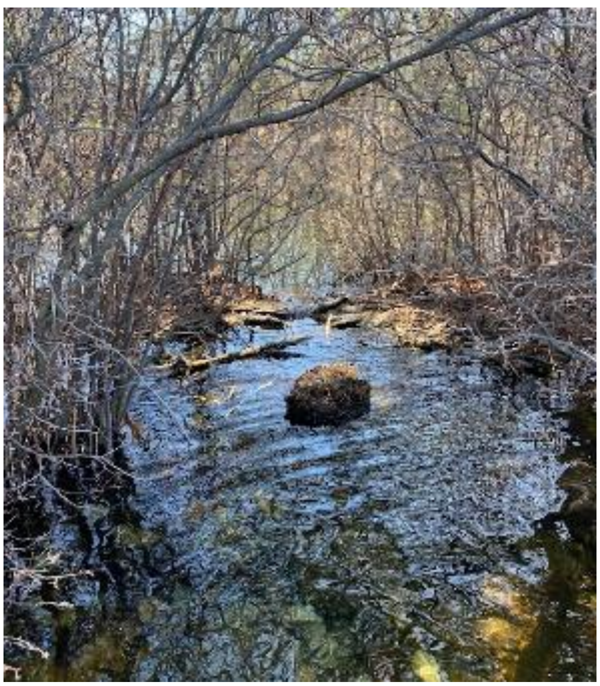
There is a historical outlet channel on the northeastern side of the lake, north of the berm outlet. It is an old irrigation ditch leading to farm fields, at approximately 42.236306, -71.341333. However, AWS did not observe a surface-water outlet at this location in 2023-2024. The FST 2025 report cites unpublished information from the Town of Sherborn's former historian, Betsy Johnson, noting that the historical outlet irrigation channel had been permanently blocked and that the pond water level was roughly 2ft higher than the irrigation ditch. A wetland stream flows northeast, presumably out of Farm Pond as groundwater seepage downstream, feeding the wetland, as viewed on Maps 1-3. This wetland is on private property and was not inspected beyond aerial imagery and LIDAR GIS data. The wetland stream that crosses Farm Road flows primarily from winter through June. That outlet stream flow originates from a combination of three sources: 1. Farm Pond groundwater seepage, 2. Farm Pond lagoon and wetland outflow from the pond east of the berm, 3. a 57-acre area outside the Farm Pond topographic watershed that directly flows to this under-road wetland stream that crosses under Farm Road. Elevation-based water flow paths are estimated via the MA 1m Digital Elevation Model LIDAR data in Map 3. The only known current surface water outlet from Farm Pond is over the berm to the Farm Pond lagoon, and then out of the lagoon indicated by a yellow arrow on the map below.

Map 3. Farm Pond outlet flows (groundwater and surface water)

The 2015 FST report includes a detailed historical account of Farm Pond's past water usage in the 19th century. In summary, a historic pipe structure, once used to withdraw drinking water for the closed Medfield State Hospital, is no longer active. Only the pipe and brick house remain.

The only surface-water outlet is now the earthen berm structure, constructed during past cranberry farming in the late 1800s (FST, 2015). The berm has served to isolate a small section of Farm Pond, creating two distinct water bodies (Farm Pond and the Farm Pond lagoon). Farm Pond overflows the berm at several eroded locations, forming a more nutrient-rich pond and wetland lagoon to the east of the berm. Residents have expressed concern about the current integrity of the berm and back-flow issues from the nutrient-rich wetland lagoon to Farm Pond. Maintaining this low-lying earthen structure is critical to preventing the eutrophic wetland pond from mixing with Farm Pond. The outlet lagoon is considerably more eutrophic than Farm Pond.

Outflow from Farm Pond over a low spot in the berm. Beavers are present.



Location where an outlet ditch was once present, but appears to no longer have surface outflow.

Map 4. Surface water outflow from Farm Pond wetland lagoon (blue star/yellow arrow)

Stream flows north, then northeast to Farm Road crossing.

Outlines of cart path and stream bed slightly visible.

The photos below were taken by T. Trainor at the outlet culvert of the Farm Pond lagoon (blue star in *Map 4*).

Photos from 4-21-24

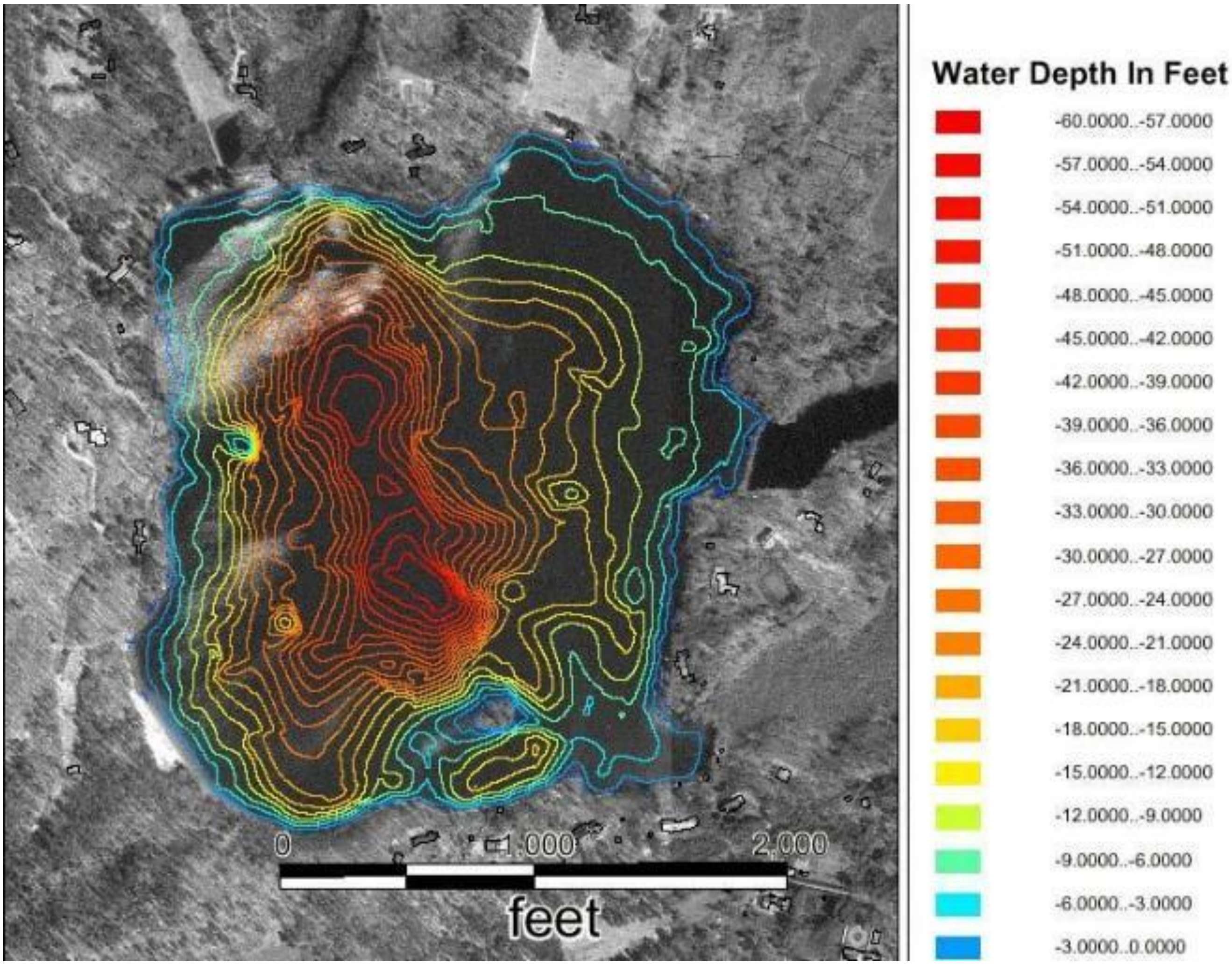
Outlet side of culvert, under cart path. Note piles of debris on both sides of culvert inlet.

View to east, along cart path. Beaver debris close to culvert. Lagoon along right of path.

View north, just downstream of culvert. Stream continues into wetlands area.

The existing Farm Pond bathymetric map and contour areas were obtained from T. Trainor (FPAC) and the FST 2015 report (***Map 5***).

Map 5. Bathymetric Map (A. Seering, 2003)



MassDEP Water Quality Assessment Report and TMDL Review

The following reports are available:

- Charles River Watershed 2002-2006 Water Quality Assessment Report

The section below summarizes the findings of any available Water Quality Assessment Report and/or TMDL that relate to water quality and water quality impairments. Select excerpts from these documents relating to the water quality in the watershed are included below (note: relevant information is included directly from these documents for informational purposes and has not been modified).

Charles River Watershed 2002-2006 Water Quality Assessment Report (MA72039 - Farm Pond)
Aquatic Life Use Water Chemistry Farm Pond was sampled by DWM on 13 September 2005 as part of a nutrient criteria development project for lakes. Monitoring included in-situ water quality profile measurements (i.e., temperature, dissolved oxygen, pH, specific conductance), water quality sampling for phosphorus analysis, chlorophyll a determinations and the analysis of apparent color. These data are not yet available and so the Aquatic Life Use is not assessed. Primary and Secondary Contact Recreational and Aesthetics Uses There is one beach along the shoreline of Farm Pond (Farm Pond Beach). There were no reported exceedances in 2001, 2004 or 2005 while no data were reported for 2002 or 2003. Currently there is uncertainty associated with the accurate reporting of freshwater beach closure information to the MA DPH which is required as part of the Beaches Bill. Therefore, no Primary Contact Recreational Use assessments (either support or impairment) decisions are being made using Beaches Bill data for this waterbody. The Secchi disk depth measured by DWM personnel on 13 September 2005 was 7.7 m. No objectionable conditions (i.e., odors, color, turbidity, algal blooms) were reported and plant cover was sparse (MassDEP 2005b). It is expected that plant cover would be less in mid-September. Although no objectionable conditions were recorded (MassDEP 2005b), because of the lack of bacteria data and enough Secchi disk depth measurements the Primary and Secondary Contact Recreational Uses are not assessed. The Aesthetics Uses is assessed as support. **Report Recommendations:** Support improvement of freshwater Beaches Bill data quality and reporting. Conduct monitoring to evaluate designated uses.

Historical and current Technical Memoranda (TM) produced by the MassDEP Watershed Planning Program are available here: Water Quality Technical Memoranda | Mass.gov and are organized by major watersheds in Massachusetts. Most of these TMs present the water chemistry and biological sampling results of WPP monitoring surveys. The TMs pertaining primarily to biological information (e.g., benthic macroinvertebrates, periphyton, fish populations) contain biological data and metrics that are currently not reported elsewhere. The data contained in the water quality TMs are also provided on the "Data" page (Water Quality Monitoring Program Data | Mass.gov). Many of these TMs have helped inform Clean Water Act 305(b) assessment and 303(d) listing decisions.

Literature review information:

The following additional reports and information are key to understanding existing water quality and watershed conditions, and associated management recommendations included in this report.

1. Development of Farm Pond Management Plan, 2015. Prepared for the Town of Sherborn, MA by Fay, Spofford and Thorndike. https://www.sherbornma.org/DocumentCenter/View/788/Farm-Pond-Management-Plan---November-2015-PDF

2. Farm Pond Advisory Committee historical volunteer water quality annual data reports by Tom Trainor.

3. Farm Pond Information Booklet - https://www.sherbornma.org/DocumentCenter/View/787/Farm-Pond-Information-Booklet-PDF - Review of the pond's history

4. The Farm Pond stormwater improvement project brochure - https://www.sherbornma.org/DocumentCenter/View/789/Farm-Pond-Stormwater-Improvement-Project-PDF

5. Farm Pond Aquatic Plant Study, 2004 Danielle Boyda (student)

6. Farm Pond 2021-2022 Volunteer Water Quality Monitoring Lab Reports

7. Farm Pond Lake Assessment (AWS, 2026)

Water Quality Impairments

The Massachusetts Department of Environmental Protection (MassDEP) 2022 Massachusetts Integrated List of Waters (MassDEP, 2023a) does not include Farm Pond. Impairment categories from the Integrated List are as follows:

Table A-2: 2022 MA Integrated List of Waters Categories

Integrated List Category	Description
1	Unimpaired and not threatened for all designated uses.
2	Unimpaired for some uses and not assessed for others.
3	Insufficient information to make assessments for any uses.
4	Impaired or threatened for one or more uses, but not requiring calculation of a Total Maximum Daily Load (TMDL), including: 4a: TMDL is completed 4b: Impairment controlled by alternative pollution control requirements 4c: Impairment not caused by a pollutant - TMDL not required
5	Impaired or threatened for one or more uses and requiring preparation of a TMDL.

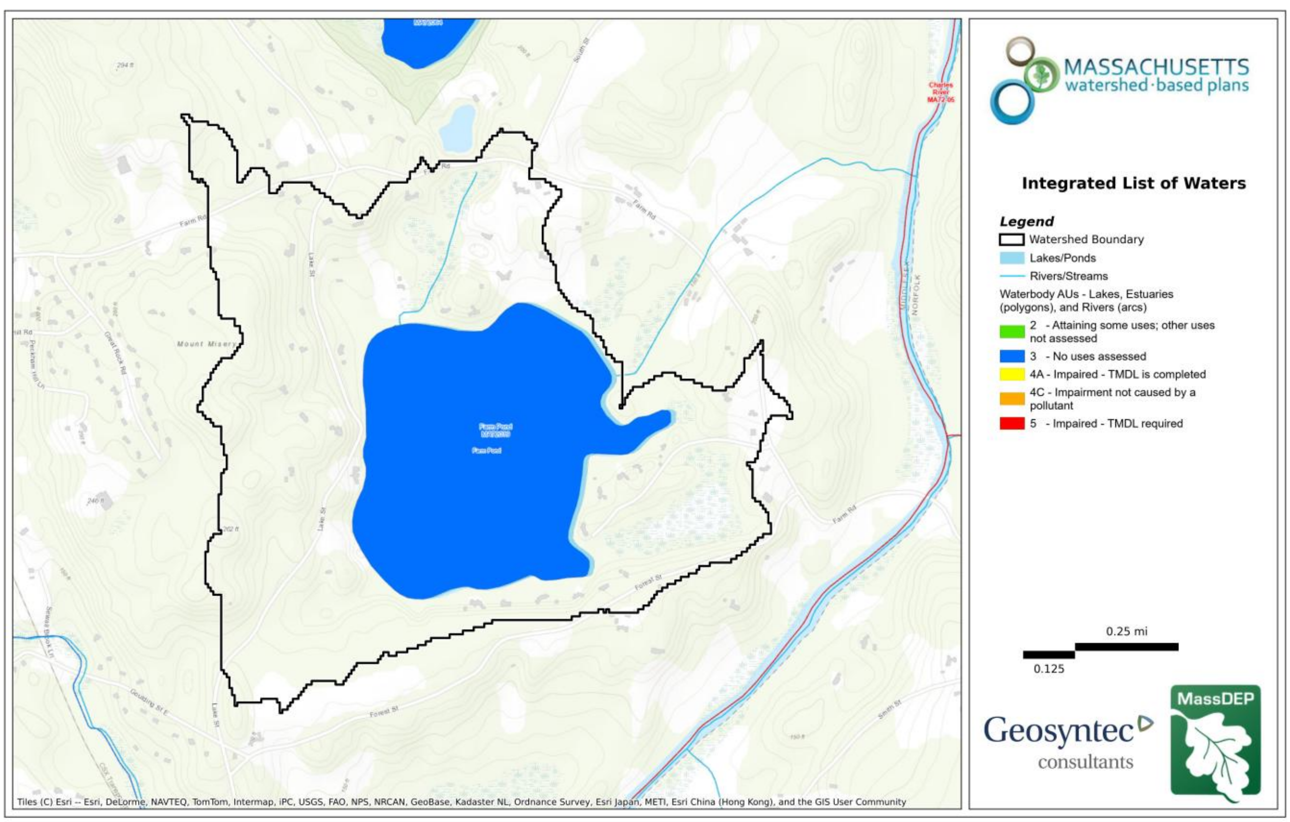
Table A-3: Water Quality Impairments (MassDEP 2023a)

No Impairments found based on MA Surface Water Quality Standards.

The presence of periodic cyanobacteria blooms that do not cover more than small shoreline accumulations is likely not enough to consider Farm Pond an 'Impaired' waterbody based on the MA Water Quality Standards (WQS). If full-lake cyanobacteria blooms become a regular seasonal occurrence, such that they do not comply with the WQS 314 CMR 4.05(5): Additional Minimum Criteria Applicable to all Surface Waters, MA DEP may consider listing Farm Pond as 'Impaired.' At present, there is no numeric nutrient (P or N) criteria for Farm Pond. MA DEP has indicated in prior public comment responses to state Surface Water Quality Standards revisions that the agency may adopt a numeric criterion for Charles River Watershed waterbodies in the future.

Farm Pond is listed as a Class 3 waterbody, as listed in **Table A-3,** identified in **Map 6**. Following the updated 2025 water quality assessment, MA DEP may choose to change the status of Farm Pond to either 2 – Attaining some uses, or to 4C – Impairment not caused by a pollutant (cyanobacteria toxins are not yet considered a pollutant in MA WQS). Nutrients (P and N) are considered pollutants; lakes with major internal P loads and low overall watershed loads from diffuse sources do not lend well to Total Maximum Daily Load (TMDL) calculations. The goal of this WBP is to establish reasonable nutrient reduction targets that prevent 'Impairment.' If MA DEP chooses to list Farm Pond as 'Impaired,' it may also classify the pond as 5 if the agency intends to develop a TMDL for P for Farm Pond or any of the waterbodies in the Charles River Watershed.

Map 6. Watershed Water Quality Impairments Map
(MassGIS, 2007; MassGIS, 1999; MassGIS, 2001; USGS, 2016; MassGIS, 2023)



Water Quality Goals

Water quality goals may be established for a variety of purposes, including the following:

a.) For **water bodies with known impairments**, a Total Maximum Daily Load (TMDL) is established by MassDEP and the United States Environmental Protection Agency (USEPA) as the maximum amount of the target pollutant that the waterbody can receive and still safely meet water quality standards. If the waterbody has a TMDL for total phosphorus (TP) or total nitrogen (TN), or total suspended solids (TSS), that information is provided below and included as a water quality goal. Farm Pond is not a good candidate for a TMDL for nutrients, as watershed nutrient pollution is diffuse and periodic.

b.) For **water bodies without a TMDL for total phosphorus** (TP), a default water quality goal for TP is based on target concentrations established in the Quality Criteria for Water (USEPA, 1986) (also known as the "Gold Book"). The Gold Book states that TP should not exceed 50 ug/L in any stream at the point where it enters any lake or reservoir, nor 25 ug/L within a lake or reservoir. For the purposes of developing WBPs, MassDEP has adopted 50 ug/L as the TP target for all streams at their downstream discharge point, regardless of which type of water body the stream discharges to.

c.) Massachusetts Surface Water Quality Standards (MassDEP 2022) prescribe the minimum water quality criteria required to sustain a waterbody's designated uses. Farm Pond is a Class 'B' waterbody[1]. The water quality goal for fecal coliform bacteria is based on the Massachusetts Surface Water Quality Standards.

Table A-4: Surface Water Quality Classification by Assessment Unit

Assessment Unit ID	Waterbody	Class
MA72039	Farm Pond	B

d.) **Other water quality goals set by the community** (e.g., protection of high-quality waters, in-lake phosphorus concentration goal to reduce recurrence of cyanobacteria blooms, etc.).

[1] Habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated…. they shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses (MA WQS summarized by NEIWPCC; https://neiwpcc.org/our-programs/pollution-control/water-quality-standards/wq-classifications-designated-uses/#:~:text=Class%20C:,fish%20and%20other%20aquatic%20life.) Class A waterbodies are used for public drinking water supply and/or are classified as Outstanding Resource Waters. Class C waters are not suitable for primary contact recreation (swimming).

Table A-5: Water Quality Goals

Pollutant	Goal	Source
Total Phosphorus (TP)	Total phosphorus should not exceed: --50 ug/L in any stream --25 ug/L within any lake or reservoir < 15 ug/L TP in surface waters for Farm Pond is recommended by Applied Watershed Sciences.	Quality Criteria for Water (USEPA, 1986)
Bacteria	**Class B Standards** Primary contact recreation: For E. coli, geometric mean of samples collected within any 90-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 90-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL. Waters adjacent to any public or semi-public beach, at a location used for bathing and swimming purposes or waters impacted by combined sewer overflows (CSO) or publicly owned treatment works (POTW) discharges: For E. coli, geometric mean of samples collected within any 30-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 30-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL.	Massachusetts Surface Water Quality Standards (MassDEP, 2022)

Land Use and Impervious Cover Information

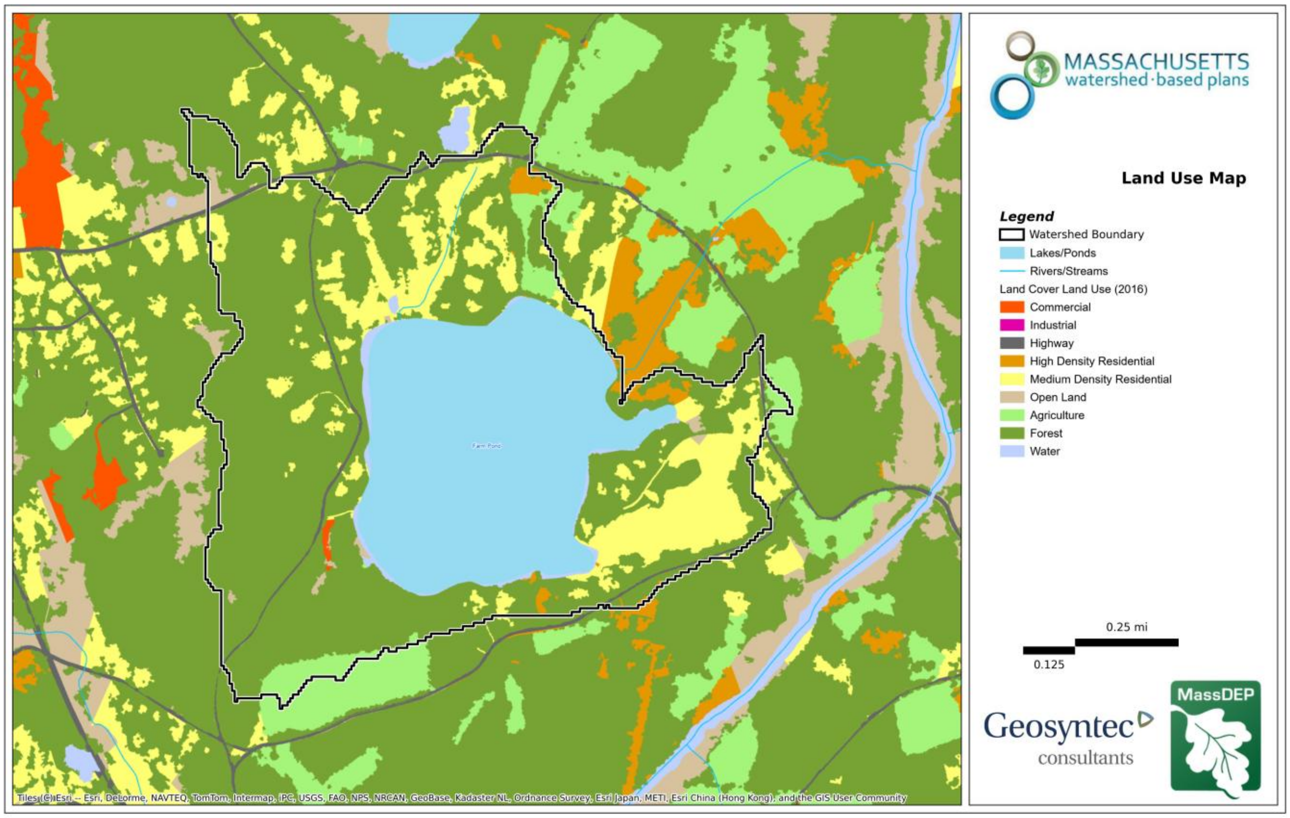
Land use information and impervious cover is presented in the tables and figures below. Land use source data is from 2016 and was obtained from MassGIS (2019). The land use and land cover categories were matched with the associated land use category using the methodology identified in the MassDEP guidance document "2016 Massachusetts Small MS4 Permit Pollutant Loading Export Rates applied to the 2016 Massachusetts Land Use/Land Cover GIS Dataset" (MassDEP, 2023b). **Table A-6** includes the area and percent of watershed of each of these land use categories.

Watershed Land Uses

Table A-6: Watershed Land Uses

Land Use	Area (acres)	% of Watershed
Agriculture	10.37	2.4
Commercial	0.6	0.1
Forest	221.62	50.9
High Density Residential	4.71	1.1
Highway	4.77	1.1
Industrial		
Medium Density Residential	61.55	14.1
Open Land	2.71	0.6
Water/Lake	129.22	29.7
Total	**435.6**	**100**

Map 7. Watershed Land Use Map



(MassGIS, 2007; MassGIS, 2019; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Watershed Impervious Cover

There is a strong link between impervious land cover and stream water quality. Impervious cover includes land surfaces that prevent the infiltration of water into the ground, such as paved roads and parking lots, roofs, basketball courts, etc. The total impervious area was estimated for the watershed based on the land use and impervious cover source data from 2016 (MassGIS, 2019). The total impervious area (TIA) for the watershed is presented in **Table A-7**.

Table A-7: TIA Values for the Watershed

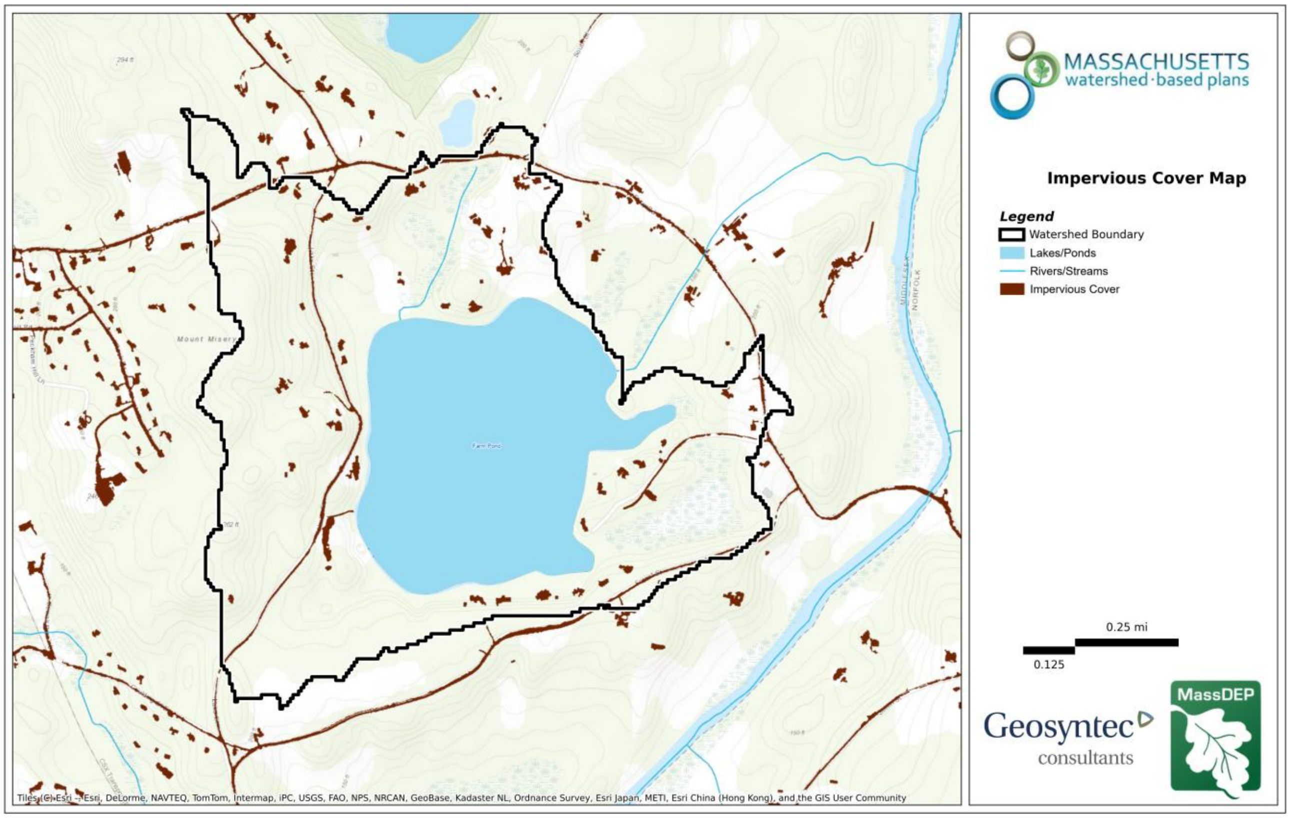
	Estimated TIA (%)
Farm Pond	3

The relationship between the total impervious area and water quality can generally be categorized as shown in **Table A-8** (Schueler et al. 2009):

Table A-8: Relationship between Total Impervious Area and water quality (Schueler et al. 2009)

% Watershed Impervious Cover	Stream Water Quality
0-10%	Typically high quality, and typified by stable channels, excellent habitat structure, good to excellent water quality, and diverse communities of both fish and aquatic insects.
11-25%	These streams show clear signs of degradation. Elevated storm flows begin to alter stream geometry, with evident erosion and channel widening. Streams banks become unstable, and physical stream habitat is degraded. Stream water quality shifts into the fair/good category during both storms and dry weather periods. Stream biodiversity declines to fair levels, with most sensitive fish and aquatic insects disappearing from the stream.
26-60%	These streams typically no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and streambank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Biological quality is typically poor, dominated by pollution tolerant insects and fish. Water quality is consistently rated as fair to poor, and water recreation is often no longer possible due to the presence of high bacteria levels.
>60%	These streams are typical of “urban drainage”, with most ecological functions greatly impaired or absent, and the stream channel primarily functioning as a conveyance for stormwater flows.

Map 8. Watershed Impervious Surface Map



(MassGIS, 2007; MassGIS, 2019; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Land use information:

The FST 2015 report details a Lake Loading Response Model (LLRM) effort that estimated land uses and respective nutrient runoff quantities, which produced slightly different nutrient loading estimates than the MA DEP WBP modeling tool, primarily as a result of a model calibration effort that was likely an over-correction of the LLRM load. The total impervious surface from this report was 25.03 acres (4.7% of the watershed area, a slight difference from what is estimated above using the MA WBP modeling tool). There was also a difference in the land-use classifications and area among this WBP and the initial modeling reviewed by the FST 2015 report, where it is not completely clear if and what kind of agriculture or cropland certain private residential estates include on cleared land. For the purposes of land-use watershed load modeling, the classifications in **Map 7** were used, which is consistent with the information contained in the Applied Watershed Sciences 2025 Farm Pond Lake Management Assessment report.

Pollutant Loading

A Geographic Information System- (GIS) was used for the pollutant loading analysis. The land use data (shown in **Map 7**) was combined with impervious cover data (shown in **Map 8**) and United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soils data (USDA NRCS and MassGIS, 2012) to create a combined land use/land cover grid. The grid was used to sum the total area of each unique land use/land cover type.

Pollutant loading for key nonpoint source pollutants in the watershed was estimated by multiplying each land use/cover type area by its pollutant load export rate (PLER) as follows:

$$L_n = A_n * P_n$$

Where L_n = Loading of land use/cover type n (lb/yr); A_n = area of land use/cover type n (acres); P_n = pollutant load export rate of land use/cover type n (lb/acre/yr)

The PLERs are an estimate of the annual unattenuated potential total pollutant load exported via stormwater from a given unit area of a particular land cover type. The PLER values for TN, TP and TSS were obtained from MassDEP and USEPA (MassDEP, 2023b; VHB et al., 2022) (see values provided in Appendix A). **Table A-9** presents the estimated land-use based TN, TP and TSS pollutant loading in the watershed.

Table A-9: Estimated Pollutant Loading for Key Nonpoint Source Pollutants

Land Use Type	Pollutant Loading[1]		
	Total Phosphorus (TP) (lbs/yr)	Total Nitrogen (TN) (lbs/yr)	Total Suspended Solids (TSS) (tons/yr)
Agriculture	5	27	0.15
Commercial	1	9	0.11
Forest	30	119	3.26
High Density Residential	2	12	0.18
Highway	9	64	3.40
Industrial	0	0	0.00
Medium Density Residential	19	149	2.18
Open Land	1	5	0.09
TOTAL (lbs)	66	384	9.38
TOTAL (kgs)	30	174	4.3

[1]These estimates do not consider loads from point sources or septic systems.

Pollutant loading information:

The Farm Pond Assessment (AWS, 2026) reviews additional watershed and internal sources of nutrients to Farm Pond. The additional annual pollutant load sources detailed in that report are summarized here:

Table A-9b: Estimated Pollutant Loading All Sources (AWS, 2026)

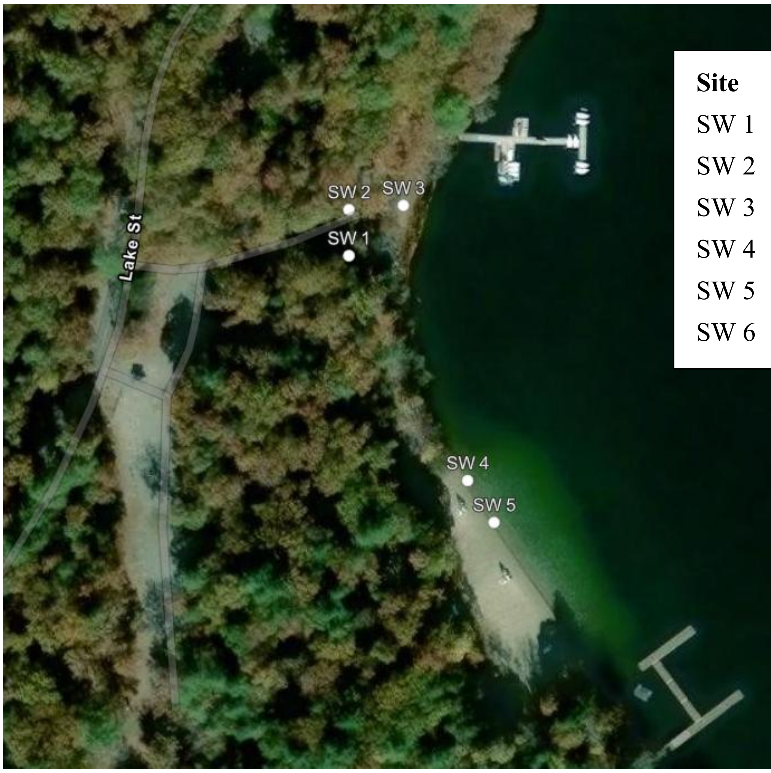
Nutrient Sources	P kg	*% of total*
Waterfowl/Geese	9.2	*11.8*
Septic/On-site wastewater	6.6	*8.5*
Direct Urine	1.6	*2.1*
Internal Load	19.8	*25.5*
Atmospheric Load	10.2	*13.1*
Watershed	30.4	*39.1*
SUM	**77.8**	**100.0**

Waterfowl, primarily resident Canada geese (estimated a 46-bird consistent population, upwards of 115 birds for much of the year) contribute roughly 20.3 lbs (9.2kgs) of phosphorus. Atmospheric phosphorus load was estimated to be 10.2 kgs, or 22.5 lbs (FST, 2015 LLRM). Internal phosphorus load was estimated to be, on average, 19.2 kgs, or 42.3 lbs P (AWS, 2026). Overall, the Farm Pond Assessment report found that internal load was the primary driver of cyanobacteria blooms, and that it could be considerably higher than normal in a given season if weather conditions were conducive. The Farm Pond Assessment report also documents volunteer stormwater sampling conducted at six sites along the western shore, primarily on Town property. Sampling took place as close to the lake as possible to sample concentrations that were entering the lake rather than from where the water originated (**Map 9: Volunteer Stormwater Sampling Locations**). Total Phosphorus concentrations ranged from 50-1216 µg/L and Total Nitrogen in stormwater ranged from 492-2065 µg/L. Only a few of the samples were on the high end of those ranges. Stormwater nutrient sampling data are included in the report. The Assessment concluded,

> *The primary threat of stormwater runoff to Farm Pond is from directly connected impervious cover along the Town roads and in areas where there may be future construction activities. The primary goal to reduce runoff is to 'disconnect' impervious cover, so that runoff can be adequately treated via infiltration (water soaks into and is filtered by native soil) wherever possible…Topsoil erosion during active construction has been documented during small-scale driveway, garden, and grading projects in the watershed. Even small amounts of topsoil erosion are a nutrient-load concern* [if that erosion reaches the roads and lake directly].

The estimated background P load from forested land is 30 lbs (13.6 kg) per year (Table A-9). That background P, combined with the atmospheric P load, is at least 31% of the total annual estimated Farm Pond P load, meaning that over a third of the total load is considered unmanageable. Similarly, the fraction of the remaining watershed runoff load that comes from anthropogenic sources can reasonably be controlled by about 50% through combined BMPs. The internal P load that could be controlled via in-lake phosphate-binding treatment is roughly 25% of the total, but this fraction represents a more easily controlled source that would yield immediate improvements in water quality. Preventing increased loads will be key across the watershed, while restoration actions will likely be needed in the lake itself.

Map 9: Volunteer Stormwater Sampling Locations



Site	Latitude	Longitude	Description
SW 1	42.23211	-71.35064	Boat ramp – above grate
SW 2	42.23224	-71.35064	Boat ramp left runoff
SW 3	42.23225	-71.35043	Boat ramp right runoff
SW 4	42.23147	-71.35018	Town beach left
SW 5	42.2313	-71.35008	Town beach paved path
SW 6	42.23441	-71.34986	Lake street drain culvert

Element B: Determine Pollutant Load Reductions Needed to Achieve Water Quality Goals

Element B of your WBP should:

Determine the pollutant load reductions needed to achieve the water quality goals established in Element A. The water quality goals should incorporate Total Maximum Daily Load (TMDL) goals, when applicable. For impaired water bodies, a TMDL establishes pollutant loading limits as needed to attain water quality standards.

Estimated Pollutant Loads

Table B-1 lists estimated pollutant loads for the following primary nonpoint source (NPS) pollutants: total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS). These estimated loads are based on the pollutant loading analysis presented in Element A.

Water Quality Goals

Water quality goals for primary NPS pollutants are listed in **Table B-1** based on the following:

- TMDL water quality goals (if a TMDL exists for the water body);
- For all water bodies, including impaired waters that have a pathogen TMDL, the water quality goal for bacteria is based on the Massachusetts Surface Water Quality Standards (MassDEP 2022) that apply to the Water Class of the selected water body.
- If the water body does not have a TMDL for TP, a default target TP concentrations is provided which is based on guidance provided by the USEPA in Quality Criteria for Water (1986), also known as the "Gold Book". Because there are no similar default water quality goals for TN and TSS, goals for these pollutants are provided in **Table B-1** only if a TMDL exists or alternate goal(s) have been optionally established by the WBP author.
- According to the USEPA Gold Book, total phosphorus should not exceed 50 ug/L in any stream at the point where it enters any lake or reservoir. The water quality loading goal was estimated by multiplying this target maximum phosphorus concentration (50 ug/L) by the estimated annual watershed discharge for the selected water body. To estimate the annual watershed discharge, the mean flow was used, which was estimated based on United States Geological Survey (USGS) "Runoff Depth" estimates for Massachusetts (Cohen and Randall, 1998). Cohen and Randall (1998) provide statewide estimates of annual Precipitation (P), Evapotranspiration (ET), and Runoff (R) depths for the northeastern U.S. According to their method, Runoff Depth (R) is defined as all water reaching a discharge point (including surface and groundwater), and is calculated by:

$$P - ET = R$$

A mean Runoff Depth R was determined for the watershed by calculating the average value of R within the watershed boundary. This method includes the following assumptions/limitations:

a. For lakes and ponds, the estimate of annual TP loading is averaged across the entire watershed. However, a given lake or reservoir may have multiple tributary streams, and each stream may drain land with vastly different characteristics. For example, one tributary may drain a highly developed residential area, while a second tributary may drain primarily forested and undeveloped land. In this case, one tributary may exhibit much higher phosphorus concentrations than the average of all streams in the selected watershed.

b. The estimated existing loading value only accounts for phosphorus due to stormwater runoff. Other sources of phosphorus may be relevant, particularly phosphorus from on-site wastewater treatment (septic systems) within close proximity to receiving waters. Phosphorus does not typically travel far within an aquifer, but in watersheds that are primarily unsewered, septic systems and other similar groundwater-related sources may contribute a significant load of phosphorus that is not captured in this analysis. As such, it is important to consider the estimated TP loading as "the expected TP loading from stormwater sources."

c. If the calculated water quality goal is higher than the existing estimated total load; the water quality goal is automatically set equal to the existing estimated total load.

Table B-1: Pollutant Load Reductions Needed

Pollutant	Existing Estimated Total Watershed Load	Water Quality Goal	Required Watershed Load Reduction
Total Phosphorus	66 lbs/yr	Reduce overall P load by 40 lbs/yr (18 kg/yr from primarily internal sediment, directly connected impervious cover, wastewater, and waterfowl sources)	20 lbs/yr (9 kg/yr)
Total Nitrogen	384 lbs/yr	Not fully assessed	
Total Suspended Solids	9 ton/yr	Not assessed	
Bacteria	*MSWQS for bacteria are concentration standards (e.g., colonies of fecal coliform bacteria per 100 ml), which are difficult to*	Class B. **Class B Standards** • Primary contact recreation: For E. coli, geometric mean of samples collected within any 90-day or smaller	

	predict based on estimated annual loading.	period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 90-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL. o Waters adjacent to any public or semi-public beach, at a location used for bathing and swimming purposes or waters impacted by combined sewer overflows (CSO) or publicly owned treatment works (POTW) discharges: For E. coli, geometric mean of samples collected within any 30-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 30-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL.	

Pollutant load reduction information:

The additional Total Phosphorus pollutant load information is detailed in the Farm Pond Lake Assessment report (AWS, 2026). Of the extra sources of phosphorus pollution, the primary management concerns are Waterfowl (11.8% of the total) and internal-P loading from lake sediments (estimated to be roughly 25% of the annual load, but higher in years with unusually warm water temperatures early in the season). The internal load is described to be dynamic, heavily influenced by climate and weather. The long-term P-reduction goal for direct external load reductions from onsite wastewater, geese, and impervious-cover runoff should be 20 lbs/yr, but must be coupled with efforts to reduce internal P load as well, given the disproportionate effects of internal P on cyanobacterial blooms.

Element C: Describe management measures that will be implemented to achieve water quality goals

Element C: A description of the nonpoint source management measures needed to achieve the pollutant load reductions presented in Element B, and a description of the critical areas where those measures will be needed to implement this plan.

BMP Suitability Index:

The following GIS-based analysis was performed within the watershed to identify high priority parcels for best management practice (BMP) (also referred to as management measure) implementation:

- Each parcel within the watershed was evaluated based on ten different criteria accounting for the parcel ownership, social value, and implementation feasibility (See **Table C-1** for more detail below);
- Each criterion was then given a score from 0 to 5 to represent the priority for BMP implementation based on a metric corresponding to the criterion (e.g., a score of 0 would represent lowest priority for BMP implementation whereas a score of 5 would represent highest priority for BMP implementation);
- A multiplier was also assigned to each criterion, which reflected the weighted importance of the criterion (e.g., a criterion with a multiplier of 3 had greater weight on the overall prioritization of the parcel than a criterion with a multiplier of 1); and
- The weighted scores for all the criteria were then summed for each parcel to calculate a total BMP suitability score.

Table C-1 presents the criteria, indicator type, metrics, scores, and multipliers that were used for this analysis. Parcels with total scores above 60 indicate high potential for BMP implementation suitability and are recommended for further investigation. **Figure C-1** presents the resulting BMP Suitability Index Map for the watershed. The following link includes a Microsoft Excel file with information for all parcels that have a score above 60: BMP Suitability Index Spreadsheet.

This analysis solely evaluated individual parcels for BMP implementation suitability and likelihood for the measures to perform effectively within the parcel's features. This analysis does not quantify the pollutant loading to these parcels from the parcel's upstream catchment. When further evaluating a parcel's BMP implementation suitability and cost-effectiveness of BMP implementation, the existing pollutant loading from the parcel's upstream catchment and potential pollutant load reduction from BMP implementation should be evaluated. Please note that all but one of the parcel's analyzed here are private property. The Farm Pond Reservation parcel is 11.7 acres (Town owned).

GIS data used for the BMP Suitability Index analysis included:

- MassGIS (2015a);
- MassGIS (2015b);

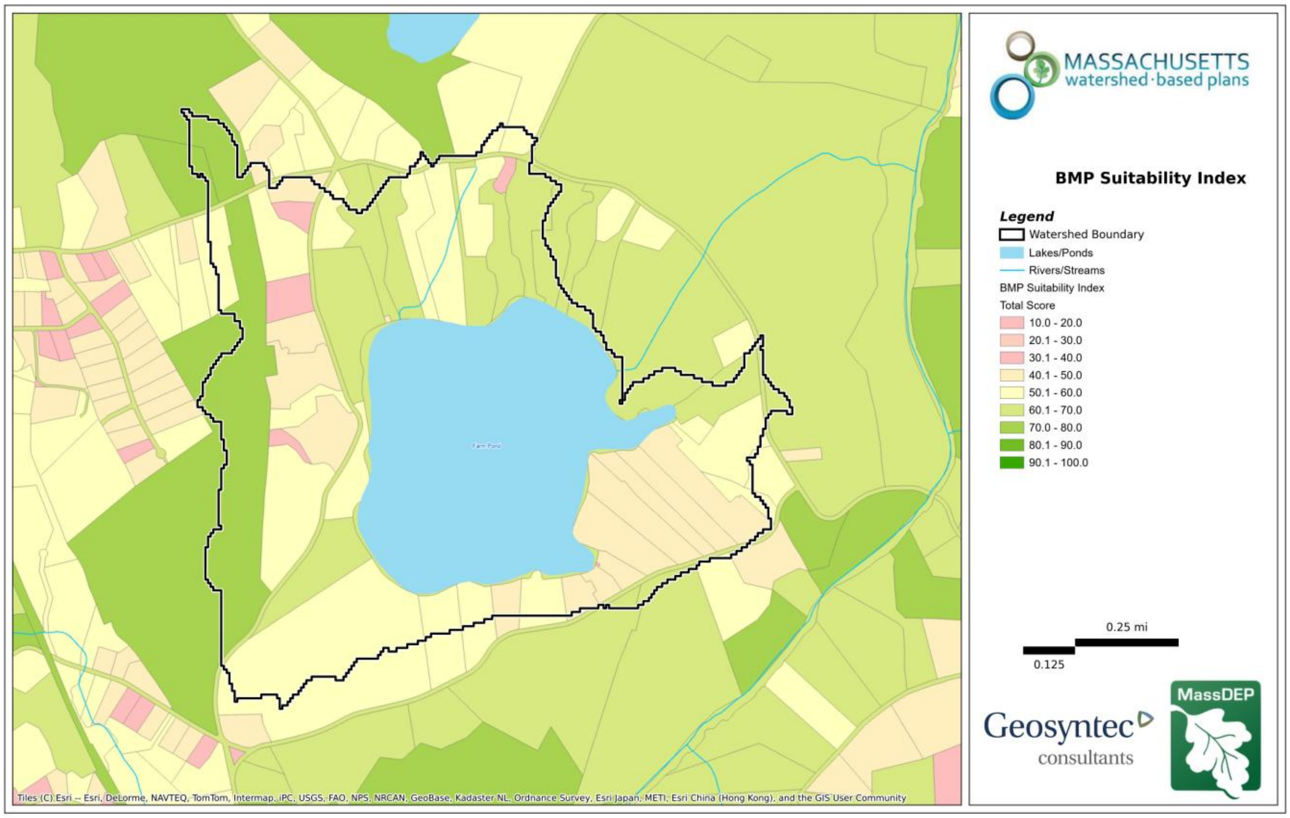
- MassGIS (2017a);
- MassGIS (2017b);
- MassGIS (2020);
- MA Department of Revenue Division of Local Services (2016);
- MassGIS (2005);
- ArcGIS (2020);
- MassGIS (2019);
- MassGIS (2012); and
- ArcGIS (2020b).

Table C-1: Matrix for BMP Suitability Index GIS-based Analysis

Criteria	Indicator Type	METRICS: Yes or No?		Hydrologic Soil Group				Land Use Type									Water Table Depth				Parcel Area			Parcel Average Slope					Multiplier	Maximum Potential Score
		Yes	No	A or A/D	B or B/D	C or C/D	D	Low and Medium Density Residential	High Density Residential	Commercial	Industrial	Highway	Agriculture	Forest	Open Land	Water	101-200 cm	62-100 cm	31-61 cm	0-30 cm	Greater than 2 acres	Between 1-2 acres	Less than 1 acre	Less than 2%	Between 2% and 15%	Greater than 15%	Less than 50%	Between 51% and 100%		
Is the parcel a school, fire station, police station, town hall or library?	Ownership	5	0																										2	10
Is the parcel's use code in the 900 series (i.e. public property or university)?	Ownership	5	0																										2	10
Is parcel fully or partially in an Environmental Justice Area?	Social	5	0																										2	10
Most favorable Hydrologic Soil Group within Parcel	Implementation Feasibility			5	5	0	0																						2	10
Most favorable Land Use in Parcel	Implementation Feasibility							1	2	4	2	4	5	1	4	X[1]													3	15
Most favorable Water Table Depth (deepest in Parcel)	Implementation Feasibility																5	4	3	0									2	10
Parcel Area	Implementation Feasibility																				5	4	1						3	15
Parcel Average Slope	Implementation Feasibility																							3	5	1			1	5
Percent Impervious Area in Parcel	Implementation Feasibility																										5	2.5	1	5
Within 100 ft buffer of receiving water (stream or lake/pond)?	Implementation Feasibility	5	2																										2	10

Note 1: X denotes that parcel is excluded

Map 10. BMP Suitability Index Map



(MassGIS (2015a), MassGIS (2015b), MassGIS (2017a), MassGIS (2017b), MassGIS (2020), MA Department of Revenue Division of Local Services (2016), MassGIS (2005), ArcGIS (2020), MassGIS (2019), MassGIS (2012), ArcGIS (2020b))

Critical Areas

Possibly the most critical area for ensuring future water quality maintenance at Farm Pond is the berm that separates Farm Pond from the Farm Pond outlet lagoon. The lagoon is considerably more eutrophic and has higher P and N concentrations than Farm Pond itself. Thus, the berm should be maintained as necessary to prevent backflow or complete mixing of the lagoon water into Farm Pond. Berm maintenance can include periodic inspections and potential use of erosion control coir logs installed where erosion has occurred. The berm shows no indication of potential failure throughout, but the areas where water flows from Farm Pond over the berm to the lagoon should be maintained at the same elevation in order to prevent the lowering of the Farm Pond water level during spring. This may require adding strategic material, such as coir logs, to both sides of the berm spillways and potentially repairing low spots in the berm with sandbags under the coir logs. All wetland regulations must be followed in the event of future repairs.

The Town parking lot and lakeshore property is also a critical area of concern. Any future maintenance and construction on these parcels must be carried out with extreme care to minimize the risk of construction-related topsoil erosion. The same is true for private residences along Lake Street, on the western side of the pond. Furthermore, shoreline property owners have done an excellent job maintaining vegetated buffer areas, but continued lake-friendly property maintenance is essential (i.e. no fertilizers whenever possible).

All wetlands that feed Farm Pond should also be periodically monitored near the Farm Pond shore to ensure they continue to function primarily as nutrient sinks. Natural organic matter buildup over time and the potential channelization of wetland surface water flows can reduce the effectiveness of natural wetlands' nutrient retention. At present, there does not seem to be direct surface water wetland inflow to Farm Pond from any of the adjacent wetlands.

Proposed Management Measures:

Watershed management measures can be generally classified into structural and non-structural practices. Structural management measures address maintenance or improvements to reduce direct sources of stormwater or nutrient pollution. These measures typically involve engineered water infiltration, simple rerouting, or water-containment or erosion-control barriers. Structural improvements are limited by topography, water volumes, and available land area. Non-structural practices are typically actions that residents can take to reduce their impact on the lake, such as using portable restrooms at the beach or refraining from using fertilizers on their shoreline properties. Non-structural management measures also include ongoing septic system inspections and pumping, as well as goose population control and deterrent tactics.

Table C-2 presents the proposed management measures as well as the estimated pollutant load reductions and costs. For private property residential parcels, such as those that have high BMP suitability index ratings, the recommendations are mainly general stormwater management, erosion control, and permit oversight for construction projects. The planning level cost estimates and pollutant load reduction estimates and estimates of BMP footprint were based off information obtained in the following sources and were also adjusted to 2016 values using the Consumer Price Index (CPI) (United States Bureau of Labor Statistics, 2016):

- Geosyntec Consultants, Inc. (2014);
- Geosyntec Consultants, Inc. (2015);
- King and Hagen (2011);
- Leisenring, et al. (2014);
- King and Hagen (2011);
- MassDEP (2016a);
- MassDEP (2016b);
- University of Massachusetts, Amherst (2004);
- USEPA (2020);
- UNHSC (2018);
- Tetra Tech, Inc. (2015);

Table C-2: Proposed Management Measures, Estimated Pollutant Load Reductions and Costs

Structural BMPs	
BMP TYPE	INFILTRATION
BMP SIZE (storm depth; inches)	1.25
DRAINAGE AREA (acres)	0.27
BMP LOCATION	Town of Sherborn North Parking Area and Boat Ramp Zone to Trench Drain
LAND USE, COVER TYPE (in drainage area)	**% OF DRAINAGE AREA**
HIGH DENSITY RESIDENTIAL, Impervious	100
ESTIMATED POLLUTANT LOAD REDUCTIONS	
TN (lbs/yr)	3.76798

TP (lbs/yr)	0.59957
TSS (lbs/yr)	118.51728
ESTIMATED FOOTPRINT (sf)	581.9
ESTIMATED COST ($)	15,000
  	The existing trench drain does not receive all of the stormwater runoff from upslope. Water is undercutting the existing drain in a few places and is also flowing around the drain corner, where repairs have been made, and an infiltration drywell exists. The existing drywell appears to be working, but during heavy rain, the amount of water that flows to this location overshoots these drains and continues to stream as overland flow to the lake. If this repaved area is turned into a vegetated swale prior to the drywell, it would better capture higher volume runoff. There is also room for a potential drywell or swale at the top of the hill (third image) to reduce water volume downslope. This site should be addressed if the Town proceeds with further improvements to the parking lot and pavement, which is eroded and crumbling from general age and use.

Additional BMPs

BMP TYPE	Catch Basins Cleaning and Community Vigilance
BMP LOCATION	Lake Street Drain Culvert - 42.23441, -71.34986
DESCRIPTION	At present, there are a small number of catch basins that can be maintained regularly along the western shore of Farm Pond, Lake Street. It is premature at this time to recommend upgrades to these catch basins, as direct close to first-flush stormwater sampling nutrient results were a result of erosion control issues due to residential driveway construction and improper containment of a newly planted slope. At the time, the Conservation Commission was made aware of the violation, and corrective measures were taken. It may be possible to daylight this culvert on private property and do a created wetland project, but the scope of designing such a project will rely on the property owners. It may also not be worth the disturbance because future uphill erosion sources can be adequately controlled during residential landscaping or driveway paving activities. Erosion enforcement actions need to continue as needed in the watershed.
ESTIMATED POLLUTANT LOAD REDUCTIONS	Unknown future potential loads.
ESTIMATED COST ($)	0

BMP TYPE	Address Internal Nutrient Load (Phosphorus)
BMP LOCATION	In-lake
DESCRIPTION	The 2026 Farm Pond Lake Assessment provides detailed information regarding options for internal nutrient management. The most probable management action to reduce the incidence of cyanobacteria blooms will be alum (aluminum sulfate) treatment. Examples of the size and dosages required for cyanobacteria control are proposed by Applied Watershed Sciences. The Town of Sherborn will likely pursue in-lake management as a primary method of cyanobacteria control, due to the very limited control options for stormwater runoff. The majority of the watershed is forested and privately owned.
ESTIMATED POLLUTANT LOAD REDUCTIONS	Up to 40 lbs/yr
ESTIMATED COST ($)	368,577

BMP TYPE	Town public restroom maintenance
BMP LOCATION	42.2310930. -71.3512931
DESCRIPTION	The restroom facilities located at the historical stone bath house at the Town beach parking lot need to be continuously inspected and maintained to ensure prolonged wastewater nutrient and bacteria control. AWS recommends pumping and inspection every 3 years. The Town also funds and maintains a portable restroom on site for most of the year, reducing strain on the public onsite wastewater system. For much of the spring and fall season, the portable restroom is the primary wastewater disposal method, as the facilities were often locked. Due to system elevation and soil types, there should not be a considerable phosphorus load from the community septic system, even with long-term and high use. However, a review of Board of Health documents indicates the Town community septic tank is ~60 years old and likely will need replacement soon. At this time, it is also recommended to create a second leach field area, to maximize long-term soil absorption and to have better records of what

	type of leach field exists (current leach field has little to no information and the system design predates MA Title V regulations).
ESTIMATED POLLUTANT LOAD REDUCTIONS	0 lbs/yr but **prevent future added loads** by preventing treatment failure (ensure lasting P sorption in soils)
ESTIMATED COST ($)	5,000 annually for portable restroom; 2,000 every 3 years for inspection and pumping; 50,000 for future system replacement

BMP TYPE	Ongoing Canada Geese Management
BMP LOCATION	Lakewide
DESCRIPTION	The large resident population of Canada Geese represents an unusually high phosphorus load fraction of the total to Farm Pond. This is because the overall watershed load to Farm Pond is relatively low, making the proportionally more of the load than geese are at many other waterbodies. Geese management options and permitting will be reviewed with US Fish and Wildlife, as well as MA Wildlife. The cost estimates reflect potential anticipated permit-acquisition costs. In addition to geese removal efforts, provide alternative resting (surface floating) areas instead of canoes, docks, paddleboards, etc. Design these resting areas to naturally capture the goose waste to minimize pollution and bind phosphorus and nitrogen via plant growth and a thin layer of soil. These would be akin to floating treatment wetlands, but with an altered design that makes them purposeful for geese.
ESTIMATED POLLUTANT LOAD REDUCTIONS	20 lbs/yr
ESTIMATED COST ($)	10,000

BMP TYPE	Ongoing Property Erosion Control & Stormwater Management
BMP LOCATION	Anywhere in watershed, including residential properties
DESCRIPTION	Resources from New Hampshire Lakes – LakeSmart program https://nhlakes.org/lakesmart/ The following pdfs have been included as attachments to this document. Vegetated Swales https://nhlakes.org/wp-content/uploads/vegetated-swale.pdf Pervious walkways and patios https://nhlakes.org/wp-content/uploads/pervious-walkways-and-patios.pdf Slope Stabilization https://nhlakes.org/wp-content/uploads/erosioncontrolchapter1.pdf Rain gardens for homeowners https://nhlakes.org/wp-content/uploads/rain-garden.pdf
ESTIMATED POLLUTANT LOAD REDUCTIONS	NA
ESTIMATED COST ($)	Site-specific

Element D: Identify Technical and Financial Assistance Needed to Implement Plan

Element D: Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

Table D-1 presents the funding needed to implement the management measures presented in this watershed plan. The table includes costs for structural and non-structural BMPs, operation and maintenance activities, information/education measures, and monitoring/evaluation activities.

Table D-1: Summary of Funding Needed to Implement the Watershed Plan.

Management Measures	Location	Capital Costs	Operation & Maintenance Costs	Relevant Authorities	Technical Assistance Needed	Funding Needed
Structural and Non-Structural BMPs (from Element C)						
INFILTRATION BASIN W/ SEDIMENT FOREBAY	Town of Sherborn North Parking Area and Boat Ramp Zone to Trench Drain	$3,000	$12,000	FPAC, Town of Sherborn, Sherborn Conservation Commission	Engineering Contractor, Town Department of Public Works	$15,000
Catch Basins Cleaning and Community Vigilance	Lake Street Drain Culvert - 42.23441, -71.34986	NA	Existing component of Town maintenance budget	Sherborn Conservation Commission, Town of Sherborn, FPAC	Town Department of Public Works	$0
Address Internal Nutrient Load (Phosphorus)	In-lake	$400,000 (estimated for treatment + and monitoring)	Future follow-up treatments unknown	MA DEP, MA DCR, Sherborn Conservation Commission	Solitude Lake Management, Applied Watershed Sciences or other consultants	$400,000
Town public restroom maintenance & portable restroom funds	42.2310930, -71.3512931	NA	$5,000/yr	FPAC, Town of Sherborn	Title V Inspector Company	$5,000
Town public septic system replacement	42.2310930, -71.3512931	$50,000				$50,000
Ongoing Canada Geese Management	Lake wide	$10,000		FPAC, Town of Sherborn	Contracted Geese Deterrents & Control	$10,000

Information/Education (see Element E)						
Alum treatment Project Planning & Permit Acquisition	In-lake	$20,000		MA DEP, MA DCR, Sherborn Conservation Commission	Solitude Lake Management, Applied Watershed Sciences or other consultants	$20,000
Residential property management outreach and future partnerships with local landscape contractors	Watershed	NA	NA	FPAC, Town of Sherborn	Local landscape companies and ecological design experts to share examples on web forums for the watershed property owners.	NA – private projects
Monitoring and Evaluation (see Element H/I)						
Farm Pond Advisory Committee Volunteer Annual Nutrient Monitoring	In-lake	$10,000	$10,000	FPAC, Town of Sherborn	Water quality consultant, MA DEP/DCR	$20,000
					Total Funding Needed:	**$520,000**
Funding Sources:						

- Town of Sherborn Capital/Operating Budget
- MA DEP Section 319 NPS Grants
- Various Climate Change Preparedness Grant Opportunities - including MA MVP Action Grant
- Land and Water Conservation Fund Grants
- Clean Water State Revolving Fund

Element E: Public Information and Education

Element E: Information and Education (I/E) component of the watershed plan used to:

1. Enhance public understanding of the project; and
2. Encourage early and continued public participation in selecting, designing, and implementing the NPS management measures that will be implemented.

Step 1: Goals and Objectives

Increase public awareness of stormwater runoff from private property. Encourage shoreline and watershed property owners to reduce or eliminate fertilizer use. Maintain public access to restrooms and portable bathrooms during the off-season. Encourage Sherborn Yacht Club camp counselors to escort children to the bathrooms several times a day to discourage urination in the lake. Ensure future construction complies with erosion control standards and that any erosion issues or violations are appropriately cited and corrected by the Sherborn Conservation Commission. FPAC members should communicate with the Conservation Commission about ongoing inspections and reporting for any construction projects in the watershed.

Step 2: Target Audience

The primary target audience for this WBP is the Town of Sherborn residents and shoreline property owners. Non-residents who use Farm Pond for recreation are also a smaller fraction of the stakeholder group. The Town of Sherborn engineering and maintenance staff, as well as the Sherborn Yacht Club staff will be essential in following through with goals and issues identified in this plan.

Step 3: Outreach Products and Distribution

Public presentations sponsored by the Farm Pond Advisory Committee. Resources for local landscapers employed to maintain property in the Farm Pond watershed. The New Hampshire LakeSmart program has ample, easily accessible handouts for various types of structural and non-structural BMPs for land management in the watershed. Make use of existing resources and handouts (links to various resources provided on page 38). Hold an annual town-sponsored 'lake day' event to increase public awareness of threats to Farm Pond and ways to reduce personal impacts to eutrophication. Host guest speakers on web forums for shoreline and watershed property management from local experts in ecological landscaping. FPAC will also need to continuously communicate with the Sherborn Conservation Commission regarding development and permitted projects in the watershed.

Step 4: Evaluate Information/Education Program

Track the number of event attendees and the number of views of publicly posted presentation recordings to track resident engagement. The Farm Pond Advisory Committee should also follow this plan with a public survey to gauge support for the recommended in-lake management actions prior to seeking permit approvals.

Elements F & G: Implementation Schedule and Measurable Milestones

Element F: Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

Element G: A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

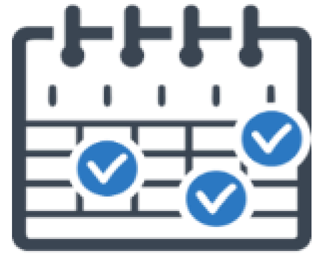


Table FG-1: Implementation Schedule and Interim Measurable Milestones

Structural & Non-Structural BMPs						
INFILTRATION *Town of Sherborn plans to revise the existing footpath from the parking lot to the beach*	100% engineering plans	RFB for construction	Begin construction	Maintenance annually, or as needed by Town Public Works.		
	Santec completed 8/1/2025	12/5/2025	3/1/2027			
INFILTRATION *Town of Sherborn North Parking Area and Boat Ramp Zone to Trench Drain*	100% engineering plans	RFB for construction	Begin construction			
	2027	2028	2029			
Catch Basins Cleaning and Community Vigilance *Lake Street Drain Culvert - 42.23441, -71.34986*	FPAC discussion with Conservation Commission	Monthly FYI Emails from ConCom to FPAC	FPAC review of ConCom agenda thereafter			
	6/1/2026	6/1/2026	Monthly thereafter			
Address Internal Nutrient Load (Phosphorus) *In-lake*	Community Internal Load Management Perception Survey	Develop Target Project Timeline and Funding Plan	Notice of Intent, 401WQC, Permit to Apply Chemical	Public Hearing for Alum Treatment NOI	Alum Pilot Treatment	Follow up monitoring
	2026	2026	2027	2027	2027	2027-2029
Town public restroom maintenance *42.2310930. -71.3512931*	Annual Report from Town Public Works to FPAC	Annually thereafter				
	End of 2026					
Ongoing Canada Geese Management *Lake wide*	Open discussion with MA Wildlife	Inspect for Eggs & Apply for Egg Addling Permits	Annually thereafter			
	2026	2026				

The interim milestones will be progress towards permits and construction for each project recommended in this plan.

<table>
<tr><th colspan="3">Public Education & Outreach</th></tr>
<tr><td>FPAC Lake Day Events</td><td>Mid-Summers</td><td>Annually or every 2 years</td></tr>
<tr><td rowspan="2">FPAC Annual Public Zoom Meetings/Webinars</td><td>Target for Mid-Summer</td><td>Annually thereafter</td></tr>
<tr><td>2026</td><td>Host a different expert for watershed topics each year. Topics include septic systems, ecological landscaping, in-lake management, aquatic invasive species prevention, water quality monitoring updates, etc.</td></tr>
</table>

<table>
<tr><th colspan="5">Monitoring</th></tr>
<tr><td rowspan="2">FPAC volunteer monitoring</td><td>FPAC volunteer monitoring - revise QAP</td><td>WMC CMC (Cyanobacteria Monitoring Collaborative)</td><td>Annual Year-End FPAC Report - Data Summary</td><td rowspan="2">Annually thereafter</td></tr>
<tr><td>2026</td><td>2026</td><td>End of 2026</td></tr>
<tr><td rowspan="2">FPAC & Conservation Commission Coordination</td><td colspan="4">Memorandum of understanding for reporting approved construction permits in watershed. Allow FPAC to formally comment on projects and erosion control plans.</td></tr>
<tr><td colspan="4">2026</td></tr>
</table>

Elements H & I: Progress Evaluation Criteria and Monitoring

Element H: A set of criteria used to determine (1) if loading reductions are being achieved over time and (2) if progress is being made toward attaining water quality goals. Element H asks "**how will you know if you are making progress towards water quality goals?**" The criteria established to track progress can be direct measurements (e.g., E. coli bacteria concentrations) or indirect indicators of load reduction (e.g., number of beach closings related to bacteria).

Element I: A monitoring component to evaluate the effectiveness of implementation efforts over time, as measured against the Element H criteria. Element I asks "**how, when, and where will you conduct monitoring?**"

The water quality target concentration(s) is presented under Element A of this plan. To achieve this target concentration, the annual loading must be reduced to the amount described in Element B. Element C of this plan describes the various management measures that will be implemented to achieve this targeted load reduction. The evaluation criteria and monitoring program described below will be used to measure the effectiveness of the proposed management measures (described in Element C) in improving the water quality of Farm Pond.

Indirect Indicators of Load Reduction

Reduction of overall incidence and severity of surface cyanobacteria blooms.

Project-Specific Indicators

FPAC must maintain an ongoing record of all watershed improvement efforts, including maintenance of existing erosion control methods, catch basin cleaning, street sweeping, goose poop management, and permits. FPAC should also keep records of public outreach events, meetings, and special-topic webinars completed.

Direct Measurements

<u>In-lake Volunteer Monitoring</u>

Refer to the approved Farm Pond QAPP for detailed information. FPAC will commit to portions of this sampling program as funds allow in future years, and the QAPP should be revised for 2026 onward to reflect FPAC volunteers' capacity and the budget allocated for annual baseline volunteer sampling. Ideally, volunteers will continue to measure Total Phosphorus and Total Nitrogen at the top, middle, and bottom of the lake on a monthly basis from April through November every year. If budget does not allow, volunteers should at least monitor surface nutrients monthly at the deep hole sampling station. Volunteer monitoring of temperature and dissolved oxygen profiles should also continue monthly during each season.

Cyanobacteria monitoring via the EPA Region 1 Cyano-Monitoring Collaborative (CMC) and the Worcester CMC program. FPAC volunteers will continue their weekly sampling of the beach area to detect the presence of cyanobacteria via fluorometry of the phytoplankton pigment phycocyanin (PC).

Adaptive Management

If any major management measures are implemented in the watershed or in-lake, appropriate monitoring and follow-up maintenance will ensure lasting benefits to Farm Pond. The Town should revisit professional review of the volunteer-collected lake data, ideally not less than every five years. Detailed monitoring recommendations are provided in the 2025 Farm Pond Lake Management Assessment report (AWS, 2026). FPAC will maintain responsibility for communicating with residents, primary education and outreach coordinators, and volunteer monitors, and for data coordination. FPAC typically meets monthly to discuss updates and critical news regarding the lake and water quality, which will continue hereafter. The primary criteria that will be used to determine the effectiveness of various parts of this plan implementation will be the incidence and severity of cyanobacteria blooms. FPAC will also rely on community feedback from outreach events and ongoing communications to ensure continued progress. FPAC will work closely with Town staff to seek funding for plan implementation, and will be responsible for overseeing any contracted lake and watershed management work outlined in this plan.

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"*Charles River Watershed 2002-2006 Water Quality Assessment Report*"

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Farm Pond Advisory Committee historical volunteer water quality annual data reports by Tom Trainor.

Farm Pond Information Booklet - https://www.sherbornma.org/DocumentCenter/View/787/Farm-Pond-Information-Booklet-PDF - Review of the pond's history

The Farm Pond stormwater improvement project brochure - https://www.sherbornma.org/DocumentCenter/View/789/Farm-Pond-Stormwater-Improvement-Project-PDF

Farm Pond Lake Assessment (AWS, 2026)

Appendices

Appendix A – Pollutant Load Export Rates (PLERs)

Land Use & Cover[1]	PLERs (lb/acre/year)		
	(TP)	(TSS)	(TN)
AGRICULTURE, HSG A	0.45	29	2.6
AGRICULTURE, HSG B	0.45	29	2.6
AGRICULTURE, HSG C	0.45	29	2.6
AGRICULTURE, HSG D	0.45	29	2.6
AGRICULTURE, IMPERVIOUS	1.52	649	11.3
COMMERCIAL, HSG A	0.03	7.14	0.3
COMMERCIAL, HSG B	0.12	29.4	1.2
COMMERCIAL, HSG C	0.21	59.8	2.4
COMMERCIAL, HSG D	0.37	91	3.7
COMMERCIAL, IMPERVIOUS	1.78	377	15.0
FOREST, HSG A	0.13	29	0.5
FOREST, HSG B	0.13	29	0.5
FOREST, HSG C	0.13	29	0.5
FOREST, HSG D	0.13	29	0.5
FOREST, HSG IMPERVIOUS	1.52	650	11.3
HIGH DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.3
HIGH DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.2
HIGH DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.4
HIGH DENSITY RESIDENTIAL, HSG D	0.37	91	3.7
HIGH DENSITY RESIDENTIAL, IMPERVIOUS	2.32	439	14.1
HIGHWAY, HSG A	0.03	7.14	0.3
HIGHWAY, HSG B	0.12	29.4	1.2
HIGHWAY, HSG C	0.21	59.8	2.4
HIGHWAY, HSG D	0.37	91	3.7
HIGHWAY, IMPERVIOUS	1.95	1,477	13.9
INDUSTRIAL, HSG A	0.03	7.14	0.3
INDUSTRIAL, HSG B	0.12	29.4	1.2

INDUSTRIAL, HSG C	0.21	59.8	2.4
INDUSTRIAL, HSG D	0.37	91	3.7
INDUSTRIAL, IMPERVIOUS	1.78	377	15.0
MEDIUM DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.3
MEDIUM DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.2
MEDIUM DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.4
MEDIUM DENSITY RESIDENTIAL, HSG D	0.37	91	3.7
MEDIUM DENSITY RESIDENTIAL, IMPERVIOUS	1.96	439	14.1
OPEN LAND, HSG A	0.03	7.14	0.3
OPEN LAND, HSG B	0.12	29.4	1.2
OPEN LAND, HSG C	0.21	59.8	2.4
OPEN LAND, HSG D	0.37	91	3.7
OPEN LAND, IMPERVIOUS	1.52	650	11.3
[1]HSG = Hydrologic Soil Group			

Appendix B – New Hampshire LakeSmart Program Handouts

LakeSmart Resource Library

Knowing where to find reliable and accurate information to help you with LakeSmart lake-friendly living projects on your property and in your home can be daunting. That's why we've compiled a resource library to help you along the way!

Get Started

LakeSmart: A Lake-Friendly Living Program

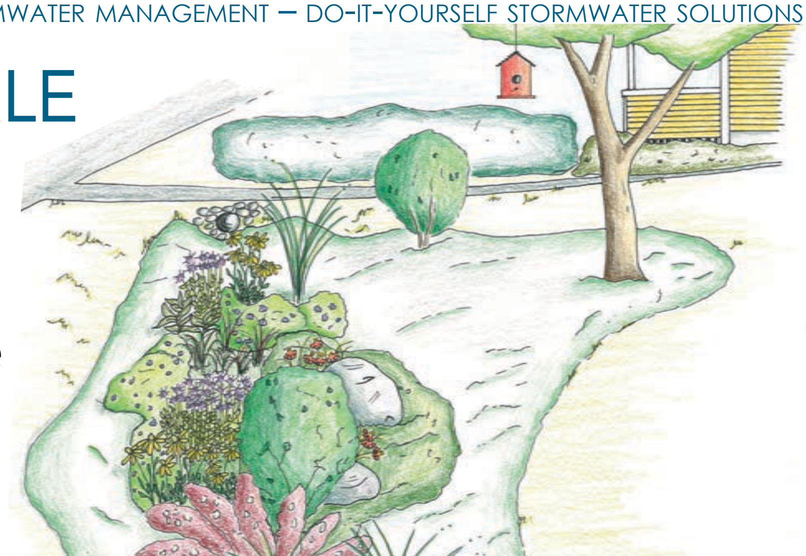
Clean water, thriving wildlife, and lasting lake enjoyment start with how we care for our properties and spend our time in, on, and around our lakes.

The LakeSmart Program helps property owners, like YOU, understand how their choices impact lake health—and how simple changes in their home, property, and lifestyle can make a big difference.

While many participants connect to us through their local LakeSmart Community, anyone can participate in this free, educational program to become more lake-friendly.

LakeSmart is a free, non-regulatory, and voluntary education and recognition program encouraging community members to adopt habits that protect lake water quality, wildlife habitat, and property values.

VEGETATED SWALE



A shallow vegetated channel used to direct runoff. The plants stabilize the soil, reduce erosion, slow the flow and absorb runoff.

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SIZING AND DESIGN

STEP 1 – **Location**. Swales are often located close to roads or driveways. They are usually built in naturally sloping areas to convey runoff safely and slowly to a vegetated area where it can infiltrate. If a vegetated area doesn't exist, consider building a rain garden, dry well or other practice at the end of the swale to encourage the runoff to soak into the ground. A slope of one inch for every foot in length is enough to slowly move the runoff through the swale. When selecting the location of your swale, consider the source of the runoff, the slope of the land, and where you want the runoff to ultimately end up. Swales should not be used to direct water off of your property, or into a road or waterbody.

EQUIPMENT & MATERIALS

- Measuring tape
- Shovels
- Rakes
- Plants - native grasses, sedges, and seedlings
- Mulch
- Wheel Barrow(s)
- Stakes
- String & string level

STEP 2 – **Length and width**. Consider the natural contour of the land when deciding on the shape and dimension of the swale. A swale that meanders down a slope will convey runoff more slowly than a straight swale. The distance from the source of the runoff to the desired outlet location will dictate the length. A swale can be any width. Constraints on the site, such as buildings and property setbacks, can influence the width and how the swale fits into other landscaped features.

STEP 3 – **Berms or check dams**. If a swale needs to be oriented straight down a hill or on a steep slope, consider adding berms or check dams to the swale design. Berms or check dams are built across a swale, similar to speed bumps in a road. They are used to slow down the speed of runoff as it flows through the swale.

STEP 4 – **Plant selection**. Refer to Native Plants for New England Rain Gardens on the *Soak Up the Rain New Hampshire* program website for plant suggestions. While this list was developed for rain gardens, many of the species would do well in vegetated swales. Hardy ground covers and grasses that produce uniform, dense cover that can withstand flood and drought conditions are best. If the swale is to be located close to a road or in an area where snow will be stored, salt-tolerant plants should be considered.

STEP 5 – **Identify staging and material disposal area(s)**. Identify an area on the site where delivered materials, such as stone, compost and mulch, can be stored temporarily while the vegetated swale is being built. Also identify an area to dispose of excess materials, like sod and soil that is excavated from the swale, where it will not wash away.

INSTALLATION

STEP 1 – **Mark out location**. Using stakes and string or spray paint, mark out the boundary of the swale according to the design. Be sure to identify the placement of any berms or check dams. These are areas that you will likely not need to dig as deeply, if at all.

STEP 2 – **Dig**. Dig out the shape of the swale. The deepest part of the swale should be about three feet deep. The width of the swale will depend on how much space you have on your site. A swale can be any size or length, but most are shaped like a trapezoid with the sides being three times wider than the width of the base. The slope of the sides should be between 1% and 4% (Figure 1).

STEP 3 – **Check dams**. For swales on steep slopes (5% or steeper), berms or check dams can be used to slow down the flow of runoff and reduce the potential for erosion. These can be made of compacted earth and reinforced with plantings and stone, or can be made of larger stones. Be creative. Check dams made with large stones can become beautiful landscape features. See Figure 2.

STEP 4 – **Secure swale inlet**. Depending on how runoff enters the swale, consider stabilizing the inlet with a splash guard, washed stone, or hardy plants to reduce erosion from fast moving water.

STEP 5 – **Plant the swale**. Use good planting practices, such as those listed below. Place plants while still in their pots into the buffer according to the planting plan. Make adjustments for spacing as needed. When you are ready to plant, remove one plant at a time from its pot.

TIP: Be careful not to compact the soil when digging because it will reduce the ability of the swale to infiltrate runoff. For clay soils or other poorly infiltrating soils, you may want to dig down an additional $1^1/_2$-inch below the bottom of the swale and create a sandy loam by mixing sand in with the existing soil, then refill the hole. This will improve infiltration.

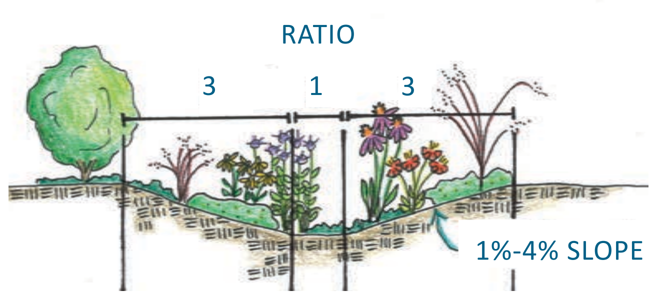


Figure 1. Profile of vegetated swale.

Figure 2. Check dams within a swale slow the flow, allowing sediments to settle out and some infiltration to occur.

- Dig a hole twice as wide as the plant's rootball and no deeper than the rootball.
- Loosen and rough up the rootball before planting, especially those rootbound in the container, to encourage healthy root growth.
- Set plants to the same depth as they were in the pot.

- If staking trees, make sure the trunks are allowed to sway in the wind.
- Water: For landscaped or enhanced buffers, water thoroughly (to a depth of two inches) just after planting and daily during the first week. During the second week, water every other day. Then, water twice a week through the first growing season.

STEP 6 – **Mulching**. Spread two to three inches of mulch over the root zone of plants to provide weed suppression, slow release of nutrients, and additional moisture retention. Be sure to keep mulch a few inches away from plant stems and trunks.

MAINTENANCE

INSPECT: Seasonally and after large storms, look for signs of erosion, accumulated sediment and plant stress, such as wilting, discolored leaves, etc.

WATER: Newly planted vegetation needs regular watering for the first two growing seasons. A good rule of thumb is for trees and shrubs to get about an inch of water twice a week each time you water. Cut back to watering once a week in fall and in the next growing season.

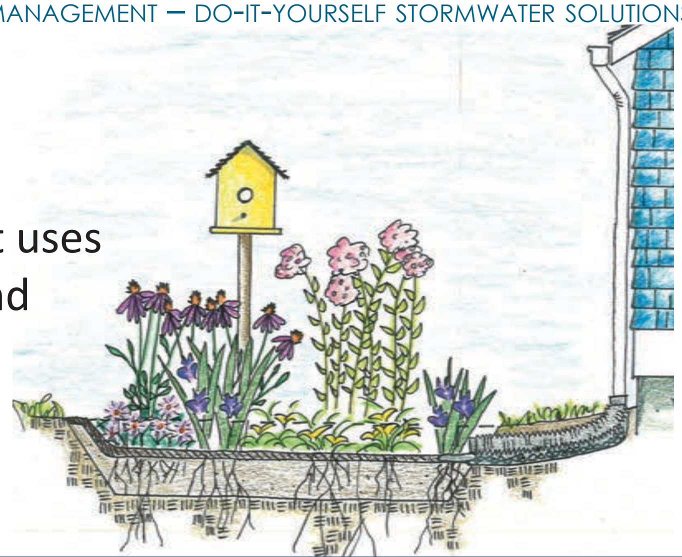
WEED: Weed as needed, or allow native and non-invasive "weeds" like goldenrod, Queen Anne's lace and yarrow to grow. Be on the look out for invasive plants, such as oriental bittersweet and purple loosestrife. Carefully remove invasives in a way that will not spread seeds and cause more to grow.

CLEAN: Remove accumulated sediment and replace vegetation as needed.

DESIGN REFERENCES

Vermont Department of Environmental Conservation. *Vermont Low Impact Development Guide for Residential and Small Sites*. December 2010.

RAIN GARDEN



A sunken, flat-bottomed garden that uses soil and plants to capture, absorb and treat stormwater. It helps to reduce stormwater runoff and recharge groundwater.

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DESIGN CONSIDERATIONS

STEP 1 – **Site constraints**. Identify site constraints in the area where the rain garden will be located, such as:

- High water table – rain gardens should not be placed in persistently wet areas or areas where puddles regularly form.
- Underground obstructions such as gas or electrical lines, other utilities, structures or bedrock. Contact DigSafe 72 hours in advance of your project.
- Place rain gardens on slopes less than 12% (less than one foot of elevation change over 8.3 feet of length).

STEP 2 – **Setbacks**. Be sure to locate the rain garden:

- At least 10 feet away from buildings with basements to prevent seepage into the basement.
- At least 15 feet away from a septic tank or leach field.
- Away from tree roots and drinking water wells.

STEP 3 – **Perform an infiltration test**. Test the ability of the soil to infiltrate water (allow it to soak in and drain through the soil). Rain gardens should only be built in areas where soils drain within 24 hours. Follow the steps below.

a. Using a shovel or a post hole digger, dig a 12-inch deep hole.

b. Fill the hole with water and allow it to drain completely (NOTE: if the hole fills with water on its own or if water is still in the hole after 24 hours, choose a new location).

c. Fill the hole with water a second time and do one of the following:

EQUIPMENT & MATERIALS

- Calculator
- Measuring tape
- Spray paint
- Yard stick
- 6-12 Stakes
- 2-4 Long stakes (4')
- String
- Shovels
- Carpenter's level
- String level
- Rakes
- Compost/Woodchips
- Mulch
- Washed stone
- Flat stones or pavers
- Tarp(s)
- Wheel Barrow(s)
- Plants
- Inlet piping, if needed

- Place a ruler or yard stick in the hole. Note the water level and time. After 15 minutes, check the water level again and note the new water level. Multiply the change in water level by four to get the number of inches of infiltration in an hour. A rate of at least $^1/_2$-inch of water per hour is appropriate for an infiltration practice.

  OR

- Cover the hole for safety and check back 24 hours later. If the water has completely drained, this indicates the soil is appropriate for an infiltration practice.

SIZING

Use the following steps to determine the dimensions of the rain garden. Use Table 3 to organize the information.

STEP 1 – **Total drainage area**. Identify the surface(s) that will drain to the rain garden. Multiply the length by the width to get the drainage area in square feet.

LENGTH (ft) X WIDTH (ft) = DRAINAGE AREA (ft^2)

If more than one surface will contribute runoff to the rain garden, add them together. For example, if two roof areas are collected by a downspout that will drain to the rain garden, add the two roof areas together.

Table 1 – Soil type based on ribbon test.

Soil Type	Ribbon Length (inches)
Sand	No ribbon will form
Silt	Weak ribbon <1.5"
Clay	>1.5"

STEP 2 – **Soil type**. The size of the rain garden is dependent on the soil type. Estimate your soil type by performing a ribbon test using the following steps:

a. Grab a handful of moist soil and roll it into a ball in your hand.

b. Place the ball of soil between your thumb and the side of your forefinger and gently push the soil forward with your thumb, squeezing it upwards to form a ribbon about $^1/_4$-inch thick.

c. Try to keep the ribbon uniform in thickness and width. Repeat the motion to lengthen the ribbon until it breaks under its own weight. Measure the ribbon and compare it to Table 1.

Figure 1 – Soil ribbon test.

STEP 3 – **Slope**. Find the slope of the land where the rain garden will be located. Slopes should be less than 12%. Follow the steps below to determine slope.

a. Place one stake at the uphill end of the rain garden area and another at the downhill end as illustrated in Figure 2.

b. Tie a string to the uphill stake at ground level. Using a string level, level the string between the two stakes, tying it off to the downhill stake.

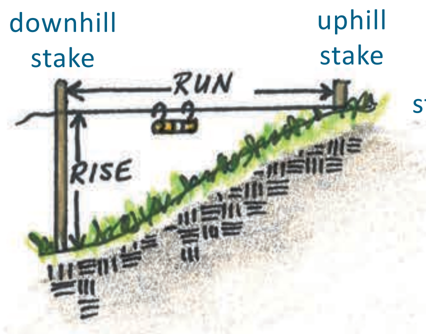


Figure 2 – Determine the slope of the landscape before digging.

c. Measure the length of the string between the stakes. This is the run or length.

d. On the downhill stake, measure the height from the ground to the string. This is the rise or height.

e. Divide the rise by the run and then multiply the result by 100. This is the slope.

SLOPE (%) = (RISE ÷ RUN) X 100

STEP 4 – **Ponding depth**. Use the slope to determine the corresponding rain garden ponding depth in Table 2. The ponding depth is the distance between the top of the mulch layer and the top of the rain garden outlet.

Table 2 – Ponding depth and size factor.

Slope		≤ 4%	5-7%	8-12%
Ponding Depth		3-5 inches	6-7 inches	8 inches
Soil Type	Sand	0.19	0.15	0.08
	Silt	0.34	0.25	0.16
	Clay	0.43	0.32	0.20

STEP 5 – **Size factor**. Match the ponding depth to the appropriate soil type in Table 2 to find the rain garden size factor. For example, if your slope is 6%, the corresponding ponding depth is 6-7 inches. If you have a silt soil, your corresponding size factor is 0.25.

STEP 6 – **Rain garden area**. Use the equation below to calculate the needed rain garden area in square feet. You can configure the shape and dimensions to best suit the site as long as it meets the total rain garden square footage.

RAIN GARDEN SIZE FACTOR x TOTAL DRAINAGE AREA (ft^2) = RAIN GARDEN AREA (ft^2)

STEP 7 – **Total depth to dig**.

a. A rain garden should have between six and 12 inches of planting bed material with 12 inches being ideal. The planting bed can include native soil, compost and other soil amendments. Choose the planting bed depth for your rain garden. A two-inch mulch layer is recommended to suppress weeds and prevent the soil from drying out in the first few years until the garden is established.

b. The total depth to dig your rain garden is the sum of the ponding depth from Step 4, the planting bed depth (anywhere between six and 12 inches), and the mulch layer depth.

PONDING DEPTH + PLANTING BED DEPTH + MULCH LAYER DEPTH = TOTAL DEPTH TO DIG

Table 3 – Rain garden sizing information.

START – Infiltration test (pass/fail)	
STEP 1 – Total drainage area (ft^2)	
STEP 2 – Soil test (type)	
STEP 3 – Slope (%)	
SETP 4 – Ponding depth (inches)	
STEP 5 – Size factor	
STEP 6 – Rain garden area (ft^2)	
STEP 7a – Planting deb depth (inches)	
STEP 7b – total depth to dig (inches)	

DESIGN

STEP 1 – **Identify staging and material disposal area(s)**. Identify an area on the site where delivered materials, such as stone, compost, and mulch, can be stored temporarily while the rain garden is being built. Also identify an area to dispose of excess materials, like sod and soil that is excavated from the rain garden, where they will not wash away during storms.

TIP: To maintain the ponding depth, it is best to design the berm to be a few inches higher than the outlet. If this makes the berm taller than 12", you can increase the "depth to dig" and decrease the berm height.

STEP 2 – **Design the berm**. If the rain garden is on a slope, a berm or low wall is needed on the downslope side of the rain garden to hold water in the garden. The berm should be the same height as the upslope edge of the garden to make the entire perimeter of the garden level. This creates the ponding area.

The berm should be no more than 12 inches high in order to blend with the surrounding landscape and to be easier to maintain. This can limit the length of the rain garden in the direction of the slope. Table 4 shows the recommended rain garden length based upon the slope of the ground where the rain garden will be located.

TIP: If the length of the rain garden cannot be adjusted, increase the "depth to dig" and decrease the berm height.

Table 4 – Suggested Rain Garden length for a 12-inch berm height.

Slope	12%	11%	10%	9%	8%	7%	6%	5%	4%	3%	2%	1%	0%
Rain Garden no longer than	8.5'	9'	10'	11'	12.5'	14.5'	16.5'	20'	25'	33.5'	50'	100'	N/A

STEP 3 – **Consider the rain garden shape**. Plan the shape of the rain garden to fit the situation. The rain garden can be any shape as long as it meets the square footage determined in Sizing Step 6. Restrictions include the length based on the berm height (as recommended above) and other potential site constraints that limit the length, width or depth of the garden.

STEP 4 – **Plan the inlet and outlet**.

a. **Inlet**. The location where runoff enters a rain garden is called the inlet. Whether stormwater runoff enters the rain garden through a gutter downspout, a swale or as sheet flow, the inlet is susceptible to erosion and scouring during rain storms so it should be reinforced with stone or gravel. A flat rock or paver can also be placed at the inlet, directly under where runoff enters the garden, to help spread out the flow. Four-inch diameter corrugated piping can be buried to extend a gutter downspout into the garden.

b. **Outlet**. The location where water exits, or overflows, from a rain garden is called the outlet. While the rain garden is designed to contain most rain storms, the outlet provides a safe and controlled place for water to overflow during storms that produce a lot of rain. Similar to the inlet, the outlet is susceptible to erosion and scour and needs to be reinforced with stone. For rain gardens with berms, an outlet is usually created along a portion of the berm on the downslope side of the rain garden. An outlet is created by lowering a one- to two-foot wide section of the berm by a couple of inches.

STEP 5 – **Select plants and create a planting plan**. Rain garden plants are not the same as water-loving plants. Rain gardens have fluctuating wet and dry conditions and can have extended periods of dry soils between storms. Similar to planning any perennial garden, soil, light, wind, climate and exposure to environmental stressors like road salt, need to be considered. Consider the following recommendations when selecting plants for your rain garden.

- Refer to Native Plants for New England Rain Gardens on the *Soak Up the Rain NH* program website.
- Choose New England native plant species to enhance the ecological function of the rain garden by supporting native wildlife species, including birds and pollinators.

- Avoid plants with lower basal leaves that may remain under water and become more susceptible to rot.
- Use sturdy plants, such as Blue Flag Iris, where runoff enters the garden at the inlet.
- Have the soil tested to determine pH, organic content and other soil conditions to plan for soil amendments you may need to encourage healthy plant growth.
- Review the spacing suggestions for each plant and design your plan accordingly to give plants the space they need to grow to full maturity.
- Create a bird's eye view drawing of your planting plan to guide you when you plant and to help remind you of their placement when you inspect and maintain the rain garden.

STEP 6 – **Determine materials needed**. Once you know the area and depth of your rain garden, follow the instructions below to approximate the amount of soil, compost, mulch and other materials you may need. If needed, convert cubic feet to cubic yards by multiplying cubic feet by 0.037.

a. Decide how thick each material (soil, compost, mulch, etc.) should be. Material thickness: ________ inches

b. Use Table 5 to match the material thickness to the area covered per cubic yard of material. Area covered per cubic yard of material: ________ ft^2

c. Determine the area (in ft^2) the material needs to cover based on your rain garden size. Use the equation below to divide the size of the area to be covered by the area covered per cubic yard. The result is the number of cubic yards you will need.

SIZE OF AREA TO BE COVERED ÷ AREA COVERED PER CUBIC YARD = CUBIC YARDS NEEDED

Table 5 – Material thickness and coverage.

Material Thickness (inches)	Area Covered (ft^2) per Cubic Yard (yd^3) of Material
1"	324 ft^2
2"	162 ft^2
3"	108 ft^2
4"	81 ft^2
5"	67 ft^2
6"	54 ft^2
7"	47 ft^2
8"	40 ft^2
9"	36 ft^2
10"	33 ft^2
11"	30 ft^2
12"	27 ft^2

SOIL AMENDMENTS The condition of the soil, organic content, pH and other factors will determine the type and amount of soil amendments for your rain garden. The University of New Hampshire Cooperative Extension offers soil testing and will provide soil recommendations for residential rain gardens. More information on soil testing can be found on the UNH Cooperative Extension Soil Testing Services webpage. Be sure to indicate on the form that the test is for a residential rain garden.

PLANTS The number and type of plants will be dictated by the size of the rain garden and localized sun or shade, soil and climate conditions, and should be specified in your planting plan.

STONE About a half of a yard of washed stone is useful for securing the inlet and outlet and achieving the pitch of the inlet pipe from the gutter. Two or more one-square-foot or larger flat stones or pavers are useful for placing at the inlet. The inlet and outlet can also be reinforced with stones that you find as you dig out the rain garden area.

INSTALLATION

STEP 1 – **Define borders**. Use string or spray paint to outline the shape of the rain garden. The berm, if needed, will be built outside of the outline.

STEP 2 – **Remove sod**. Remove the grass within the outlined area. You can either dig through the lawn or lay a tarp or sheet of black plastic within the rain garden area for several weeks to kill the grass. Herbicides are not recommended.

STEP 3 – **Start digging**. Remove the soil from within the rain garden area. Form a gentle slope along the edges as you dig. Lay out tarps to temporarily sort and store sod, top soil and lower soil layers to use later in building the berm and preparing the soil planting bed. Consider the following:

a. On a Slope: If the rain garden is on a slope, a berm will be needed. The sod and soil material excavated from digging the garden should be reserved to build the berm (Figure 2).

b. On Level Ground: If the rain garden is on level ground, no berm is necessary and the excavated soil and sod can be removed or used elsewhere on the property.

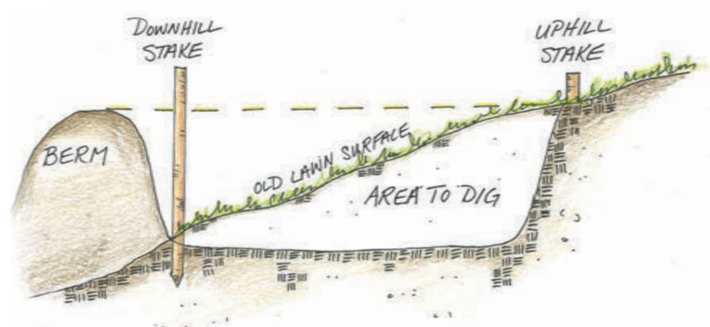


Figure 2. Where to dig and how to create the berm on a sloped site.

STEP 4 – **Set the berm height**. Once you are close to having the entire garden area dug down to the "total depth to dig," hammer stakes along the perimeter of the rain garden about three to four feet apart, starting with the highest edge and working around the garden. Attach a string to the base of the highest stake. Use a string level to mark that height on each stake around the perimeter of the garden. This will be your berm height. Tie a string from the stake to stake at that level to guide you while building the berm. See Figure 2.

STEP 5 – **Level the bottom**. The rain garden must have a level bottom to encourage the water to spread evenly throughout. Once all of your stakes are marked with the berm height, use a leveled string and a yard stick or measuring tape to measure the distance from the bottom of the rain garden to the string, crisscrossed throughout the rain garden. You may find that you need to dig out additional material or rake it out to get rid of high or low spots.

STEP 6 – **Prepare the soil**. Combine native soil, compost and other soil amendments to create a planting bed between six and 12 inches deep.

STEP 7 – **Prepare inlet**. If your rain garden is capturing roof runoff from a gutter, you can dig a trench to bury your inlet pipe from the gutter downspout to the garden. Carefully remove the sod growing over the trench and set it aside to replace it when the trench is complete. Be sure to pitch the trench toward the rain garden so that the water easily drains from the gutter to the garden and doesn't back up. You can use a carpenter's level to check the pitch.

Inside the rain garden, stabilize the inlet area with washed stone to prevent erosion and scour of the inlet. Place one or more flat stones or pavers directly under the inlet pipe to further reduce erosion and to prevent a channel from forming.

STEP 8 – **Build berm and outlet**. Using the marked stakes along the edge of the rain garden as a guide, use overturned sod and soil to build and shape the berm to the specified berm height. Designate a one- to two-foot section of the berm to be the outlet. The outlet should be one to two inches lower than the rest of the berm height. After shaping the berm and the outlet, compact the soil. Reinforce the outlet with stone.

STEP 9 – **Add planting bed materials**. Before adding the planting bed materials to the rain garden, hammer tall stakes into the bottom of the rain garden and mark them with the planting bed depth. Use this line as a guide as you evenly distribute a mix of native soil, compost and other amendments, as needed, to create a planting bed. Mix well and be sure to place some planting bed material up the sloped sides of the rain garden so that they may also be planted. Rake the bed level. To avoid compacting the planting bed, work from the center of the garden outward.

STEP 10 – **Plant**. Place plants while still in their pots into the garden according to the planting plan. Make adjustments for spacing as needed. When you are ready to plant, remove one plant at a time from its pot and loosen the rootball with your fingers to encourage root growth. Plant to the same depth that they were in the pot.

STEP 11 – **Apply mulch**. Apply a two-inch layer of mulch over the entire rain garden to help retain moisture in the soil and to prevent weeds. Keep mulch one to two inches away from plant stems.

STEP 12 – **Water thoroughly**. Water thoroughly (to about two inches deep) immediately after planting. Give the plants an inch of water every week for the first growing season. Once the plants have been established, water only as needed during extended dry weather.

MAINTENANCE

Rain garden maintenance is similar to the maintenance of any perennial garden, with a few extra tasks:

INSPECT: Check after storms to verify the inlet and outlet are stable, no channels have formed, that plants are healthy and that it is draining. Adjust and repair if needed.

PLANT CARE: Weed and water as needed. Replace dead plants as needed. Cut back, prune or divide plants when appropriate to encourage growth.

CLEAN: If the rain garden is receiving runoff that contains sand or debris, such as from a driveway or roadway, clean out accumulated materials as needed.

DESIGN REFERENCES

Winooski Natural Resources Conservation District. *The Vermont Rain Garden Manual "Gardening to Absorb the Storm"*. 2009

Wisconsin Department of Natural Resources. *Rain Gardens: A Guide for Homeowners and Landscapers*. 2018.

Figures adapted from Wisconsin Department of Natural Resources. *Rain Gardens: A How-to Manual for Homeowners*. 2003.

Erosion Control

Slope Stabilization

On slopes that are being eroded away, slowing down of surface water is needed. To accomplish this installation of devices meant to slow down the water is needed. These come in two different forms: erosion control blankets and fiber rolls.

Erosion Control Blankets

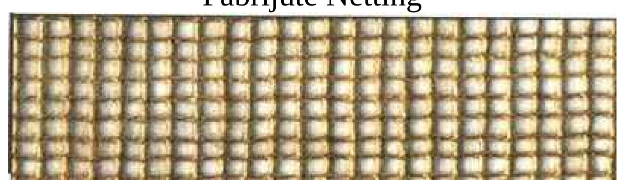
Erosion control blankets are usually woven from a chosen material and are meant to slow down the speed at which water moves across the surface. The material chosen is usually something with lots of ridges and obstructions for the water to slow down on. There are many different types of erosion control blankets, some that are synthetic and some that are natural. There are even a few that are both synthetic and natural. These blankets can be made out of straw, coconut fiber, aspen fiber, jute, and polypropylene (plastic). Most of these blankets can be bought in many sizes. Common ones are 80 to 100 square yards. Most of these are rolled up and cut into widths ranging from 3 to 8 feet wide.

Types of Erosion Control Blankets

Jute Netting

Made from the natural fiber jute, this netting is used as an erosion control device alone or used to hold together other erosion control materials.

Fabrijute Netting



This netting is made entirely from plastic, it mimics natural fibers. Netting like this is used to hold together erosion control blankets or just as erosion control itself.

Straw Single Synthetic

(i)

This netting is made from straw and held together by a single layer of synthetic netting

Straw double jute net

(i)

Made from ordinary straw, this is held together by a double layer of jute netting.

Straw double synthetic

(i)

Made from ordinary straw it is held together by a double layer of synthetic netting

Coir Double Jute Blanket

(i)

Made from coconut fiber it is held together by a double layer of jute netting.

Coir Double Synthetic Blanket

(i)

Made from coconut fiber it is held together by a double layer of synthetic netting

Excelsior (Aspen fiber) blanket

(i)

Made from shredded Aspen it is held together by a single plastic net.

Excelsior (Aspen Fiber) Double Synthetic

(i)

Made from Aspen which is then held together by a double layer of synthetic netting

Installation of Erosion Control Blankets

The erosion control blankets are relatively easy to install. The largest concern is making sure the water moves over the top of the blankets. To do this you need to ‘key’ it into the slope by digging a small trench on the top of the slope. In this trench you lay the top end of the material into the trench to line it. To line it the edge is folded underneath itself and then it is secured using staples. The trench is then filled in to the previous soil level. The end result is pictured in Figure 5. The edge of the blanket that is upwind needs to be overlapped underneath the blanket next to it as shown in the Figure 6.

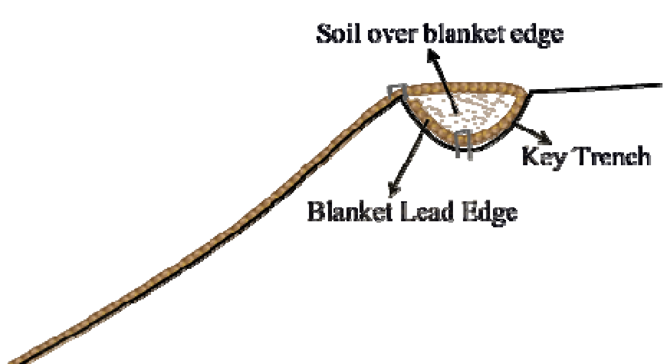


Figure 1

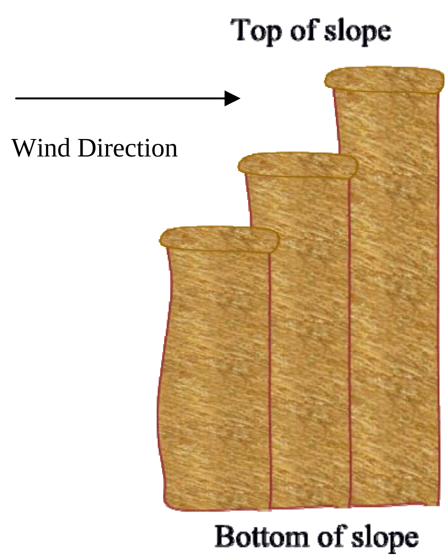


Figure 2

Fiber Rolls

Fiber rolls are the other type of erosion control device. These are usually made of the same materials used in erosion control blankets but are rolled into large diameter “logs.” These logs can be made to just about any diameter and are usually incased in some kind of netting sewing into the desired shape. The purpose of these logs is to pool up and slow down water long enough for any sediment that is in the water to settle out. The three major materials used in fiber rolls are coconut fiber, rice wattle and wheat wattle. The concept behind the fiber roll is the same regardless of the material.

Wheat straw rolls being used to stabilize a slope

(i)

These rolls are made from wheat and will slow down water movement long enough for it to drop sediment out.

Rice Straw Wattle on long slope

(iii)

Installed rice straw wattle 1 year after original installation

Coir log after Installation

(iv)

Coir logs are the most commonly found throughout the world with rice and wheat following closely behind.

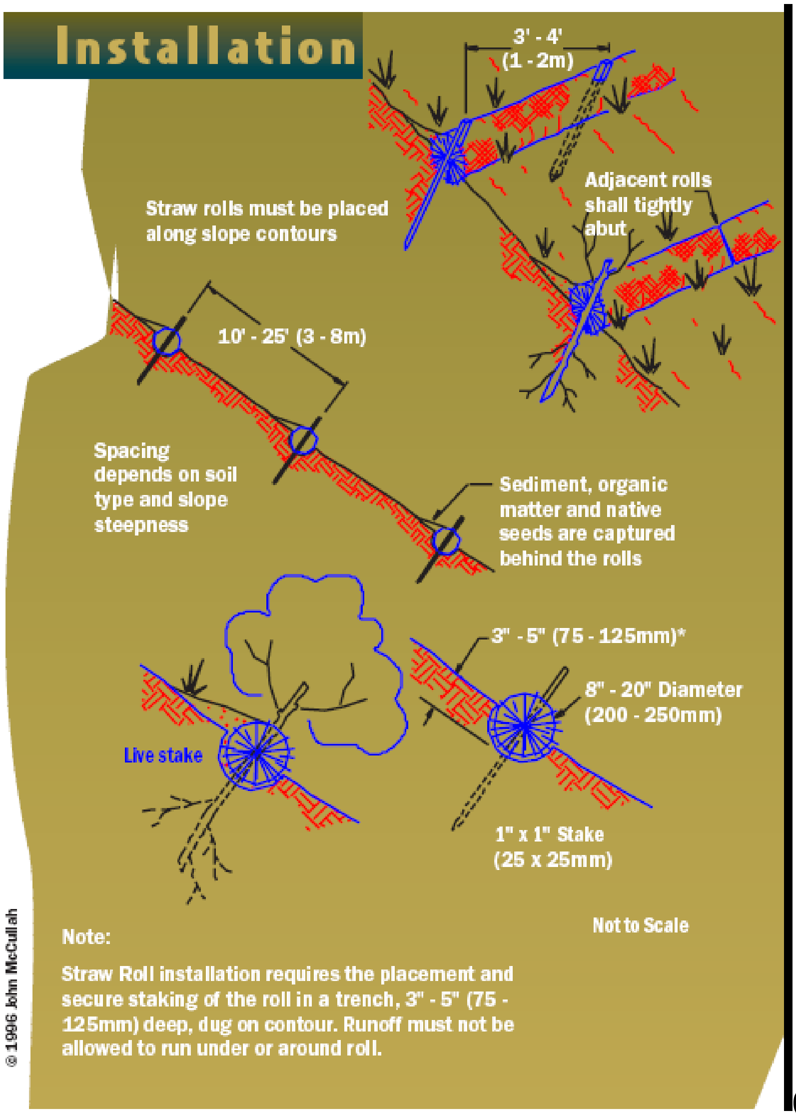
Straw Wattle Installation

(ii)

Long wooden stakes are placed through the middle of the fiber roll into the ground.

Fiber Log Installation

The installation of the fiber logs does not change based on the material used. The basic concept of a fiber log is to lock it into place so that soil and water cannot remove it from where it is installed. A trench is dug at a depth equal to half of the diameter of the log. This is so that the fiber log can become part of the slope. Wooden stakes are used to hold them in place. They are approximately 2 – 3 feet apart and the type of stake is dependant on the situation. If a species that can be live staked can survive in your location, it is a good idea to use a live stake to hold the log in place and to also to start vegetative establishment. Planting into the fiber log is also a good way to establish plants.



(vi)

Installation diagram from EarthSaver™ Erosion Control Products

Alternatives

Some alternatives to erosion control blankets and coir logs are hydro mulch, temporary silt fencing or using real logs and rocks to create locations for water to settle out. Hydro mulching can be expensive and is not effective during the rainy season, but if the species that colonize the site can be established before the mulch runs off, it can be very successful. The downside is that unless you plant the species you want, invasive species can show up. Temporary silt fences are usually meant to catch any runoff from the construction of the project, but they can be used until the slope re-establishes itself enough to stop any runoff. Once this is accomplished, removal of the fences is required. Finally using the natural material to create runoff catch basins can be a very cheap process if there are available materials on site. Another benefit is that the catchment areas can appear to be natural to the untrained observer. A problem with these natural catchments is that you can only create them in areas that the water funnels to and they cannot be made on a large scale.

Silt Fence


(i)

The silt fence is used as a temporary device to catch any sediment that moves during the construction.

Hydro Mulch


(i)

An alternative to using erosion control blankets, hydro mulching consists of organic mulch such as wood fiber or paper cellulose that is mixed with water and sprayed on the slope. There is mulch that contains soil stimulants that encourages the development of mycorryhizal organisms.


(v)

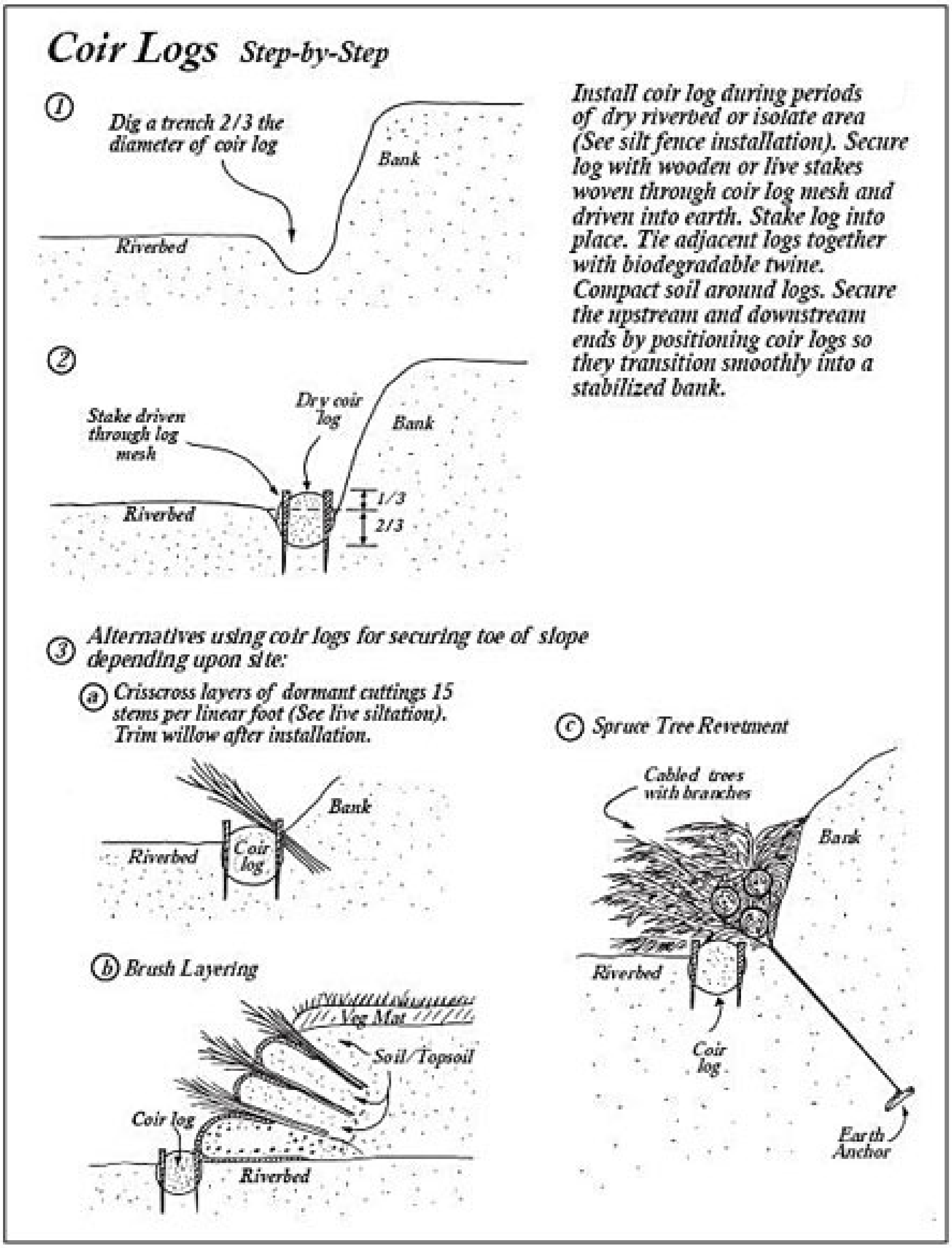
Run-off trap using hay bales and fallen logs.

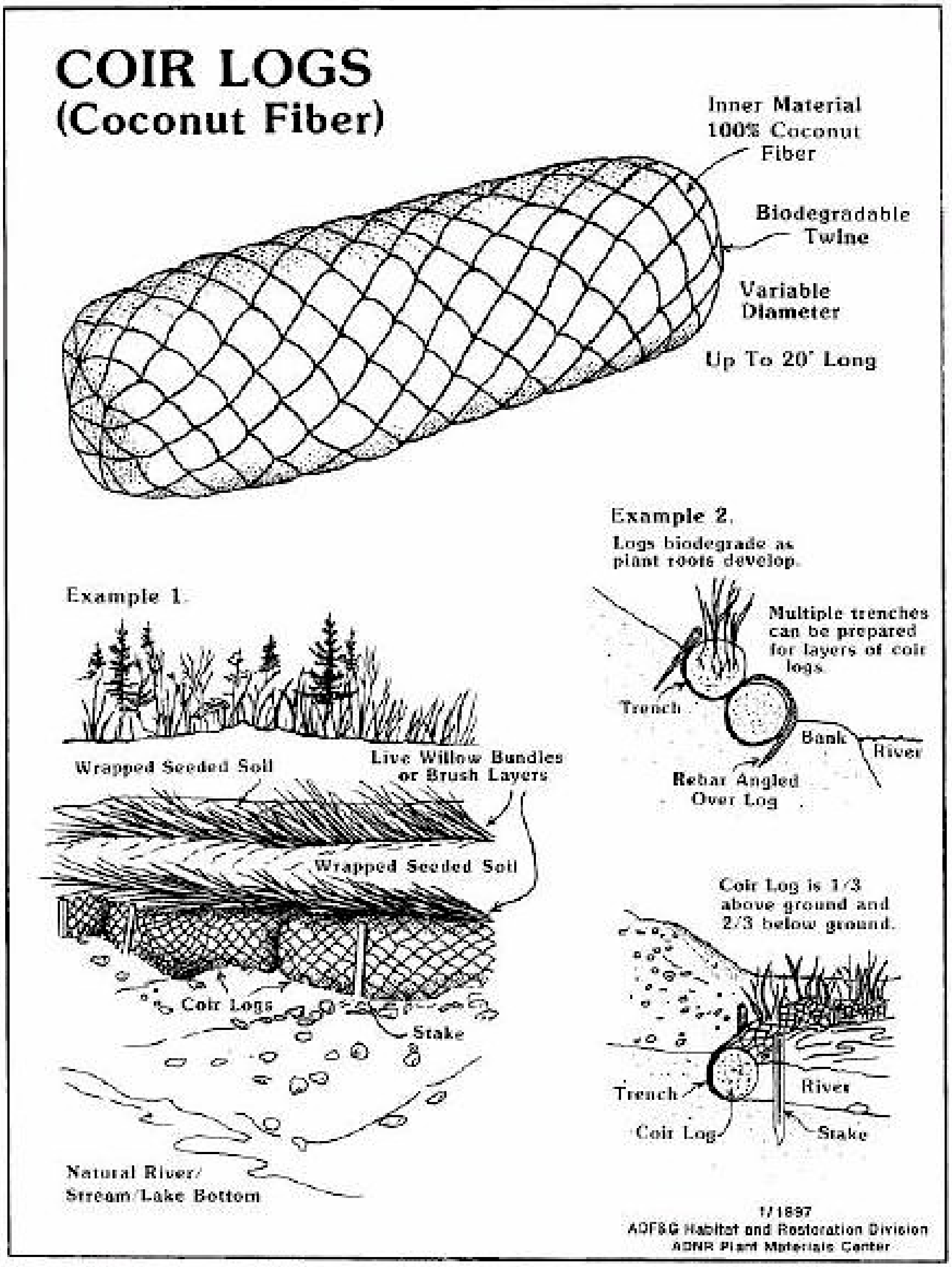

(v)

Run-off trap using fallen logs and rocks

Stream-bank Stabilization

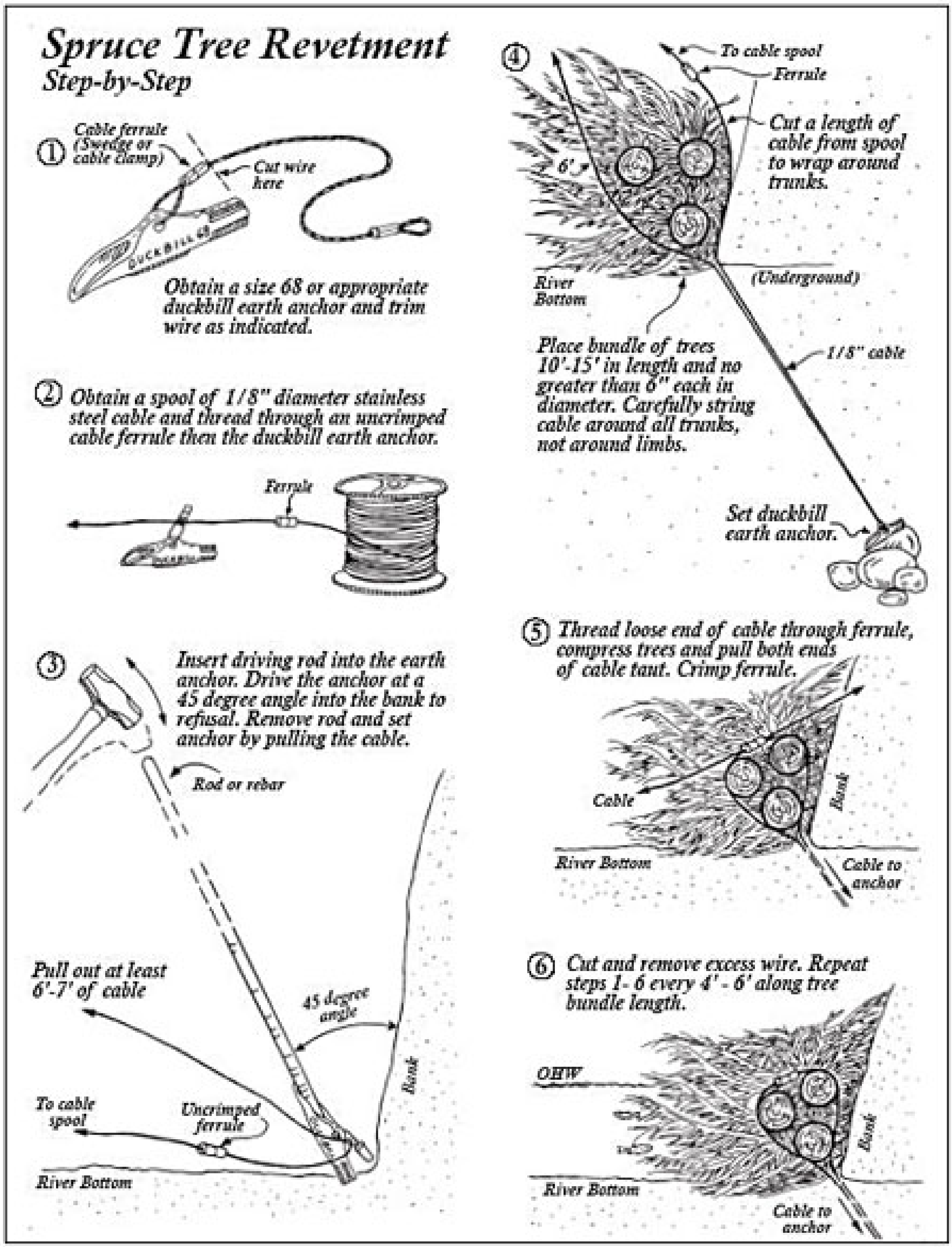
Coir Logs
Coir logs supply protection to a stream-bank from erosion in areas with a low-velocity current. They are secured at the toe of the slope using wooden stakes. The logs provide a growing medium for newly installed vegetation. Seeds or cuttings are installed into the log. As the coir log begins to biodegrade, the plants establish their root system into the bank helping to stabilize the stream-bank against erosion.




COIR LOGS
(Coconut Fiber)
Inner Material
100% Coconut
Fiber
Biodegradable
Twine
Variable
Diameter
Up To 20' Long
Example 2.
Logs biodegrade as
plant roots develop.
Multiple trenches
can be prepared
for layers of coir
logs.
Trench
Bank
River
Rebar Angled
Over Log
Example 1.
Wrapped Seeded Soil
Live Willow Bundles
or Brush Layers
Wrapped Seeded Soil
Coir Logs
Stake
Natural River/
Stream/Lake Bottom
Coir Log is 1/3
above ground and
2/3 below ground.
Trench
River
Coir Log
Stake
1/1997
ADF&G Habitat and Restoration Division
ADNR Plant Materials Center

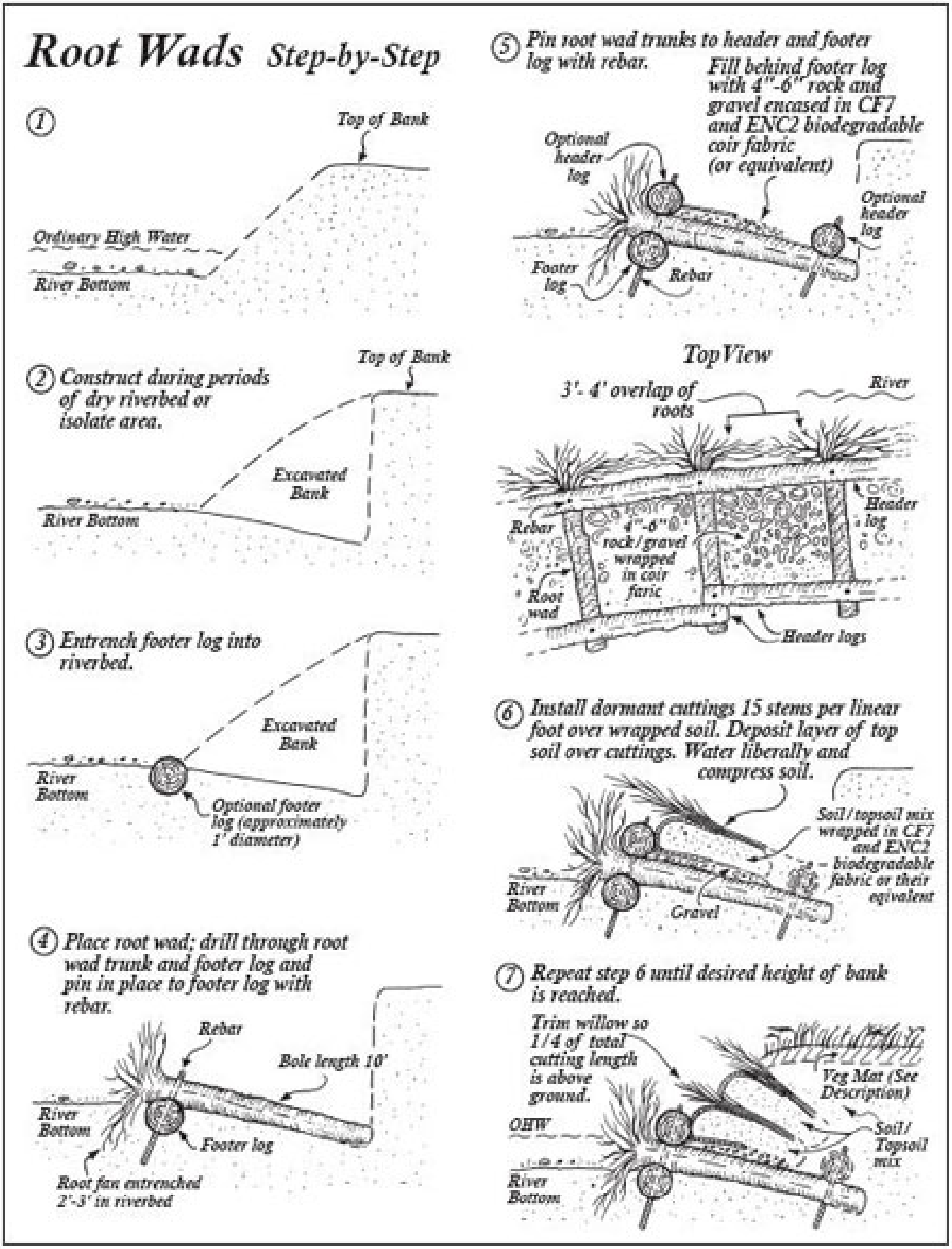
Tree Revetments

Tree revetments are installed into the steam-bank using a cable duckbill anchor system. Layers of trees are criss-crossed together usually using multiple layers. The trees revetments slow the current along stream-bank. This decreases erosion and provides habitat for fish and wildlife. Overtime the tree revetment decays, increasing sediment buildup. This provides a medium for vegetation to establish a seed bank. Eventually, the stream-bank is stabilized by the roots of the newly established vegetation.



Root Wads

Root wads are a portion of the trunk of a tree attached to its root mass. They are driven into the stream-bank and orientated upstream at a 90° angle. They are used to protect a stream-bank by deflecting currents away from the bank. They also provide structural support to the stream-bank, and habitat for fish and wildlife. Overtime sediment builds up around the root wad providing stabilizing the bank. Used for high-velocity streams.



Compiled By: Kelly Sutton and Ryan Williams

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Appendix C

Farm Pond
Lake Management Assessment

Prepared for:

The Town of Sherborn, MA, and the Farm Pond Advisory Committee

Revised April 8, 2026

Prepared by:

Hillary Kenyon, M.S.
Certified Lake Manager #17-07M (NALMS)
Applied Watershed Sciences LLC

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Overview

Farm Pond is a cherished water resource. It is a natural glacially-formed kettle lake in eastern MA. The lake is roughly 125 acres and has a watershed of approximately 436 acres, including the lake itself. The Town of Sherborn and its Farm Pond Advisory Committee (FPAC) have done a phenomenal job of maintaining valuable volunteer water quality and aquatic invasive plant monitoring programs. Prior to about 2019, the lake had excellent water quality and clarity, but it has recently experienced increased cyanobacterial Harmful Algal Blooms (HABs) that disrupt public health, recreation, and the local ecology. The Town of Sherborn contracted with Applied Watershed Sciences (AWS) to conduct a Farm Pond Lake Management Assessment & Watershed-Based Plan (WBP). The overall goal of the plan was to identify the causes of reduced clarity and cyanobacteria blooms and to develop a plan to manage excess nutrients.

In addition to reviewing historical volunteer data, AWS conducted detailed water-quality field assessments of the lake in 2023 and 2024. This Farm Pond Lake Management Assessment is provided alongside a formal Watershed-Based Plan (WBP). Combined, the two documents review Farm Pond water quality, aquatic plants, and nutrient loads, which have been used to develop management action items for future Farm Pond management.

Although Farm Pond has had a few dramatic cyanobacteria blooms, most notably in 2021 and 2022, the lake generally has excellent surface water quality throughout much of the year. There were no lake-wide blooms during the 2023 or 2024 seasons. Residents reported a limited shoreline surface bloom on August 25, 2025. This bloom prompted MA Department of Public Health to recommend that the Sherborn Board of Health post a swimming advisory for two weeks.

The data assembled in this report provide key insights into what drives poor water quality and how to predict if and when Farm Pond may have future blooms. Specific circumstances exacerbated by climate change leave the lake in a vulnerable position, where dramatic shifts in surface water quality can occur due to in-lake nutrient recycling.

Continued watershed management is essential to the long-term health of Farm Pond. Yet, in-lake data presented in this report demonstrate that nutrient recycling from lake sediments has reached a critical tipping point, posing a long-term threat to surface water quality and public enjoyment of the lake. It is unlikely that cyanobacteria bloom risk can be sufficiently mitigated by watershed management alone; thus, in-lake management is recommended in conjunction with watershed nutrient-reduction strategies.

The following section of this report provides an executive summary of the findings, insights, and proposed management action items within this report. This summary refers to terms used and defined later in the publication, which are also listed in the list of scientific terms in Appendix A.

Farm Pond is an interconnected ecological system in which humans, wildlife, and public health intersect. Lake management seeks to harmonize ecological preservation and the human use and enjoyment of water resources. In practice, lake management is a community health and ecosystem resilience endeavor that must balance ecological, social, and economic priorities to ensure water resources are sustained for generations to come.

Executive Summary

1. Cyanobacteria blooms occur at Farm Pond, but the incidence and severity of blooms are not consistent from season to season. The severe bloom conditions that the Pond experienced in 2022 were not observed during the 2023 and 2024 study period.

2. The data suggest the primary cause of the 2022 severe cyanobacteria bloom was a result of internally-released sediment phosphorus (P), related to a higher volume of anoxic area coupled with a potential wind event that caused partial water column mixing. Such an event would bring deep-water nutrients to surface waters. There was no high-resolution temperature logger data from 2022 to evaluate, but the temperature logger data from 2023 and 2024 indicate that such a mid-summer mixing event is possible.

3. Farm Pond maintained excellent open water clarity in 2023-2024, exceeding 6.0m across numerous sampling visits. Volunteer data from 2025 indicate that clarity was not as good and did not exceed 6.0m.

4. The relationship between rainfall and open-water clarity can be evaluated, but it was not part of the scope of work of this project. It would require volunteers to schedule additional water-quality monitoring visits to the lake on the day before and the day after a major storm event.

5. The use of continuous temperature, conductivity, and dissolved oxygen sensors in the water column provided key information used to define early-season metrics that may indicate higher chances of cyanobacteria blooms later in the summer.

6. Long-term dissolved oxygen (DO) monitoring data suggest anoxic bottom-waters occur annually, but that Farm Pond may have recently reached a tipping point where the volume of anoxic water in some years threatens overall surface water quality by stimulating P release from larger sediment areas.

7. Farm Pond normally has very low surface water nutrients: Total Phosphorus (TP) and Total Nitrogen (TN). Yet there is a seasonal accumulation of high nutrient concentrations beneath the summer thermocline due to anoxic release from lake sediments.

8. The internal P load estimate provided in this report is considered an average. In reality, that load can be higher if various physical (temperature, wind, oxygen) lake conditions exist in a given season. Internal P load was estimated to be approximately 25% of the annual total P load from all sources, including watershed sources identified in the Watershed-Based Plan (WBP).

9. Management options for in-lake internal P load control were reviewed. The primary options are phosphate-binding treatments (e.g., aluminum sulfate) and/or hypolimnetic oxygenation or aeration. The costs associated with various dosages and treatment areas are provided. It is not essential for the Town to act immediately on internal P load management, but if the Town wishes to pursue treatment(s), additional sediment sampling and lab tests are recommended prior to submitting a permit application for either alum treatment or oxygenation. Ideally, the Town Lake consultant would work alongside a selected potential implementation contractor.

10. The water level of Farm Pond is a concern that will continue to be monitored throughout the years. Persistently low water levels could increase the incidence of cyanobacteria blooms.

11. This study effort included volunteer watershed stormwater sampling of six areas. Runoff data and general watershed observations were incorporated into the accompanying Watershed-Based Plan (in a separate document). The primary threat to stormwater runoff to Farm Pond is from directly connected impervious cover, primarily along the Town roads and in areas where there may be future construction activities. The primary goal to reduce runoff is to 'disconnect' impervious cover, so that runoff can be adequately treaded via infiltration (water soaks into and is filtered by native soil) wherever possible. Several sites are identified in the WBP. Topsoil erosion during active construction has been documented during small-scale driveway, garden, and grading projects in the watershed. Even small amounts of top-soil erosion are a nutrient-load concern.

12. Waterfowl and geese are an unusually high source of P to Farm Pond, due in part to the watershed load being so low compared to many other lakes in MA. Waterfowl was estimated to be nearly 12% of the total annual P load. Scare-tactics, preventing geese reproduction, and ensuring that geese poop on moored boats and docks does not end up in the lake are primary management measures recommended in the WBP. Experimental use of manufactured geese floating vegetated 'islands' are also discussed in the WBP.

13. Septic systems and direct urination in the lake present a combined similar P load of roughly 10.6%. Atmospheric load was estimated to be 13.1% of the annual total. Management options for wastewater are to ensure that all old shoreline systems are brought into compliance with Title V standards, and/or certified as functioning properly with regular inspections. The Town community restroom facility is far enough away in elevation and distance from the shore, that the P load was estimated to be relatively low, yet it should still be prioritized for updated compliance because it is difficult to determine if such a system short-circuits at all via bedrock fractures below the soil treatment area.

14. The aquatic plant survey found no aquatic invasive species present in 2023. Volunteers found and hand-removed a new invasive Water chestnut (Trapa natans) plant near the Town beach in 2024; it did not return in 2025.

15. Prevention and containment strategies for aquatic invasive species (AIS) are outlined in this report. Farm Pond is extremely vulnerable to invasion by invasive plants. Rapid response is essential. The threat of new AIS to Farm Pond is equal to, if not greater than, the threat of cyanobacteria blooms.

16. The highest priority FPAC monitoring recommendations include the following:

    a. Ice-out nutrients sampling annually; fall-turnover sampling annually
    b. Pre- and post- storm event sampling during summer
    c. Maintain ongoing volunteer monitoring program
    d. Formal aquatic plant surveys every 3 years, with volunteer weed watchers annually
    e. Metalimnetic algae and/or fluorometry sample collection when dissolved oxygen peaks in the middle of the water column in summer
    f. Digitize the existing bathymetric map in GIS
    g. Site inspections for active ground-disturbance construction in the watershed
    h. Proceed with initial pre-permitting steps for alum treatment plan and/or oxygenation

Water Clarity

A **Secchi disk**, an 8-inch circular black-and-white disk attached to a measuring tape, is commonly used to measure water clarity. FPAC volunteers have been measuring water clarity since 1998. The Secchi disk is lowered into the water on the shady side of the boat and observed using a view scope to shade out light in one's peripheral vision. The depth at which the Secchi disk disappears from view is considered the water clarity depth measurement. The view scope is essential for recording excellent clarity and seasonal changes; all historical and present Farm Pond Secchi measurements were taken using a view scope.

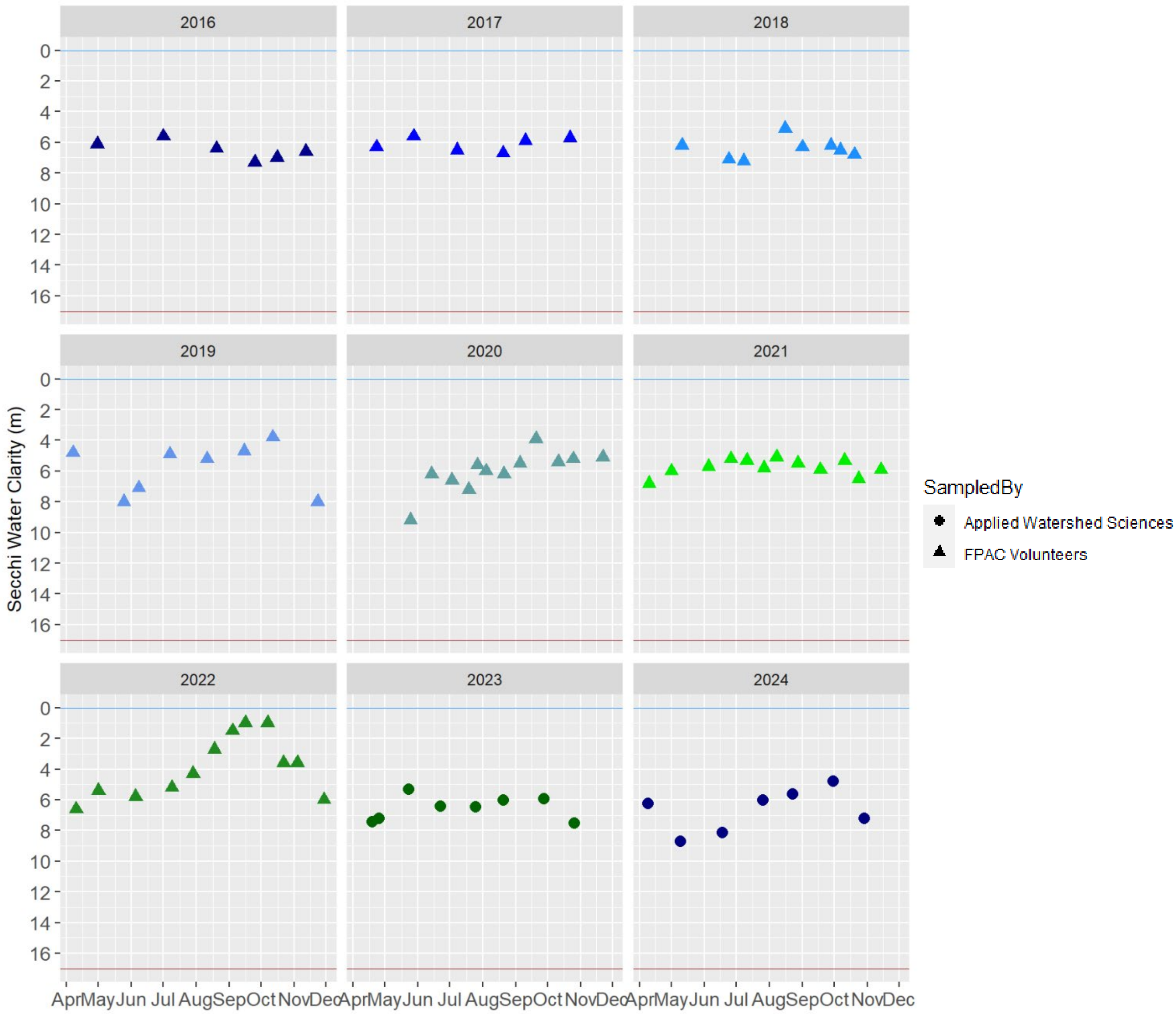
The historical FPAC clarity data demonstrates slight variation between users. Volunteer observations were collected by two individuals. Field measurements were repeated for quality control whenever individual measurements differed by more than 10%. It is normal to have upwards of 0.25-0.5 meters of difference between user readings taken under the same field conditions. When historical FPAC Secchi clarity data is shown in this report, the values are the daily averages as recorded by multiple volunteer monitors.

Secchi transparency is a measure of light penetration, related to water column turbidity. Phytoplankton, suspended sediments, and microscopic organic matter influence light penetration and water turbidity. Clearer waterbodies possess higher Secchi transparency values. Open-water measurements greater than 6 meters (19.7ft) indicate clear water and generally correlate to low phytoplankton chlorophyll in the water column. In comparison, measurements less than 2 meters (6.6ft) indicate a high likelihood of impaired water quality and an increased risk of harmful cyanobacterial blooms or very high levels of non-algal particulates.

Secchi clarity is often lower in near-shore areas compared to central open-water monitoring sites, so one cannot directly compare the clarity at a shoreline dock to a measurement taken in open water. There is naturally increased algal and non-algal turbidity in near-shore zones, often due to bottom disturbances and increased availability of nutrients. Secchi monitoring at Farm Pond is done offshore, at or near the deep-hole zone, termed Station 1 (St1). Offshore conditions are more stable and representative of the whole lake.

Secchi clarity fluctuates throughout the season, especially for larger waterbodies. At least monthly water clarity monitoring from April to October is recommended. Secchi disk measurements are the simplest and most affordable method of tracking water quality and serve as the foundation for many volunteer monitoring programs.

Figure 1. Deep Site (St1) Secchi Water Clarity (m) 2016-2024



From 2016 to 2024, the water clarity at Farm Pond, as demonstrated in **Figure 1**, has almost always been greater than 4 meters. Note that the figure is inverted to visualize the 0-meter depth as the top of the water column. The more recent data is compared against the long-term Secchi clarity measurements in **Figure 2.** The most recent 2025 FPAC data is shown in **Figure 3.** In all three figures, the brown horizontal line at 17m represents the lake bottom at the deep (St 1) monitoring site.

There are years where the lake experienced excellent water clarity in May and June, but these spring ‘clear-water’ phases do not appear consistent and may have both physical and biological drivers. High populations of large-bodied zooplankton that eat phytoplankton can improve water clarity for short periods. The initial onset of thermal stratification in late spring also often results in increased clarity due to phytoplankton succession and particulate settling. The development of water column temperature gradients influences which types of phytoplankton remain dominant in surface waters. Historically, summer clarity at Farm Pond is commonly between 5 and 7 meters.

The 2022 algae and cyanobacteria bloom period is evident (**Figure 2**), with clarity diminished to less than 2 meters. This 2022 lakewide bloom, along with initial documented smaller shoreline blooms in 2020 and 2021, prompted the more in-depth lake and watershed assessment in 2023 and 2024.

Figure 2. Long Term Secchi Monitoring Data 1998-2025

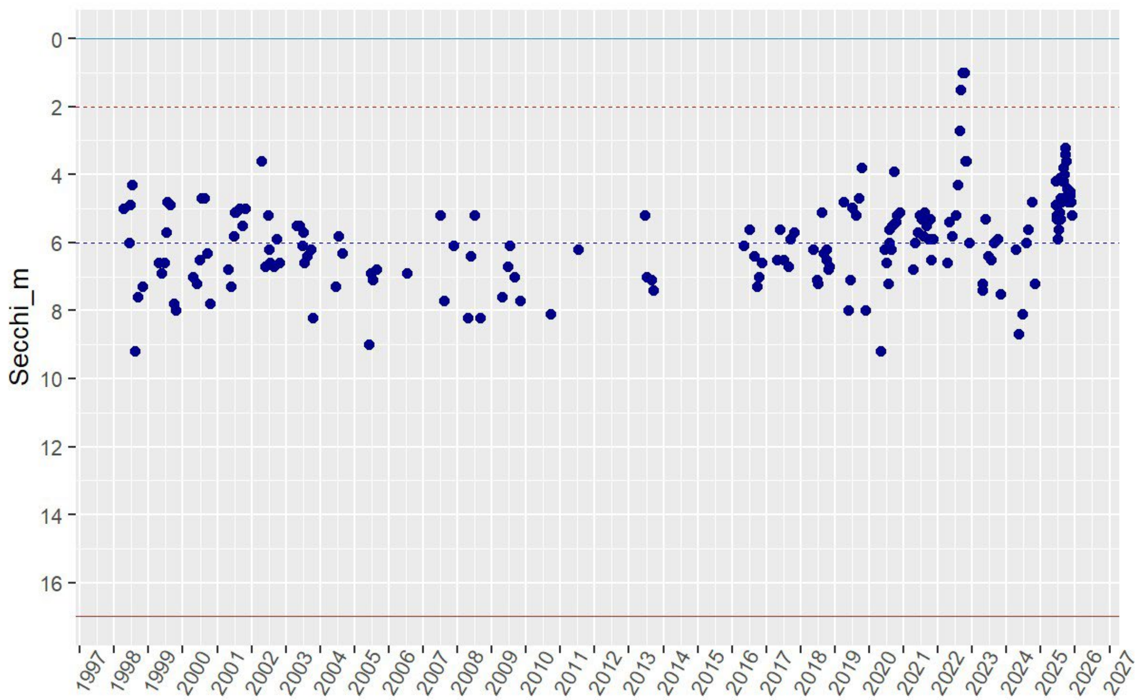
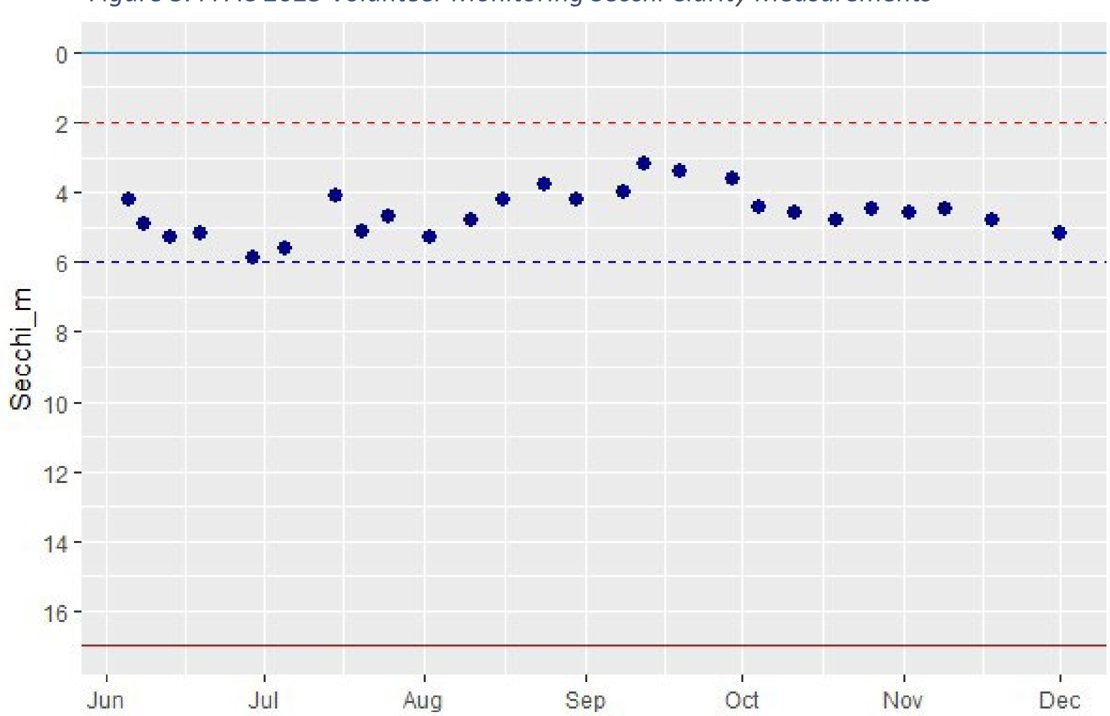


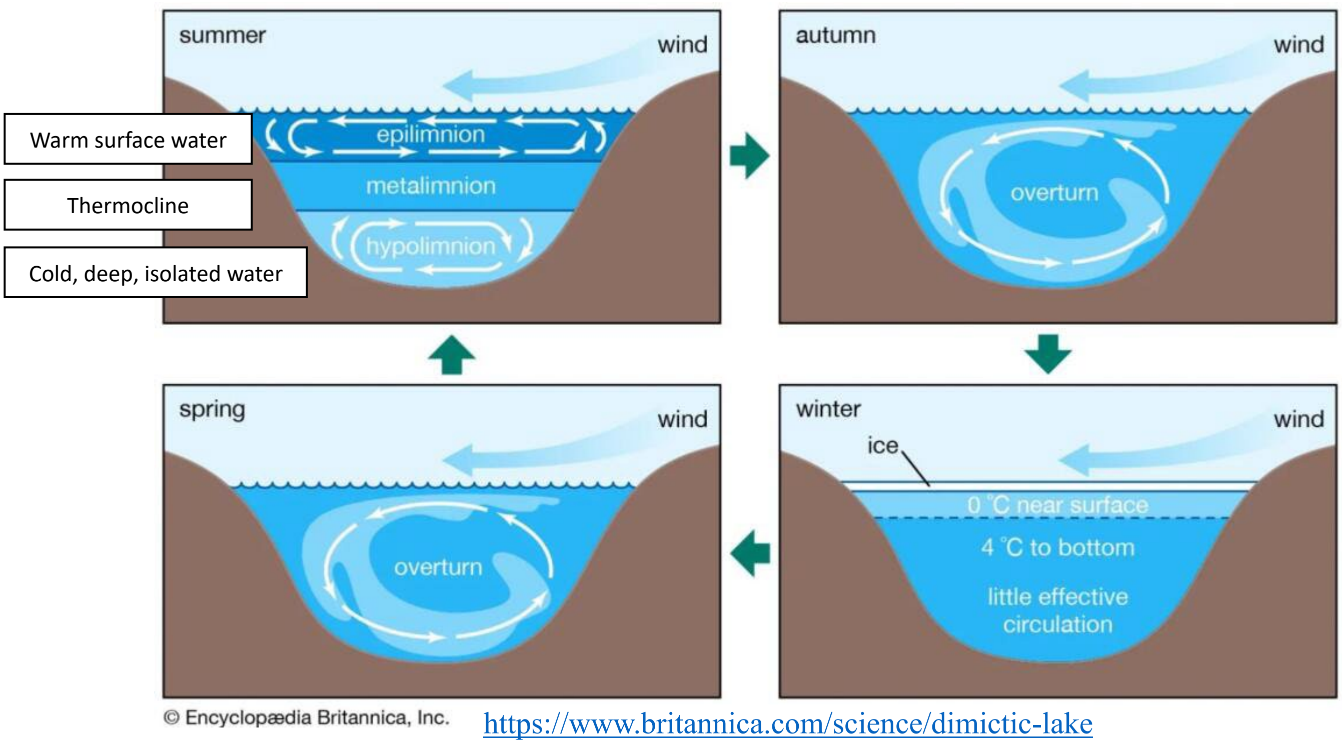
Figure 3. FPAC 2025 Volunteer Monitoring Secchi Clarity Measurements



Temperature

<u>Water temperature</u> in lakes and ponds in the northeast follows a semi-predictable seasonal pattern of warming and cooling. In early spring, following ice melt, lakes and ponds will exhibit a near-uniform temperature profile from top to bottom, indicating water-column mixing throughout. As the sun's rays penetrate the water column, the surface waters warm faster than the bottom waters, resulting in the development of a thermally stratified water column. This **thermocline**, defined as a zone of rapid temperature change with depth, depends on the overall waterbody bathymetry (depth contours), lake surface area, climatic conditions, and water clarity. A thermocline indicates a strong temperature-driven density difference between the water above and below. This zone is also referred to as the metalimnion. Warmer surface water is less dense than cooler water at the bottom of the lake, which triggers a cascade of changes in other lake parameters during the thermal stratification period.

Figure 4. Visual Demonstration of Lake Seasonal Stratification courtesy of Britannica



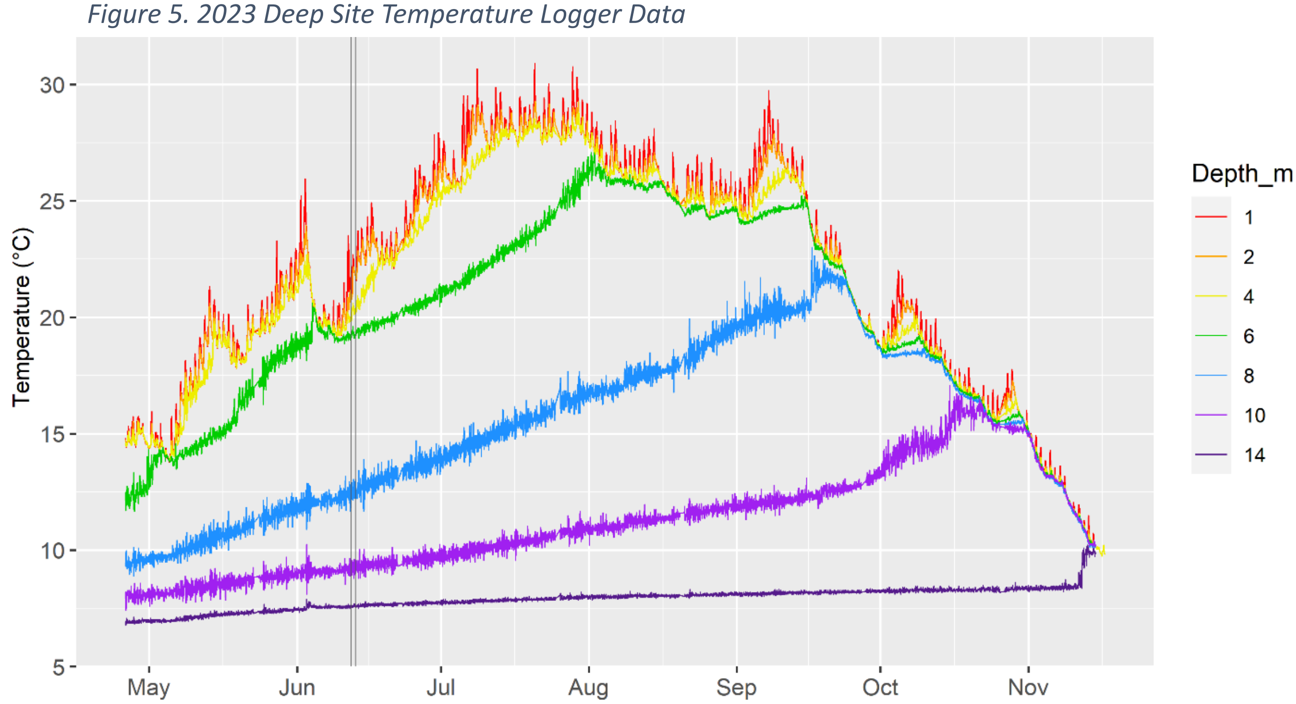
https://www.britannica.com/science/dimictic-lake

In the northeast, lakes typically experience thermal stratification from late May to October. In the fall, as air temperatures drop, lake water temperature also drops, weakening the thermocline and eventually leading to water "turnover." Lake turnover occurs when the temperature becomes uniform from top to bottom, and the thermocline disappears as the lake regains full water column mixing conditions in late fall. Shallow lakes may experience multiple thermal-mixing events (partial turnover) in a single season, but it takes more severe weather to cause partial mixing events in deeper lakes. Based on historical temperature profile data, Farm Pond exhibits classic dimictic status, mixing twice per year, once each in spring and fall (**Figure 4**). The summer stratification period causes loss of bottom-water dissolved oxygen because the thermocline acts as a barrier, temporarily isolating bottom waters.

As part of the 2023-2024 AWS lake assessment project, the Town of Sherborn funded the purchase and installation of high-resolution temperature data loggers. Data loggers were set to record data at 30-minute intervals throughout the water column at the deep site and two shallower sites. The temperature sensor array at the deep site was deployed to capture short-lived anomalies associated with wind, rain, heat waves, and other weather events. Short-lived weather anomalies can have dramatic impacts on the lake and can stimulate cyanobacteria blooms. Additional temperature loggers were set to record in mid-depth waters, which often serve as a seed bank for cyanobacteria resting/overwintering cells on and near the sediment surface. Research suggests that cyanobacterial cell germination and sediment-attached vegetative growth are temperature-dependent, and that temperature also influences the timing of recruitment to the water column and potential surface accumulations. Sediment-derived "pop-up" blooms can occur in oligotrophic lakes, despite the overlying water column having low nutrients, because cyanobacteria can access nutrients from littoral sediments. However, there were no notable cyanobacteria blooms in 2023 or 2024 to which to test this at Farm Pond. During this period, there were only minimal accumulations of surface cyanobacteria in stagnant water near the Sherborn Yacht Club, which dissipated within a day or so.

AWS maintained and serviced the deep-water temperature sensor array during the monitoring visits in 2023 and 2024. The accuracy and precision of the loggers were verified upon installation and during fall turnover, when all loggers recorded the uniform temperatures in December 2024. The high-resolution temperature data are shown in **Figure 5** (2023) and **Figure 6** (2024), with each line indicating temperature at a water depth where a monitoring device was placed. The array was kept taut and vertical within the water column by strong anchors and surface buoys. There was a lapse in temperature data in 2024 following the loss of the array hardware. The subsequent replacement array was installed with fewer sensors than the original.

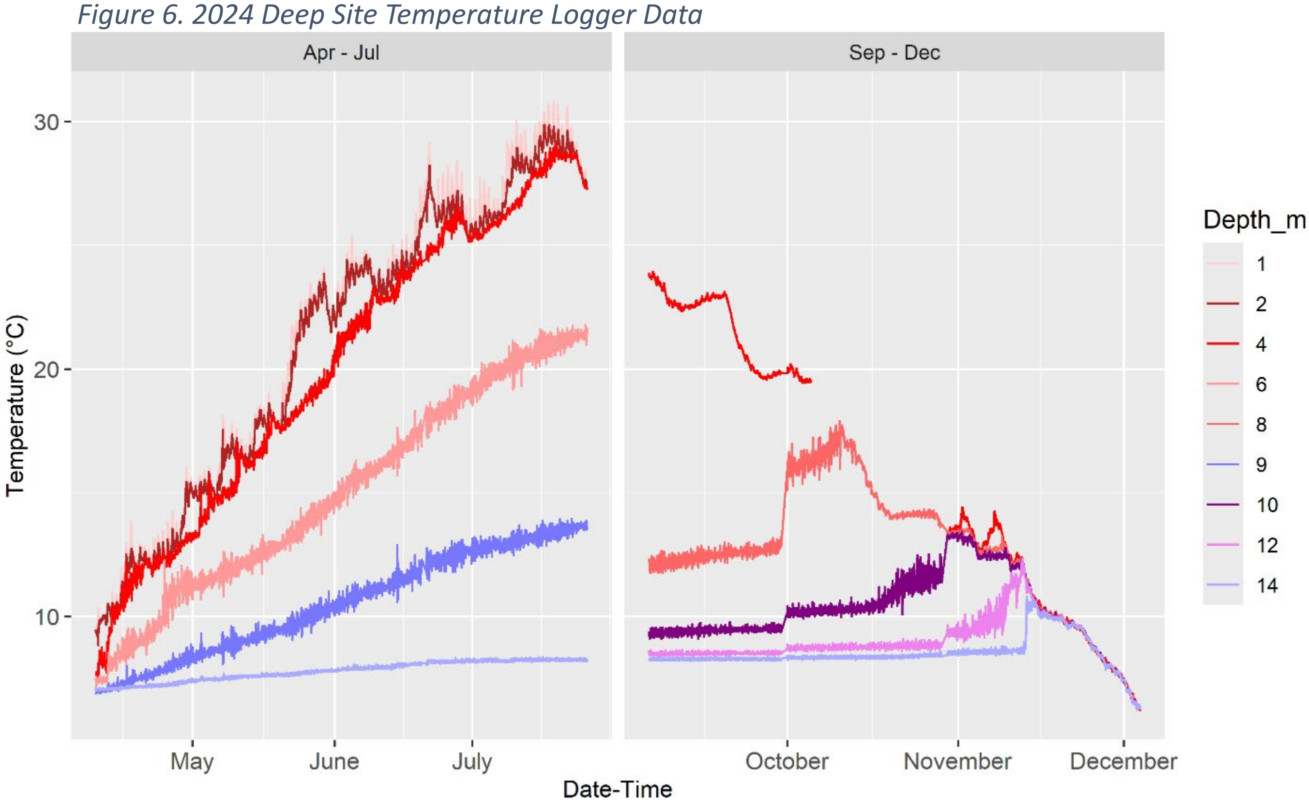
Figure 5. 2023 Deep Site Temperature Logger Data



An anomalous event occurred in June 2023, marked in **Figure 5** by the vertical grey lines, where a bright orange scum was noted on the northern shoreline. The unusual bloom was not cyanobacteria. The sample contained what appeared to be precipitated iron minerals. This event occurred after a notable partial mixing of the water column several days earlier. The 2023 temperature data plots indicate that there were no temperature mixing events during the summer that considerably disturbed water temperature at or below 8m. The 8m open-water logger data indicate a steady seasonal increase in temperature through September, until surface temperatures were considerably reduced. The erosion of the thermocline down to 8m is evident in the middle of September, while complete thermally mixed conditions were not reached until the middle of November 2023.

Two key metrics to watch during future high-resolution temperature monitoring are the 6m and 8m depths, and if and when they reach 20 °C. This temperature is repeatedly cited in the literature to favor *Microcystis* cyanobacteria growth, and it may play a role in what phytoplankton dominates the metalimnion in a given year. In 2023, the 6m depth reached 20 °C in early June, while in 2024, that threshold was not reached at 6m until the beginning of July. The 8m depth did not reach 20 °C until September 2023, and it is uncertain whether that temperature threshold was reached in 2024. Higher temperatures in this depth range will likely increase phosphorus release rates from mid-depth sediments if they lose dissolved oxygen during a given season.

Figure 6. 2024 Deep Site Temperature Logger Data



Earlier onset of stratification with above-average air temperatures and warmer spring temperatures will negatively impact Farm Pond's seasonal loss of bottom-water dissolved oxygen. The relationship is explained further in the following Dissolved Oxygen section.

As part of this analysis, AWS determined that several key temperature thresholds can serve as early seasonal indicators for cyanobacteria bloom risk at Farm Pond. High-resolution temperature monitoring is considerably cheaper than high-resolution monitoring of other parameters, making temperature a cost-effective early warning indicator.

- If the open water deep site (St1) 4-6m water temperature exceeds 20 °C before the first week in June, the dissolved oxygen loss rate will be higher than usual, and the peak anoxia and internal nutrient load may be higher later that season.
- If the water column temperature below 6m drops at all in summer, it is likely due to a partial water column mixing event, spurred by either cool air temperatures or sustained wind events, that is large enough to mix hypolimnetic nutrients into the surface waters.
- If the water temperature at 10m reaches about 15 °C in summer, this indicates potential increased sediment P mineralization rates, higher phytoplankton growth rates in the metalimnion, and a higher likelihood of unusually high surface phytoplankton blooms (based on 2022 data).

The classic display of water column temperature profiles for 2023 and 2024 is shown in the **Figure 7** below. The thermocline (metalimnetic zone) during the summer months is about 6-12m deep. The seasonal increase in bottom temperature is less than 5 °C. Bottom water remains cold for the entire season, while the 10m zone increases about 6 to 9 °C from May to the end of October.

Figure 7. St1 Temperature Profiles 2023-2024

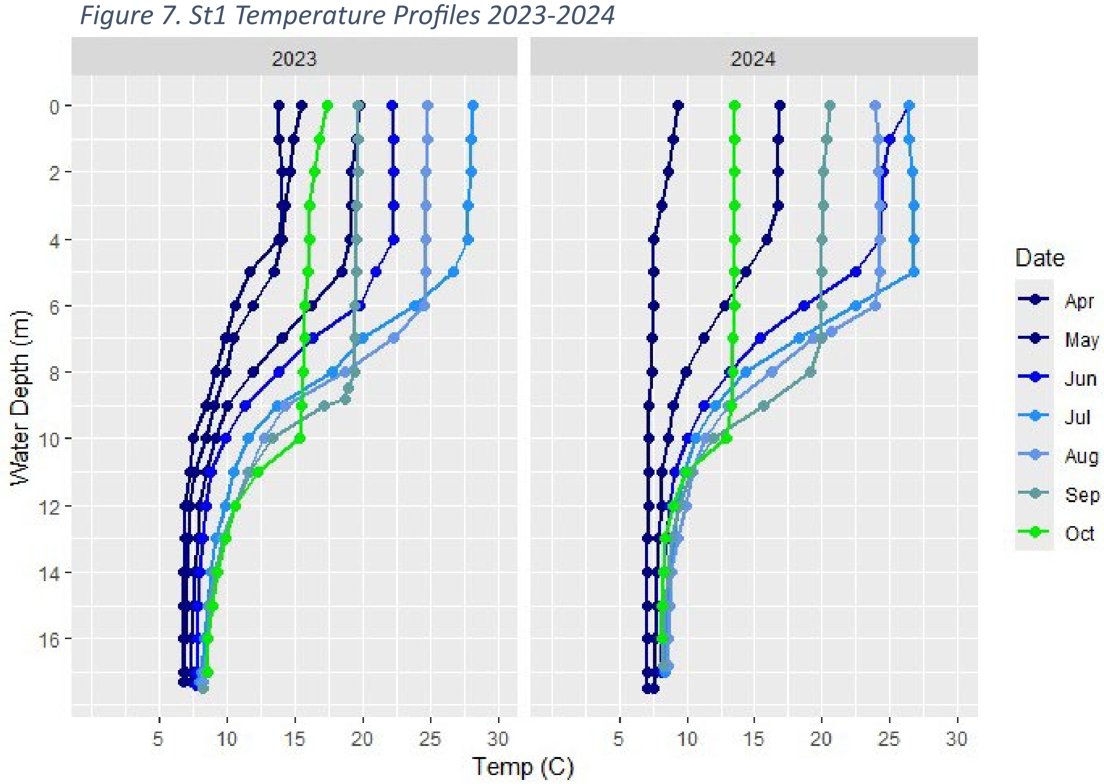


Figure 8 displays the annual progression of temperature below 7-meters. This figure makes it easier to see if particular years stand out for earlier warming of the lower water column.

Figure 8. 2016-2024 Meta-Hypolimnetic Seasonal Temperature (>7m deep profile data)

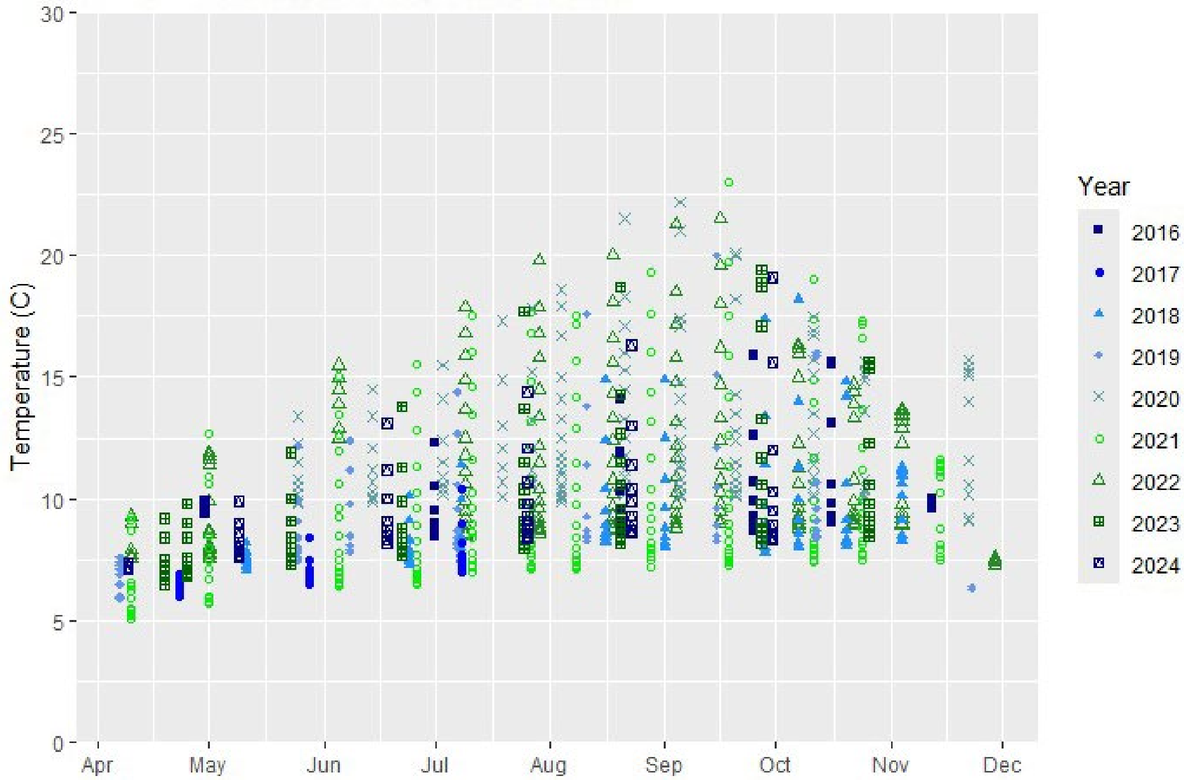
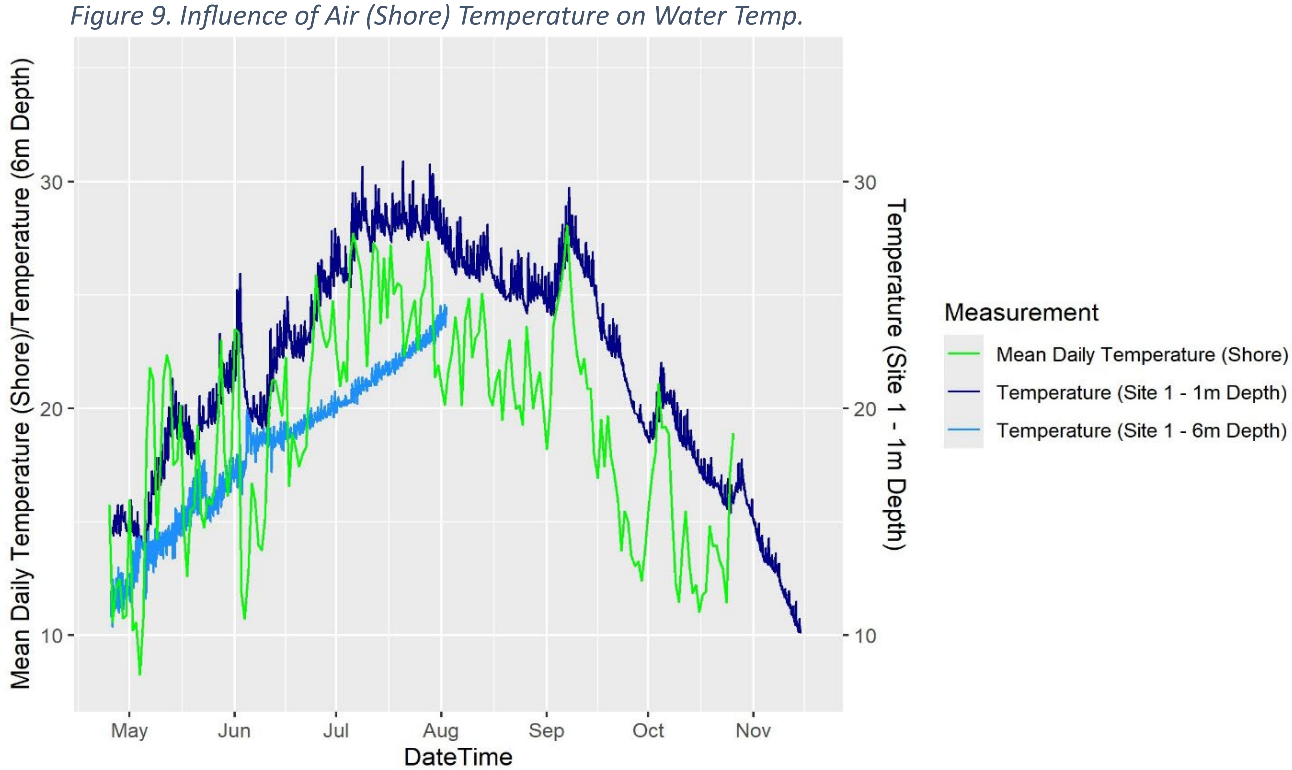


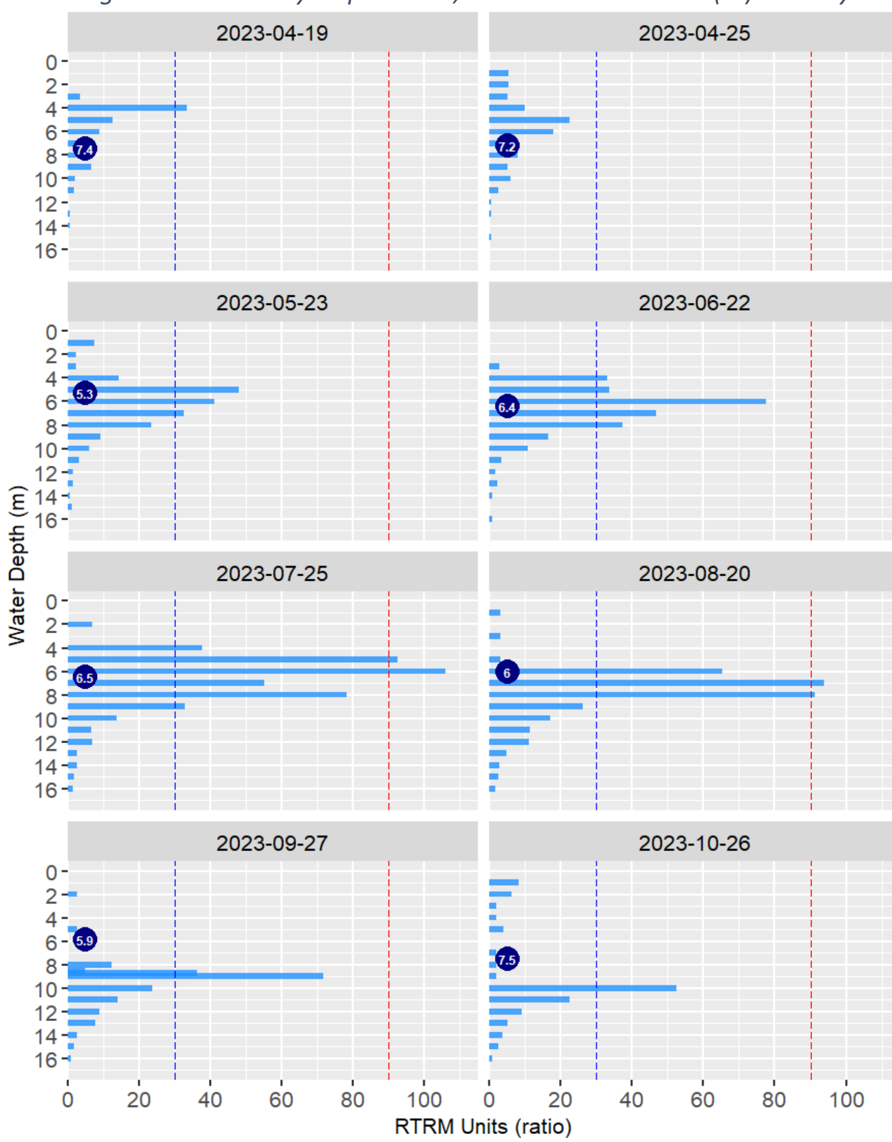
Figure 9. Influence of Air (Shore) Temperature on Water Temp.



Relative Thermal Resistance to Mixing

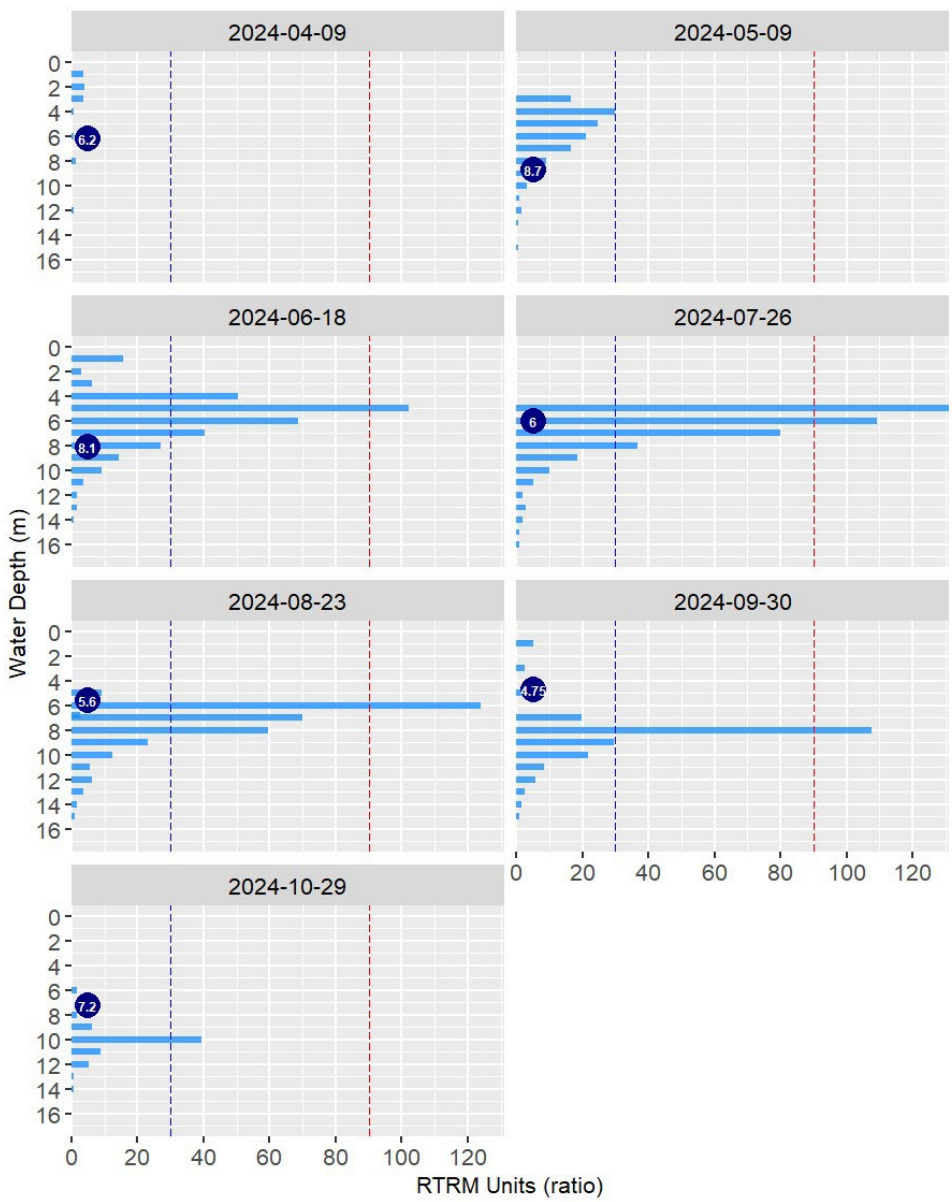
<u>Relative Thermal Resistance to Mixing (RTRM)</u> is a unitless index that quantifies a lake's resistance to vertical mixing due to temperature stratification. It measures how much energy is required to mix the water column against the temperature-driven density gradients between each layer of water. A higher **RTRM** indicates stronger thermal stratification and greater resistance to mixing, while a lower **RTRM** suggests weaker stratification or well-mixed conditions. RTRM is useful in limnology to assess seasonal thermal dynamics, lake stability, and the potential for nutrient mixing from deeper waters. A value of greater than 30 typically represents a weak thermocline condition, while values over 90 are very strong thermocline conditions. RTRM values graphed here provide a visual representation of the strength and width of the seasonal thermocline over time. It is also a useful method for quantifying changes in the thermocline over many years and for demonstrating the impacts of climate change on a lake's thermal structure over time.

Figure 10. RTRM by Depth 2023, w. Secchi Data Point (m) Overlay



RTRM values are also useful to compare short-term weather impacts on Farm Pond. There is also often a relationship between summer water clarity and the depth of the thermocline due to the tendency of phytoplankton to accumulate in the metalimnion in lakes with low epilimnetic nutrient concentrations, like Farm Pond. Certain types of phytoplankton preferentially occupy the middle of the water column where they have access to both light and nutrients (nutrients from settling decomposing organic matter and from the hypolimnion). The Farm Pond thermocline depth deepens in late August and September, and the water clarity decreases (**Figure 11).** Cyanobacterial blooms can be stimulated at the onset of thermocline deepening and erosion, particularly when the anoxic boundary rises above the thermocline depth. This did not occur at Farm Pond in 2023 or 2024, but it occurred in 2022 and was followed by epilimnetic re-stratification in early October 2022, which exacerbated surface cyanobacterial bloom formation.

Figure 11. RTRM by Depth 2024, w. Secchi (m) Overlay



Dissolved Oxygen

Dissolved oxygen (DO) is an essential parameter for aquatic life and plays a critical role in the health of a lake. DO levels vary throughout the water column and season. It is influenced by temperature, plant and algae productivity, and aerobic (oxygenated) respiration processes, including the decomposition of organic mud at the lake bottom. In general, DO levels are highest in the spring and fall when the water is well-mixed and absent at the bottom of Farm Pond in summer when the lake is thermally stratified. The thermocline acts as a barrier to oxygen transfer between the surface and bottom of the lake, leading to low summer DO levels in the hypolimnion, also known as the bottom layer of the lake.

Physical water-column stratification and consumption of bottom-water DO during summer result in **anoxic** (< 1 mg/L DO) conditions in the deeper waters of many lakes. Such conditions change the bottom nutrient chemistry at the sediment surface. It is critical to track oxygen loss beneath the thermocline and/or the level of anoxia**,** because, as alluded to in the temperature section, DO loss has implications for surface-water cyanobacteria and algal conditions. The **anoxic boundary** is the water depth at which dissolved oxygen is depleted to <1mg/L DO in the summer. Anoxic conditions spread from deep water to higher up in the water column, affecting a considerably larger volume of water towards the end of summer, just before fall's turnover.' At fall turnover, DO is replenished to the bottom in most northern lakes. Anoxia tends to worsen over time but is subject to weather and can be exceptionally worse or better in a given year. Less severe anoxia can also form under winter ice in some waterbodies, which could influence spring phytoplankton. The date at which bottom water becomes anoxic should be tracked at Farm Pond as an indicator of overall severity that might be predicted for the remainder of the season.

DO concentrations in lakes are reported in milligrams per liter (mg/L). A healthy lake should have DO levels of at least 6 mg/L throughout the water column to support most fish species, particularly in the epilimnion. However, DO levels can vary significantly depending on the time of day, weather conditions, and the lake's biological activity. Low DO levels are sometimes natural and not an immediate concern for specific waterbodies, often wetland-dominated systems. However, low DO levels can harm aquatic life in Farm Pond and stimulate harmful algal blooms by increasing phosphorus and nitrogen, the primary nutrients for plants and algae. This occurs when nutrients are released from sediments into the water column via internal recycling, driven by iron-phosphorus (Fe-P) complexation under anoxic conditions.

As part of the Farm Pond water quality analysis, AWS reviewed volunteer-collected profile data from 2016-2022. There were apparent differences among monitoring years. The DO saturation percentages, considering the direct effect of water temperature on DO, were not recorded directly by FPAC volunteers and should be in the future. The DO meter will have that information, helping to compare DO profiles over time by accounting for water temperature fluctuations. In some years, there were sustained metalimnetic peaks in dissolved oxygen. In 2024, the DO peak was very sharp, indicating highly concentrated phytoplankton cells occupying the metalimnion. In 2024, samples at the depth of peak DO indicated that non-cyanobacteria *Ceratium* (dinoflagellate) dominated the 2024 metalimnetic phytoplankton bloom. Yet, it is also common to see cyanobacteria occupying metalimnetic depths, particularly *Planktothrix* genera. Metalimnetic oxygen maximum (MOMax) ought to prompt deep-water phytoplankton sampling to determine if cyanobacteria are accumulating at that depth. This extra sampling would depend on FPAC volunteer time and resources.

Figure 12. Deep Hole St1 2023 Dissolved Oxygen Profiles

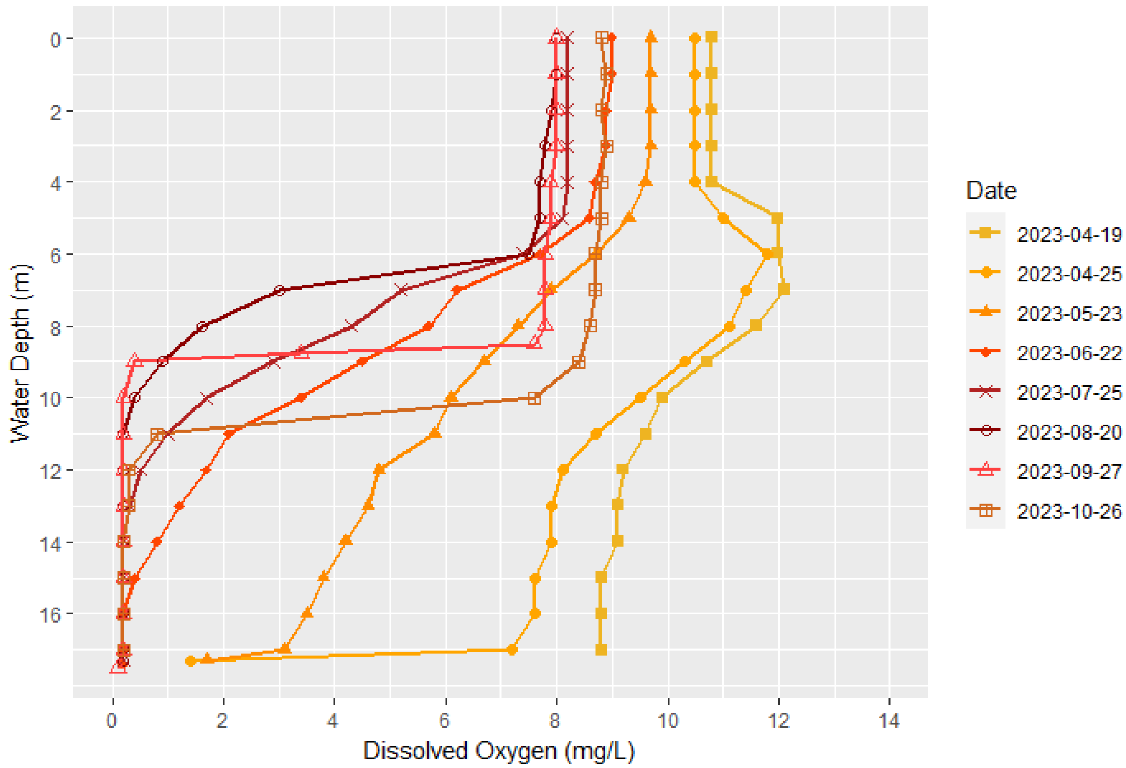
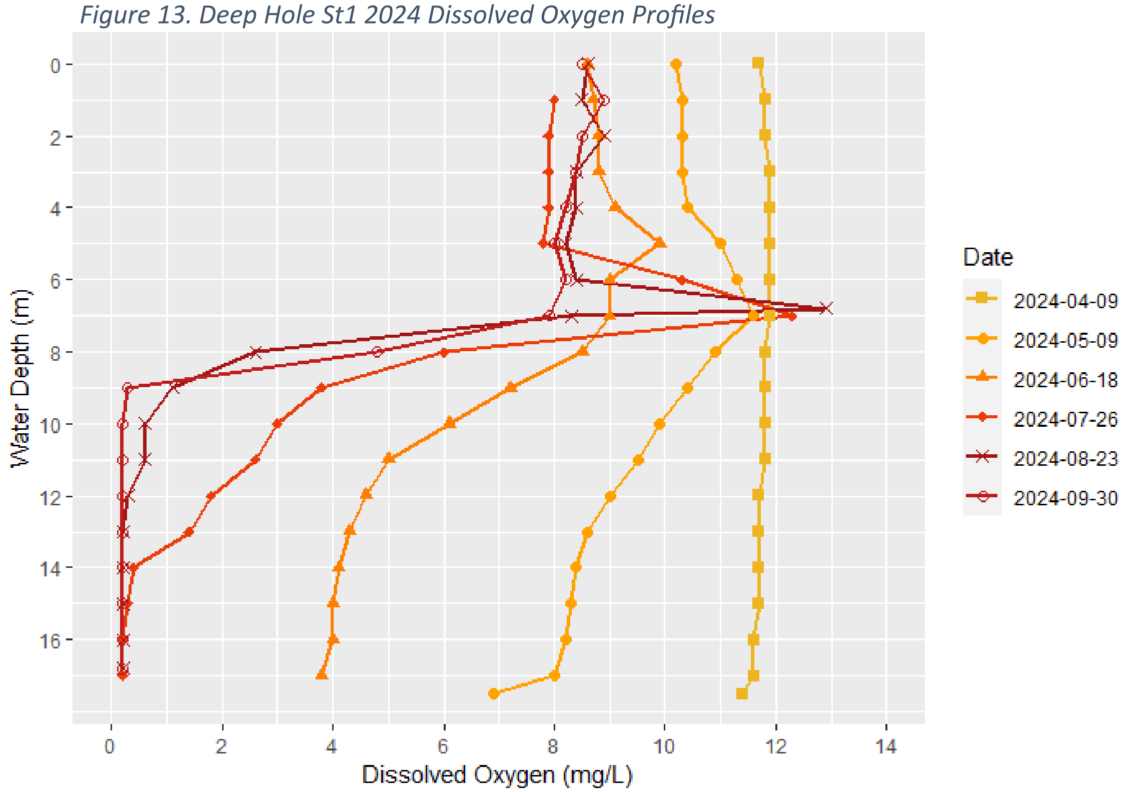


Figure 13. Deep Hole St1 2024 Dissolved Oxygen Profiles



Anoxic Zone Calculations

AWS used the historical FPAC data and 2023-2024 project DO data to estimate the approximate area and volume of anoxia throughout the season. Dissolved oxygen profiles collected by FPAC in 2020, 2021, and 2022 were compared to profile data collected in 2023-2024. The approximate depth of the anoxic boundary, if present, was used to predict the surface area and volume of the anoxic zone using a polynomial equation based on the lake hypsographic data. The depth vs. surface area and volume, based on bathymetry, as reported by FST 2015, are included in **Table 1.** The hypsographic curve and polynomial models are displayed in **Figure 14** and **Figure 15**. The resulting modeled anoxic area for each year is displayed in **Figure 16**. The modeled anoxic volume for each year is shown in **Figure 17.** These depth analyses were all based on the FST 2015 report, which relied on the detailed Farm Pond bathymetric map produced in 2003, from 500 GPS points collected and mapped by Adam Seering (**Map 1** on the following page).

The 2020-2021 anoxic area seasonal maximum was about 25% of the lake's total surface area. The 2022 peak was over 50 acres of anoxic sediments, roughly 41% of the lake's surface area that was then subject to anoxic release of sediment iron-bound phosphorus. The 2022 anoxia was considerably worse than in all other modeled years, leading to more than 20 additional acres of anoxic sediment surface that could contribute to greater internal phosphorus release via iron-bound phosphorus dissolution. This increase in P-contributing sediment was likely one of the driving factors in the considerable 2022 cyanobacteria blooms that plagued Farm Pond, prompting this project. Referring to the 2022 FPAC profile data, there was also evidence of a mid-summer 2022 partial water column mixing event in the temperature and dissolved oxygen data. Sustained winds can drive this type of mixing event. The greater anoxic area was shallow enough in 2022 to allow for a dramatically increased entrainment of sediment-derived nutrients into the surface waters during this partial mixing event. Though the specific weather patterns needed to cause lake-wide blooms as severe as 2022 appear unlikely in most years, the risk is elevated due to earlier spring warming and climate change.

Table 1. Farm Pond - Depth, Area, Cumulative Volume (total volume below depth)

Depth_m	Area_Cum_acres	Vol_Cum_acre-ft
0.00	126.0	2668.3
1.52	112.5	2072.2
3.05	93.2	1558.7
4.57	71.6	1148.0
6.10	56.9	827.6
7.62	45.8	571.5
9.14	34.5	371.5
10.67	24.1	225.8
12.19	15.7	127.2
13.72	10.8	61.5
15.24	5.7	21.1
16.76	2.0	2.7
17.98	0.0	0.0

Map 1. Bathymetric Map (Water Depth Contours; Adam Seering, 2003)

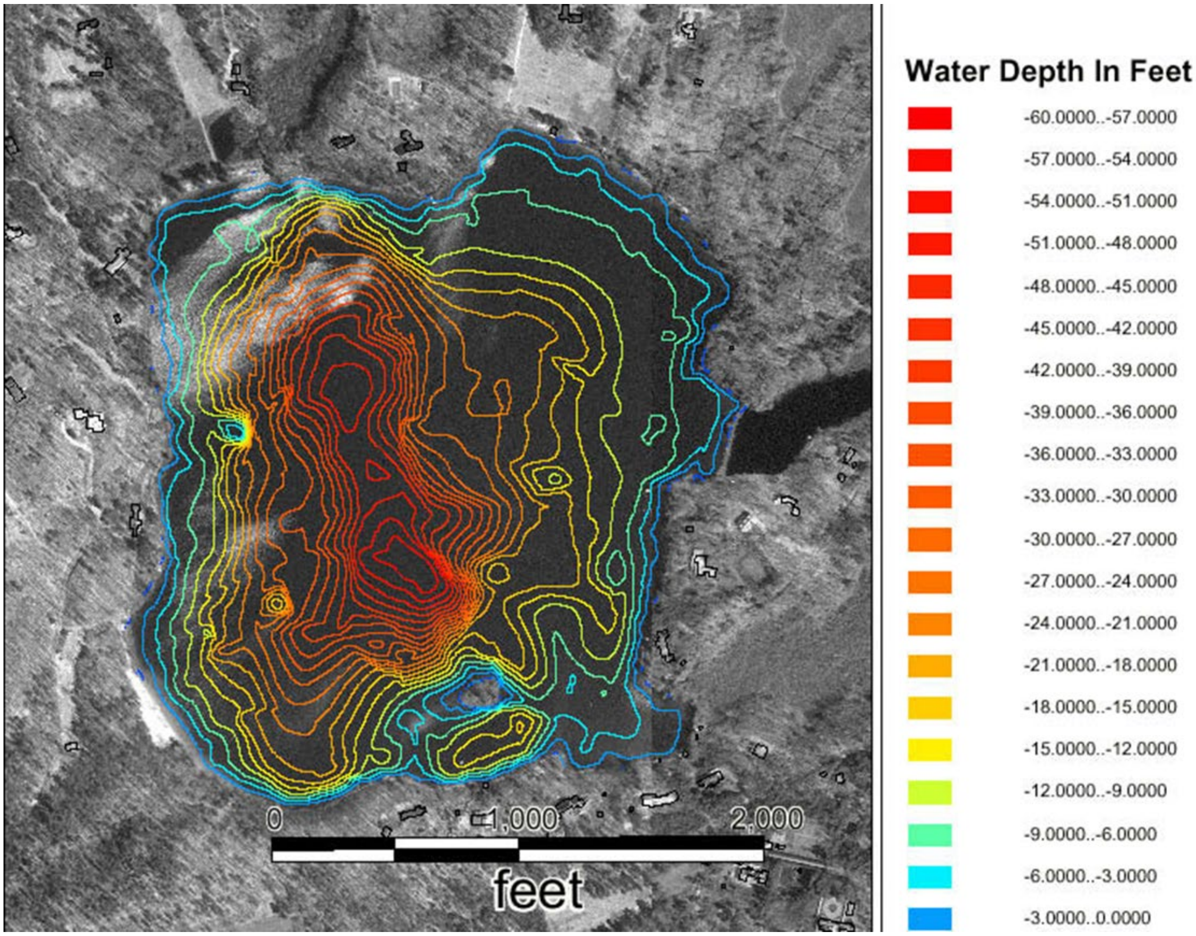


Figure 14. Depth-Specific Cumulative Surface Area & Equation

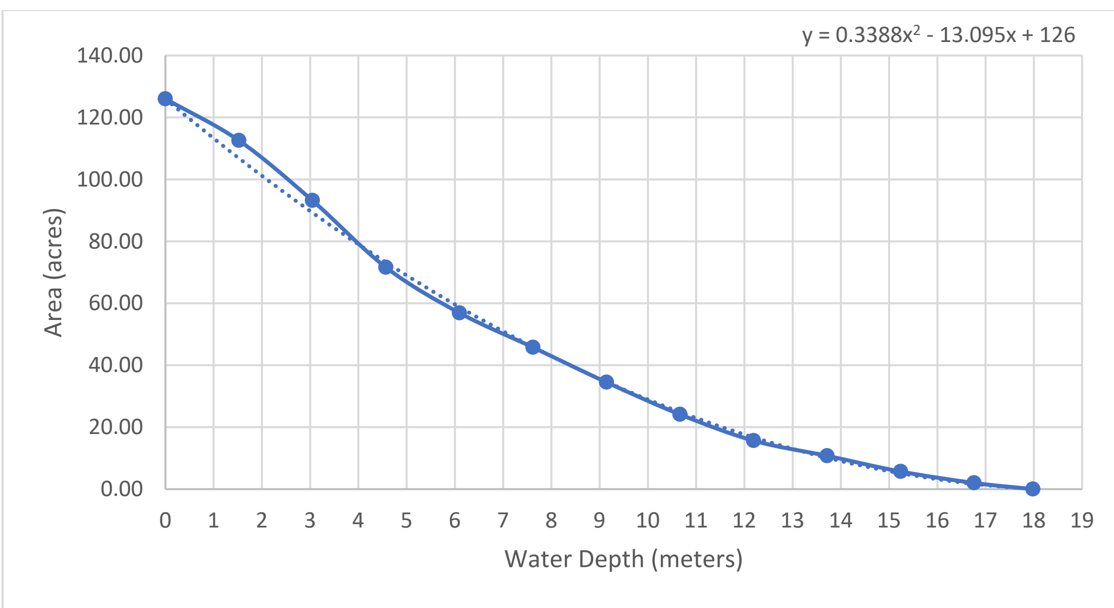


Figure 15. Cumulative Water Volume by Depth & Equation

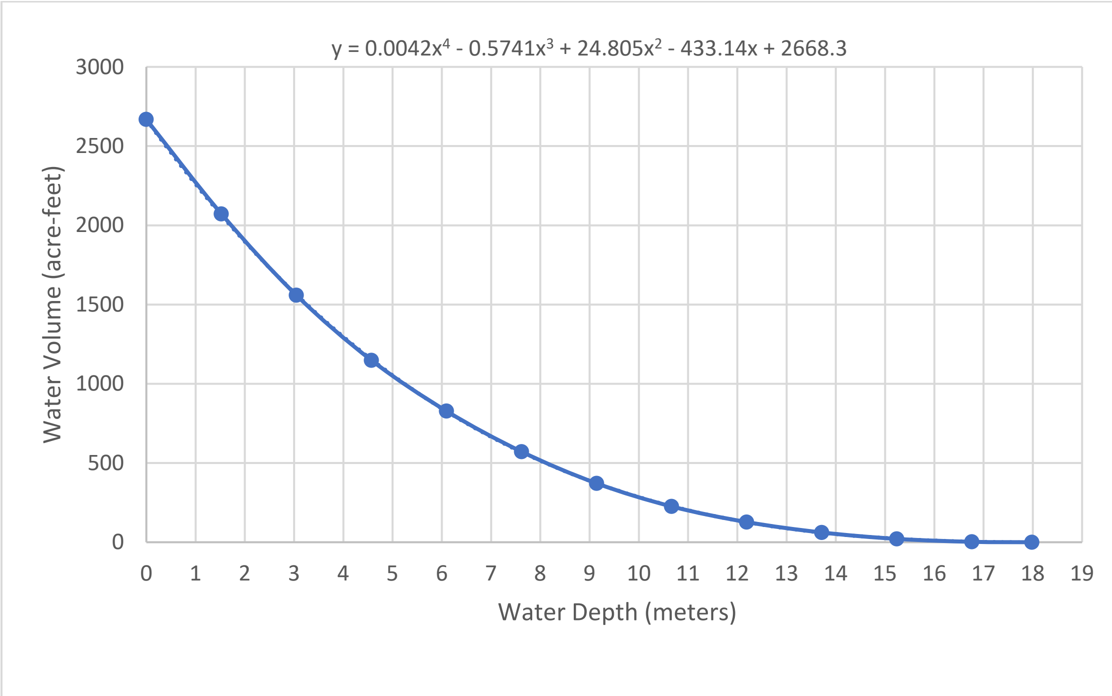


Figure 16. St1 (Deep Site) Anoxia Area in acres

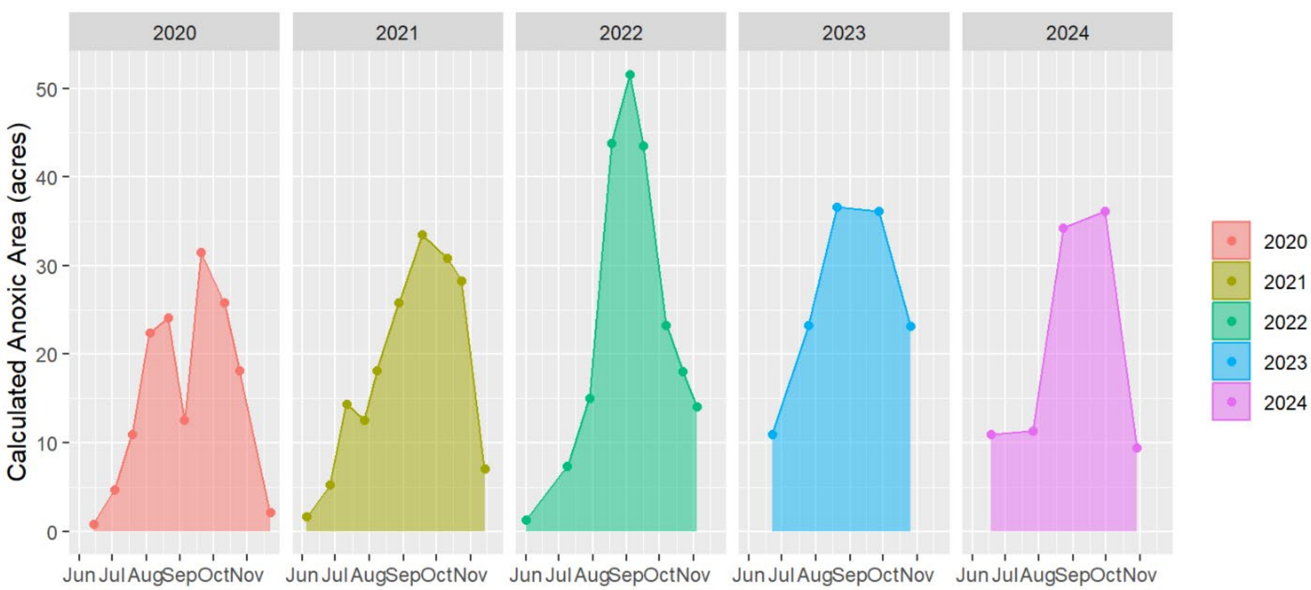
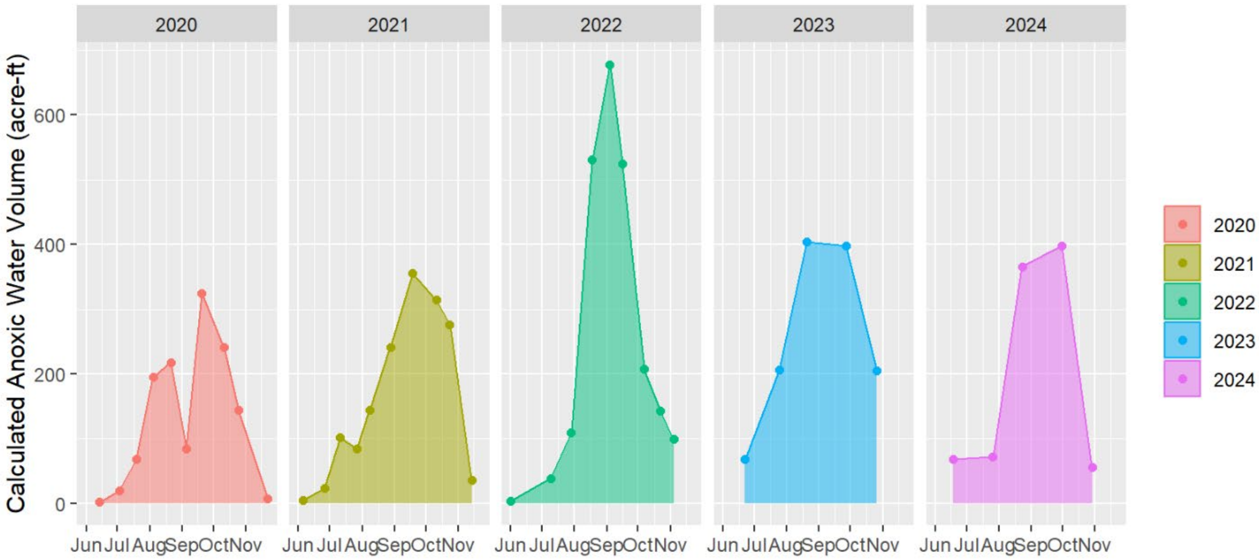


Figure 17. St1 (Deep Site) Anoxic Water Volume in acre-feet

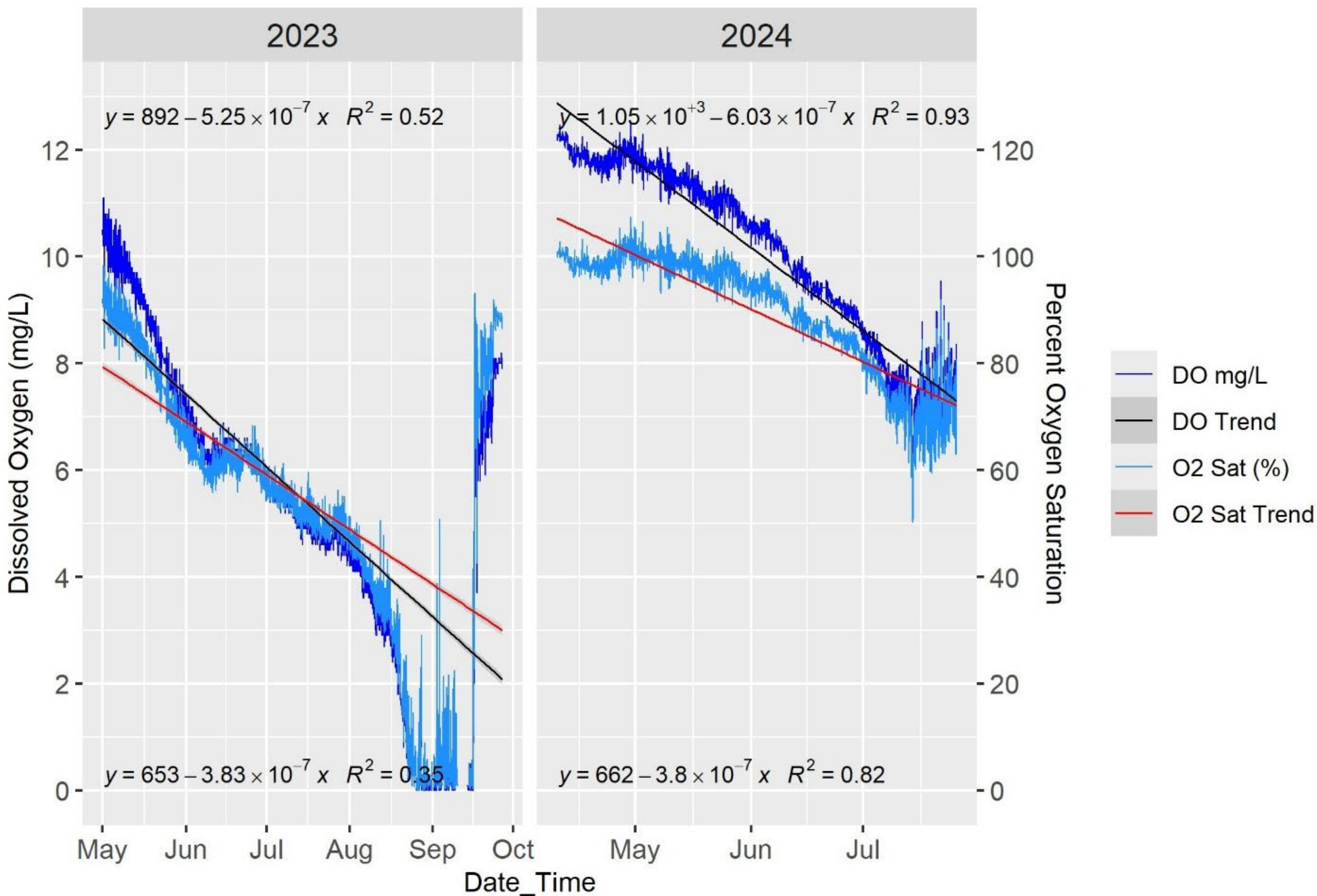


The bloom that occurred in 2020 was presumably different than the sustained and considerably worse cyanobacteria bloom that occurred in 2022. The 2020 bloom did not affect open water Secchi clarity at the time of the July 18th shoreline bloom. Open water clarity remained relatively good at that time in 2020. The 2022 Secchi clarity started to decline in July and got considerably worse through October. September and October 2022 were considered full-blown algae and cyanobacteria bloom conditions. There is open debate as to whether the dominant phytoplankton was cyanobacteria or green algae in 2022. Both were present, and shoreline scum samples, unfortunately, do not always represent open water phytoplankton conditions or dynamics. AWS has observed green algae blooms in oligotrophic and mesotrophic lakes that look like cyanobacteria blooms.

Based on dissolved oxygen data presented in the FST 2015 report, there was minimal to no anoxia present in August 2014. The August 2014 data contrasts considerably with what the current conditions are at Farm Pond, where anoxia is an annual and prolonged occurrence in recent years. It is common for anoxia to get worse over time as a lake becomes more productive, yet there is an inconsistency in the similarity of the 2014 and 2017 profile data, in that little to no anoxia was present in mid-summer historically. In contrast, in 2016, 2018, and onwards, anoxic conditions began towards the end of June and grew through fall turnover at the end of October to the beginning of November. At this time, we can offer no complete explanation about why that change seemed to have occurred within a year, but it is likely related to ambient temperature. General climate change has been documented to increase anoxia in deep-water northern lakes, which aligns with the observed increase in anoxia at Farm Pond since 2018. Volunteers should track future ice-on and ice-melt time dates, and early spring warming that drives earlier stratification. Warmer temperatures at the sediment-water interface, particularly in the bottom of the metalimnetic zone and top of the hypolimnetic zone, increase the rate of organic matter mineralization and oxygen consumption at the lake bottom.

High-resolution DO and temperature monitoring provides a better understanding of the hypolimnetic oxygen depletion rates in a given year. The DO data logger device was placed at ~9m deep in 2023 and 2024. The figure below shows the differences between seasonal DO loss rates, where DO loss at ~9m occurred earlier and faster in 2023 than in 2024. That DO loss rate was a response to higher temperatures at depth earlier in 2023.

Figure 18. Deep Hole St1 2023-2024 9m DO Logger Data



The early June rate change point of DO loss in 2023 (**Figure 18**) appears to be related to the deep-water temperature mixing event that occurred just before. The depth chosen for DO monitoring in 2023 and 2024 represents near the bottom of the typical metalimnion layer depth, and it is close to the maximum annual height of anoxic waters. When anoxia reaches this depth or shallower, Farm Pond is vulnerable to greater phosphorus release and transport from the hypolimnion to the epilimnion, resulting in a likely cyanobacteria or epilimnetic algae phytoplankton bloom.

Key Nutrients

In-Lake Nutrient Results

Water samples and field data should generally be collected monthly from ice-off (late winter/early spring) to fall turnover in at least the deepest part of the lake (November at Farm Pond). The most critical times for sampling are early spring, mid to late summer, and fall. Sampling depths usually incorporate top, middle, and bottom depths. Deeper lakes need more samples arranged vertically in the water column because thermally stratified lakes can have dramatically different nutrient concentrations in the top (epilimnion), middle (metalimnion), and bottom (hypolimnion) depths. The 2023-2024 Farm Pond monitoring project budgeted for at least 4 vertical water samples, and for duplicates and blank samples to validate laboratory results. The sampling plan was outlined in a QAPP (Quality Assurance Project Plan) approved by MA Department of Environmental Protection (MA DEP). Lake water samples were tested for total **phosphorus** (TP), total **nitrogen** (TN), total ammonia nitrogen (tNH3), and nitrate+nitrite nitrogen (NOx). The essential baseline parameters for ongoing annual monitoring programs are TP and TN.

In 2023 and 2024, Farm Pond water samples were collected using a horizontal VanDorn sampling device at 1m (top of epilimnion), 5m (bottom of epilimnion), 10m (lower metalimnion/top hypolimnion), and 1m above the sediment surface at the bottom of the deep hole St1 site. The actual bottom depth sample was slightly different each date based on the water level of the lake at that time. Bottom sample depth was measured to be 15-16.7m deep throughout the study period, with the lake water level highest in spring and lowest in late fall. On some dates, additional TP sampling depths were added to the sampling plan for the benefit of the project, primarily to increase the accuracy of lake-wide phosphorus mass estimates.

It is important to keep the bottom sampling depth the same distance off the bottom sediment surface. Sampling closer to the sediment surface typically yields higher nutrient results. During periods of anoxia and internal nutrient loading from sediments, there is typically a gradient of increasing TP and TN in the hypolimnion with depth, closer to the sediment surface.

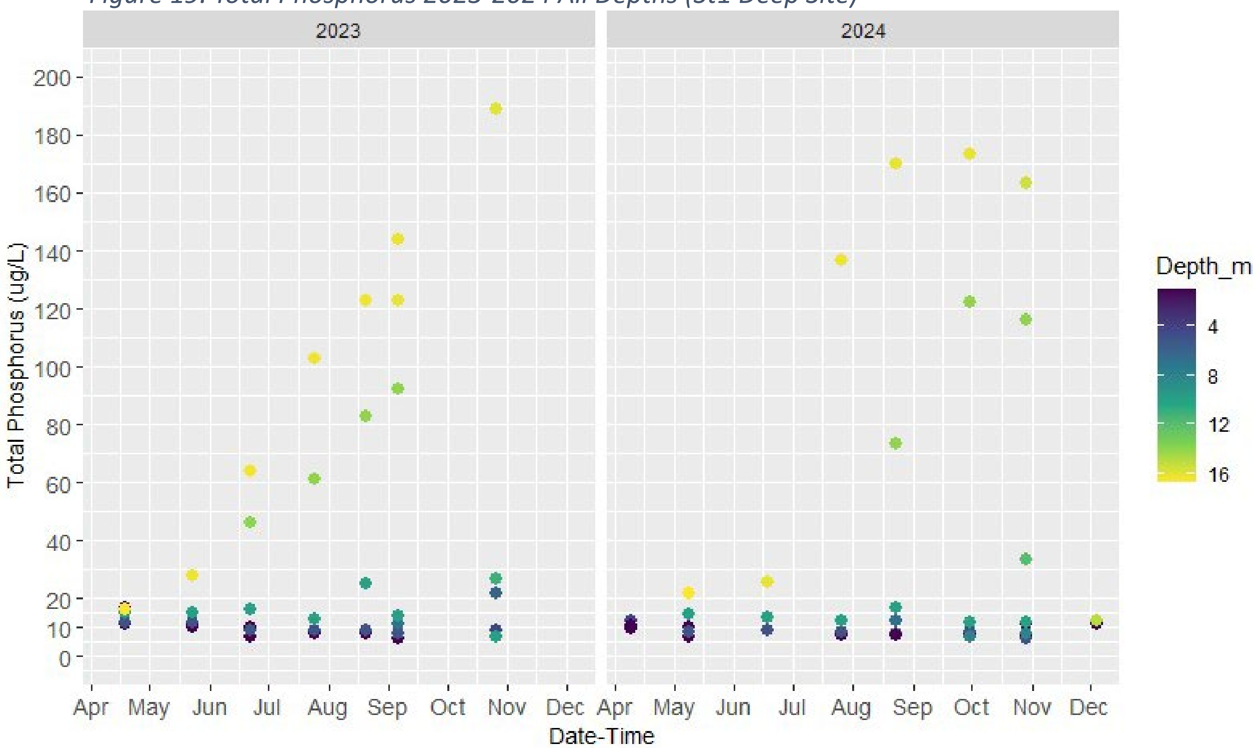
Phosphorus

The Farm Pond TP data demonstrates that internal sediment release of phosphorus seasonally until fall turnover around October to November (**Figure 19**). Phosphorus and nitrogen are the principal plant nutrients that drive aquatic plant and algae growth. Generally, when TP in surface waters exceeds roughly 20 µg/L, there is an increased chance of harmful cyanobacteria blooms, particularly in late summer.

MA DEP assesses waterbodies across the state for 'impairment,' often by excessive nutrients. MA DEP has published various numerical TP surface water quality criteria via Total Maximum Daily Loads (TMDL) for various waterbodies that are sometimes as low as 15 µg/L. Numerical TP criteria have not been formally established as part of a TMDL for Farm Pond because it is not listed on the 303d Impaired Waterbodies list in MA. Until recently, Farm Pond had overall excellent water quality and very low nutrients. Farm Pond is currently listed as a Class B, Category 3 waterbody, meaning that water quality impairments have not been formally assessed by MA DEP.

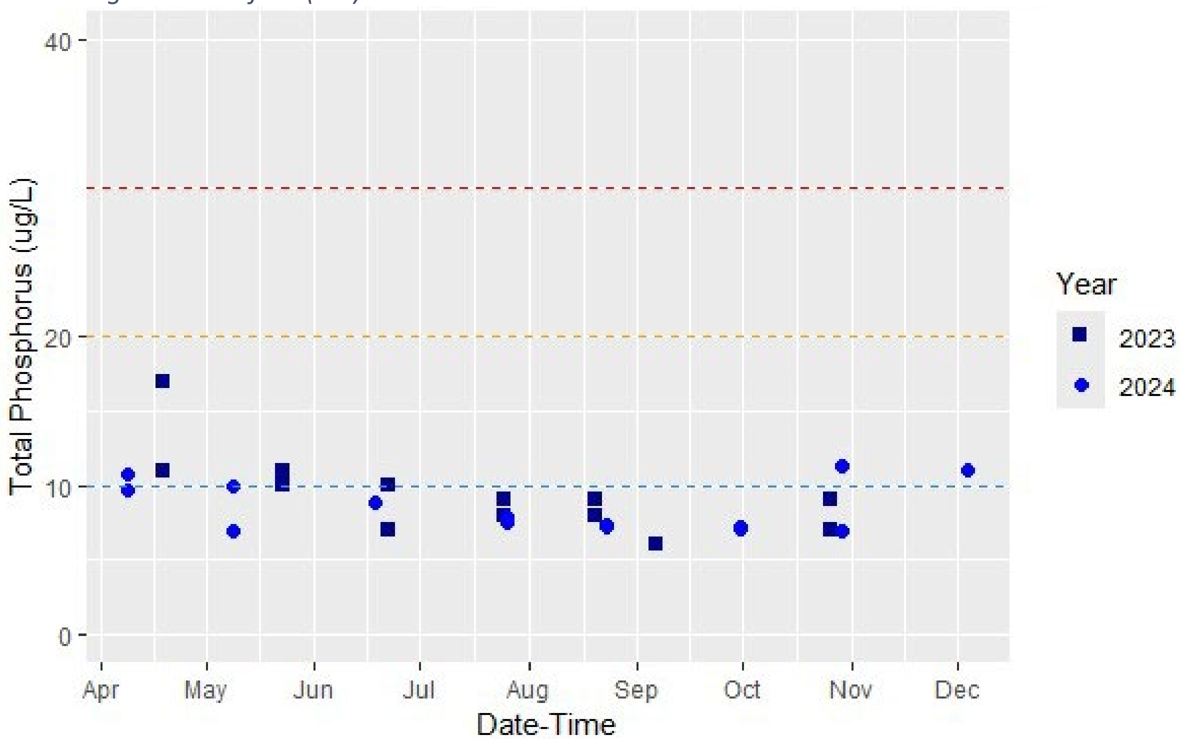
Just as anoxia usually increases over time, phosphorus and nitrogen increase as a waterbody becomes more eutrophic or dominated by plants and algae. In baseline assessments, several additional parameters are also needed that are reviewed in the Additional Water Column Parameters section of this report.

Figure 19. Total Phosphorus 2023-2024 All Depths (St1 Deep Site)



The figure above demonstrates that there is a fairly linear increase in bottom TP concentration from May to October. The 10m sample data presents a similar pattern of TP increase across the season, but the samples collected within the metalimnion and epilimnion do not simultaneously increase. Instead, there was a slight decrease in the 1m TP concentration from spring up to the point of fall turnover (**Figure 20**). The y-axis scale is changed to better view the 1m data, as the surface TP concentrations are very low in comparison to bottom concentrations (**Figure 19**).

Figure 20. Surface (1m) TP 2023-2024



The surface TP concentrations measured in 2023-2024 were largely consistent with the excellent water clarity observed. Surface TP < 10 µg/L are considered excellent for MA waterbodies. The horizontal dashed lines in the figure above indicate general trophic thresholds for TP in lakes, where TP < 10 µg/L is generally classified as oligotrophic low-nutrient waters, 10-30 µgTP/L is generally regarded as mesotrophic, or moderate nutrient concentrations, and where eutrophic high-nutrient systems typically have > 30 µgTP/L. These TP thresholds are not static, they are a simplified way to classify lakes to better understand change over time.

Nitrogen

Nitrogen concentrations at Farm Pond were measured in three different forms, Total Nitrogen, and bioavailable dissolved total ammonia nitrogen (tNH3) and nitrate+nitrite nitrogen (NOX). Only the top and bottom samples were analyzed for dissolved N components. In scenarios with sediment release of nutrients under anoxic conditions, tNH3 increases in the hypolimnion. In scenarios where there is enough TP to stimulate algal/cyanobacterial blooms, it is often N forms and concentrations that drive the type of phytoplankton bloom (cyanobacteria vs. green algae or dinoflagellates). The water column stability also determines what type of algae can come to dominate at a given time. TN and tNH3 have also been related to the toxicity of cyanobacteria during bloom events.

Like TP, both the TN and tNH3 bottom concentrations demonstrated a seasonal increase at Farm Pond (**Figure 21**). Yet in both 2023 and 2024, there appears to be an increase in late spring to early summer N that did not occur with a simultaneous increase in TP. That TN increase could be related to groundwater N inputs, as groundwater tends to have lower P mobility. NOx and tNH3 tended to remain very low and often below the laboratory limit of detection in surface waters. There was a slight increase in NOx in surface water in June 2023, as well as a mid to late summer moderate increase in tNH3, roughly < 35 µg/L, which were considered normal in a phosphorus-limited waterbody. The seasonal bottom water TN increase appears to be mostly tNH3, which is released from sediments during anoxic periods. Surface water TN was generally low throughout the season.

Figure 21. Total Nitrogen 2023-2024 (St1) All Depths

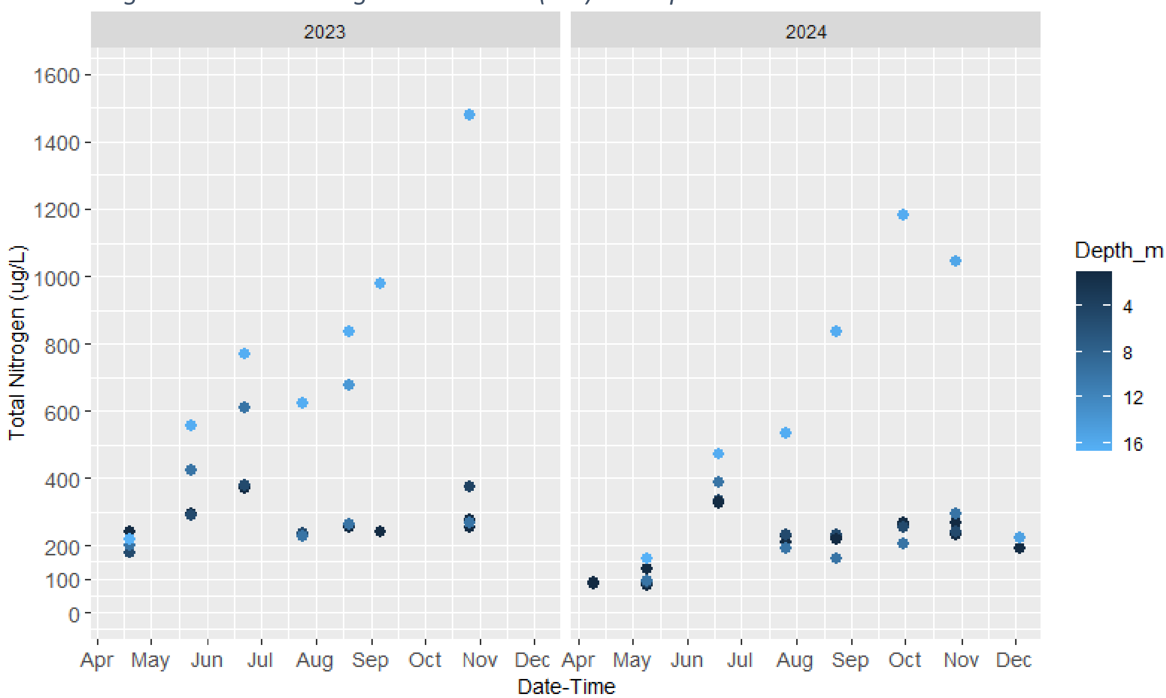


Figure 22. Total Ammonia Nitrogen 2023-2024 (Top and Bottom, St1)

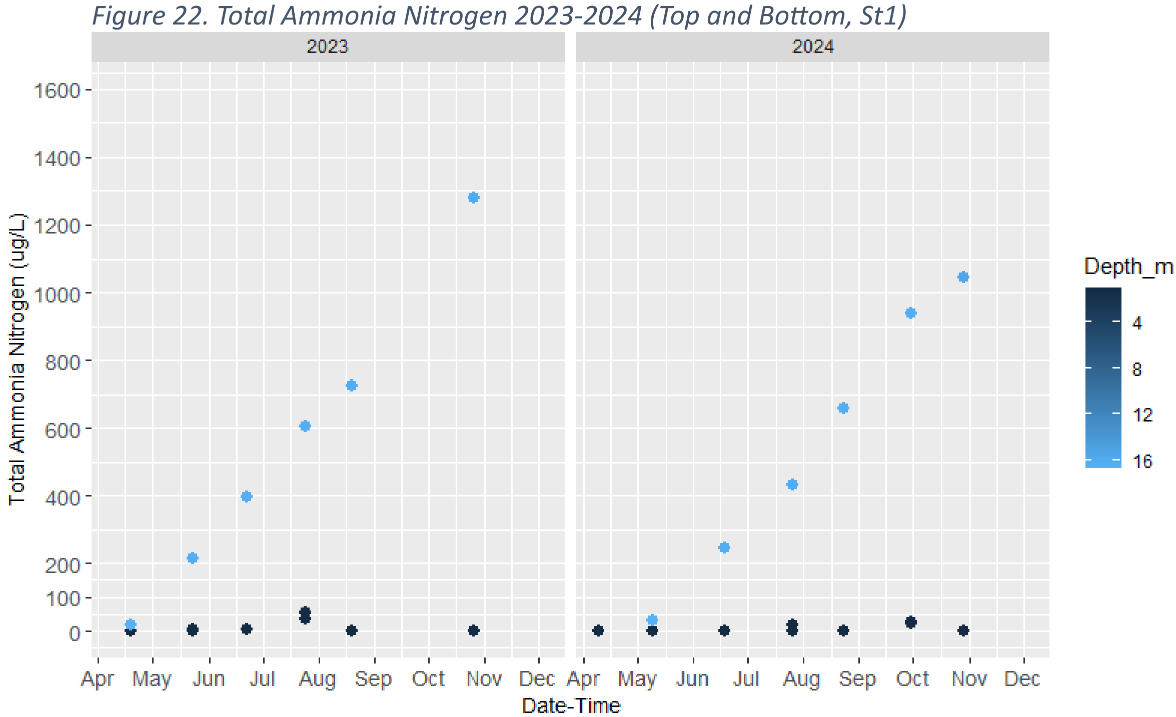
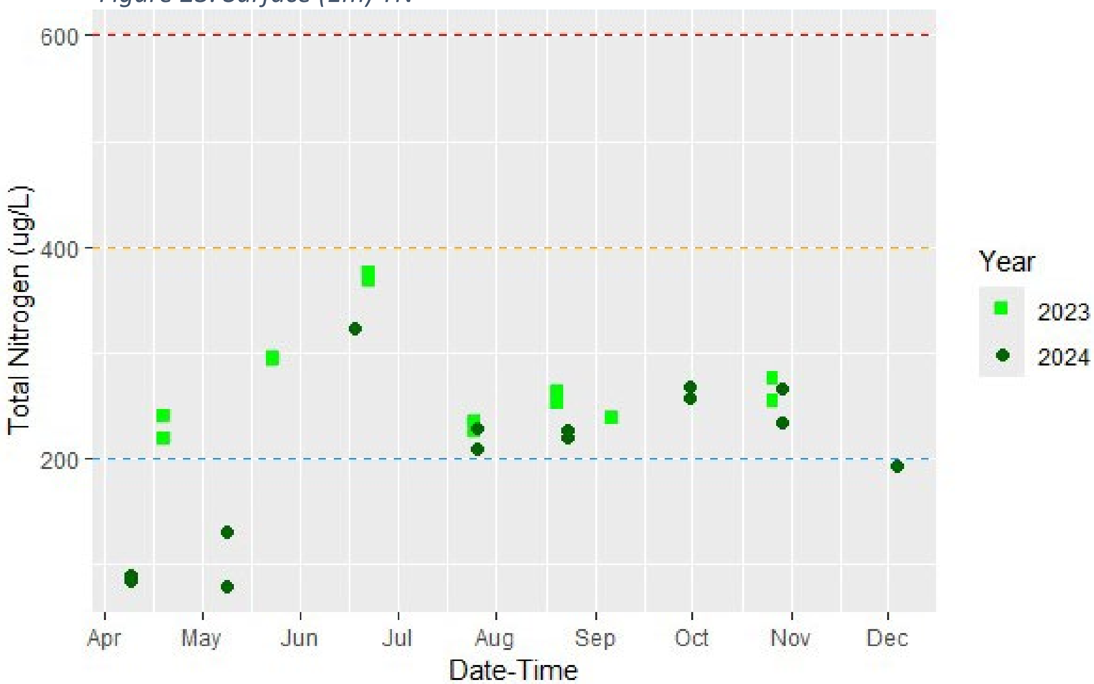


Figure 23. Surface (1m) TN



Additional nitrogen data not displayed in the above figures was delivered via an electronic Excel file to the Farm Pond Advisory Committee and Town of Sherborn.

A note about QAPP QC analysis: As part of the approved QAPP duplicate TP and TN samples were taken on each sampling date at 1m to verify the validity and usefulness of the lab data. The Upstate Freshwater Institute laboratory precision (RPD) is 15% to pass the lab's QC duplicate process for reporting. However, due to the very low nutrient concentrations at Farm Pond, approximately 30% of the field duplicate TP samples differed by more than 25%. In most of these cases, the 25% difference between field duplicates was ~2 µg/L TP, which is generally excellent for low-concentration laboratory TP precision. There were two samples with a considerable >40% difference in TP concentrations between the field duplicate TP samples. This is not ideal, but the values were flagged and used anyway (duplicate results included in the figures), under the understanding that the data is still useful even if the %difference was higher than typically deemed appropriate, because the range of values is important in itself.

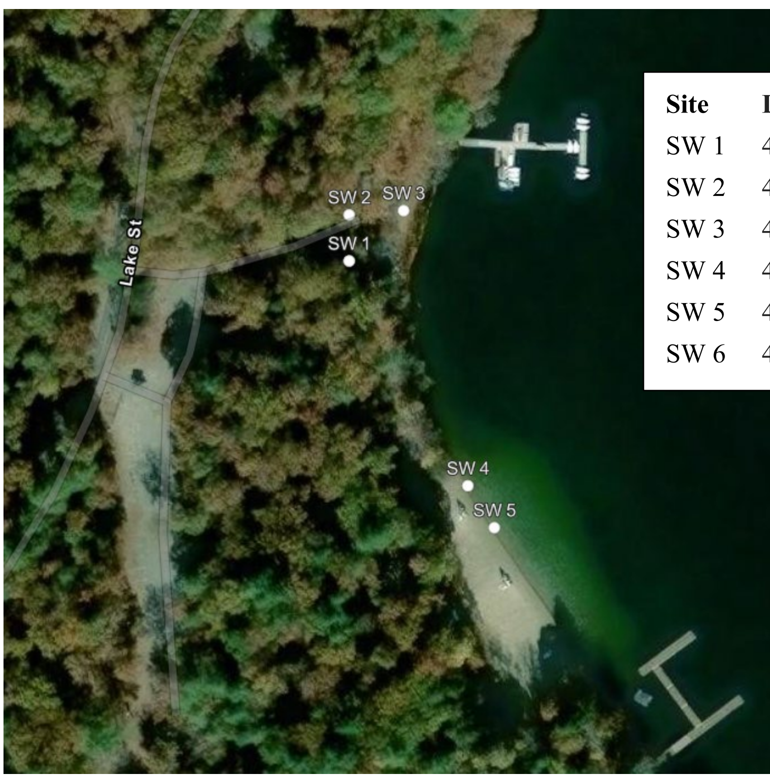
In all but one sampling date, the field blank samples returned TP below the detection limit, thereby verifying the usefulness of the TP data. Only one TN duplicate exceeded 15% difference; all TN data was also used based on professional judgement. Almost all of the tNH3 1m sample results were below detection or very close to the detection limit of 15µgNH3/L. One tNH3 sample was determined to be inaccurate and removed for analyses. Nearly all of the 1m NOx samples were below the laboratory detection limit.

Watershed Nutrient Sampling

The watershed nutrient load estimates included in the Watershed Based Plan were developed by the statewide WBP modeling tool, which predicts phosphorus loads from various watershed sources based on land use and impervious surface area. The monitoring component of the 2023-2024 Farm Pond assessment also included a series of volunteer-collected stormwater sampling events. The stormwater sampling was designed to identify specific locations of nutrient hot-spots in the watershed and to better capture potential high-nutrient load events, primarily from impervious surface runoff and erosion issues in the watershed. In some watersheds, stormwater sampling can also identify short-circuiting or failures of septic systems in the watershed.

FPAC volunteers aimed to sample near the beginning of heavy stormwater runoff events, during active rainfall at 6 watershed locations. In many watersheds, there are many more stormwater sampling locations, but the Farm Pond watershed has limited development and an overall low proportion of runoff from impervious surfaces. Five of the sampling locations were on Town's Farm Pond Reservation property, 3 at the boat ramp, 2 at the public beach. The 6th site was at the outfall pipe from a stormwater runoff culvert from Lake Street Drive that enters Farm Pond at lake level. With permission, AWS was also able to investigate several private shoreline properties to look for potential erosion or indicators of nutrient pollution or incoming surface water runoff locations, but most private property had well-vegetated buffer zones to diffuse, intercept, and infiltrate stormwater runoff.

Map 2. FPAC Volunteer Stormwater Sampling Locations by Town Boat Ramp and Beach



Site	Latitude	Longitude	Description
SW 1	42.23211	-71.35064	Boat ramp – above grate
SW 2	42.23224	-71.35064	Boat ramp left runoff
SW 3	42.23225	-71.35043	Boat ramp right runoff
SW 4	42.23147	-71.35018	Town beach left
SW 5	42.2313	-71.35008	Town beach paved path
SW 6	42.23441	-71.34986	Lake street drain culvert

Figure 24. FPAC Volunteer Stormwater Sampling TP Results

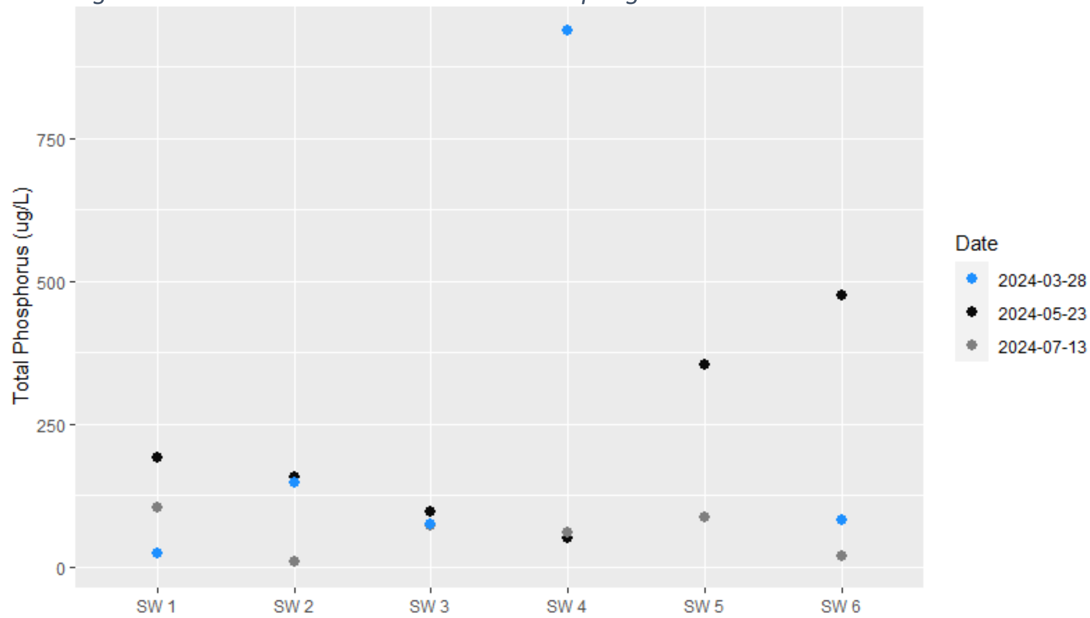
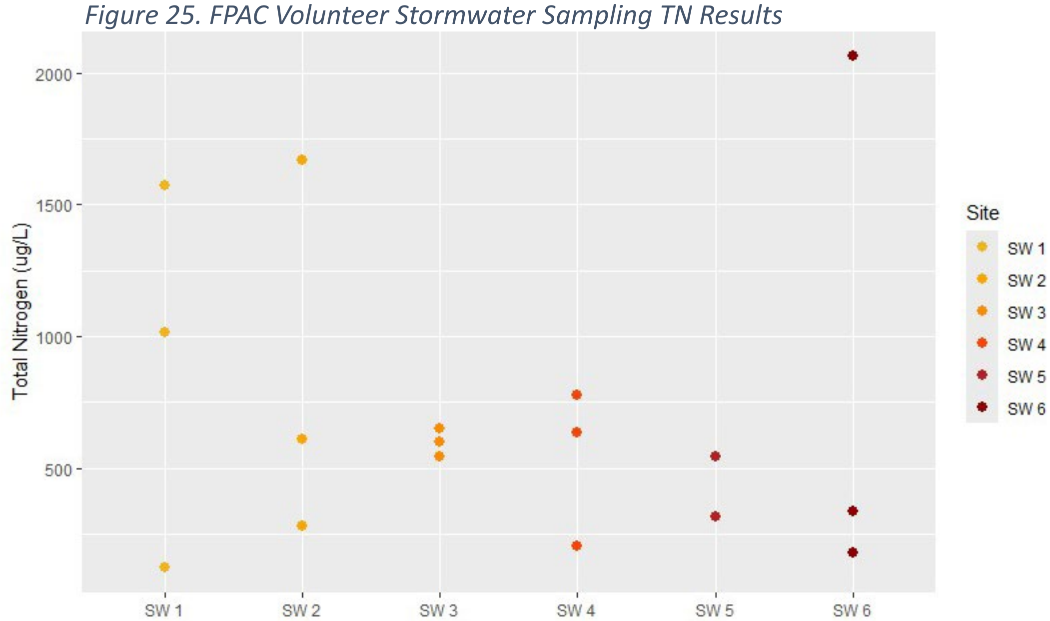


Figure 25. FPAC Volunteer Stormwater Sampling TN Results



The FPAC volunteer stormwater sampling results indicate that although there are generally few surface water runoff locations to Farm Pond, Town property accounts for some very high TP and TN inflows, including erosion documented near the Sherborn Yacht Club to the left of the boat ramp. Although dissolved components were not tested, the often cloudy, dark color of the samples indicates erosion, and particulate organic matter accounts for much of the nutrient load. The TN stormwater data did not indicate any significant problems with fertilizers or failing septic systems (usually >2000µg/L). Filamentous algae observed growing near the beach and boat ramp likely respond to the localized high nutrient concentrations in this area. Recommendations for stormwater management are detailed in the Watershed Based Plan that accompanies this assessment report.

Baseflow watershed sampling was done when flowing water was observed. The northwestern wetland inlet that flows under Lake Street coincides with a large wetland prior to entering Farm Pond, but the flowing water was sampled at Lake Street twice in spring 2024 (April and May). TP baseflow concentrations ranged from 19-38 µgP/L and TN ranged from 181 to 289 µgN/L. The TN is very low, the TP is somewhat higher than what would be ideal for baseflow into Farm Pond. However, since this stream enters another wetland and did not appear to have surface inflow to Farm Pond, additional P is likely attenuated in the wetland and soils along the northern edge of the lake. By July there was no longer surface flow under Lake Street at this location.

Map 3. Wetland Inlet Spring Sampling Location 2024 (marked via yellow star)

Additional Water Column Parameters

Conductivity

Specific conductance (conductivity) is a measure of the ability of water to conduct an electrical current. It is influenced by the concentration of dissolved ions in the water, such as salts, minerals, and organic matter. In a lake water column, conductivity typically increases slightly with depth as there are more dissolved ions in the deeper water. High conductivity can indicate that a lake is polluted with salts or other contaminants. Increasing conductivity in the watershed and streams can often be traced to road salting practices or effluent from shoreline septic systems. Conversely, low conductivity is typical of oligotrophic, clear-water lakes. A conductivity meter measures the electrical resistance of a sample of water. Results are reported in units of micro-Siemens per centimeter (µS/cm).

One of the major reasons for installing a continuous conductivity data logger 0.5m above the sediment surface in the deep site was to see if internal sediment release and nutrient loading could be visualized at Farm Pond. Conductivity generally increases in hypolimnetic anoxic zones, concurrent with the sediment release of nutrients. You can see on the figure below that there are periods where conductivity increases and then decreases slightly **Figure 26**, indicating that, despite a general increase in conductivity over the season, there are small periods of increases and decreases that may show increased water movement near the sediment-water interface. Hypolimnetic nutrient concentrations provide only small snapshots of deep-water TP dynamics, but lakes are in constant motion. Given more data specific to Farm Pond, it may be possible to model fluctuations in internal TP loading based on bottom water high-resolution conductivity data. The daily average conductivity sensor data explained 92% of the bottom sample TP variation of a simple regression model. When insitu probe data was added to the model, the R^2 value dropped to 0.74.

The model is certainly not able to predict accurate TP concentrations at depth, but the use of a conductivity sensor seems to be a cost-effective way to monitor internal loading as it progresses seasonally, giving us an idea of a range of bottom-water TP progression that might be used to compare rates of seasonal internal load over years if volunteers are unable to collect monthly deep-water lab samples every year. Farm Pond is the first lake that AWS tested this hypothesis on, after noticing a pattern across many lakes of conductivity patterns during periods of internal loading. Coincidentally, in 2023 and 2024, the Jefferson Project, an IBM-sponsored research partnership with Rochester Polytechnic Institute at Chautauqua Lake in New York, found the same relationship for the first time through its intensive high-resolution sensors project. Moreover, the data demonstrate that internal loading is not static and that ion release (and presumably P) is also dependent on water column movement. The red dots in the figure are conductivity probe measurements that verify the accuracy of the logger data throughout the season.

Figure 26. Bottom (~16.5m) Specific Conductivity 2023

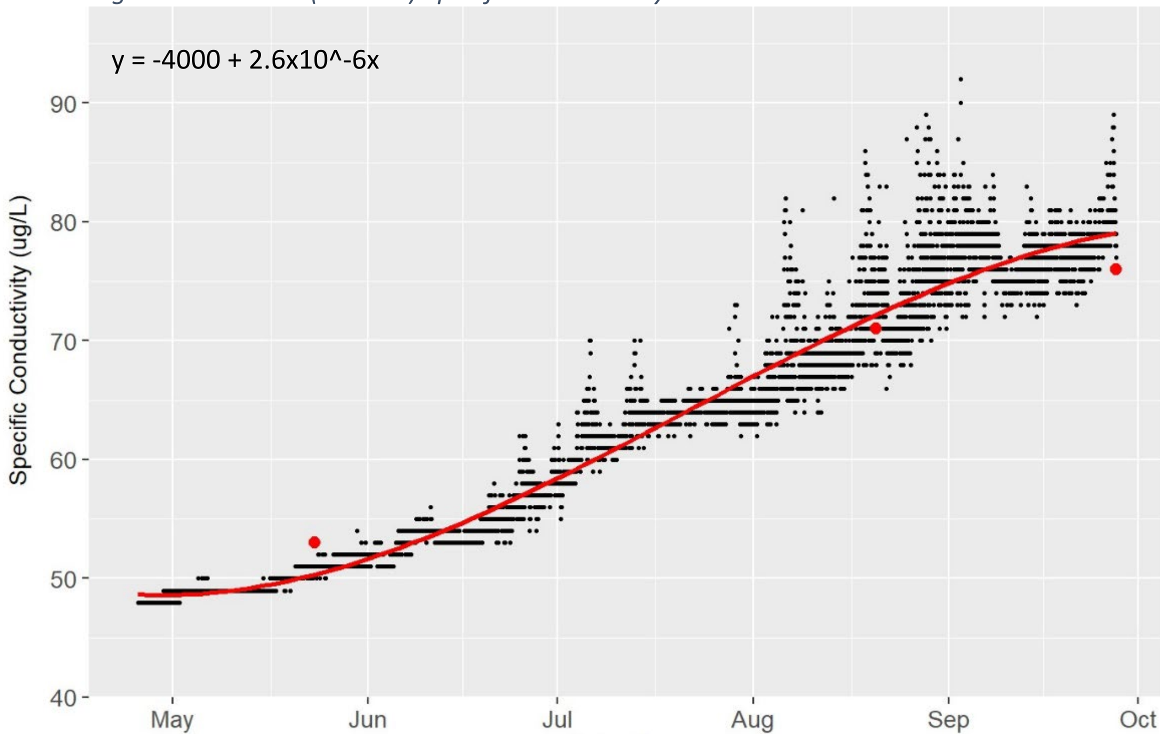
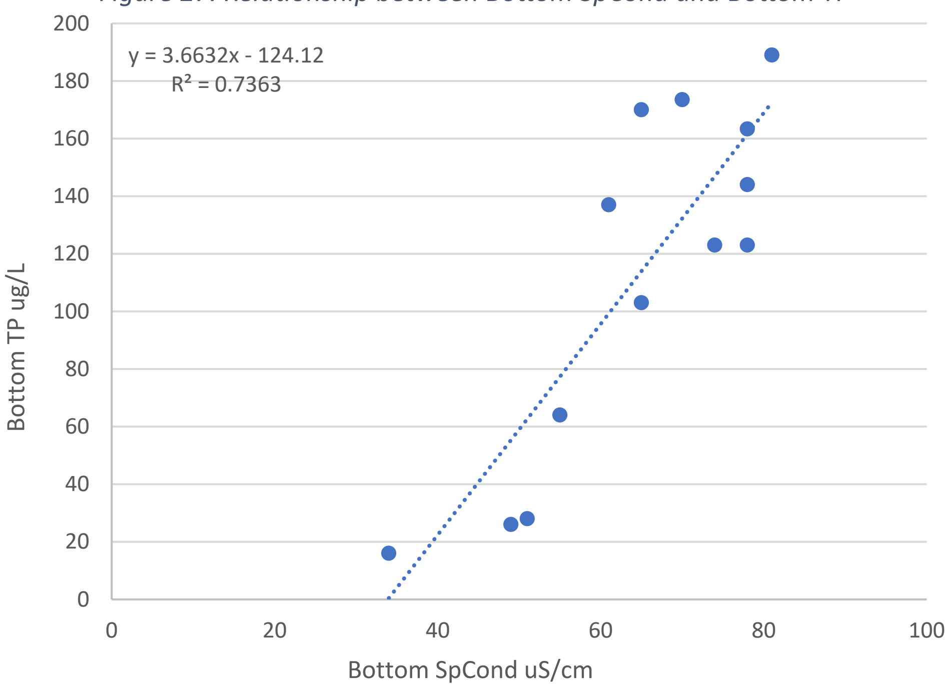


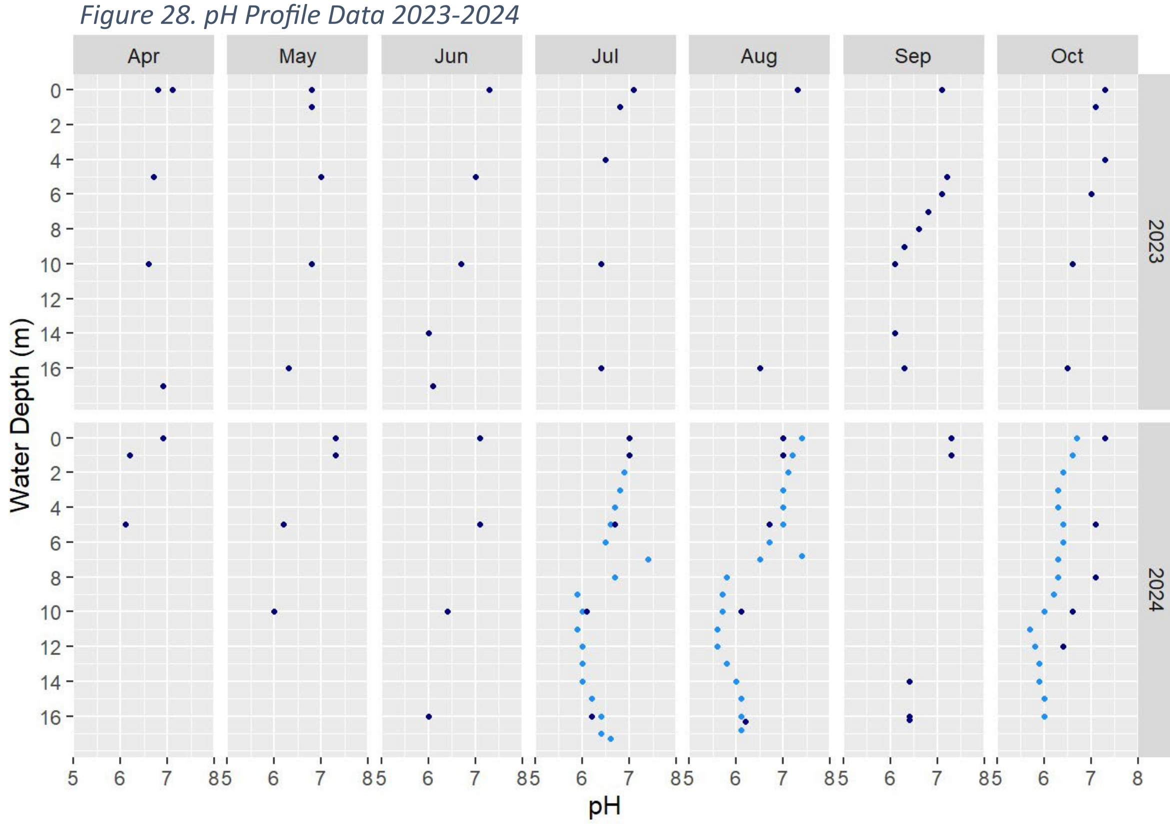
Figure 27. Relationship between Bottom SpCond and Bottom TP



pH & Alkalinity

Historical pH at the Farm Pond surface waters in the 1970s-1980s (FST, 2015) was considerably lower than it is today, indicating that Farm Pond has since recovered considerably from the prior decades of acid rain atmospheric acidification (from mid-western coal-based power plants). This is true of many northern oligotrophic waterbodies. Note that in July 2024, AWS introduced a new and redundant YSI pH probe capable of monitoring to the lake bottom (light blue). Surface and epilimnetic pH were near 7 for most of the season. Several hypolimnetic pH measurements were less than 6 in summer. The dark blue points are the Apera pH probe with a short chord, which required taking VanDorn samples and testing the samples for pH in a bottle at the surface. Calibration was done for both pH probes on either the night before sampling or the morning of sampling, as well as post-calibration checks. It is unclear why there was a difference in the October 2024 pH values between the two different meters, but it may be a result of the Apera-analyzed pH measurements being exposed to surface air prior to measurement. The other two dates where the YSI probe was used, had lower differences when compared to the Apera pH probe measurements.

Figure 28. pH Profile Data 2023-2024



Alkalinity, measured as mg/L of calcium carbonate, was measured at the top and bottom of Farm Pond several times each season. Some samples were below the UFI detection limits. Alkalinity results reported were 6.7 to 11.8 mgCaCO3/L, which is low. Alkalinity is the buffering capacity, or acid-neutralizing capacity of the water. Alkalinity is generally a factor of the surrounding bedrock and minerals of a lake basin. Many lakes in the eastern MA and CT area have very low alkalinity. Generally, lakes with alkalinity <10 mgCaCO3/L are highly sensitive to acid inputs. As a lake with low pH and low alkalinity, it will be prudent to use a buffering agent if any future Aluminum-based P-binding treatments are pursued.

Figure 29, below, shows the change in pH and alkalinity over time, as the lake was monitored by the UMASS Acid Rain Monitoring program.

Figure 29. UMASS Acid Rain Long-Term Monitoring Program (ARM) Data for Farm Pond (compiled by FPAC)

(FPMP = Farm Pond Management Plan report FST, 2015).

In-situ Algae Pigment Fluorometry

Although not part of the initial sampling design, AWS added several profiles of in-situ chlorophyll and phycocyanin fluorometry measurements, reported as Relative Fluorescence Units (RFU). The RFU was standardized and calibrated using rhodamine dye. The RFU profiles taken revealed generally less than 1 RFU of phycocyanin (PC), a cyanobacteria pigment, in most of the water column, but there were low-level PC peaks at 6-8m deep from July through August, indicating that cyanobacteria do accumulate at depth at Farm Pond. The frequency of metalimnetic cyanobacteria blooms is unknown at this time, but deep-water fluorometry samples should be added to the volunteer monitoring program to serve as an early indication of potential surface cyanobacteria blooms. Volunteers can follow EPA Region 1 citizen sampling protocols.

Plankton

Part of the FPAC volunteer monitoring in recent years has been participating in the City of Worcester Cyanobacteria Monitoring Collaborative (WCMC), which runs alongside the EPA Region 1 CMC program. During the summer months, FPAC volunteers collect shoreline water samples from near the Town of Sherborn Farm Pond boat ramp. A few of the Farm Pond samples have been positive for cyanobacteria, but most samples run very low to Not Detected (ND) for phycocyanin (fluorometric analysis). The highest phycocyanin reading during the 2022 substantial bloom was 17 µg/L. All WCMC reports and sample analysis methods can be found on their website:

https://www.worcesterma.gov/sustainability-resilience/recreational-waters/cyanobacteria

Algae samples collected by AWS during the 2023-2024 field sampling, as 3-meter epilimnetic composite samples, had overall very low phytoplankton cells/mL. Samples were scanned under the microscope for cyanobacteria presence after each sampling date. *Microcystis* and *Dolichospermum* cyanobacteria were occasionally present in very low numbers. AWS also took monthly 40ft vertical plankton net tow samples using a Wisconsin zooplankton sampling net, and several phytoplankton samples at the observed metalimnetic oxygen maximum in summer. *Ceratium* dinoflagellates dominated the deep-water phytoplankton samples in 2023 and 2024. This may not always be the case at Farm Pond, as *Ceratium* and cyanobacteria can occasionally occupy similar ecological niches in the metalimnion. Zooplankton samples were preserved but not counted as part of this study. Those samples can be identified and enumerated at a later date if needed.

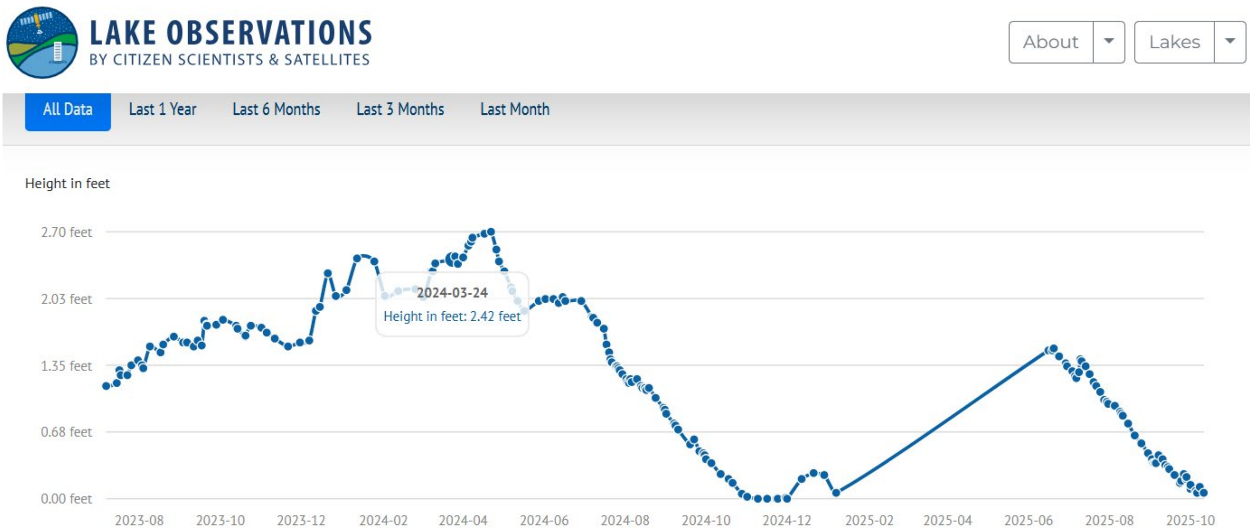
Water Level

Beginning in 2023, the FPAC began a water level monitoring program under the Lake Observations by Citizen Scientists & Satellites (LOCSS), which is a partnership between NASA and several research universities. The program is an internal research effort and currently includes 3 lakes in MA, including Farm Pond. More information https://sherbornma.org/671/Farm-Pond-Water-Depth-Gauge about the program and monitoring effort can be found on the Town of Sherborn website (**Figure 30**).

https://sherbornma.org/671/Farm-Pond-Water-Depth-Gauge https://www.locss.org/gauge/farm-pond

Water level is an important factor in Farm Pond nutrient cycling, as low water levels in summer increase P retention rates and can potentially cause warmer waters. A detailed analysis of rainfall and water quality was not performed during this assessment, but the water level monitoring data demonstrate that Farm Pond normally experiences a 2-3ft level variation from high in late winter to low in late summer. According to FPAC data, water levels had not rebounded to historically normal late-winter levels in recent years, and remain at relatively low historical levels as of March 2026.

Figure 30. LOCSS Farm Pond Water Level Records 2023-2025



Recommendations for Future FPAC Monitoring

Future general FPAC water quality monitoring recommendations are summarized below. Follow-through will be determined based on funding and volunteer availability:

- Track the date at which the bottom water becomes anoxic, as an indicator of potential overall severity for the remainder of the season.
- Record DO saturation percentages with the profile data; the DO meter should have the calculated value displayed, in addition to the DO concentration (mg/L).
- Metalimnetic oxygen maximum (MOMax) should prompt deep-water phytoplankton sampling at the time of event, to determine if cyanobacteria are accumulating at that depth.
- Prioritize tracking future ice-on and ice-melt time dates, as well as early spring warming that drives earlier stratification. This will require on-water sampling in late March or early April annually. If this time of year is too cumbersome for volunteers, the Town can alternatively allocate baseline consultant monitoring funding for ice-off spring and late fall turnover annual sampling.
- Use ice-off surface TP and TN to track watershed load improvements over time.
- If FPAC intends to collect more regular bottom-water TP concentrations, it is important to keep the bottom sampling depth approximately 1m off the sediment surface. This means that the depth of the bottom sample will change slightly as the season goes on based on water levels. Volunteers should use the insitu profile probe to determine the water depth and then sample 1m above that depth. Some monitoring programs sample close to the sediment surface (e.g. 0.25 or 0.5m above the sediment surface), which will typically yield higher TP than 1m samples, but these samples are not as valuable for P mass modeling (likely overestimates total hypolimnetic P), and it is easier for sample contamination by accidentally disturbing bottom sediments.
- Deep-water fluorometry samples should be added to the volunteer monitoring program to serve as an early indication of potential surface cyanobacteria blooms. FPAC can inquire if the WMC program would be able to accommodate extra deep-water phycocyanin samples in addition to surface shoreline samples that are already collected.

Phosphorus Loading Sources

The overall estimated annual P sources to Farm Pond are summed in **Table 2**. The background 31% P load is a combination of the atmospheric load and the portion of the watershed load that is attributed to undeveloped land. Overall, waterfowl constitute almost 12% of the total annual P load (**Table 2**). In most waterbodies, Geese and other waterfowl are a lower percentage of the annual total nutrient load, but because Farm Pond has such a low total P load, the resident Canadian Geese are more impactful on the lake's water quality than they would be in a more eutrophic system with higher watershed nutrient inputs and/or higher flushing rates.

This lake assessment was designed to obtain enough in-lake water quality data to estimate the internal P load, which is the amount of P annually recycled within the lake. Lakes retain a large portion of the annual external P load in their sediments. A portion of that sediment P is then recycled back into the water column. The anaerobic dissolution of iron-bound P in anoxic lake sediments often constitutes a large portion of that annual P load. Aerobic mineralization of littoral zone sediments also occurs, but it is typically not a net source of P in oligotrophic lakes. Littoral zone sediments tend to be thinner, coarser, and oxygenated at the sediment-water interface. Details regarding the internal P load quantification methods are included in the Internal P Load section of this report. The estimated background forested watershed load was estimated to be 13.6 (WBP model) kg P/year. This load, plus atmospheric load constitutes roughly 31% of the total annual P load, meaning that 31% of the total P load is considered unmanageable.

Table 2. Total Estimated P Load Estimates by Source

Nutrient Sources	**P kg**	***% of total***
Waterfowl/Geese	9.2	*11.8*
Septics	6.6	*8.5*
Direct Urine	1.6	*2.1*
Internal Load	19.8	*25.5*
Atmospheric Load	10.2	*13.1*
Watershed	30.4	*39.1*
SUM	**77.8**	**100.0**

External Load

Watershed Runoff

The 2015 Farm Pond watershed modeling report details the Lake Loading Response Model (LLRM) parameters used to estimate watershed P and N inputs from various sources. That effort calibrated the model using data collected prior to documentation of prolonged seasonal hypolimnetic anoxia and with very low overall surface TP concentrations. The estimated 2015 total load was 32.3kgP and 724.0kgN. Of that 2015 estimate, the direct watershed runoff was estimated to be 22% of the P load (7.2kg). AWS reviewed the parameters used in the 2015 LLRM model and believes that, given the updated in-lake epilimnetic average TP concentrations in 2023 and 2024, the basin attenuation coefficient for watershed P and N would be higher than what was used in the 2015 LLRM model, meaning more P passes through the watershed to the lake than was originally modeled.

The MA Watershed-Based Planning tool has a built-in model that is generally accepted for MA waterbodies. It is also based on precipitation, land use, and GIS-quantified impervious surface in a watershed. The model's details and results are in the accompanying Watershed-Based Plan document. Overall, this model predicted considerably higher watershed runoff P to Farm Pond. The WBP model outputs are displayed in lbs/yr and have been converted to kg/yr TP and TN in the table below.

Table 3. Watershed-Based Plan Nutrient Load Model Results

Land Use Type	TP (lbs/yr)	TN (lbs/yr)	TP (kg/yr)	TN (kg/yr)	TSS (tons/yr)
Agriculture	5	27	2.3	12.2	0.15
Commercial	1	9	0.5	4.1	0.11
Forest	30	119	13.6	54.0	3.26
High Density Residential	2	12	0.9	5.4	0.18
Highway	9	64	4.1	29.0	3.4
Industrial	0	0	0.0	0.0	0
Medium Density Residential	19	149	8.6	67.6	2.18
Open Land	1	5	0.5	2.3	0.09
TOTAL	**66**	**384**	**30.4**	**174.6**	**9.38**

The WBP model outputs do not have the same level of calibration capacity as the LLRM model. The LLRM output prior to setting a basin attenuation factor was very similar to the WBP model result. Had the LLRM model been calibrated with updated TP data, predicting a higher epilimnetic TP concentration, the final model P load estimate would have been higher and closer to the WBP tool estimate. AWS also used the Model My Watershed tool, which is based on the 2019 National Land Cover Data and the GWLF-E (MapShed) model, with 30-year average precipitation data from EPA National Climate Data. A preliminary run of this third model yielded an estimate that groundwater flows constitute about half of the Farm Pond watershed's P load (not including septic systems), simply due to the largely natural, consistent movement of shallow groundwater dissolved/colloidal P at low concentrations (0.014mgP/L) and the high fraction of water that moves through the watershed as shallow groundwater from forested land and residential parcels. Wetlands also carry consistent nutrient flows to the lake via groundwater and surface water. The MA WBP model results indicate high P from forested land as well, but do not specify the proportion of surface, stream, or shallow groundwater flows. The LLRM model seems to underestimate background shallow groundwater P movement and possibly overestimate forested land runoff, which is more problematic for watersheds with lower runoff volumes relative to the total water flows through a system annually. Of the forested land, WBP's total P load, shallow groundwater is likely about half of that source load (based on 0.014 mgP/L colloidal P in soil water), as only about 10% of the water that falls on forested land is expected to produce runoff.

Ultimately, these are models with inherent uncertainty and applicability. As evidenced by the variability of storm events, a watershed's ability to retain P will vary considerably from year to year. These P mass loads are estimates, aligned with average conditions that fit into the regulatory framework of lake management under the federal Clean Water Act. MA DEP currently uses the WBP tool modeled load estimates, so that is what has been used here to calculate estimated P load source contribution percentages.

Wastewater Sources

AWS reviewed the parameters used in the septic systems LLRM 2015 model and modified the estimate slightly using attenuation factors aligned with current literature for properly functioning septic systems <300ft to shore. AWS found no indication of shoreline septic system failures during the shoreline investigation; there were no septic smells along shore and no observed large surface mats of filamentous algae present downhill from known septic locations. Groundwater sampling took place in about 3ft of water near the shoreline downhill from a known location of a septic system in an area presumed to have positive groundwater flow in June 2024. Multiple sites were attempted but only a handful of shallow groundwater samples were successfully obtained.

Filtered groundwater samples had low overall specific conductivity, 64-108 µS/cm. Samples obtained were filtered immediately with a 1.6-micron filter and then lab-tested for TP and TN. Note that the filter size was purposely larger to account for colloidal P and N in groundwater. TP concentration ranged from 7-82 µgP/L, and TN concentrations ranged from 366-2,722 µgN/L. It was unclear if the one sample with a high filtered TN concentration was a result of a septic N plume, because it was also near a location with high potential wetland N sources as well. Ultimately, the groundwater sampling proved challenging at Farm Pond, and if it is done again, it should be done in early April when the groundwater table and seepage are expected to be higher. The best use of this technique is to find wastewater plumes, sometimes in excess of 6000 µgN/L.

Based on observed field conditions, AWS adjusted the LLRM model to reflect the current number (27) of septic systems in the watershed within 300ft of the shoreline (GIS file obtained from the Sherborn Groundwater Protection Committee well/septic mapping project). There were several additional systems in the watershed that were not within 300ft of the shoreline and were not included. Similarly, there were a number of cesspools in the watershed, but since the mapped cesspools were next to mapped septic systems on the same parcel, they were presumed inactive and not included in the model. Only one system was located within 100ft of the shoreline. AWS also added in the Town public restrooms to the model, assuming 60 people per day for 25% of the year, and 98% soil P retention from the commercial system. With that high presumed soil retention rate adding in the community system was negligible. In total AWS estimated that residential systems had about a 3-5% higher soil P retention than assumed in the 2015 model, based on local soils maps and distance from shore. That amounted to a total estimate of 6.6kgP/yr from onsite wastewater / septic systems in the watershed, about 1.2kgP lower than the 2015 LLRM estimate.

Direct urine contribution from children and adult swimmers at Sherborn Yacht Club and the Town Beach was estimated to be roughly 1.6kgP/yr. The urine estimate is based on a presumed 750mgP/L in urine concentration, 60 people for 70 days of the year, and 0.13 gallons of urine per person. This estimate is very hypothetical and a very low percentage of the annual P load. Yet, urine is primarily a bioavailable nutrient form and may be a reason for localized filamentous green algae along that shore.

Waterfowl Sources

Waterfowl, primarily Canadian Geese, at Farm Pond were counted on several AWS visits to the lake. The number of geese present ranged from 46-115 on summer observation dates. The evidence of geese nutrient pollution is visible in all the droppings left on moored canoes, kayaks, and paddleboards at the Sherborn Yacht Club. AWS updated the LLRM waterfowl loading model with several scenarios for how many days per year the geese are present. Assuming that 115 geese are present fulltime, yields an estimate of roughly 23kgP/yr load. But since fewer geese were observed on numerous sampling dates in 2023-2024, and assuming that a portion of the geese do not remain at Farm Pond all year, a total of 46 geese were used in the model. The LLRM base model estimates 0.2kgP/yr per bird, or 9.2kgP/yr from geese at Farm Pond. This is about double the 2015 estimate and amounts to about 12% of the annual P load. Actual P inputs from waterfowl are highly variable. Geese should be better managed at Farm Pond to preserve overall water quality. Various methods are suggested in the WBP report.

Atmospheric Sources

The atmospheric P load estimate from 2015 remains accurate and was not changed in this estimate. Atmospheric P load may increase considerably during a year of high particulates from wildfires, which is something that has not been factored into the modeling but that may yield short-term epilimnetic increases in P. Pollen also presents a short-term seasonal atmospheric P source. It is common to find cyanobacteria present in pollen surface scums. No attempts were made to quantify these specific atmospheric sources, since they are not manageable. Still, FPAC can be vigilant for if future cyanobacteria or other phytoplankton blooms occur coincidentally with short-term atmospheric loads. Atmospheric loading tends to be more impactful on water quality at oligotrophic lakes; it constitutes roughly 13% of the total annual P load at Farm Pond.

Internal P Load

2023 Spring Sediment Sample Results

Deep water sediment sampling was done via Ekman dredge, capturing approximately the top ten centimeters of sediment, at three deep locations in April 2023. Sampling in early spring is essential to capture the full sediment P, prior to the onset of anoxia, where sediment P generally begins to move into the overlying water column. These samples serve as a baseline for the various forms of P and potential for release via internal loading.

The fractionation procedure for lake sediments was performed by Upstate Freshwater Institute (UFI). Under normal pH ranges, Al-bound P, Ca-bound P, and Refractory organic P are generally considered stabile and not available. Fe-bound P, also known as reductant soluble P, is the P that is typically released during anaerobic internal loading scenarios. The loosely sorbed P is considered readily bioavailable. The labile organic P is sometimes factored into the potentially available P sum, but it depends on the microbial community present, and temperature at the sediment-water interface.

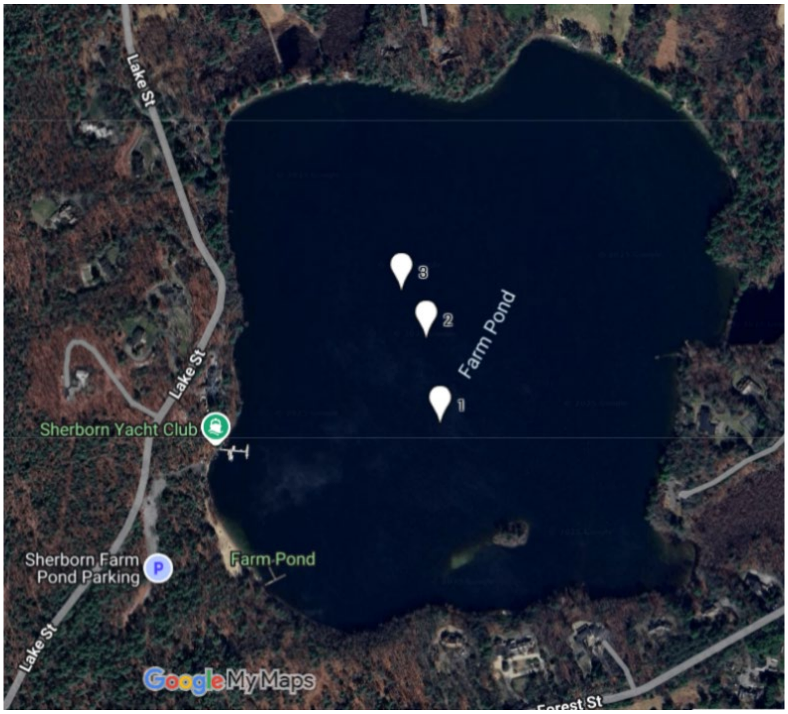
In total, four samples were taken at Farm Pond (three sites and 1 duplicate sample at the deep hole). The potentially available P is on average 1490 mg/kg dry weight. Sediment data is used in calculating potential P-binding treatments to manage internal load.

Map 4 shows the locations where sediment samples were taken.

Table 4. Sediment Sampling Results 2023

Parameter Averages	Method#	*Average (mean)*	Pot. Available P (mg/kg dwt)
%solids	SM18 2540B	***9.00%***	
%water		***89.50%***	
Total P (additive)		***2133***	
Loosely-bound P (NH4CL)	SM18 4500PF	***33***	33
Fe-bound P (DITHIONATE)	SM18 4500PF	***1208***	1208
Al-bound P (NAOH)	SM18 4500PF	***440***	
Labile Organic -P	EPA 365.1	***248***	248
Ca-bound P (HCL)	SM18 4500PF	***77***	
Refractory organic P	EPA 365.1	***126***	
SUM Pot. Available P			**1490**
SUM Reductant Soluble P	(minus Organic-P)		**1241**
Total N (mg/kg)		**202.8**	
% Organic Matter	Loss On Ignition	**33.9%**	

Map 4. April 2023 sediment sampling locations



Estimating Internal P Load

One method to estimate the internal P load in stratified lakes is to use in-lake P mass increases in the hypolimnion throughout the anoxic period. These estimates require accurate in-lake TP data and accurate bathymetry to account for water volume at specific depth zones. Volume data used in the lake P mass calculations came from FST 2015, included in Table 1 of this report. Lake-wide and hypolimnetic TP mass estimates based on April 2023 and 2024 data were compared to September and October data in each year. Seasonal hypolimnetic P mass increase was roughly +17.1-24.7 kg P. A seasonal total water column P change over the same dates was +12-16 kg P. Despite some settling of surface organic matter to the hypolimnion during the summer, the hypolimnetic P mass estimates are likely closer to the internal P load because the error range in P mass calculations also increases considerably in shallower water with very low concentrations and larger surface area. Estimates should be considered general ranges for 2023-2024.

During the 2022 cyanobacteria bloom, epilimnetic and metalimnetic samples were taken by FPAC. The dramatic increase in TP between 8-18-2022 and 9-16-2022 was estimated to be about 32 kg in the epilimnion. This considerably higher P mass increase is likely in part attributed to higher internal load related to the increased 2022 anoxic area and volume (**Figure 16**). The sediment P Release Rate (RR in $mgP/m^2/day$) is known to increase with temperature. As shallower waters became warmer and anoxic, the RR of sediment at that particular depth would increase at a different rate than deeper sediments.

RR can be measured in laboratory incubation experiments to quantify the amount of P released from sediment cores, but incubation experiments typically provide a maximum possible RR, which does not always translate well to real-world scenarios. Anoxic core laboratory RR results will vary heavily with depth of the sample, temperature, longevity of the experiment, and the initial sediment P content and forms (typically sample depth dependent). Costs associated with RR lab experiments are high, but if internal load treatment is pursued it is recommended alongside sequential alum dose testing on updated sediment cores from various depths. Oligotrophic lakes tend to have generally lower RR, despite often having high sediment P in deep-water sites. Similarly, deep water that remains cold for most of the season is associated with lower RR. The LLRM model references the median RR to be roughly 2.0 mgP/m²/day across study lakes, with a mean RR of roughly 6.0 mgP/m²/day. AWS used various peer-reviewed RR empirical models based on sediment P fractions and organic matter percentage and determined that the RR estimates of >3 mgP/m²/day were likely too high for the majority of the Farm Pond hypolimnion (Nurnberg, 2025). They did not align well with the calculated water column P mass increases.

Back-calculated RR, based on in-lake mass estimates in Farm Pond in summer 2022, 2023, and 2024, estimated the RR range to be 1.3-3.4 mgP/m²/day, where the higher RR was calculated based on the mass increase from August to September 2022 (FPAC TP data). AWS ultimately decided that the most accurate P release rate to use in modeling was roughly 1.8mgP/m²/day for the anoxic period. A detailed internal P RR model was used given the DO profile data and calculated area of sediment anoxia per sampling date x # days between sampling dates. That model resulted in about 24.5kgP/yr internal load estimate on average since 2020. To err on the side of not over-estimating internal P load, that estimate was then reduced by 20%, which better matched the in-lake P mass data seen in 2023-2024. The final estimate for internal load was 19.6kgP/yr, reflecting conditions in which lower internal load does not result in considerable cyanobacteria blooms. With increasing longevity of anoxia and a higher likelihood of warmer sediments with future climate change, this estimate is conservative. Still, it accounts for about 25% of the total annual P load. In warmer and drier years, internal P load will be higher and constitute a higher percentage of the total.

It is also important to consider that cyanobacteria are particularly adept at taking advantage of internally loaded P, as it is more bioavailable than particulate watershed P. Internal load also occurs during a condensed time of year where cyanobacteria have a competitive advantage over other types of phytoplankton algae (summer). Whereas a large portion of the watershed load occurs in high precipitation months of winter and spring.

Management Options for Internal P Mitigation

Phosphorus Inactivation

The most common method to manage anoxic sediment internal P loads that fuel cyanobacteria blooms is to treat the benthic lake sediment with aluminum compounds. **Aluminum sulfate** + sodium aluminate as a pH buffer (**alum** + aluminate) is the most common treatment performed in waterbodies across the country and in New England. The aluminum hydroxide floc that forms during treatment binds to phosphorus in both the water column and at the sediment surface, creating stable Al-P minerals, even under anoxic conditions. Lake alum treatments have taken place as early as the 1980s. Since the early 2000s, the technical aspects of dosing and application strategies have dramatically improved. If the Town plans to mitigate cyanobacteria bloom risk by managing internal P load, alum treatment is highly effective in most cases and has a good track record of use in MA. The permitting process for alum treatment in MA lakes requires additional information and would likely take at least a year to plan and obtain the necessary MA DEP and local Conservation Commission Wetlands Protection Act permits.

There are other forms of phosphorus inactivation treatments, such as the use of zeolites and calcium-based mineral applications, iron-oxides in combination with aeration/oxygenation, natural solid aluminum minerals, lanthanum hydroxides, lanthanum chloride, lanthanum modified bentonite (Phoslock/EutrosorbG), etc. All of these P-biding treatments have utility, but aluminum sulfate is often used because it is typically the most cost-effective and efficient method to mitigate a variety of lake internal loading conditions. Poly-Aluminum chloride (PAC) may also be appropriate for Farm Pond, but there are far fewer case studies of large-scale lake PAC treatments than aluminum sulfate treatments, because the cost is greater. The primary rationale for using PAC over Alum in certain cases is to avoid adding sulfur to the lake. The bottom of Farm Pond already produces hydrogen sulfide gas during the late summer, a result of the prolonged anoxic conditions. Although sulfur measurements were not part of the monitoring effort, the sulfurous smell was distinct in bottom samples from July to October 2023 and 2024.

Phoslock/Eutrosorb lanthanum-modified bentonite (LMB) products are useful for inactivating P in sediments. Still, they are not flocculants and would not provide water column clearing and may not react as readily with P in the water column. There is also concern that these products, which are clay-based and appear brown during application, may not fully settle out of the Farm Pond water column, potentially leading to prolonged elevated turbidity if another flocculant is not used concurrently. This is a concern for use at Farm Pond, where water clarity is typically excellent. There are also many fewer large-scale LMB treatment case studies, and the per-acre cost is more than double that of alum treatment.

Treatment Methods

When the internal P load exceeds 15% of the overall annual nutrient load, phosphorus inactivation should be considered. Cyanobacteria are adept at using internally loaded P to fuel whole-lake bloom events. Water-column use of phosphorus-inactivation flocculation products, such as alum, binds P and allows it to settle to sediments in a stable mineral form that is not subject to dissolution under anaerobic conditions, making it unusable by algae and cyanobacteria. Treatment of the water column alone requires lower alum dosages based on water-column P concentrations, and the resulting water-quality improvements are typically short-lived. Whereas higher alum dosages are calculated based on sediment P fractions and an anticipated dose intended to bind P at the sediment surface. Sediment P-inactivation attempts to achieve a ‘cap’ on the sediment surface to minimize the sediment release of P, particularly under anaerobic (no oxygen) conditions. If a sediment P inactivation treatment is initially under-dosed, due to the complicated nature of dose determination, the internal load may only be partially controlled, and water quality improvements may not be realized unless additional product is applied to reach an adequate dose. If the initial sediment P dose is sufficient, the timeline for water quality improvements following sediment treatment depends on the incoming P load.

If watershed and external P sources remain high, even a high dose of alum to target sediments will eventually be covered up by newly settled sediment. In cases where it is financially infeasible to apply a high alum dose to treat the sediment all at once, it is possible to conduct partial inactivation treatments across the target sediment areas, aiming to move towards the full recommended dosage over several years. Overall, Farm Pond is a good candidate for alum treatment, particularly given its low flushing rate and low annual watershed P load.

Alternatives to Phosphorus-Binding Treatments

There are theoretically multiple alternatives to aluminum-based in-lake nutrient inactivation treatments. Yet all alternatives have their own potential inadequacies. Aeration and oxygenation are frequently used to attempt to control internal loading by minimizing dissolved oxygen loss through various methods. Yet countless case studies have shown that simply aerating the water column above sediments cannot always prevent the recycling of various forms of sediment phosphorus (Kirol et al., 2024). Few aeration systems adequately oxygenate the sediment-water interface throughout. Pockets of low redox conditions at the sediment-water interface are possible. Additionally, if labile organic P constitutes a considerable fraction of total sediment P in mid-depth zones, the addition of oxygen may increase P mineralization rates under oxidized conditions.

Farm Pond is too deep for whole lake **circulation aeration**, as these types of systems disrupt the natural stability of the water column. Artificial lake mixing would negatively change Farm Pond’s ecology. Simply circulating a lake can also increase the entrainment of internally-loaded nutrients into surface waters, often increasing lake turbidity and phytoplankton biomass. Circulation aeration is generally not a good whole-lake option for Farm Pond or lakes deeper than 20ft.

However, a small **surface-water circulation** system could be helpful in the Town swimming area and near the Sherborn Yacht Club. Surface water circulators do not affect internal P loading, but they can be effective in preventing a build-up of surface cyanobacteria scums in recreationally important areas. Surface water circulators do not attempt to aerate; instead, they move the surface water enough to prevent cyanobacteria scums from accumulating along shore. These systems are typically less than $30,000 to purchase and install for beach areas. Summer mornings at Farm Pond are often very calm and still, with low wind. Even very low lake wide cyanobacteria presence can form small shoreline scums under those calm conditions. Small surface accumulations of cyanobacteria were observed in both 2023 and 2024 near the Farm Pond boat ramp, but they were naturally dissipated within a couple days while open-water clarity remained good.

Hypolimnetic oxygenation systems include various technologies ranging from unconfined oxygen bubble diffuser lines, hypolimnetic aeration chambers that use oxygen infusion, downflow bubble contact chambers, and sidestream oxygenation systems. These methods are designed to maintain natural thermal stratification. Oxygenation is often considerably more costly to implement than phosphorus binding treatments, but there is dual benefit of simultaneously increasing dissolved oxygen in the lake. In most cases where oxygenation or aeration is considered successful, typically in drinking water reservoirs, there is a secondary benefit of increasing the dissolved oxygen in downstream flows from deep-water releases. Many oxygenation systems also aim to reduce the amount of iron, manganese, and other compounds in source water to reduce drinking water treatment costs. Oxygenation and aeration can also successfully prevent and/or limit the accumulation of ammonia nitrogen in deep waters. Oxygenation is a costly capital investment that frequently exceeds the total costs of an alum treatment. There are then ongoing annual operating costs of oxygenation that the Town would have to assume, primarily for electricity and maintenance. There is also a space requirement for land-based operations. Oxygenation could be a viable option for Farm Pond, but further planning would be needed because designing and installing a system would likely exceed $600,000 as the initial investment. It is also risky in that Farm Pond currently accumulates hydrogen sulfide gas, indicating likely formation of iron-sulfide minerals that strip away the sediment's capacity to bind P with iron even in oxygenated conditions. Some oxygenation projects must also add iron to the hypolimnion to ensure enough P binding capacity. Oxygenation, despite higher expected long-term costs, may be a good option for Farm Pond in the face of future climate change. It may also not be required to run an oxygenation system for the whole season. FPAC might consider this approach and seek a preliminary quote for a sidestream oxygenation system from Clarity Resources Group Oxygen Saturation Technology (OST™).

For further reading, there is a detailed discussion of the types of oxygenation systems that could be potentially used in MA waterbodies in the updated 2025 draft of The MA Guide to Algae and Aquatic Plan Management. This publication is still in draft form but was released for a public comment period earlier in 2025. It is intended as an update to the 2004 Generic Environmental Impact Report on Eutrophication and Aquatic Plant Management in MA and accompanying Practical Guide to Lake Management in MA. The 2025 draft Guide also provides a very detailed explanation of the various permittable phosphorus inactivation treatments. The Guide covers information needed for a proper permit application, as well as potential risks and considerations.

Algaecides use at Farm Pond is generally not recommended as a long-term management strategy. Algaecides are appropriate for situations where a community is working towards nutrient reduction, and where temporary relief is needed. Algaecides are either copper based of peroxide based,

Alum Dose Determination

An Alum dosage recommendation was determined based on the following:

- **Alum treatment area should ideally include the total surface area of the bottom sediment that is subject to annual dissolved oxygen loss and anoxic conditions (defined here as <1mg/L).** Based on the dissolved oxygen (DO) profile data collected by FPAC volunteers and AWS, and the high-resolution DO logger data recorded in 2023 and 2024, the anoxic conditions at Farm Pond are variable from year to year. Variability is influenced by weather and seasonal air temperatures. The peak ascent of the anoxic boundary appears to have occurred in 2022 at roughly 7 meters. The 2023 and 2024 anoxic boundary peaked at about 9 meters. Since it was the 2022 7m anoxic zone that stimulated whole-lake algae and cyanobacteria blooms, the target sediment area should include the 7m zone. The surface area of the sediment greater than or equal to 7m is approximately 50 acres.

- **The target sediment depth for P-inactivation was set to 10cm.** The 2023 sediment samples represented roughly the top 10cm of sediment. Some treatments target only the top 4-6cm of sediment. It is standard for modern alum treatments to plan a dosage that addresses the top 10cm and the associated sediment volume (Wagner et al. 2017), particularly in the absence of additional centimeter-level sediment data. In some waterbodies, releasable P may extend shallower or deeper. Though P minerals are often less reactive deeper in the sediment profile, and Fe-P tends to be highest at the sediment surface in the top couple of centimeters. Additional sediment P fractionation tests can be done at the 0-5cm, 5-10cm, 10-15cm, and 15-20cm core depths to further refine the target treatment depth and dose. Retesting is recommended if the Town does not pursue alum treatments within 5 years.

- **The reductant soluble sediment-P concentration (mg/kg) includes the loosely sorbed and iron-bound, not labile organic P. Reductant soluble P is 1241 mg/kg on average across the deep zone).** Some sediment inactivation alum treatments include the labile organic P fraction into the dosage estimates, but labile organic P tends to be of greater importance in internal P recycling in shallower waterbodies that have higher temperatures and periods of light availability at the sediment surface. Labile organic P is an overall small part of the total potentially available P from Farm Pond deep sediments, but it may be a larger fraction of the 7-9m depth sediments. No samples were taken from this depth at Farm Pond, but this should be a priority to verify the calculated dose in the 7-9m depth zone if sediment-inactivation alum treatment is pursued.

- **The P mass per square meter to be treated was based on an assumed sediment bulk density of 1100 kg/m³. The average percent solids value of 9% was used in the calculation.** The resulting P mass to be treated was estimated to be at least 12.3gP/m².

- Al:P ratio of 12:1 (based on reductant soluble P) should be suitable for Farm Pond sediment-inactivation. This is a moderately ratio, above the frequently cited essential 10:1 ratio for modern Alum treatments (Wagner et al. 2017). The resulting treatment dose was calculated to be 147gAl/m² needed to presumably control internal load by 90%+. This proposed dosage is similar to dosages used in many New England lake alum treatments. The Al:P ratio for a 'full' sediment-binding dose may need to be >20:1 (also shown in **Table 5**), but internal load partial control will likely still generate long-term reduced hypolimnetic P and result in considerably reduced incidences of widespread surface cyanobacteria blooms. Sediment alum dose-response curves can be determined before treatment plan finalization to predict the anticipated % internal load control from test dosages. Test dosages are recommended for at least three sediment depth ranges.

- **Based on phytoplankton monitoring at Farm Pond, alum treatment of 147gAl/m^2 is expected to reduce the intensity and duration of cyanobacteria blooms for upwards of 20 years.** FPAC should not expect alum treatment to prevent 100% of cyanobacteria blooms. Small surface accumulations and potential narrow shoreline scums are likely to occur even after an alum treatment. However, significantly reducing the P in the water column and the overall internal P load will reduce the incidence of lake-wide poor clarity and prolonged dense cyanobacteria blooms stimulated by internal load. Alum treatment cannot prevent the germination of Dolichospermum akinetes in shallow sediments, nor can it prevent the migration of Microcystis from shallow and mid-depth sediments into the overlying water column. Alum treatment can, however, dramatically reduce water-column P, thereby reducing available P and increasing cyanobacterial growth in the water column.

- **It is not necessary for the Town to pursue full-dose alum treatment right away. Incremental treatment strategies are proposed.** Proposed sediment-dose scenarios rely on a hypothetical 5-year treatment program, with costs associated with treating sediment at various depths. Because the 7-9m zone has been identified as the critical depth of anoxia that is likely to push Farm Pond into full-lake cyanobacteria blooms, this area may need to be the only depth treated to prevent cyanobacteria blooms in the near future. There is one similar case study in Rhode Island that used this 'donut-shaped' alum treatment approach with success. Similarly, it may be most beneficial and cost-effective for Farm Pond to treat the 7-12m depth zone, rather than the whole >7m sediment surface. This area would be approximately 35 acres. If the Town chose to spread a full sediment inactivation dose across this area, the added costs of a 5-yr treatment strategy would likely be at least $33,000 – simply due to inflation and increased costs of product and labor. Additional permitting requirements may also be required to enact a 5-yr plan. However, for low alkalinity and low pH waterbodies like Farm Pond, this would also be seen as an ecologically beneficial approach to minimizing potential risks for aluminum toxicity to juvenile fish or invertebrates.

- **Water column stripping of the Farm Pond hypolimnetic P would also present a unique opportunity to see how the lake responds to a lower dose alum treatment.** A conservative estimate of hypolimnetic P stripping treatment would require roughly 3.5g/m^2 Al across the 50-acre zone (based on 35kg P to treat in hypolimnion and 20:1 Al:P binding ratio). This type of P stripping of the deep-water zone would require deep-water alum injection and the dose should be tested using a standard alum jar test and actual lake samples, where P, alkalinity, and pH are measured before and after several test dosages. Such a treatment would likely cost less than $15,000 but may not provide adequate P reduction for multiple seasons.

- **A comprehensive pre-, during, and post-alum treatment monitoring plan would need to be developed as part of the permit application package.**

Table 5. Alum Treatment Sediment Inactivation Dose Determinations

	Al Full Dose Determination Scenarios			Unit
Dose Scenario	**12:1 Al:Fe-P**	**20:1 Al:Fe-P**	**12:1 (RDP+labile-orgP)**	
Literature References	Wagner et. al. 2017	Huser 2012, James & Bischoff 2015	Kuster et. al. 2020	
Average Sediment Available P	1241	1241	1490	mgP/kg dwt
Estimated Bulk Density	1100	1100	1100	kg/m^3
Estimated Active Layer	0.1	0.1	0.1	m
Average Solids (minus water content)	0.09	0.09	0.09	decimal %
Mobile Phosphorus to Treat	12.3	12.3	14.8	g P m^{-2}
Total Aluminum Dose for P-Inactivation	147	246	177	g P m^{-2}
Treatment Area (Potential)	50	35	50	acre
Treat Area m2	202,343	141,640	202,343	m^2
Targeted Ratio of Alum to Sodium Aluminate	2:1	2:1	2:1	ratio

Literature References:

Kuster AC, Kuster AT, Huser B. 2020. A comparison of aluminum dosing methods for reducing sediment phosphorus release in lakes. Journal of Environmental Management, Vol. 261:1. https://doi.org/10.1016/j.jenvman.2020.110195

Huser, B.J. 2012. Variability in phosphorus binding by aluminum in alum treated lakes explained by lake morphology and aluminum dose. Water Res. 2012 Oct 1;46(15):4697-704. doi: 10.1016/j.watres.2012.06.005.

James, W., Bischoff, J. 2015. Relationships between redox-sensitive phosphorus concentrations in sediment and the aluminum:phosphorus binding ratio. Lake and Reservoir Management. 31:339-346.

Wagner, K., Meringolo, D. Mitchell, D.F., Moran, E. Smith, S. 2017. Aluminum treatments to control internal phosphorus loading in lakes on Cape Cod, Massachusetts. Lake and Reservoir Management. 33:171-186.

Table 6. Pricing Estimates for Various Treatment Scenarios

Treatment Pricing Estimates		Higher Dose:	Adequate Dose:	Scenario: Distribute Adequate Al Dose Over 5 Years					
		246 g/m2 Al	147 g/m2 Al						
				Year 1 $	Year 2 $	Year 3 $	Year 4 $	Year 5 $	5yr Plan Total
Depth zone (m)	Treatment Acreage	Estimated Cost $ (All at once)	Estimated Cost $ (All at once)	Half dose	No treatment	Quarter dose	No treatment	Quarter dose	Extra ~$33,541
						+20% cost increase		+10% additional cost increase	(Above: Additional $ expected from splitting treatment to 5 years)
7 to 9	15	$184,289	$110,573	$55,287	$0	$33,172	$0	$36,489	
7 to 12	35	$430,007	$258,004	$129,002	$0	$77,401	$0	$85,141	$291,544
10+	30	$368,577	$221,146	$110,573	$0	$66,344	$0	$72,978	
7+	50	$614,295	$368,577	$184,289	$0	$110,573	$0	$121,630	

Actions Required Before Alum Permit Application Submittal

The Town's limnological consultant would ideally work alongside a selected potential treatment applicator to gather remaining data, conduct lab tests, and fine-tune the project details for a successful permit application.

1. Obtain and test sediment cores from the 7-12m depth zones to verify the proposed dosages, which were based on sediment samples from the deepest part of the lake.
2. Conduct alum sediment-inactivation sequential dose testing on at least mid-depth sediment cores to verify dose ranges.
3. Conduct alum jar tests on hypolimnetic water samples.
4. Engage an alum treatment applicator company. SOLitude Lake Management is the most experienced alum applicator for large treatments in New England.
5. Calculate the gallons of aluminum sulfate and sodium aluminate needed for each phase of the treatment, and an application strategy that meets the water quality standards for aluminum in surface waters. It is expected that no more than 25g/m² Al can be applied per day.
6. Develop a pre-, during, and post-treatment monitoring plan – detailed with responsibilities and safety protocols for adjusting treatment to meet real-time pH change needs.
7. Hold a public information session and post information online to engage the community before filing permit applications. Address initial public questions that arise from public review of this Management Plan. Permits needed will include a Wetlands Protection Act (WPA) permit from the local Conservation Commission and MA DEP, and a license to apply chemicals (WM04 permit) from MA DEP.

Aquatic Plants

Plant Survey Methods

An aquatic plant survey was conducted over several visits in summer 2023. The survey was a meander-based survey, with waypoints spaced about every 200ft throughout the littoral zone. New or rarely present species are more likely to be found with "meander" survey techniques than with transect-based surveys, or surveys with pre-determined point-intercept gridded waypoints. This is based on the fact that certain species grow in particular depth ranges, sediment types, and slope conditions that may otherwise be missed by just predetermined point-intercept surveying. With the meander style survey, high-resolution down-imaging SONAR is fixed to a survey boat and used continuously with a GPS. Waypoints provide geographic sampling units to estimate community species richness, diversity, abundance, and species-specific densities. The core survey will make waypoints throughout the littoral zone, spaced approximately 200ft apart, but if the plant community changed rapidly within a small area, additional waypoints were also made. Although, in clear-water lakes like Farm Pond, the meander survey allows for concurrent visual inspection of the entire shallow littoral zone, between waypoints. The SONAR imaging in deeper water is also continuously viewed and if any unusual deep-water plant beds are seen on the SONAR record, additional waypoints are made as needed. In both the visual and SONAR survey depth ranges, raking is used to verify the species' presence and approximate percent coverages.

At Farm Pond, the species' percent coverage values at each waypoint were based primarily on visual estimates of roughly a 10x10m zone. Raking then verifies that no species were missed or growing underneath observed vegetation. The >10ft depth zone is not as readily visible from the surface and so these waypoint species densities were based primarily on depth raking and SONAR. Rake tosses involve throwing a 30ft line to tow along the bottom to rake up plants. Plants retrieved by the rake are estimated semi-quantitatively as a percent cover:

- Very Sparse (1-9% cover, fingerful of plants on rake)
- Sparse (10-19%, handful of plants)
- Moderate (20-59% cover, plants covering about half of the rake tines)
- Dense (60-79%, plants covering more than half of the rake tines)
- Very Dense (80-100%, plants covering nearly all the rake tines)

Coverage percentages are used to distinguish between Very Sparse, Sparse, Moderate, Dense, and Very Dense plant beds for mapping. The numeric percent cover at each waypoint is only semi-quantitative. Across all waypoints, the data can be used more quantitatively over time if users recognize the inherent limitations of percent cover estimates per species at individual waypoints. It is also important to note that the total percentage of all species at a single waypoint will often not add to 100% because species occupy different heights in the water column, and coverage of a low-growing species may be 60%, while another species may also be 60%, with coverage primarily in the upper water column.

The biovolume of the species is estimated using a combination of visual and SONAR readings to document the average height of each species relative to the depth of the water at each waypoint. Biovolume is estimated based on a Growth Form (G) scale of 1-5, where:

1 = Plants low to the lake bottom, not more than a few inches tall
2 = Plants reach ~25% of the water column
3 = Plants grow to a little more than half of the water column depth
4 = Plants grow close to the surface, ~1ft or less from surface
5 = Plants "topped out" and breaking the surface, often flowering or with floating leaves.

If a plant bed is observed with equal amounts of a species at Growth Form 4 and 5, the species is recorded as a 4.5. Point-density maps utilize the latitude and longitude coordinates of the survey waypoints, which are organized into a table (.csv) of the raw survey data. Column data denotes the species-specific %coverage, which is then translated to a point size palette in R. Google basemaps are used. R-generated point-density maps are for visual representation and are not used to calculate the area of invasive species; approximate lakewide coverage zones can, however, be inferred and calculated from the maps. The size of the points corresponds to the %coverage estimates, not the growth form, because the G value typically changes more dramatically as the season progresses.

Plant Survey Results

In summary, the aquatic plant survey results found only one location with emergent shoreline invasive purple loosestrife (*Lythrum salicaria*). All other submerged and emergent aquatic plants were native species. Needle spikerush (*Eleocharis acicularis*) was the most frequently observed species, present at about 40% of the waypoints surveyed. The plant-like macroalgae *Nitella*, was the second most frequent species found. It was frequently the dominant species blanketing the 10-16ft water depth zone.

Table 7. Plant Survey Species List, Frequencies & Average % Cover

Scientific Name	Common Name	#Observations	Frequency%	AVG%Cover
*Nothing present	NA	13	11	NA
Elatine minima	Small waterwort	24	20	7
Eleocharis acicularis	Needle spikerush	48	40	30
Eriocaulon aquaticum	Pipewort	1	1	20
Filamentous algae	Mixed types	21	17	23
Fontinalis	Aquatic moss	21	17	10
Gratiola aurelia	Golden hedge-hyssop	10	8	20
Isoetes echinospora	Quillwort	20	17	20
Ludwigia sp.	Water primrose	2	2	35
Lythrum salicaria	Purple loosestrife	1	1	Emergent
Myriophyllum humile	Native low watermilfoil	1	1	5
Nitella sp.	Plant-like macroalgae	43	36	26
Nuphar variegata	Yellow waterlily	2	2	10
Polygonum sp.	Water pepper	1	1	Emergent
Potamogeton berchtoldii	Slender pondweed	2	2	8
Potamogeton bicupulatus	Snail-seed pondweed	1	1	5
Sagittaria graminea	Grassy arrowhead	21	17	23
Sparganium americanum	American bur-reed	2	2	8

Nitella sp. (Plant-like macroalgae, deep-water dominant)

Needle-spikerush (*Eleocharis acicularis*) – likely culprit for "grass clippings" seen after windy days

Quillwort (*Isoetes*)

Aquatic Moss (*Fontinalis*)

Sagittaria graminea

Quillwort, Aquatic Moss, and Grassy arrowhead plants were common in the shallow zones up to about 8ft deep. Quillwort was more dominant in shallower water. Aquatic moss was often dominant in shaded areas with overhanging trees, but was also found in deeper water in a number of locations. The Grassy arrowhead (Sagittaria graminea) was common in the 3-8ft depth range. No submerged invasive species were found during this survey. However, the following year, FPAC volunteers found and removed two small invasive Water chestnut (*Trapa natans*) plants in the Town swimming beach area. It did not reappear in the 2025 season.

Overall, the Farm Pond aquatic plant community is diverse. The shallow sediments were generally sandy and gravelly, with slightly more organic matter below 4ft. As the Farm Pond sediments accumulate more organic matter over time, they will likely start to support denser aquatic plant growth in some areas. Native narrow-leaf pondweed species (*Potamogeton bicupulatus* and *Potamogeton berchtoldii*) were observed at only a few locations, but in oligotrophic lakes, they tend to grow in small clumps in deep water and may have been undersampled. AWS did a diving inspection of the littoral zone extending perpendicular to shore from the boat ramp. Nitella growth was observed to be a higher percent cover in this zone in deep water, up to about 20ft deep, which was not all sampled via the boat-based survey. Swimmers reported seeing an increase in the deep-water Nitella growth in recent years.

Aquatic plants and algae survey maps are included in Appendix B.

Proposed Plant Management Goals

There are currently no nuisance-level or submerged invasive plant species present at Farm Pond. No species-specific management is proposed at this time. The future of plant management at Farm Pond will consist of 1-Prevention of Aquatic invasive Species (AIS), and 2-Containment if any AIS are found.

Prevent AIS

The following prevention measures are proposed:

- Increase public awareness of AIS – Maintain prominent public signage at public access locations, and encourage attendance at AIS educational events
- Continue FPAC boat and watercraft washing inspections and Town boat sticker program
- Identify sites with nearby AIS and potential routes of infestation – One of the largest threats will be the Charles River, particularly its population of invasive Water chestnut.
- Increase scouting of potential new AIS – Identify community volunteers, frequent swimmers who see the public access sites regularly.
- Keep track of fishermen and fishing at Farm Pond. People who fish typically frequent many locations, which inherently increases the chance of new AIS being brought in.
- Be mindful that invasive Water chestnut and some other AIS can also spread via birds and seeds.
- Increase the frequency of full lake aquatic plant surveys to at least every 3 years. Document changes in native plants and early detection for any potential new AIS. Consider adding in snorkel-based formal surveys for high-use areas.

Contain Future Potential New AIS

If someone spots a new or unknown aquatic plant, FPAC should encourage residents to take a photo and report it to the Town/FPAC. Farm Pond is incredibly vulnerable to AIS like Hydrilla, Eurasian milfoil, and Fanwort. Any introduction of these species would be catastrophic for overall lake management, particularly if it occurs outside the first year or two of infestation. These species would easily spread throughout the littoral zone and would likely cost up to $60,000 annually for multiple years of management. Aquatic plants present the highest risk for Farm Pond, as the lake's naturally low alkalinity makes it unlikely to support invasive Zebra mussels.

If a new invasive plant is found at Farm Pond, hand removal of a few individual plants is appropriate and does not require a formal permit. Water chestnut is easily hand-removed, but invasive Milfoil, Fanwort, and Hydrilla are not easily removed and require care to uproot without breaking or fragmenting it. Decisions can be made on a case-by-case basis, but if a new AIS patch is found to be larger than 3ft in diameter, it is often better to place a small benthic barrier over it, as hand-pulling could accidentally fragment it and leave small roots to repropagate.

It would be worth pursuing an AIS Wetlands Protection Act (WPA) Ecological Restoration Limited Project permit to cover the emergency deployment of benthic barriers if a new AIS species is found that warrants barrier use. There may also be a general statewide rapid-response WPA allowance, but the Town and FPAC should consult with the Conservation Commission and MA DEP/MA Wildlife in advance. If granted a rapid-response AIS management permit, it would dramatically reduce the time to action and increase the chance of eradication. An Order of Conditions can be renewed multiple times, so a rapid response WPA permit remains active into the future. Fast response using benthic barriers has a higher rate of successful eradication than Diver Assisted Suction Harvesting (DASH) on medium-sized new AIS plant patches. DASH or diver hand-removal might be a useful rapid-response tool if there are many small, scattered plants of a new AIS, but the prevention plan will minimize this risk.

Conclusions

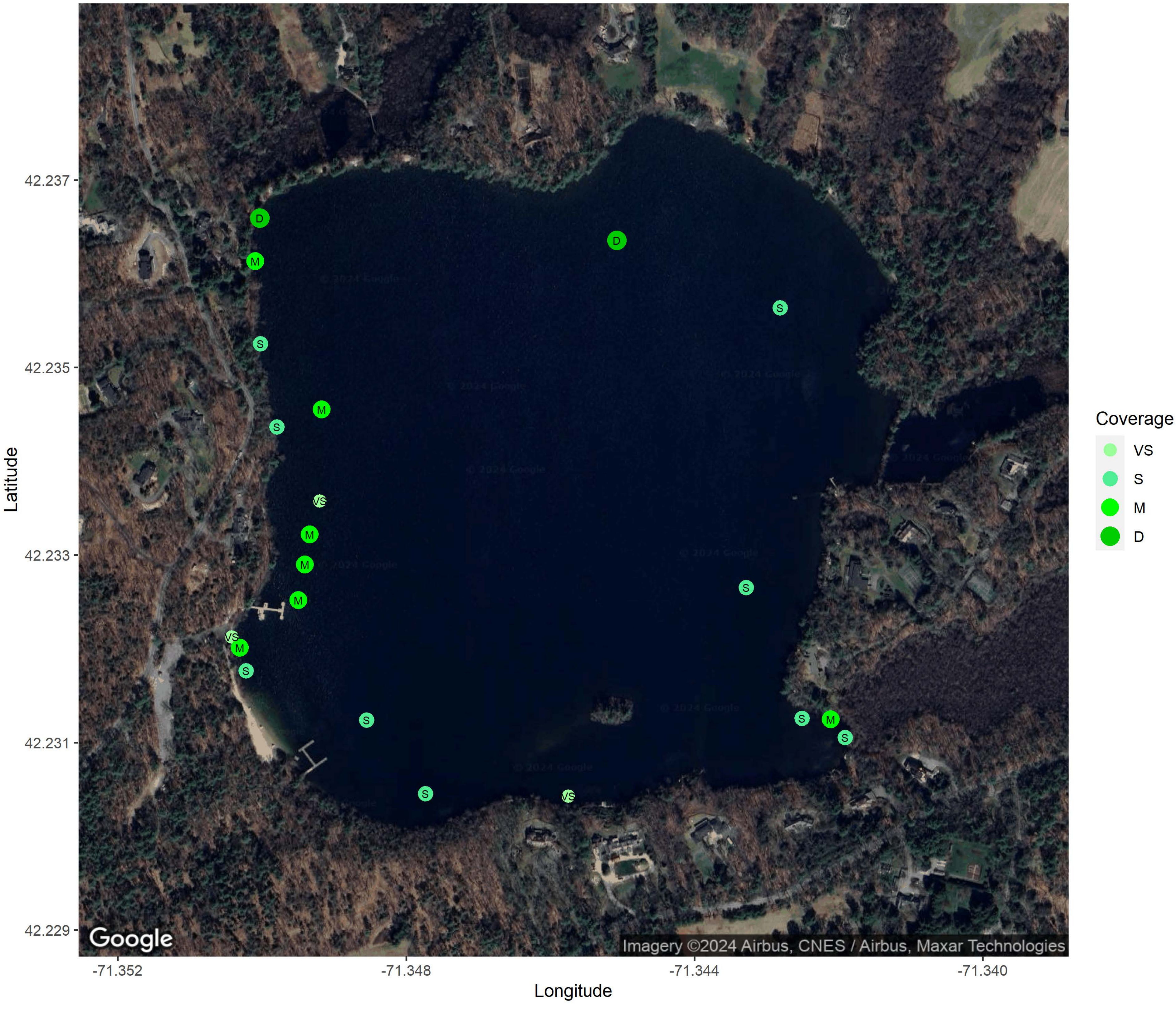
Farm Pond is a vital resource for the Town of Sherborn. This updated lake management assessment provides reasonable, actionable strategies to minimize the risk of future cyanobacteria blooms and invasive species colonization. This report accompanies the Farm Pond Watershed-Based Plan, which itself is not well structured to focus on the technical details of in-lake nutrient cycling dynamics or plant management. At present, the internal nutrient load, primarily phosphorus, appears to have the most direct causal impact on surface cyanobacterial blooms. While it is essential for continued watershed improvements and stormwater runoff reductions, the in-lake data demonstrate that watershed management alone is unlikely to significantly reduce the incidence of future potential cyanobacteria blooms, particularly in the face of climate change changes to lake thermal structure.

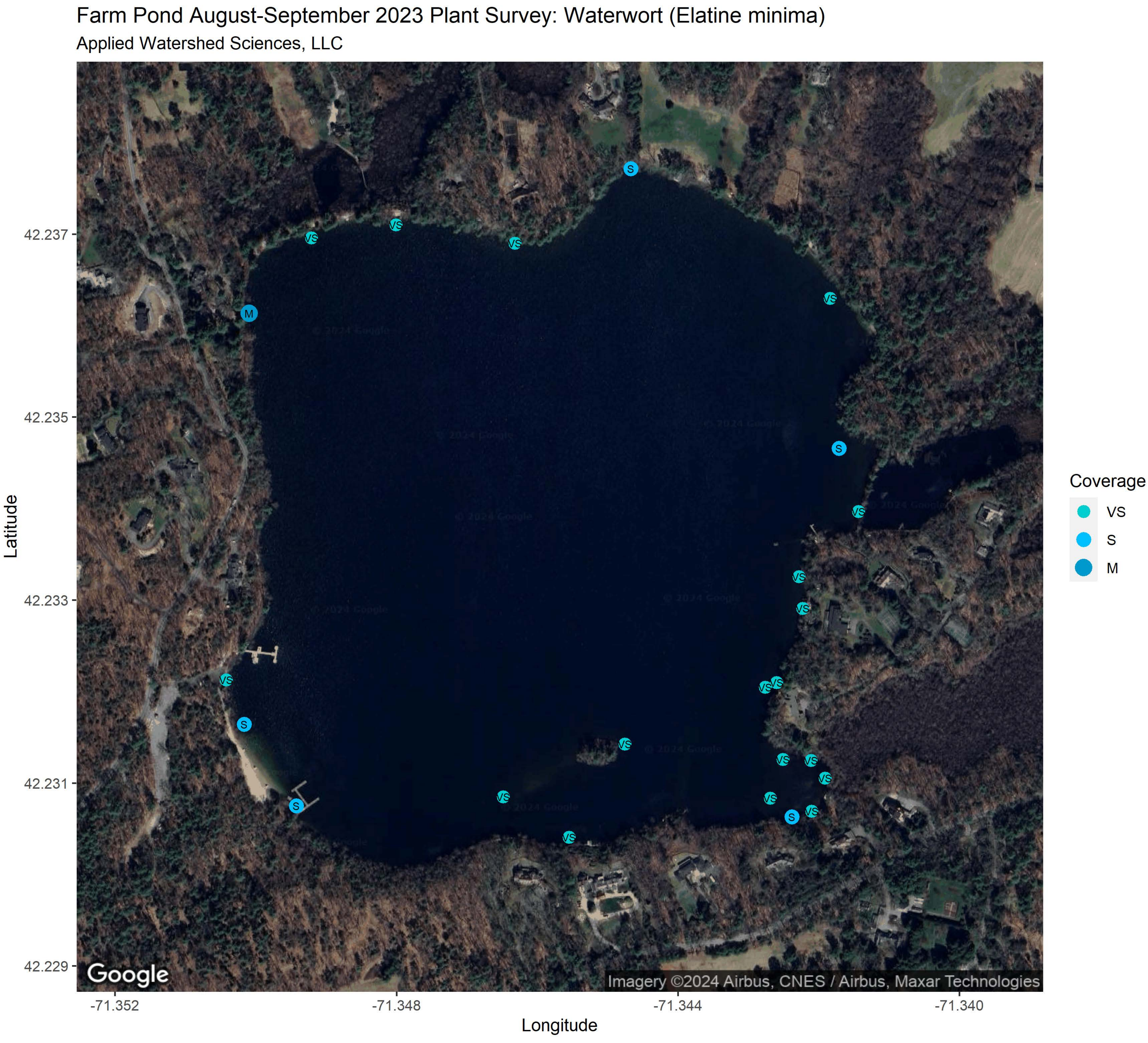
In addition to the recommendations made throughout this report for in-lake management and future monitoring, it is worth emphasizing that in-lake management is a long-term, somewhat experimental process. An alum treatment could provide many years of water-quality improvements at Farm Pond, but it is unrealistic for the community to expect complete control of all surface cyanobacteria blooms. Alum treatments and oxygenation systems designed to tackle internal phosphorus loading are best suited to prevent widespread dense cyanobacteria blooms that cause poor clarity events or large surface shoreline scums that remain for weeks. Several of the surface wispy cyanobacterial accumulations noted from 2023-2025 have been relatively minor and, thankfully, mostly did not interfere with recreation offshore or along the opposite sides of the waterbody. It is likely that Farm Pond, even if in-lake management were pursued, would still experience occasional small, short-lived shoreline cyanobacteria accumulations; blooms that would dissipate completely in the afternoon as winds mix the surface water. If in-lake management is pursued, it will be essential to communicate reasonable expectations to the community.

And while cyanobacteria prompted this lake management assessment and accompanying Watershed-Based Plan, invasive species pose an equal threat to the lake. It cannot be overstated how vulnerable Farm Pond is to potential invasive aquatic plants. The existing FPAC boat and watercraft inspection program is paramount to the future health of Farm Pond. This plan recommends plant surveys every 3 years, but if funding allows, annual aquatic plant surveys and an active weed-watchers program will greatly enhance management efforts; rapid response to invasive species is essential.

Farm Pond August-September 2023 Plant Survey: Filamentous algae (Green Clouds & Brown Periphyton)

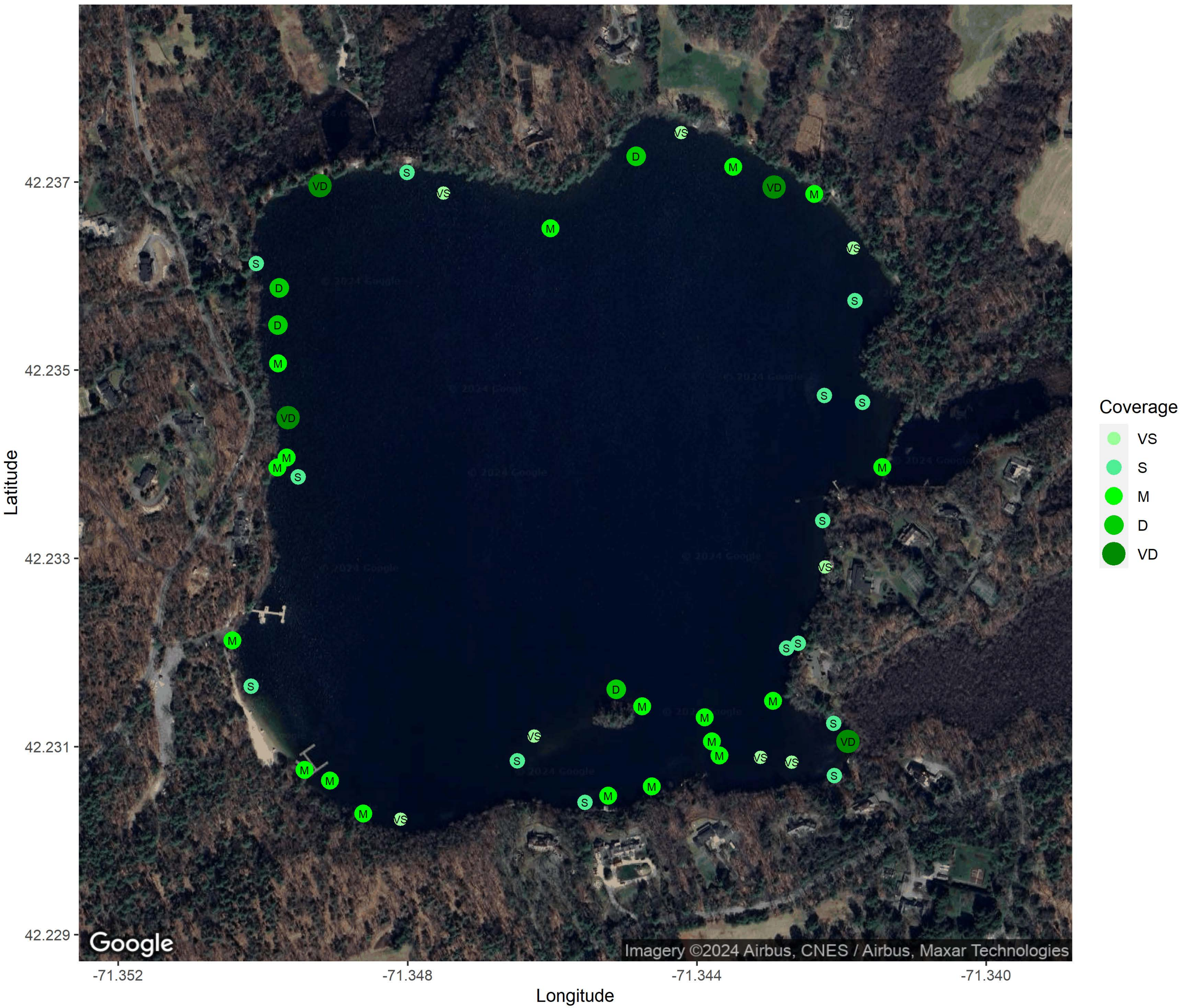
Applied Watershed Sciences, LLC




Farm Pond August-September 2023 Plant Survey: Waterwort (Elatine minima)
Applied Watershed Sciences, LLC
Latitude
42.237
42.235
42.233
42.231
42.229
Longitude
-71.352
-71.348
-71.344
-71.340
Coverage
VS
S
M
Google
Imagery ©2024 Airbus, CNES / Airbus, Maxar Technologies

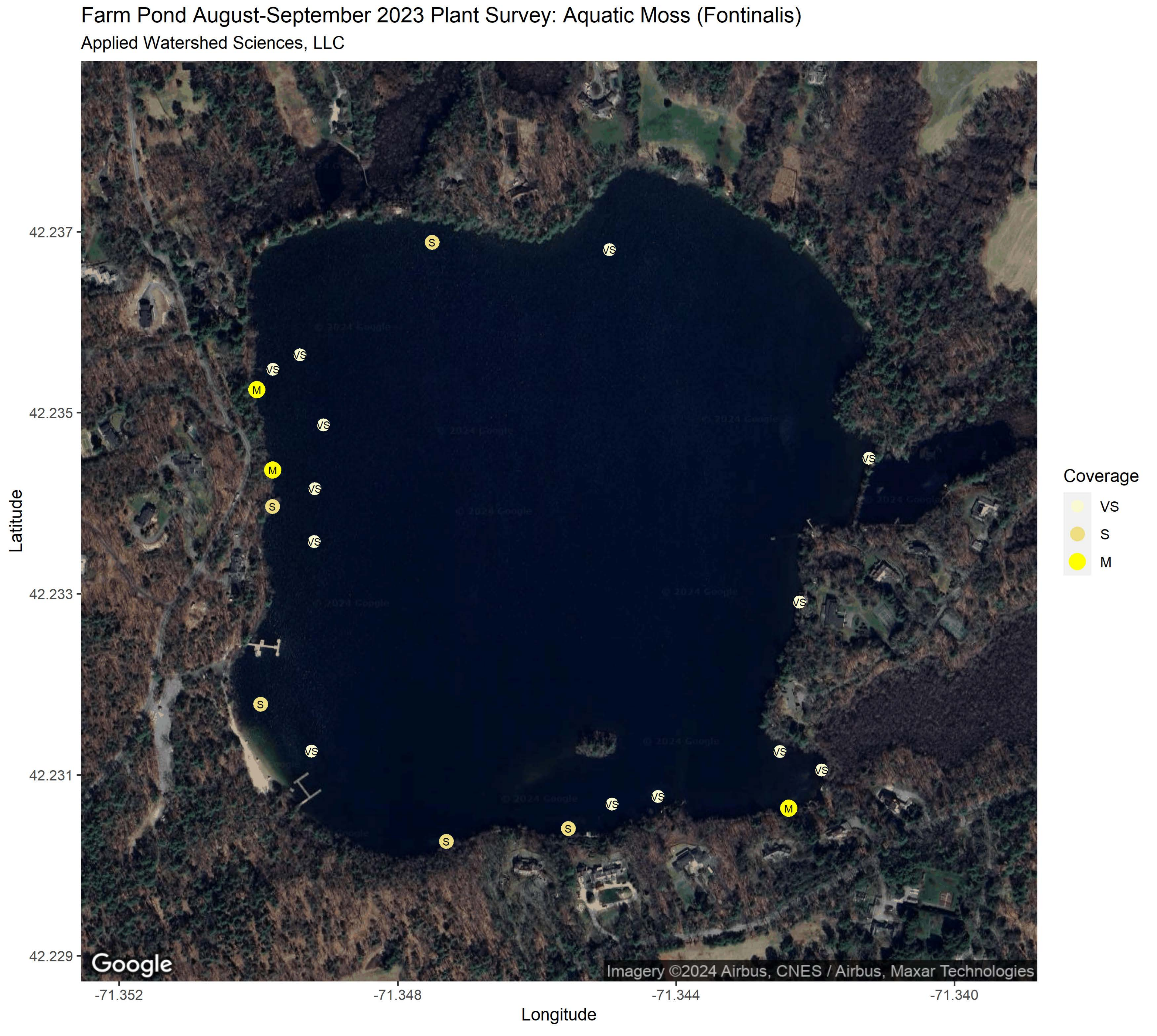
Farm Pond August-September 2023 Plant Survey: Needle spikerush (Eleocharis asicularis)

Applied Watershed Sciences, LLC



Farm Pond August-September 2023 Plant Survey: Pipewort (Eriocaulon aquaticum)

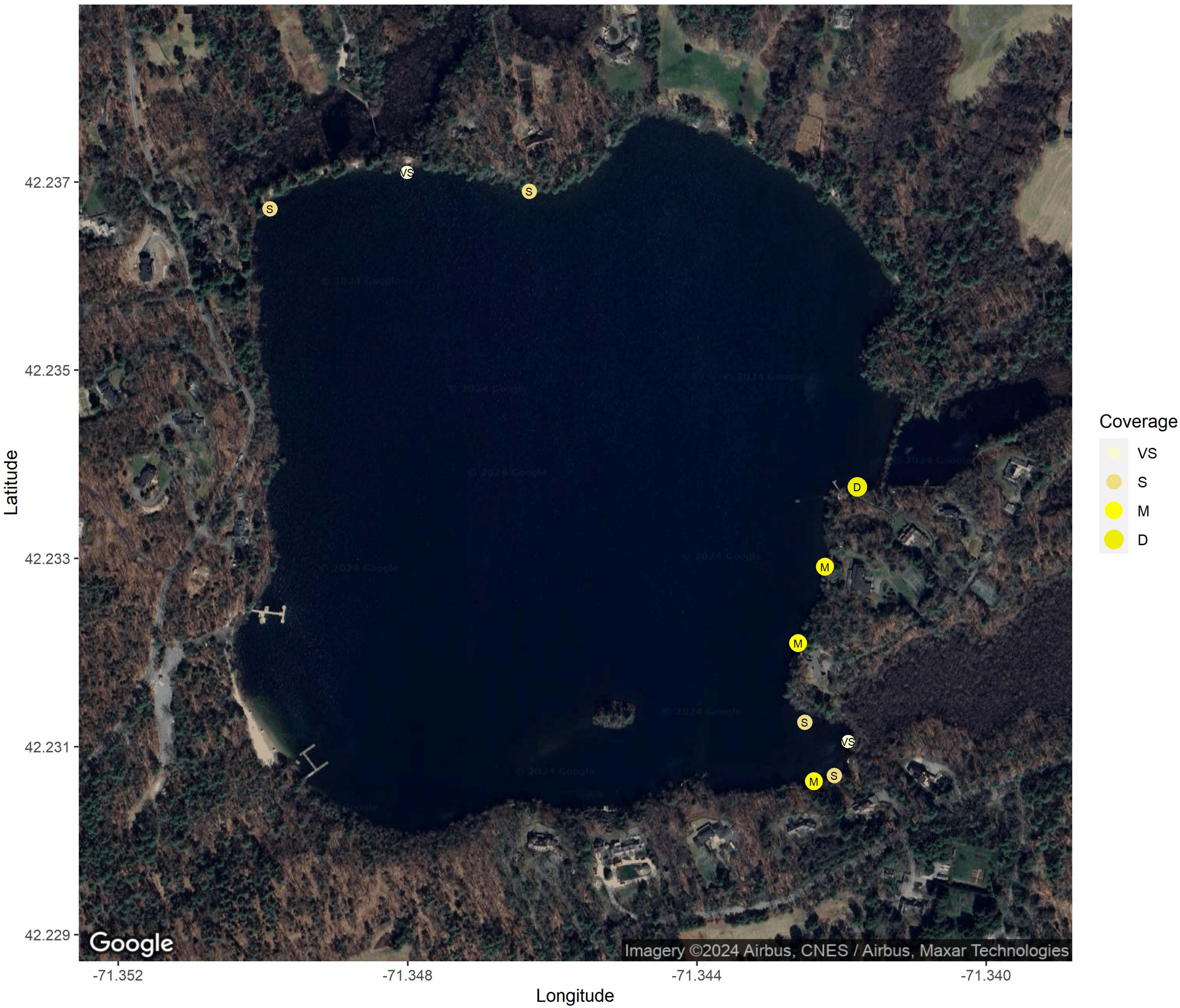
Applied Watershed Sciences, LLC



Farm Pond August-September 2023 Plant Survey: Aquatic Moss (Fontinalis)
Applied Watershed Sciences, LLC
Latitude
42.237
42.235
42.233
42.231
42.229
Longitude
-71.352
-71.348
-71.344
-71.340
Coverage
VS
S
M
Google
Imagery ©2024 Airbus, CNES / Airbus, Maxar Technologies

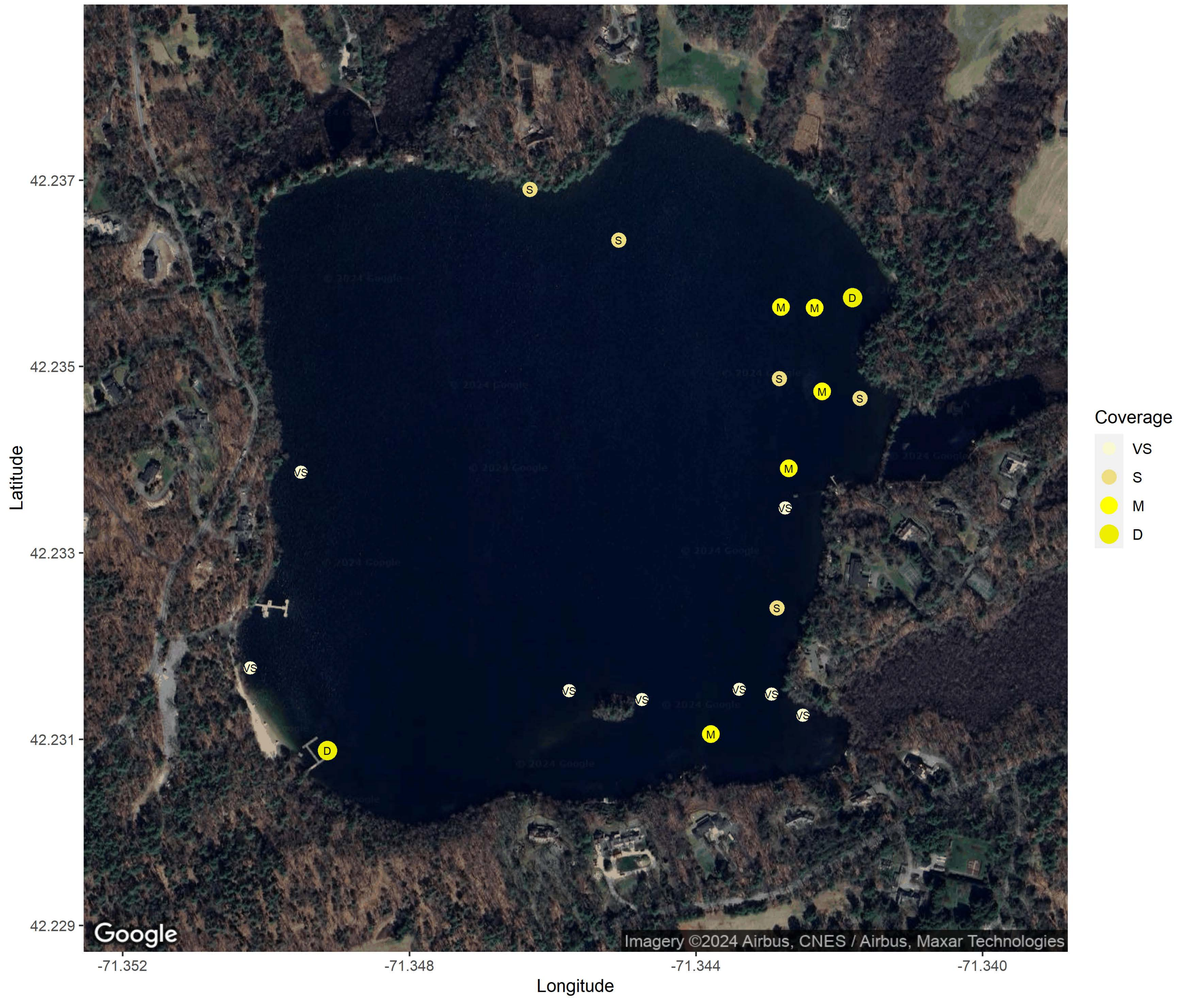
Farm Pond August-September 2023 Plant Survey: Golden hedge-hyssop (Gratiola aurea)

Applied Watershed Sciences, LLC



Farm Pond August-September 2023 Plant Survey: Quillwort (Isoetes echinospora)

Applied Watershed Sciences, LLC



Farm Pond August-September 2023 Plant Survey: Invasive Purple Loosestrife (Lythrum salicaria)

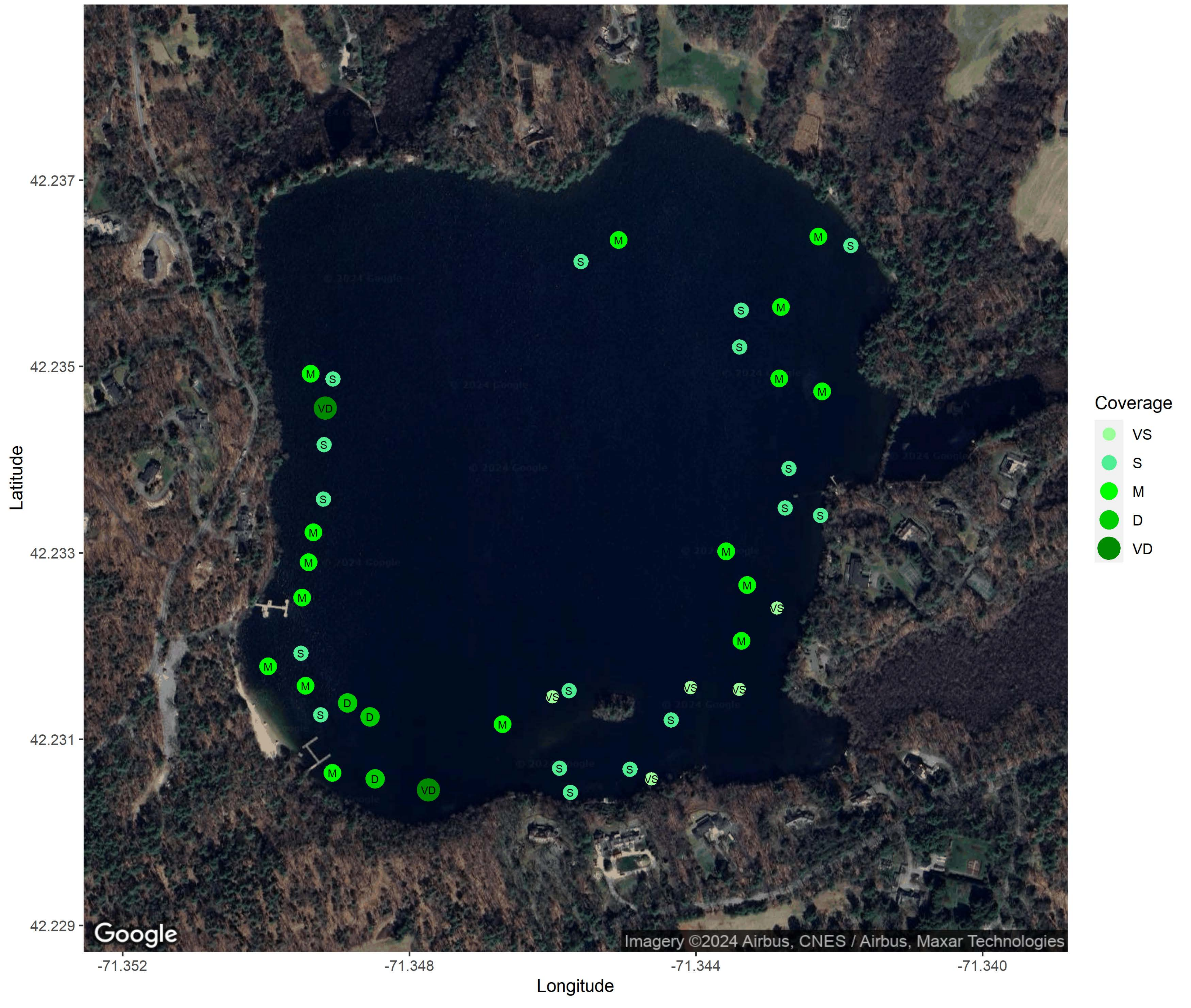
Applied Watershed Sciences, LLC

Farm Pond August-September 2023 Plant Survey: Native Low watermilfoil (Myriophyllum humile)

Applied Watershed Sciences, LLC

Farm Pond August-September 2023 Plant Survey: Plant-like Macroalgae (Nitella sp.)

Applied Watershed Sciences, LLC



Farm Pond August-September 2023 Plant Survey: Yellow waterlily (Nuphar variegata)

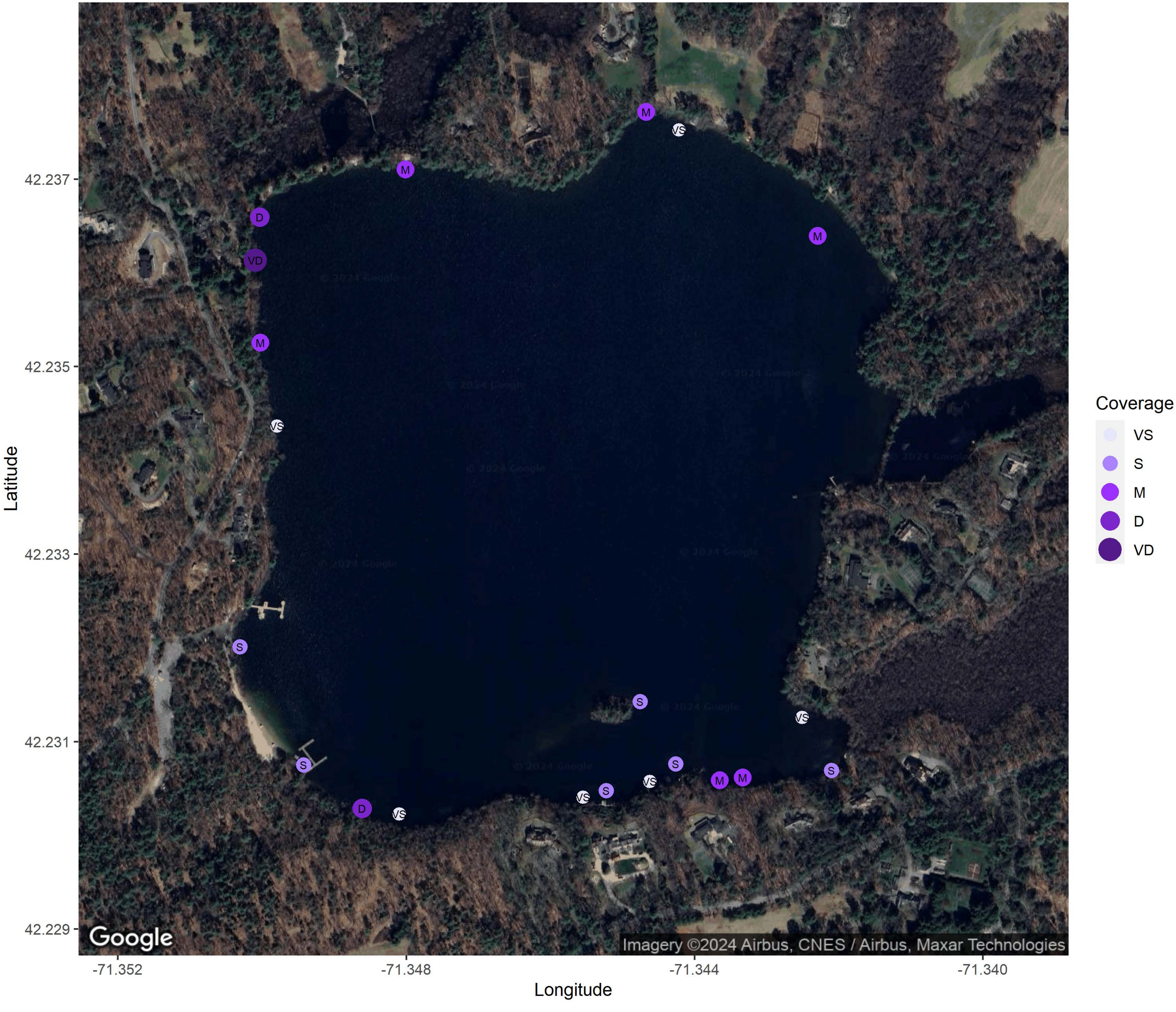
Applied Watershed Sciences, LLC

Farm Pond August-September 2023 Plant Survey: Narrow-leaf Pondweeds

Applied Watershed Sciences, LLC (Potamogeton berchtoldii & Potamogeton bicupulatus)

Farm Pond August-September 2023 Plant Survey: Grassy Arrowhead (Saggittaria graminea)

Applied Watershed Sciences, LLC



Farm Pond August-September 2023 Plant Survey: Emergent Bullrush (Sparganium americanum)

Applied Watershed Sciences, LLC