WATERSHED-BASED PLAN

Bare Hill Pond

HARVARD, MA

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Prepared By:

Bare Hill Pond Watershed Management Committee
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MassDEP
Commonwealth of Massachusetts
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Contents

Executive Summary

Bare Hill Pond (or the "Pond") is a 321-acre Pond in the Nashua watershed that sits within a 2427 acre local watershed in the center of Harvard, MA. In its natural state, Bare Hill Pond was approximately 200 acres prior to the addition of a dam in 1838 to power mills in the Town. The increased area was formerly used as sheep meadow and the hills surrounding the Pond had been heavily deforested for lumber; thus the name "Bare Hill Pond." Sheep farming declined after the opening of the Erie Canal in the 1840s leading to reforestation of pine, hemlock and chestnut trees in the 1800s. The expansion of the Pond over former sheep meadow and runoff from the surrounding hills added significant nutrient load to the Pond sediments over many years.

The watershed remained largely undeveloped prior to the 1950s as Harvard was a mostly rural and farming community. Over time, homes and seasonal homes were built around the shore of the Pond and there are approximately 100 homes around the Pond at this time with considerable re-growth of forest. Excessive growth of invasive species was first noted by residents in the mid-1950s. Beginning in 1959, the Select Board appointed a Bare Hill Pond Committee and private funding was raised for a five-year herbicide program using Silvex. It was reported to have cleared the pond of "weeds." Treatments continued in the 1960s and 1970s and a harvester was acquired in the 1970s to address what herbicides did not address. Concerns about the safety of the then-available herbicides emerged in the late 1970s. Even with the herbicide treatments, variable milfoil grew uncontrolled in many locations. In 1983, the Town voted to restrict future use of herbicides and purchased a larger harvester. The result, in hindsight, is that use of herbicides over 20 years likely resulted in removing native and non-native plants, but when the practice was discontinued, and harvesting became the primary method of control, milfoil spread throughout the Pond leading to the 1987 Whitman and Howard Study and the 1998 TMDL Report finding that Bare Hill Pond was endangered due to excessive growth of invasive species (milfoil, fanwort and water chestnut). The harvesting provided temporary relief to some areas, but by 2001, the Pond was nearing a eutrophic state in late Summer with phosphorus readings of 0.044 mg/l. Areas were becoming impassible to boats and swimming was hazardous in many locations.

The Bare Hill Pond Watershed Management Committee ("BHPWMC") engaged experts to consider its options and determined that the prior efforts to focus on "weeds" alone was treating a symptom and was not addressing the underlying challenges of eutrophication, high phosphorus and invasive species. The Committee reviewed its options, and as discussed in this Watershed Management Plan, adopted a habitat-based approach that was designed to address the goals of the 1998 TMDL report. The strategy was to begin to use winter drawdowns to reduce phosphorus by increasing turnover in the Pond, and to control the invasive species that were differentially impacted by winter drawdowns. The harvester was re-purposed to operate only in locations of the Pond that were dominated by water chestnut plants.

This work was planned, and then put in operation using practices in the newly issued GEIR and using specific habitat assessments and guidelines based on two studies by ENSR for the BHPWMC in 1998 and 1999. Careful protocols were established and submitted to the Conservation Commission for regulation under an Order of Conditions. Central to the strategy was to proceed incrementally to ensure habitat protection and restoration, based on well-defined protocols for data monitoring and assessment. The initial drawdown was 1.5 feet, and it was followed by 3 years of gravity-based drawdowns at the dam of 3.5 feet. At this time the

BHPWMC applied for a Section 319 grant, because it became evident that while the drawdown was improving the Pond and its habitat, a 3.5-foot winter drawdown was not sufficient to achieve the TMDL goals. With the award of the Section 319 grant, the Committee (largely through volunteers) constructed a pump house to conduct deep winter drawdowns under careful protocols established under the oversight of the Conservation Commission. Incremental increases of depth at 6” per year led to the conclusion that the habitat could be both protected and restored with annual 6.5-foot drawdowns. The goals of the TMDL were met after several years.

Much has been learned since 2003, with over 20 years of monitoring data. First, not all winter drawdowns will have strong freezes and there can be excess rainfall or pump mechanical issues that can limit or interfere with the plan. Second, the impact is not a one-year impact but one that builds on prior years. That said, data demonstrates there is a significant return of native species that now out compete invasive species in the drawdown zone. Third, taking a year off completely or from pumping below 3.5 feet can create setbacks as phosphorus increases and invasives rebound. Monitoring of fish, turtles, frogs, mussels and other plants and species indicate that the selected timing and rate of the winter drawdowns does not appear to be harmful to their populations or habitats.

Drawdowns do not control seed reproducing species like water chestnut. Water chestnut plants were historically being marginally controlled by containing them using hand pulls to contain them to the Clapps Brook inlet in the NW area of the Pond. By devoting the harvester only to that area, and focusing hand pulls on stray water chestnuts observed in other areas, water chestnuts have gone from an infestation to nearly extinct in the Pond. This took 6-8 years of harvesting prior to plants flowering and creating new seeds. Eventually there was too little to harvest and by pulling and marking where any remaining plants are seen, water chestnut plants are now handled by one person pulling a few plants a year. Water chestnuts have been virtually eradicated from Bare Hill Pond and native species have returned. Those areas are shallow, and the drawdowns have made it difficult for milfoil and fanwort to take hold where water chestnut plants have been dominant.

Based on these efforts, a second strategy was implemented to control storm water non-point source pollution. Rain gardens were designed and constructed to capture the majority of high priority storm water from Town Center, schools, and roads that were draining into the Pond. A second Section 319 grant was sought and used to fund their construction. The goal was to reduce, to the extent possible, additional phosphorus entering the Pond. A phosphorus input study was conducted and identified the sites that should have rain gardens. Some streams enter the Pond after being filtered in existing wetlands and did not require intervention. Notably, the largest contributor to phosphorus in the water column is from Pond bottom sediment or in-lake loading.

The drawdowns have reduced the phosphorus well below the TMDL goal of 0.030 mg/l at most sample locations in the Pond. This creates important resiliency that helps to stave off eutrophication. This is in large part because the pump draws water from below 12 feet in depth where in-lake loading is likely at the highest concentration.

All of that said, several challenges remain in the watershed. The first is increased in-lake loading due to higher temperatures and drought conditions in the summer due to Climate change. In 2020 and 2021, the Pond experienced the first recorded hazardous algal blooms. In those years, anoxic conditions rose from the 14 foot level to 10-12 feet in depth. Higher phosphorus levels were found at a number of locations in late July. In the winters prior to these expanded, anoxic conditions, pump mechanical issues and excess rain in December made it difficult to have successful drawdowns, reducing the resiliency of the Pond to these climate related effects. Sunlight reaches the bottom in the 10-12 foot zone and likely triggered the algal blooms in those 2 years. In the subsequent 2 summers the drawdowns achieved the depth goal, and despite significant heat and anoxic conditions, there were no algal blooms likely due to the resiliency created by the drawdowns. Thus, a key additional strategy that was not considered in the early years is to use the drawdowns to address this climate change challenge.

Lastly, the deep drawdowns do not address spot areas of the Pond that remain wet in winter or that are deeper than the drawdown zone. Invasive species are still the predominant natural species in these areas, and pose a hazard to swimmers and other users of the Pond. A high priority area is the Town beach because it is in an area that exceeds 6.5 feet, the drawdown has limited or little effect. These areas range from less than half an acre to 1-3 acres. The BHPWMC is planning to utilize diver assisted suction hose contractors to remove selectively the smaller areas that remain unaddressed. The plan would be to permit the use of this technology on the Pond, to engage a contractor for control in the Town Beach and boat ramp area and to allow other Pond abutters to use that permit and engage the contractor in areas that they control.

Throughout all of these activities, the BHPWMC engaged in outreach and information sharing at meetings, in the local paper, in mailings and at annual pond tours with our expert wetlands consultant. Funding of these activities requires Town meeting discussions and approvals as well. Because Bare Hill Pond is actively used by so many residents in Town, there is continual interest in understanding and learning about the Committee's activities. A continued focus is on best practices for residents in the watershed and the avoidance of fertilizers. Lastly, under the Town By-laws, the BHPWMC is required to comment at ZBA hearings on special permits in the watershed and is required to comment at Planning Board meetings on development in the watershed that impacts storm water runoff, and is asked to comment on applications for Notices of Intent in the watershed by the Conservation Commission. All of these activities serve an important role in educating and enhancing watershed protection.

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, as described below.

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 Bare Hill Pond Watershed Management Committee (the "BHPWMC" or the "Committee") is a Town Committee appointed by the Select Board. It was formed by the Town in 1983 to care for Bare Hill Pond and its Watershed. Its mission "is to preserve, protect, maintain and enhance the environmental, aesthetic, recreational and economic values of Bare Hill Pond, and to promote watershed management, within the Town of Harvard." The Committee website can be located here. The Committee performs its activities under the oversight of the Conservation Commission where it has regular annual updates which are open to and attended by interested members of the community. The Town Park and Recreation Commission which manages the Town Beach and the public access to Bare Hill Pond regularly provides input and collaborates on the activities in the Watershed Management Plan.

Data Sources

This WBP was developed using the framework and data sources provided by MassDEP's WBP Tool. Significant additional research and studies have been performed by the BHPWMC. These studies continued the work noted in the 1987 Whitman and Howard Report and the 1998 TMDL Report cited in the data sources cited and provided by MassDEP. Additional sources include:

- 1998 ENSR Water Quality and Aquatic Plant Evaluation
- 2002 ENSR Wildlife, Habitat and Vegetative Assessment
- Annual Updates and Reports to Conservation Commission (see 2023 ARC Report and 2023 Committee report for a cumulative update)
- Chronology of Pond Management from early 1800s to 2000
- 2005-06 Watershed Survey and Plan

Summary of Completed Work

Significant work has been completed since the 1998 TMDL Report.

In 2003, the Committee adopted a new strategy based on the watershed reports listed above, that sought to control eutrophication, invasive species growth and excess phosphorus based on a plan to seek to restore more native plants and species and to control nonpoint source phosphorus. The Committee proposed a plan for annual habitat assessment coupled with winter drawdowns to seek to control the invasive plants and reduce phosphorus loading. Based on several years of gravity drawdowns, the Committee applied for and was awarded a 319 grant to construct a pumping station in 2006 that enabled it to incrementally increase the depth of the drawdowns. This proceeded incrementally with extensive habitat monitoring as the level of phosphorus was reduced and the invasive milfoil and fanwort were increasingly controlled but not eliminated. Native plants over time out-competed the invasive species and returned to the Pond over time.

The drawdown demonstration was successful in that phosphorus was reduced below the TMDL Report goals and by approximately 50 percent. In years following drawdowns with hard freezes in January, invasive species populations were reduced. In parallel, the Town's harvester was limited to harvesting invasive water chestnut plants which over 7 years were eliminated from Bare Hill Pond except for a very small number of plants that can be pulled when they appear. Fish, amphibian, reptile, and crustacean populations were monitored and were found to be stable and healthy. See a picture from a turtle count and from a mussel check.

This initial project helped to address an acute risk of eutrophication, however, there were several stormwater inputs to Bare Hill Pond that could put this work at risk. A second 319 Grant was sought and awarded to construct nature-based rain gardens to capture the storm water flowing into the Pond from Town Center, its roads, the schools, the library and its parking lots. These rain gardens were built and are maintained and tested to continue to ensure their performance.

In planning for the rain gardens, the inputs were measured as well as the Pond sediment. While controlling the storm water inputs was clearly important, the largest source of phosphorus input to Bare Hill Pond is in-lake loading from sediments – likely due to the Pond being enlarged over sheep pasture in the 1800s. Thus, there remains eutrophication risk as a result of heat caused anoxic conditions in the Pond. In addition, there are spot areas (i.e., the deep part of the Town Beach swimming areas) of the Pond where stream and spring flow do not allow for adequate freezing and control of invasive milfoil and fanwort even with a deep winter drawdown.

In addition, during the past 25 years, the Committee comments on development in the watershed to help assure permitting that requires best practices and protects the watershed health. It has regular educational and community activities to inform the community and its residents of its activities and plans.

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 Information

Table A-1: General Watershed Information

Watershed Name (Assessment Unit ID):	Bare Hill Pond (MA81007)
Major Basin:	NASHUA
Watershed Area (within MA):	2427.3 (ac)
Water Body Size:	321 (ac)

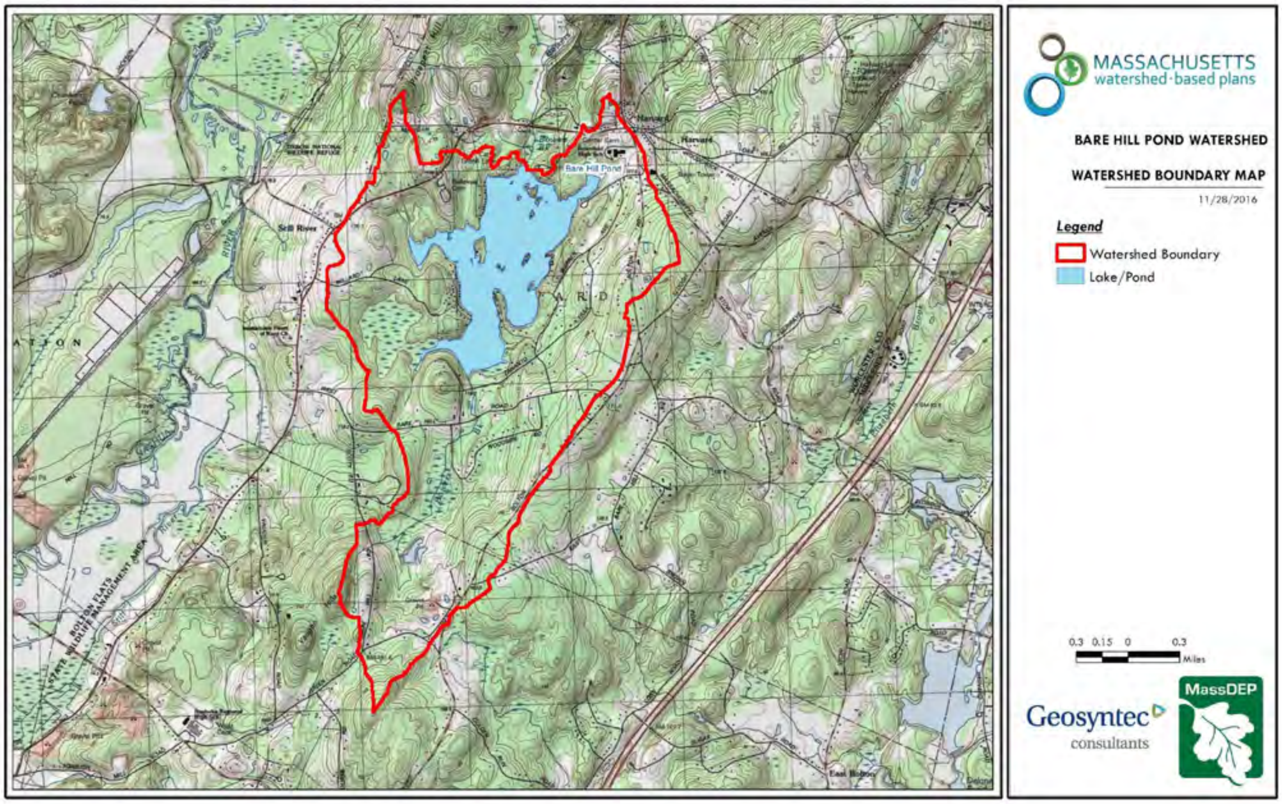


Figure A-1: Watershed Boundary Map (MassGIS, 1999; MassGIS, 2001; USGS, 2016)

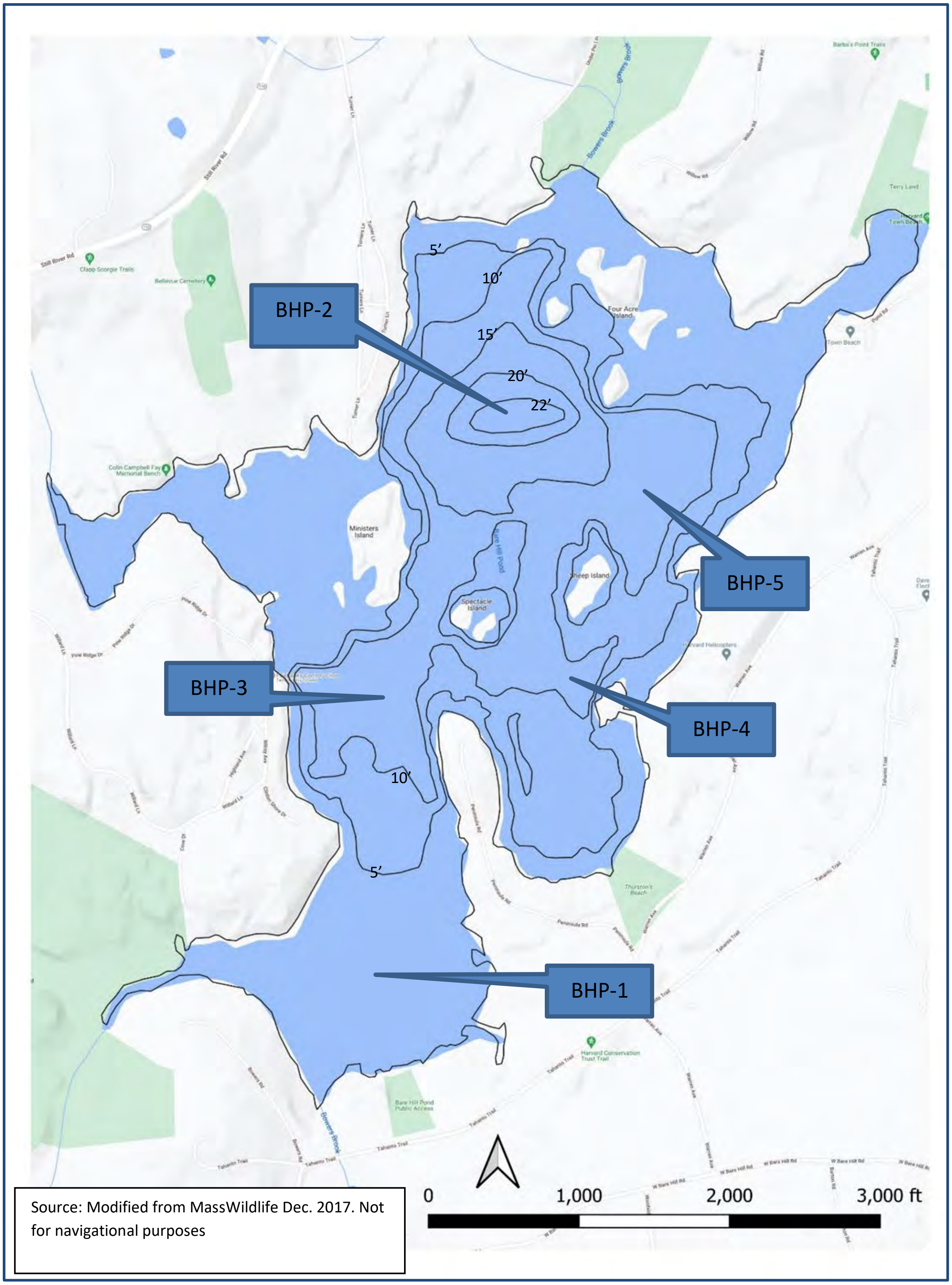
Ctrl + Click on the map to view a full sized image in your web browser.

General watershed information:

Since the completion of the 1998 TMDL study and the 1998 Bare Hill Pond Water Quality and Aquatic Plant Evaluation, substantial progress was made in developing a watershed strategy for Bare Hill Pond. Bare Hill Pond, its habitat and its protection, are overseen by a Town Committee, the Bare Hill Pond Watershed Management Committee. The following activities have been implemented and accomplished since 2001, and form the foundation for this Bare Hill Pond Watershed Management Plan. In 2002, based on a significant increase in the growth of fanwort and milfoil, the Bare Hill Pond Watershed Management Committee (BHPWMC), in reliance on the data in the TMDL Study and Whitman and Howard reports, cited below that found the Pond was endangered due to high phosphorus and invasive plant growth, initiated winter drawdowns of Bare Hill Pond (1.5 feet in 2002-03), under the regulatory review of the Town Conservation Commission. To allow for the permitting of this activity, in 2002, ENSR was engaged to perform a WILDLIFE, HABITAT AND VEGETATIVE ASSESSMENT OF BARE HILL POND, WITH MANAGEMENT IMPLICATIONS that defined the proper timing, approach, and monitoring and assessments needed to conduct the drawdown , and future drawdowns in accordance with the then newly developed GEIR for Lake and Pond Management. The results of the drawdown indicated that it was only effective in the drawdown zone and had limited effect beyond the 1.5 depth. In 2003 based on the assessments and monitoring data after the prior drawdown, the BHPWMC obtained Conservation Commission authorization to increase the depth of the winter drawdown to up to 3.5 feet (the maximum level that might be achieved by removing boards from the Dam). The Committee conducted 3.5 foot drawdowns for the next 3 winters following the procedures provided for in the Order of Conditions and monitored and collected data each year to update the Wildlife, Habitat and Vegetative Assessment in order to determine the risks and benefits of the activities. The reports for each year (2003-2006) are located on the Annual Reports page of the BHPWMC.

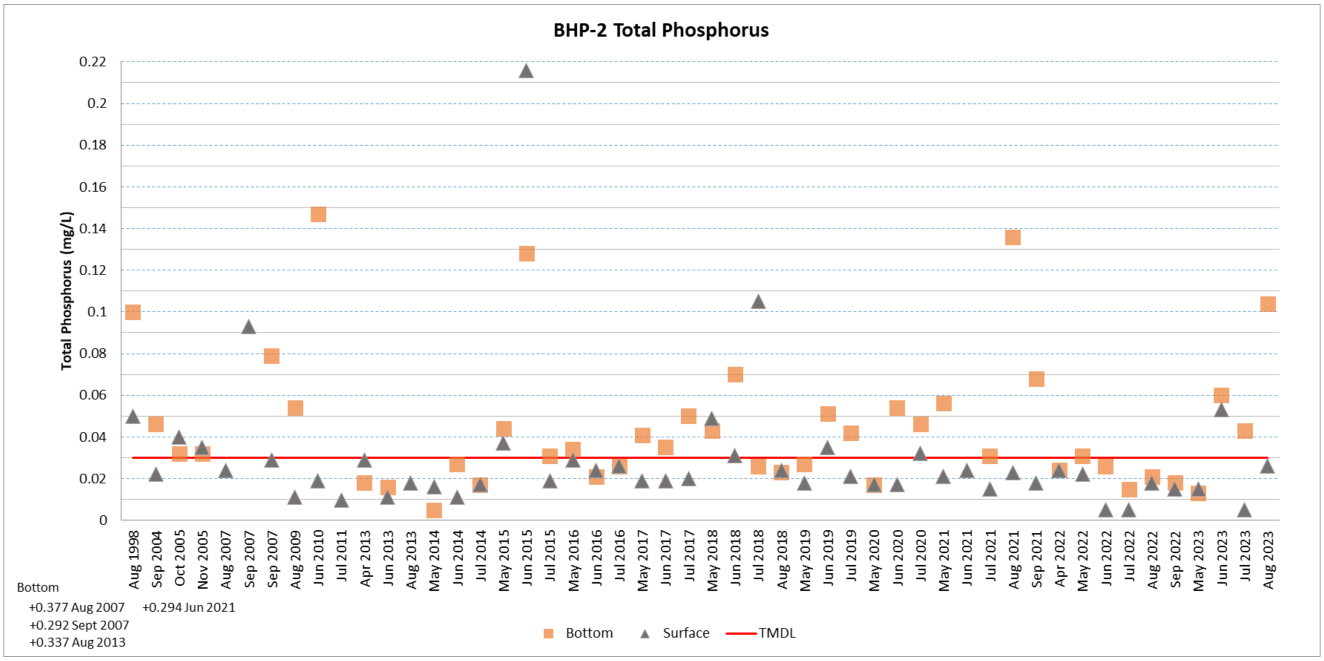
After 3 years it was evident that the schedule for conducting the drawdown was not impairing habitat, fish, amphibians, reptiles and mammal, and that there was benefit in the drawdown zone showing control of the invasive aquatic species that were susceptible to drawdowns. It was also becoming clear that phosphorus was remaining high, and that invasive plants were still aggressively growing in the 3.5-7 foot zones of the Pond where sunlight was present. The BHPWMC recognizing that a deeper drawdown would be necessary to address the phosphorus and the deeper zones, applied for a Section 319 grant in 2003 that was awarded in March 2004. The purposed on this grant was to do a demonstration study to demonstrate that a deeper drawdown , when carefully managed and assessed, could reduce phosphorus from the 0.044mg/l level in the TMDL to under 0.30 mg/l and that the invasive aquatic species could be controlled as native plants returned to Bare Hill Pond's habitat. Also, a Watershed Survey or watershed management strategy plan was prepared in 2005 to assist in considering additional work to be performed to achieve these objectives. The project cost approximately $420,000 of which $195,000 was Section 319 DEP/EPA funded, a pumping station was permitted, designed and constructed, and then operated for 3 years (monitored and assessed). The results of the three year project demonstrated significant additional control of invasive aquatic species, and a significant reduction in phosphorus in Bare Hill Pond (achieving the goal of reducing phosphorus to below 0.30mg/l and significantly restoring native plants and species over the next 15 years. *Each year*, as required by the Order of Conditions in effect for the conduct of the deep drawdowns, a habitat assessment and monitoring report is submitted to the Conservation Commission and reviewed to support a plan for the next winter drawdown . The Order of Conditions and the monitoring and other activities are based on the QAPP designed and delivered in this 319 project.

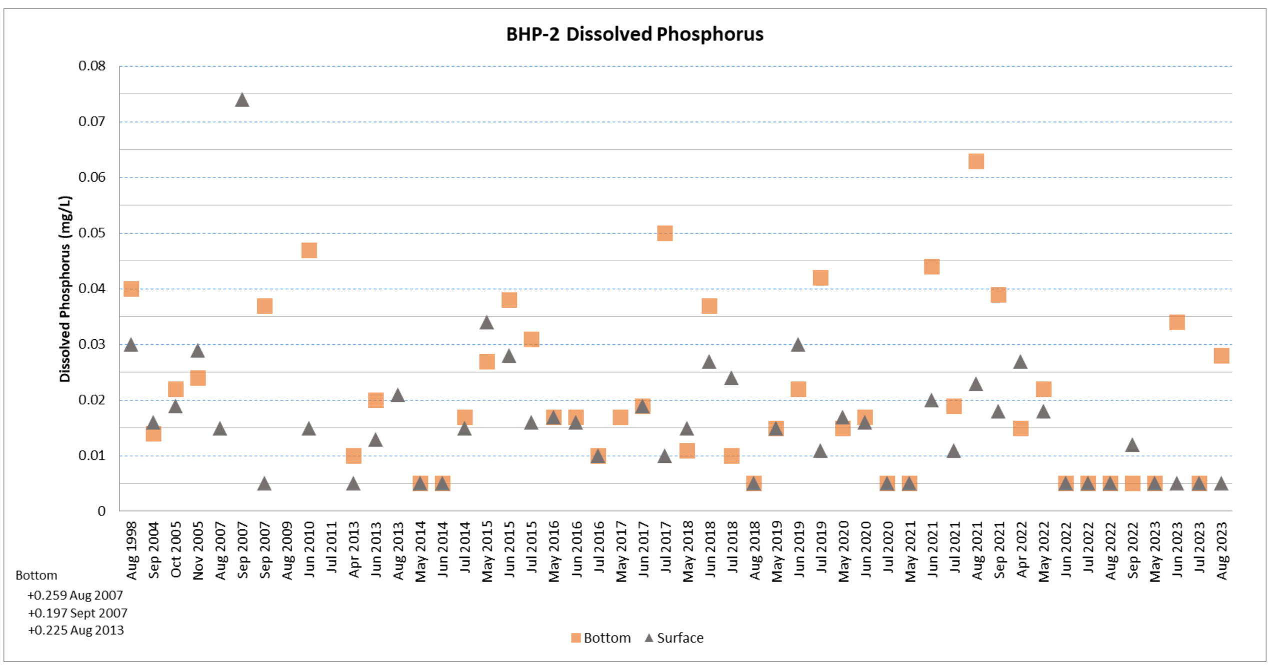
Phosphorus readings are taken at the prescribed locations in the QAPP show on this map from the 2023 ARC In Lake Water Quality Assessment and Annual Report (the "ARC Annual Report"):



Source: Modified from MassWildlife Dec. 2017. Not for navigational purposes

The following data in the 2023 ARC Annual Report shows the reduction in phosphorus and the impact of performing the drawdowns over the years:

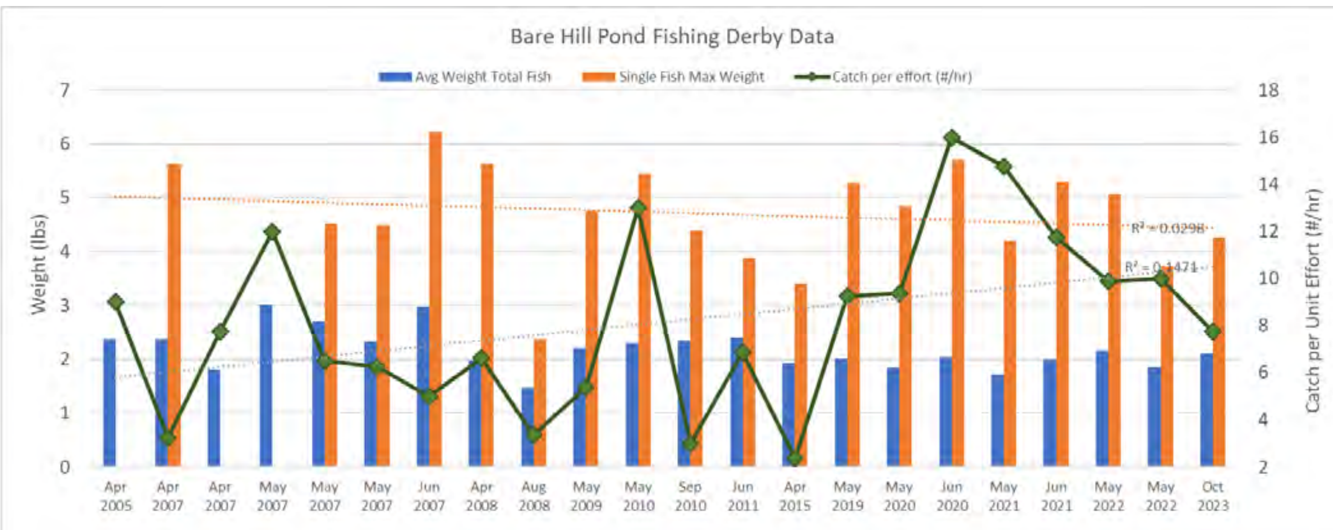




Note the increases that occurred in years following those when the deep drawdowns were not performed (2008-09, 2013-14, 2018-19) and the increase at the bottom but not in the water column due to in-lake loading.

The depth of the deep drawdown was increased incrementally as it became clear that was needed to address invasive species in the 5-7 foot zone. See the 2023 ARC Annual Report. See also the 2023 BHPMC Committee Annual Report to the Conservation Commission.

As noted in these reports and in other annual reports, much has been learned since 2003 about this strategy and the winter drawdowns. First, in years where the drawdown was skipped to see if bi-annual drawdowns might be able to maintain control, the invasive species rebounded. This also occurred in years in which mechanical failures aborted drawdowns before a hard freeze occurred or in years where the freeze was limited in duration. The result of the initial demonstration study was that the deep drawdowns were benefitting the habitat and restoring native species to Bare Hill Pond and its watershed. Fish populations were stable and thriving. Amphibian and reptile counts were stable. Blue herons and Eagles returned to Bare Hill Pond suggesting that food sources were plentiful, and otter, beaver, mink, and fox are routinely observed.



Thus, it has formed the foundation of the watershed management strategy for protecting and preserving Bare Hill Pond. When DEP Scientist, Peter Mitchell came to do water quality testing in 2018, he was pleasantly surprised to see the reduction in the phosphorus levels. After his visit, he wrote, " I think it is a brilliant strategy you have. I do believe that the reduction in phosphorus has much to do with the drawdown. It also has much to do with the BMPs around the pond. I am very happy that it appears to me that the pond appears to be meeting the TMDL limits. Please, keep up the great work!"

The monitoring of native and non-native plant species is conducted annually at designated transects in the QAPP. As noted in the 2023 Annual Report.

As Peter Mitchell noted, the BMPs installed around the Pond also play an important role. The BHPWMC applied for and received a second Section 319 grant in 2008 for the design and construction of stormwater BMPs to capture and control phosphorus from impervious surfaces and streams that connect to Bare Hill Pond. See the BMP Project summary at page 209.

To plan the BMP design and installation, the Horsley Whitten Group performed a stormwater management assessment in 2008 identifying the key sites in the watershed that could benefit from the construction of rain gardens to capture stormwater and remove phosphorus. See the project sites. The BMPs were constructed, tested and continue to be tested on a defined 3 year schedule to ensure they are maintained and functioning pursuant to an Operation and Maintenance Plan designed in the project and implemented by the Town Dept. of Public Works. The selection of the sites took into consideration the presence of wetlands in the watershed and areas with high concentrations of impervious surfaces. The map above shows that there are two streams that flow into Bare Hill Pond at the opposite ends of the Pond from the Town Beach, Clapp's Brook and Bowers Brook. These streams enter the Pond through extensive wetlands and it was determined that they provide sufficient filtration for those streams. The BMPs installed capture the water from the roads, parking lots and streets in Town Center, at the schools, the library and near the Pond.

Below is a map of the 8 BMP rain gardens for the 8 drainage areas that were installed under the 319 Grant:

Here are photos of the installations at several of the sites:

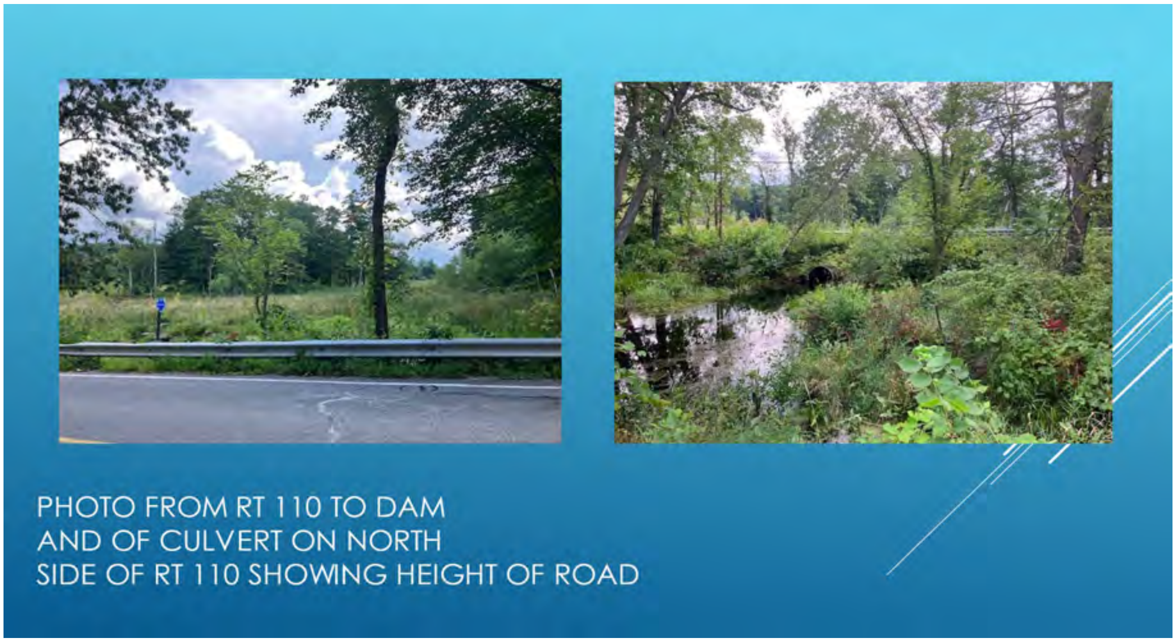


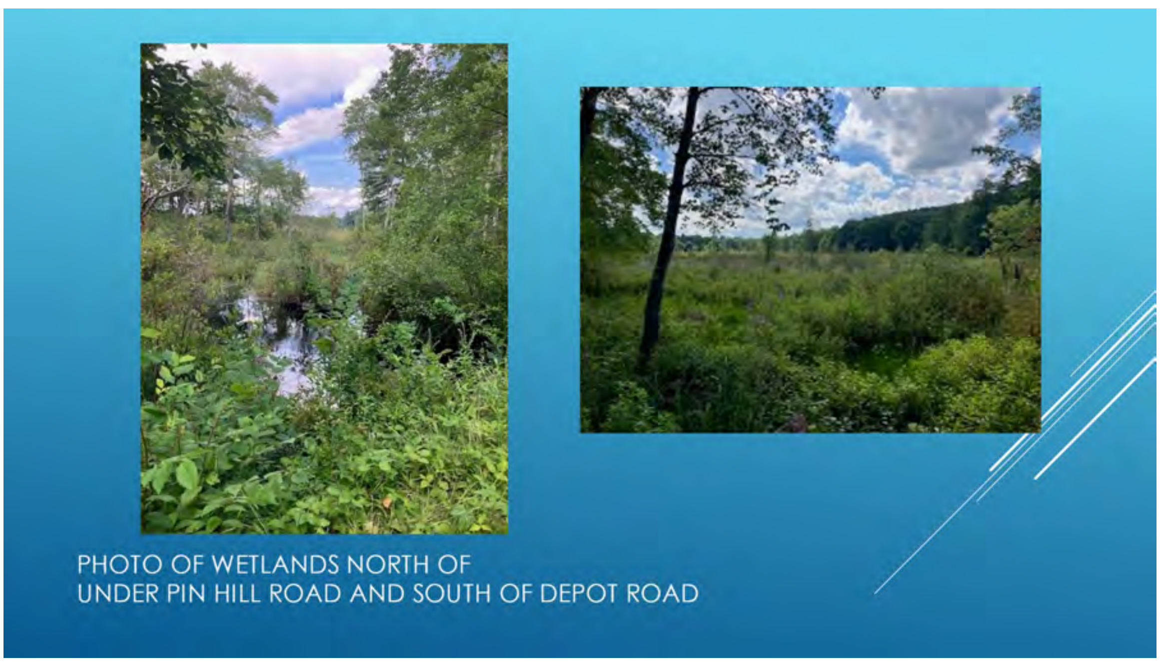

It is also important to note the extensive downstream wetlands at the outflow of the Pond and then continuing throughout much of the Bowers brook watershed until it reaches Ayer over 4-5 miles. These wetlands were formed by the existing roads and Route 2 in particular. This provides significant protection against excess phosphorus entering the downstream watershed.

They provide a nature-based solution for the removal of phosphorus from the water leaving Bare Hill Pond to protect downstream watershed areas. Also, they significantly moderate the flow of water during the drawdown which occurs at approximately 2" per day as required in the QAPP.

Here are photos showing the dam and adjacent wetlands and their health looking north to Rt 110:

Here are additional photos of the wetlands in the first mile or two below the dam:

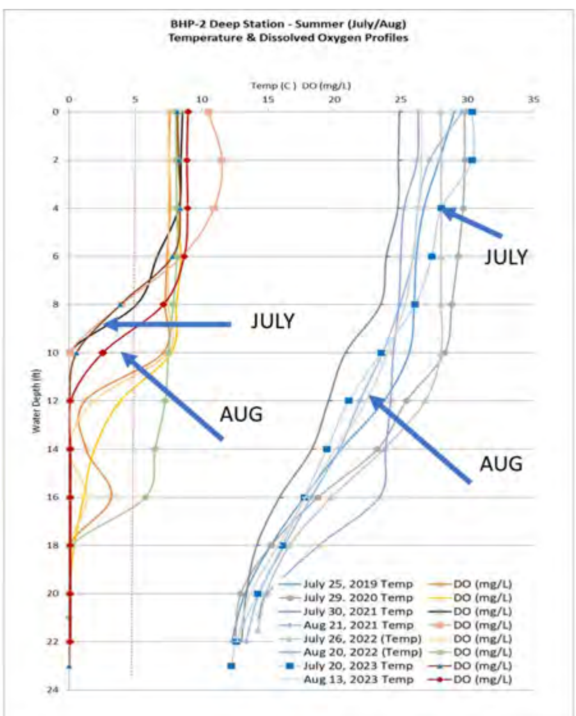


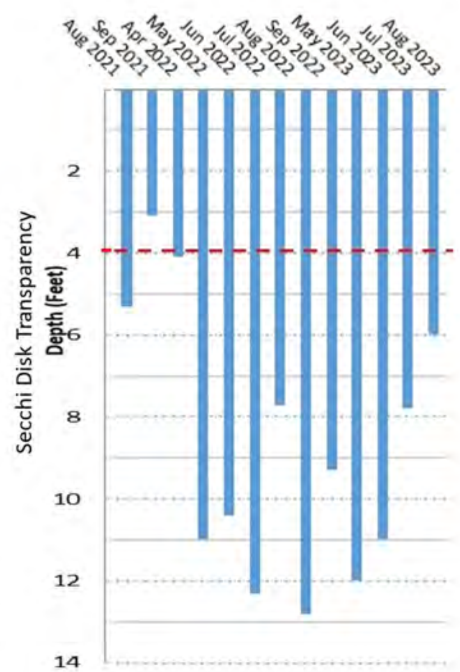


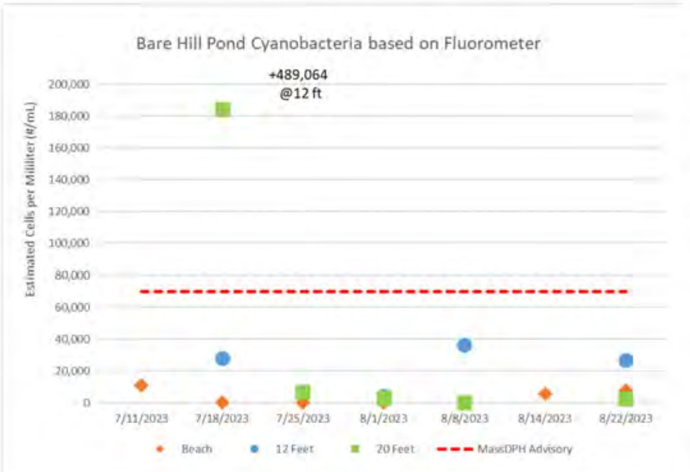
Over twenty years of data also demonstrate that the refill is routinely completed early in Spring and that downstream flow rates during the drawdown are maintained.

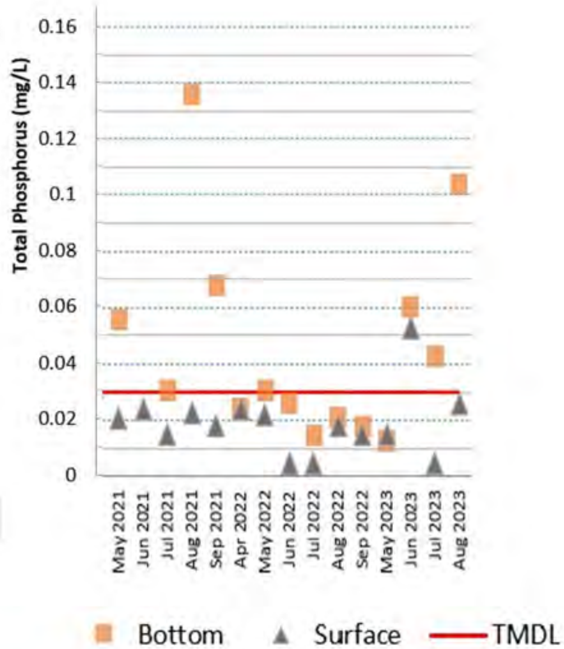
While the winter drawdowns have worked effectively to address and reduce the phosphorus and invasive species challenges in Bare Hill Pond, there are still problem areas that remain to be addressed. Climate change and droughts have led to temperature increases in Bare Hill Pond. Annual monitoring has detected a significant expansion in the anoxic zones in Bare Hill Pond. During 2020 and 2021, the anoxic zones rose from 14 foot or greater depths to as high as 12 feet. This allows for growth of hazardous algae (normally present in the deepest zones) to migrate to sunlit areas of the Pond and bloom. Temperatures are higher due to climate change but also due to droughts when the spring flow declines. Bare Hill Pond is heavily spring fed and the springs, when normally flowing, help keep the Pond cooler and allow for more water turnover in the summer. When the temperatures rose in 2020 and 2021, and rainfall was limited, the recharge rate was low and Pond temperatures rose. As a result, the level of phosphorus increased from in-lake loading. Anoxic conditions were found at 12 feet which appear to have triggered hazardous algal blooms. In those summers the preceding winter drawdowns were also not fully achieved due to excess rainfall in December and pump malfunction which to some extent may have impacted the phosphorus reduction those years. In years prior, and in the years since when there was phosphorus reduction from drawdowns, there were no hazardous algal blooms, suggesting the drawdowns provide a level of resiliency to address climate change.

The following data from the [2023 ARC Annual Report] and prior annual reports show the impact of increased temperatures and anoxic zone expansion over the last few years. One can also see the impact of phosphorus release in the sample sites in the deeper zones.



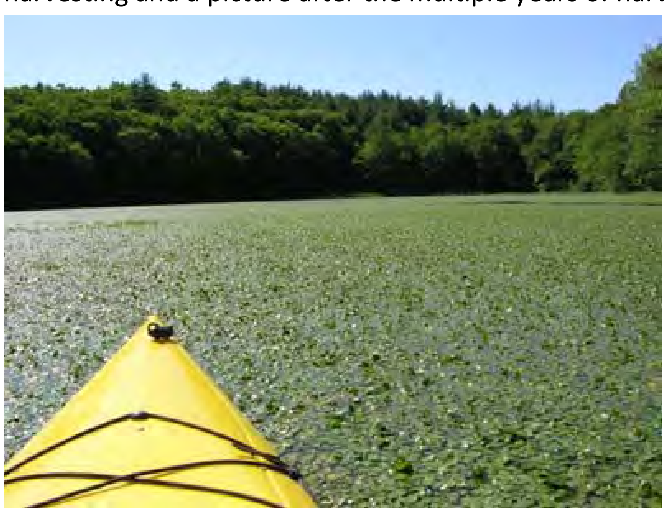






Algal blooms have not occurred on Bare Hill Pond following storm events suggesting that they are not triggered by stormwater but by in-lake loading as noted above. Rather they have occurred during heat waves and droughts. Thus, drawdowns now appear to play a role not originally envisioned when they were initiated in 2003.

Invasive water chestnut plants were also identified as a goal for removal in the 1998 TMDL. Here is a picture of the Clapps Brook area of Bare Hill Pond as it typically appeared in mid-summer prior to 6 years of harvesting and a picture after the multiple years of harvesting.



Today an occasional water chestnut plant is observed and hand pulled from time to time. The area is now largely populated with native species due to the area being in the drawdown zone allowing native plants to out-compete the fanwort and milfoil.

Lastly, it is increasingly evident that there are site specific areas that remain wet due to organic activity and stream flow and that continue to support invasive aquatic plants. Additional strategies can be considered for addressing these site-specific areas. Typically, they are not large in acreage and one option might be diver assisted suction removal. An area of particular concern is the deep area at the Town beach swimming area which is over 6.5 feet in depth and is not controlled by the winter drawdown. In these areas, the plants create a hazard for swimmers. Many other residents have similar issues on areas of their shorelines and a unified permitted removal program could provide an efficient and effective way to control these smaller zones.

MassDEP Water Quality Assessment Report and TMDL Review

The following reports are available:

- BARE HILL POND WATER QUALITY AND AQUATIC PLANT EVALUATION 1998
- Bare Hill Pond, Harvard, MA. (MA81007) TMDL
- DIAGNOSTIC FEASIBILITY STUDY BARE HILL POND HARVARD, MASSACHUSETTS
- Nashua River Watershed 2003 Water Quality Assessment Report
- Northeast Regional Mercury Total Maximum Daily Load

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).

Bare Hill Pond, Harvard, MA. (MA81007) TMDL

(MA81007 - Bare Hill Pond)

Bare Hill Pond, (MA81007) is a 321 acre, municipally-owned pond located in Harvard Massachusetts in the Nashua Basin at approximately 71°35’46”W, 42°29’29”N. Although the pond’s shoreline is moderately developed, the lakeshore community maintains a rural atmosphere due largely to the forested environs. The pond has three beaches, one located along the northern shore at the Camp Green Eyrie Girl Scout facility, a town beach off Pond Road at the northeast corner of the lake, and a small, informal beach on Harvard Conservation Commission Land near Thurston’s Brook. Public access to the town beach is restricted to Harvard residents but the general public can gain pond access via Harvard conservation land.

According to Whitman and Howard (1987), in colonial times Bare Hill Pond was surrounded by Pasture lands and was roughly 200 acres in size. From 1838, when the pond’s dam was built and enlarged to its present size, until 1920, the water level varied depending upon the industries drawing from the pond’s water supply. Since 1920, the size and depth of the pond have remained relatively constant. It is not surprising that a majority of the present-day shallow, weedy areas are those inundated after the 1838 pond expansion. It has also been theorized that erosion of enriched soil into the pond from former agricultural areas provided the conditions necessary for some of the aquatic plants to reach nuisance proportions.

Extensive growths of water lilies, milfoil, smartweed and pondweed have hampered boating activities and swimming in certain sections of the pond. The Massachusetts Division of Water Pollution Control (MDWPC) conducted a baseline survey of the pond in 1983. Their findings suggest that the pond is mesotrophic, displaying elevated nutrient levels and moderate hypolimnetic dissolved oxygen concentrations and transparency. However, a more detailed analysis is presented in the Diagnostic/Feasibility report of Whitman and Howard (1987), which concludes that in terms of phosphorus concentrations and macrophyte growth, the pond is eutrophic. The Whitman and Howard (1987) report shows the lake to have very dense or moderately dense aquatic vegetation over about 40-45 percent of the lake area, mostly in protected shallow coves and bays. Myriophyllum heterophyllum (Watermilfoil) is the dominant species, followed by Polygonum sp. and Brasenia schreberi. Recent surveys in 1998 by DEP staff and by ENSR (1998) reported slightly less extensive plant coverage (about 30%), but noted the presence of the non-native water chestnut (Trapa natans), as well as Fanwort (Cabomba caroliniana) which adds to the problem. The pond was listed on the 1998 Massachusetts 303d list for Nuisance Aquatic Plants (DEP, 1998). The overall goal is to restore the uses of the pond for primary and secondary contact recreation by reducing the nuisance aquatic plant growth. This will be accomplished by a combination of reducing the phosphorus loading to the lake and by direct control of macrophytes.

A detailed study of the nutrient sources and sediment sources was included in the Diagnostic/Feasibility Study of Whitman and Howard (1987). The average total phosphorus concentration at the surface was 0.044 mg/l which is relatively high, yet Secchi disk transparency was greater than expected, ranging from 2.7 to 4 meters with an average of 3.5 meters in the center of the lake. The more recent ENSR (1998) study reported a mid-August surface concentration of 0.05 mg/l with a Secchi disk depth of only 2.0 m (6.5 feet), possibly suggesting that conditions are worsening. The Whitman and Howard (1987) report concludes that the excessive weed growth in the pond is due to favorable habitat conditions such as shallow depths with bottom sediments rich in nutrients and the sustained nutrient enrichment from the pond's watershed. The model used to determine the pond's trophic status was the phosphorus loading model of Dillon and Rigler (1974).

The major sources according to the land use analysis were residential area and wastewater (on site septic systems), which accounted for more than half the total from the watershed. A very rough estimate of the load from internal cycling yielded a value of 763 KG P/yr. This was based on taking a mid-range value from the literature that reported a low of -2 mg/m2/day and a high of 9.6 mg/m2/day (Whitman and Howard, 1987). Thus, the internal load could be a dominant source, but the estimate is highly uncertain. Given this, DEP re-estimated sediment recycling as described below. Given that reductions on the watershed will eventually impact the internal cycling, watershed management is still fruitful to pursue. The main impact from the internal cycling would be extending the time for noticing improvements in water quality from watershed management efforts.

DEP, 1998. Massachusetts Section 303(d) List of Waters- 1998. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.
Dillon, P.J. and F.H. Rigler. 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Bd. Can. 31:1771-1778.
ENSR. 1998. Bare Hill Pond Water Quality and Aquatic Plant Evaluation. ENSR Northborough, MA.
Whitman and Howard. 1987. Diagnostic/Feasibility Study Bare Hill Pond. Harvard, Massachusetts. + Appendices. Prepared by Whitman and Howard, Inc. 45 William St. Wellesley, MA.

Aquatic Life
Two non-native species (Trapa natans, Myriophyllum heterophyllum) have been observed in Bare Hill Pond.

Fish Consumption
MA DPH has issued a fish consumption advisory due to mercury contamination for Bare Hill Pond. Children under 12, pregnant women, women of childbearing age who may become pregnant and nursing mothers should refrain from consuming largemouth bass fish in order to prevent exposure to developing fetuses, nursing infants and young children to mercury. The general public should limit the consumption of Largemouth fish to two meals per month.

Primary Contact
No data were available to assess the Primary Contact Use.

Secondary Contact
No data were available to assess the Secondary Contact Use.

Aesthetics
No data were available to assess the Aesthetic Use.

Report Recommendations:
Continue to monitor for the presence of invasive non-native aquatic vegetation and determine the extent of the infestation. Prevent spreading of invasive aquatic plants.

Conduct water quality monitoring to assess Primary and Secondary Recreational Use.

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:

As noted above:

It is important to include the following Reports that support the information in this Watershed Management Plan:

1) Chronology of Bare Hill Pond Management from 1800s to 2000

2) Water Quality & Aquatic Plant Evaluation, ENSR, 1998

3) Wildlife, Habitat and Vegetative Assessment, ENSR 2002

4) 2005 - Watershed Survey and Management Plan

5) 2023 Bare Hill Pond In Lake Water Quality and Plant Survey, Aquatic Restoration Consulting

6) Prior annual assessments on In Lake Water Quality and Plant Survey are contained on the Annual Reports Page

7) BHPWMC 2023 Annual Report and drawdown Plan https://www.harvard-ma.gov/bare-hill-pond-watershed-management/files/letter-con-com-2023 Prior annual reports to the Conservation Commission are listed on this page too.

8) Bare Hill Pond Watershed Storm Water Management Final Assessment, Horsley Whitten,

9) Final Report, Bare Hill Pond Section 319 Grant 2004-2007 https://www.harvard-ma.gov/bare-hill-pond-watershed-management/files/final-grant-report-dep-2007

10) MassDEP Stormwater Section 319 Project Summary at page 6

Water Quality Impairments

Known water quality impairments, as documented in the Massachusetts Department of Environmental Protection (MassDEP) 2018/2020 Massachusetts Integrated List of Waters (MassDEP, 2021), are listed below. Impairment categories from the Integrated List are as follows:

Table A-2: 2018/2020 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 2021)

Assessment Unit ID	Waterbody	Integrated List Category	Designated Use	Impairment Cause	Impairment Source
MA81007	**Bare Hill Pond**	**4A**	Fish Consumption	Mercury In Fish Tissue	Atmospheric Deposition - Toxics
MA81007	**Bare Hill Pond**	**4A**	Fish Consumption	Mercury In Fish Tissue	Source Unknown
MA81007	**Bare Hill Pond**	**4A**	Fish, other Aquatic Life and Wildlife	Curly-leaf Pondweed	Introduction Of Non-native Organisms (accidental Or Intentional)
MA81007	**Bare Hill Pond**	**4A**	Fish, other Aquatic Life and Wildlife	Fanwort	Introduction Of Non-native Organisms (accidental Or Intentional)
MA81007	**Bare Hill Pond**	**4A**	Fish, other Aquatic Life and Wildlife	Non-native Aquatic Plants	Introduction Of Non-native Organisms (accidental Or Intentional)
MA81007	**Bare Hill Pond**	**4A**	Fish, other Aquatic Life and Wildlife	Water Chestnut	Introduction Of Non-native Organisms (accidental Or Intentional)

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.

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 (314 CMR 4.00, 2013) prescribe the minimum water quality criteria required to sustain a waterbody's designated uses. Bare Hill Pond is a Class 'B' waterbody. 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
MA81007	Bare Hill 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.).

Table A-5: Water Quality Goals

Pollutant	Goal	Source
Total Phosphorus (TP)	TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For this case, the TMDL is expressed in terms of allowable annual loadings of phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual rather than daily loadings of nutrients. The target in-lake total phosphorus concentration chosen is based on consideration of the typical concentrations expected in lakes in the region. The phosphorus ecoregion map of Griffith et al. (1994) indicates the lake is in an ecoregion with concentrations of 10-14 ppb, based on spring/fall concentrations, while the phosphorus ecoregion map of Rohm et al., (1995) suggests that typical lakes in this ecoregion would have concentrations between 30 and 50 ppb, based on summer concentrations. Considering the above suggested ranges and that the chlorophyll concentrations are generally well below 10 ppb (Whitman and Howard, 1987), DEP has set the target TP	Bare Hill Pond, Harvard, MA. (MA81007) TMDL

concentration at 30 ppb. Any value lower than this would be difficult to attain given the forested nature of most of the watershed and a higher value may allow algal blooms, potentially leading to violations of the four-foot transparency standard for swimming. The ENSR report (1998) suggests that due to the high dissolved organic carbon in the lake, as indicated by the color of the water, much of the total phosphorus may be unavailable for growth and that light may also limit algal production despite the relatively high total phosphorus concentrations. Thus, a relatively high phosphorus target is justified in this lake. The 30 ppb target represents a 32 percent reduction from the current total phosphorus concentration of 44 ppb. Note that the lake already meets the 4-foot transparency requirement for swimming beaches and the proposed reduction in phosphorus loading would likely increase the transparency even more. Following the methods of Whitman and Howard (1987), the Dillon-Rigler model would estimate that a Total Maximum Daily Load of 538 kg/yr would meet the target of 30 ppb (0.030 mg/l). This target is generally consistent with the Stage I implementation plan of Whitman and Howard (1987) which suggested a 33.5% reduction in phosphorus loading. The lower phosphorus concentrations will lessen the chance of nuisance algal blooms, which may occur as macrophyte biomass is reduced by direct controls.

ENSR. 1998. Bare Hill Pond Water Quality and Aquatic Plant Evaluation. ENSR Northborough, MA.
Griffith, G.E., J.M. Omernik, S.M. Pierson, and C.W. Kiilsgaard. 1994. Massachusetts Ecological Regions Project. USEPA Corvallis. Massachusetts DEP, DWM Publication No. 17587-74-70-6/94-D.E.P.
Rohm, C.M., J.M. Omernik, and C.W. Kiilsgaard. 1995. Regional Patterns of Total Phosphorus in Lakes of the Northeastern United States. Lake and Reservoir Man. 11(1): 1-14.
Whitman and Howard. 1987. Diagnostic/Feasibility Study Bare Hill Pond. Harvard, Massachusetts. + Appendices. Prepared by Whitman and Howard, Inc. 45 William St. Wellesly, MA.

Bacteria	**Class B Standards** • Public Bathing Beaches: For E. coli, geometric mean of 5 most recent samples shall not exceed 126 colonies/ 100 ml and no single sample during the bathing season shall exceed 235 colonies/100 ml. For enterococci, geometric mean of 5 most recent samples shall not exceed 33 colonies/100 ml and no single sample during bathing season shall exceed 61 colonies/100 ml; • Other Waters and Non-bathing Season at Bathing Beaches: For E. coli, geometric mean of samples from most recent 6 months shall not exceed 126 colonies/100 ml (typically based on min. 5 samples) and no single sample shall exceed 235 colonies/100 ml. For enterococci, geometric mean of samples from most recent 6 months shall not exceed 33 colonies/100 ml, and no single sample shall exceed 61 colonies/100 ml.	Massachusetts Surface Water Quality Standards (314 CMR 4.00, 2013)

Note: *There may be more than one water quality goal for bacteria due to different Massachusetts Surface Water Quality Standards Classes for different Assessment Units within the watershed.*

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 2005 and was obtained from MassGIS (2009b).

Watershed Land Uses

Table A-6: Watershed Land Uses

Land Use	Area (acres)	% of Watershed
Agriculture	77.98	3.2
Commercial	69.33	2.9
Forest	1639.54	67.5
High Density Residential	3.36	0.1
Highway	0	0
Industrial	0	0

Low Density Residential	262.98	10.8
Medium Density Residential	11.57	0.5
Open Land	47.15	1.9
Water	315.39	13

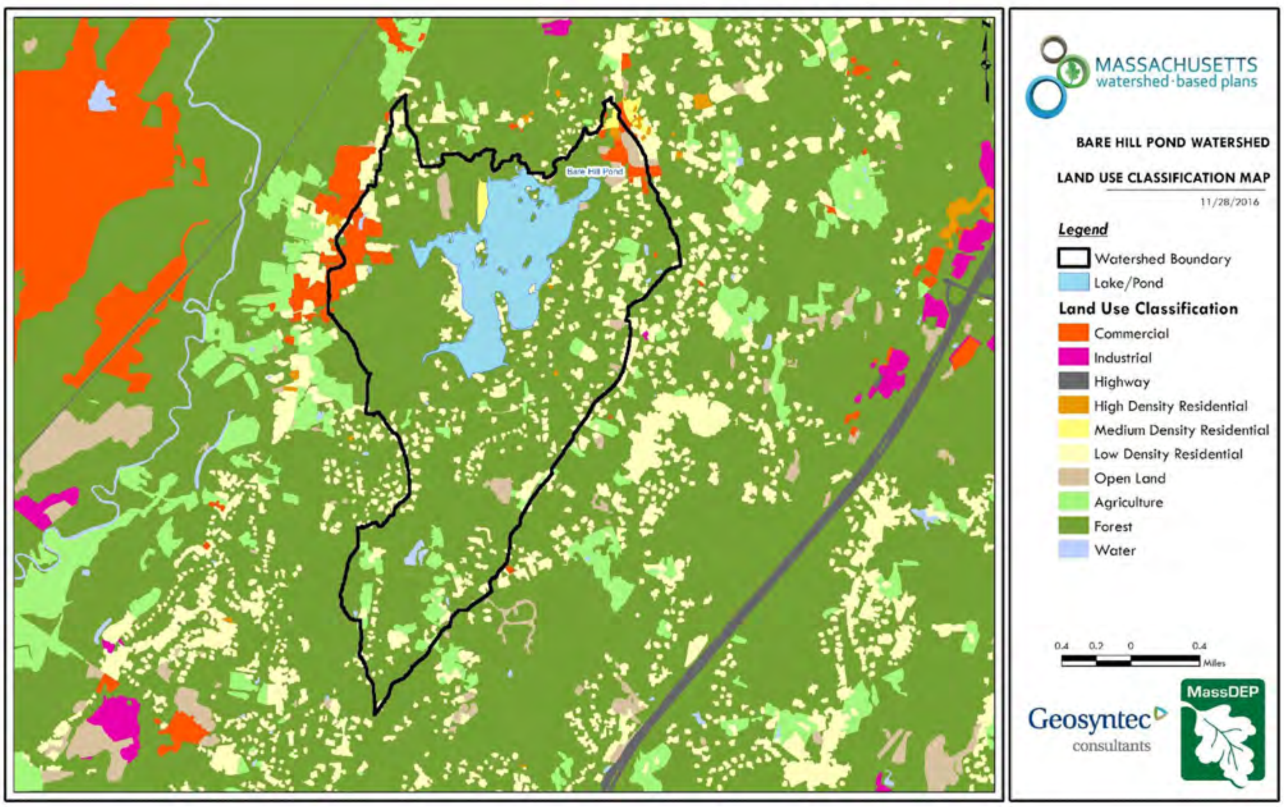


Figure A-2: Watershed Land Use Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Ctrl + Click on the map to view a full sized image in your web browser.

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.

Impervious areas that are directly connected (DCIA) to receiving waters (via storm sewers, gutters, or other impervious drainage pathways) produce higher runoff volumes and transport stormwater pollutants with greater efficiency than disconnected impervious cover areas which are surrounded by vegetated, pervious land. Runoff volumes from disconnected impervious cover areas are reduced as stormwater infiltrates when it flows across adjacent pervious surfaces.

An estimate of DCIA for the watershed was calculated based on the Sutherland equations. USEPA provides guidance (USEPA, 2010) on the use of the Sutherland equations to predict relative levels of connection and disconnection based on the type of stormwater infrastructure within the **total impervious area (TIA)** of a watershed. Within each subwatershed, the total area of each land use were summed and used to calculate the percent TIA.

Table A-7: TIA and DCIA Values for the Watershed

	Estimated TIA (%)	Estimated DCIA (%)
Bare Hill Pond	5.5	3.6

The relationship between TIA 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 (TIA) 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.

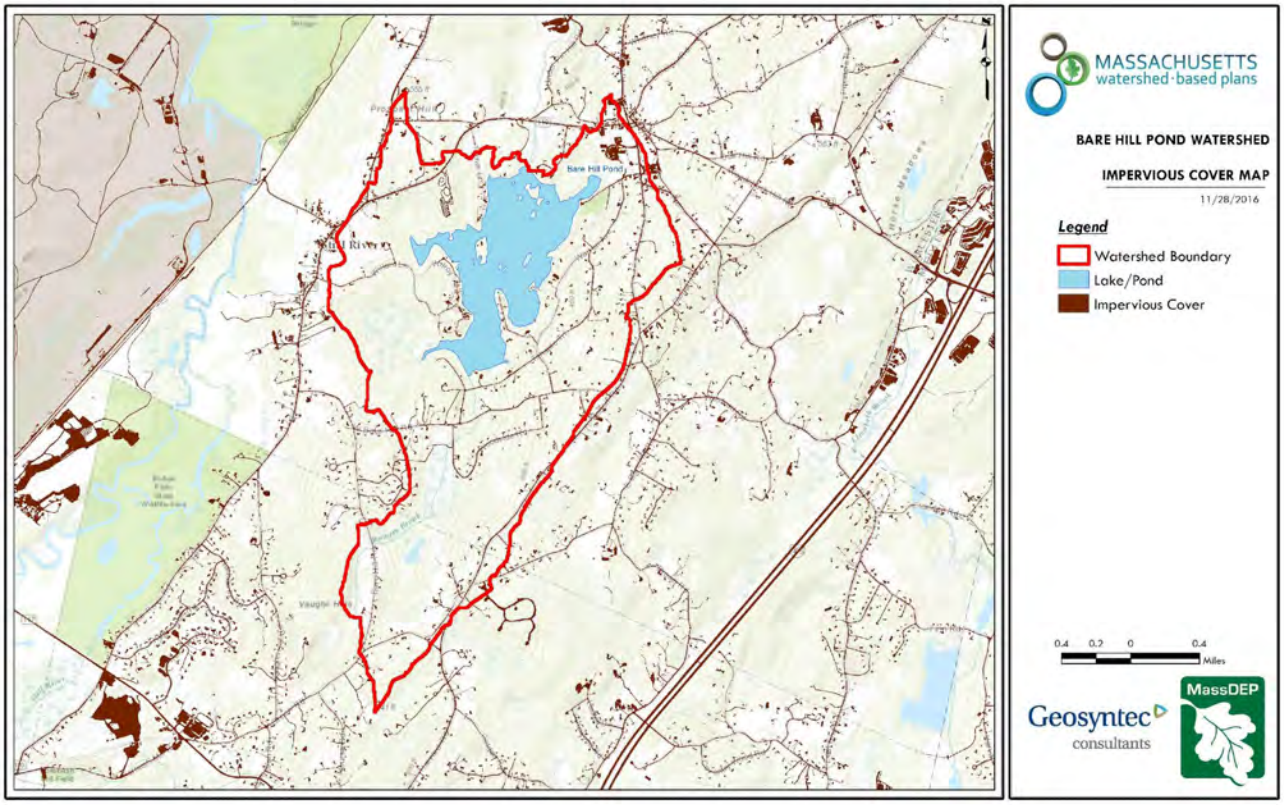


Figure A-3: Watershed Impervious Surface Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Ctrl + Click on the map to view a full sized image in your web browser.

Land use information:

See the Horsley Whitten Final Report for details that identify the locations for installation of BMPs for stormwater treatment and the areas that are treated by existing wetlands. The vast majority of the impervious cover locations that generate runoff into Bare Hill Pond are now treated from the installation of the BMPs in the 2008-2010 Section 319 Project Grant previously awarded and completed. Other streams are from rural areas of town and flow through extensive wetlands prior to entering the Pond. Rain gardens were determined to be of limited utility on those streams.

Pollutant Loading

Geographic Information Systems (GIS) was used for the pollutant loading analysis. The land use data (MassGIS, 2009b) was intersected with impervious cover data (MassGIS, 2009a) 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.

The amount of DCIA was estimated using the Sutherland equations as described above and any reduction in impervious area due to disconnection (i.e., the area difference between TIA and DCIA) was assigned to the pervious D soil category for that land use to simulate that some infiltration will likely occur after runoff from disconnected impervious surfaces passes over pervious surfaces.

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 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 USEPA (USEPA, 2020; UNHSC, 2018, Tetra Tech, 2015) (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	38	230	2.90
Commercial	28	271	3.37
Forest	246	1,308	53.40
High Density Residential	2	12	0.17
Highway	0	0	0.00
Industrial	0	0	0.00
Low Density Residential	74	755	10.12
Medium Density Residential	4	31	0.44
Open Land	19	169	3.54
TOTAL	410	2,776	73.95

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

Pollutant loading information:

The cumulative data from annual monitoring of phosphorus is shown in the 2023 ARC Bare Hill Pond In-Lake Water Quality and Plant Survey . Following the winter drawdown, phosphorus was measured at 0.015 to 0.022 mg/l which is consistent with data in other years since the deep drawdowns were initiated. Higher readings (0.031 - 0.104 mg/l) at some locations in June, July and August correlate with deeper locations that were experiencing high temperatures and anoxic conditions; not due to stormwater or it would not be in specific and deeper locations. This suggests that in-lake phosphorus loading is occurring from higher temperatures. Rain events do not appear to impact the phosphorus readings and may even reduce them due to higher spring flows and turnover rates. This indicates that control of in-lake loading is an important objective. The drawdown builds resiliency into the phosphorus level and creates room for in-lake loading due to climate change.

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 Section 4 of 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 (314 CMR 4.00, 2013) 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 Load	Water Quality Goal	Required Load Reduction
Total Phosphorus	See TMDL information below	See TMDL information below	See TMDL information below
Total Nitrogen	2776 lbs/yr		
Total Suspended Solids	74 ton/yr		
Bacteria	*MSWQS for bacteria are concentration standards (e.g., colonies of fecal coliform bacteria per 100 ml), which are difficult to predict based on estimated annual loading.*	Class B. **Class B Standards** • Public Bathing Beaches: For E. coli, geometric mean of 5 most recent samples shall not exceed 126 colonies/ 100 ml and no single sample during the bathing season shall exceed 235 colonies/100 ml. For enterococci, geometric mean of 5 most recent samples shall not	

		exceed 33 colonies/100 ml and no single sample during bathing season shall exceed 61 colonies/100 ml; • Other Waters and Non-bathing Season at Bathing Beaches: For E. coli, geometric mean of samples from most recent 6 months shall not exceed 126 colonies/100 ml (typically based on min. 5 samples) and no single sample shall exceed 235 colonies/100 ml. For enterococci, geometric mean of samples from most recent 6 months shall not exceed 33 colonies/100 ml, and no single sample shall exceed 61 colonies/100 ml.	

TMDL Pollutant Load Criteria

Total Phosphorus (MA81007)

DEP chose a margin of safety of 5 percent of the total TMDL. In this case, the margin of safety is 538 kg/yr*.05 or 27 kg/yr. Point source loading is zero, which leaves 511 kg/yr for the load allocation to nonpoint sources as indicated in the right side of the following table (from "Bare Hill Pond, Harvard, MA. (MA81007) TMDL", 1999). Loading allocations are based on the measured phosphorus budget; not the landuse modeled phosphorus budget.

Table TMDL Load Allocations.

Source	*Current TP Loading (kg/yr)*	*Target TP Load Allocation (kg/yr)*
Atmosphere	63.	63.
Groundwater	50.	31.
Clapp's Brook	61.	38.
Pond Road Subwatershed	71.	44.
Thurston's Brook	43.	26.
Bowers Brook	104.	64.
Sprague Swamp Subwatershed	56.	34.
Sediment Recycling	342.	211.
Total Inputs	790.	511.

Obviously the estimate for sediment recycling of phosphorus of 763 kg/yr suggested by Whitman and Howard (1987) is highly uncertain since it was based on the midpoint of a range of literature values. Using the Dillon- Rigler model, DEP estimated a total phosphorus load of 790 kg/yr would coincide with the observed in-lake phosphorus concentration of 0.044mg/l. Given this, the internal sediment phosphorus recycling was then estimated using the mass balance approach as the difference between the total load of 790 kg/yr estimated above, and the measured external watershed loading of 448 kg/yr. Thus, an internal (sediment) recycling load of 342 kg/yr was used in this analysis.

Phosphorus loading allocations for each subbasin and other sources are shown (are rounded to the nearest kg/yr) in the table. No reduction in atmospheric loading is targeted, because this source is impossible to control on a local basis. The reduction of phosphorus loading from wastewater septic systems of 150.8 kg/yr is based on Whitman and Howard (1987) analysis assuming 50% reduction in loading due to increase tank cleaning with 100% participation of homeowners. This represents a 33.5 percent reduction in the watershed loading. This is allocated as a proportional phosphorus loading reduction among the groundwater and stream subwatersheds based on the approximately equal distribution of houses around the watershed. An additional of 4.9 percent in phosphorus loadings due to watershed management will reduce total loadings to the target of 511 kg/yr (a total of 38.4% reduction) as indicated in the table. This assumes that internal recycling of phosphorus will be proportionately reduced 38.4%, as the external loading is reduced, although it is expected that reductions in recycling will lag behind reductions in external loading. Note that atmospheric inputs are assumed to be constant at 63 kg/yr.

The TMDL is the sum of the wasteload allocations (WLA) from point sources (e.g., sewage treatment plants) plus load allocations (LA) from nonpoint sources (e.g., landuse sources) plus a margin of safety (MOS). In this case the TMDL is:

TMDL = WLA + LA + MOS = 0 kg/yr + 511 kg/yr + 27 kg/yr = 538 kg/yr.

Modeling Assumptions, Key Input, Calibration and Validation: No models currently exist to predict a reduction of nuisance aquatic macrophytes as a result of phosphorus controls, therefore, no macrophyte models were used. Control of nuisance aquatic macrophytes is based on established literature and best professional judgment. In-lake nutrient concentrations were modeled to estimate how nutrient management may reduce in-lake nutrient concentrations and reduce the probability of algal blooms in the future. Based on the Dillon-Rigler (1974) model the in-lake total phosphorus concentrations is predicted from:

P = PI * (1-R)

where Pi=(Lp/(Z/T) and R (phosphorus retention=(0.426e-0.271Z/T + 0.574e-0.00949Z/T) and Lp (areal loading rate or 790 kg/yr / 1300000 * 1000g/kg)=0.608 g/m2/yr, Z (mean depth)= 3m, and T(hydraulic retention time)=0.64 to 0.73 years. The predicted total phosphorus averages 0.044 and agrees with the measured average total phosphorus concentration of 0.044 mg/L (44 ppb), because the loading rate, and specifically, the internal loading rate was adjusted as noted above. Note that the loading rate used by Whitman and Howard (1987) of 1213 kg/yr, which included the higher estimate of sediment phosphorus recycling, would result in a predicted lake concentration of 0.064 to 0.074 mg/l.

The Dillon-Rigler model is based on the typical assumptions of a single compartment, fully mixed open system which was calibrated on 13 Canadian lakes. The model was designed for use on algal dominated lakes and may become inaccurate in lakes with large areas dominated by macrophytes such as Bare Hill Pond. Otherwise, Bare Hill Pond falls within the range of the calibration dataset for lake area, mean depth and areal loading of phosphorus. The model was calibrated to spring overturn total phosphorus conditions and the spring values for Bare Hill Pond ranged between 0.03 and 0.05 mg/l, thus the yearly average of 0.044 mg/l is representative of spring conditions. As noted above, for the purposes of this TMDL we estimated the internal loading to be 342 kg/yr.

Seasonality: As the term implies, TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For this case, the TMDL is expressed in terms of allowable annual loadings of phosphorus. Although critical conditions occur during the summer season when weed growth is more likely to interfere with uses, water quality in many lakes is generally not sensitive to daily or short term loading, but is more a function of loadings that occur over longer periods of time (e.g. annually). Therefore, seasonal variation is taken into account with the estimation of annual loads. In addition, evaluating the effectiveness of nonpoint source controls can be more easily accomplished on an annual basis rather than a daily basis.

For most lakes, it is appropriate and justifiable to express a nutrient TMDL in terms of allowable annual loadings. The annual load should inherently account for seasonal variations by being protective of the most sensitive time of year. The most sensitive time of year in most lakes occurs during summer, when the frequency and occurrence of nuisance algal blooms and macrophyte growth are usually greatest. Therefore, because the Bare Hill Pond phosphorus TMDL was established to be protective of the most environmentally sensitive period (i.e., the summer season), it will also be protective of water quality during all other seasons. Additionally, the targeted reduction in annual phosphorus load to Bare Hill Pond will result in the application of phosphorus controls that also address seasonal variation. For example, certain control practices such as stabilizing eroding drainage ways or maintaining septic systems will be in place throughout the year while others will be in effect during the times the sources are active (e.g., application of lawn fertilizer).

Dillon, P.J. and F.H. Rigler. 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Bd. Can. 31:1771-1778.
Whitman and Howard. 1987. Diagnostic/Feasibility Study Bare Hill Pond. Harvard, Massachusetts. + Appendices. Prepared by Whitman and Howard, Inc. 45 William St. Wellesly, MA.

Bare Hill Pond, Harvard, MA. (MA81007) TMDL

Pollutant load reduction information:

Horsely Whitten in Appendix A to its final report computed the load reductions to be performed by the BMPs to be constructed. Notably, the advice of Horsley Whitten was that additional stormwater BMPs were not likely to improve phosphorus reduction further due to the extensive wetlands that capture those sources. Notably, the table above confirms that the single largest source of phosphorus loading is from anoxic conditions that trigger in lake loading. This is consistent with the TMDL Table Load Allocations, shown above. Further storm water reductions and removal of enough Pond sediment are unlikely and/or impractical. Thus, the opportunity to continue deep drawdowns of up to 6.5 feet to add resiliency to the water column is warranted given the data collected over the past 15 years.

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 Hotspot Map:

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 priority 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 are recommended for further investigation for BMP implementation suitability. **Figure C-1** presents the resulting BMP Hotspot Map for the watershed. The following link includes a Microsoft Excel file with information for all parcels that have a score above 60: hotspot 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.

GIS data used for the BMP Hotspot Map 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 (2009b);
- MassGIS (2012); and
- ArcGIS (2020b).

Table C-1: Matrix for BMP Hotspot Map GIS-based Analysis

Criteria	Indicator Type	METRICS																											Multiplier	Maximum Potential Score
		Yes or No?		Hydrologic Soil Group				Land Use Type									Water Table Depth				Parcel Area			Parcel Average Slope						
		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	3	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

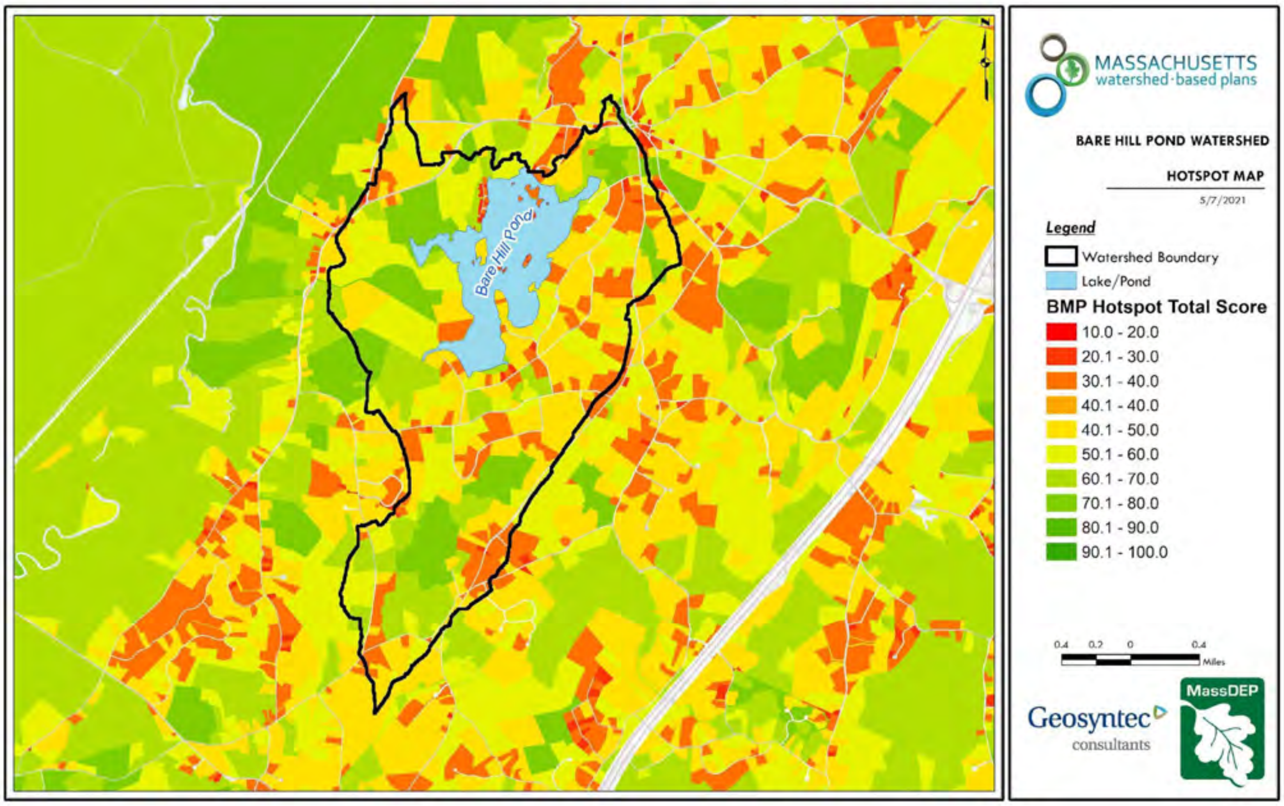


Figure C-1: BMP Hotspot Map (MassGIS (2015a), MassGIS (2015b), MassGIS (2017a), MassGIS (2017b), MassGIS (2020), MA Department of Revenue Division of Local Services (2016), MassGIS (2005), ArcGIS (2020), MassGIS (2009b), MassGIS (2012), ArcGIS (2020b))

Ctrl + Click on the map to view a full sized image in your web browser.

Proposed Management Measures:

Table C-2 presents the proposed management measures as well as the estimated pollutant load reductions and costs. 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	BIORETENTION AND RAIN GARDENS
BMP SIZE (storm depth; inches)	1.00
DRAINAGE AREA (acres)	90.00
BMP LOCATION	Town Center, Schools, Pond Road, Route 111,
LAND USE, COVER TYPE (in drainage area)	**% OF DRAINAGE AREA**
COMMERCIAL, Impervious	25
MEDIUM DENSITY RESIDENTIAL, Impervious	25
OPEN LAND, Pervious	50
ESTIMATED POLLUTANT LOAD REDUCTIONS	
TN (lbs/yr)	528.05950
TP (lbs/yr)	66.88811
TSS (lbs/yr)	19495.73056
ESTIMATED FOOTPRINT (sf)	104,362.1
Actual COST ($)	Capital cost: $ 497,463 Operating Cost: $1500/year

Additional BMPs

BMP TYPE	Pumped Winter drawdown In Place
BMP LOCATION	Bare Hill Pond
DESCRIPTION	As described in the overview, the BHPWMC conducts an annual winter drawdown using the facilities constructed under Section 319 Project 03-05/319 to reduce phosphorus and control invasive species, as well as to increase resiliency for handling

	temperature triggered in-lake phosphorus loading of Bare Hill Pond.
ESTIMATED POLLUTANT LOAD REDUCTIONS	Reducing TP in water column from TMDL from 0.044 mg/l to under 0.030 or lower
Actual COST ($)	Capital Cost $418,368 plus operating costs of $30-35,000 per year

BMP TYPE	Invasive Species Removal
BMP LOCATION	Bare Hill Pond
DESCRIPTION	Removal of invasive fanwort and millfoil from Town Beach Swimming areas by means such as diver assisted such hose technology and in other high use Town locations that are not controlled by the drawdown
ESTIMATED POLLUTANT LOAD REDUCTIONS	1-3 acres per year
ESTIMATED COST ($)	30,000 per year in operating costs.

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)						
BIORETENTION AND RAIN GARDENS	Town Center, Schools, Pond Road, Route 111,	-	$10,000	DPW currently performs inspection and maintenance	Operation and Maintenance Guidance provided by Horsley Whitten	$1500/ year
Pumped Winter drawdown	Bare Hill Pond	$100-150,00 every 15 years	$7500	BHPWMC and DPW perform activities under Conservation Commission annual review and Order of Condition	Expert Assessment and Monitoring by Aquatic Restoration Consulting, LLC (Wendy Gendron)	$7500 plus capital budget
Invasive Species Removal from Spot Areas in Pond	Bare Hill Pond		$30,000 or less per year	Diver Assisted Suction Hose Contractor and BHPWMC	Aquatic Restoration Consulting, LLC	$30,000/ year for 3-4 years
Information/Education (see Element E)						
Education Communication and Mailing costs	Town of Harvard		$2,500/ year	BHPWMC Conducts	Aquatic Restoration Consulting, LLC	$2,500/ year
Monitoring and Evaluation (see Element H/I)						
Annual Bare Hill Pond In-lake Wildlife, Plant and Habitat Assessment	Bare Hill Pond	$0	$15,000/year	BHPWMC Conducts with Expert Consultant	Aquatic Restoration Consulting, LLC	$15,000/year
StormWater BMP Quality Assurance Assessment	Town of Harvard Rain Gardens	$0	$2,500	BHPWMC performs for review by Conservation Commission	Aquatic Restoration Consulting, LLC	$2,500 every 3 years
					Total Funding Needed:	**$90,000**
Funding Sources:						

- Town of Harvard Budget for BHPWMC
- MA DEP Section 319 Program
- Community Preservation Act

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

The goals and objectives for the watershed information and education program.

The goals are to inform the Town and its residents of: 1) the importance of the protection of the watershed, activities in the watershed that benefit or harm the watershed, and best practices for land use for reducing nonpoint source pollution. 2) the ongoing activities of the Bare Hill Pond Watershed Management Committee to use drawdowns to control invasive aquatic species and to reduce phosphorus in Bare Hill Pond. 3) the rationale and benefits of the drawdown project, including its assessment reports and the data demonstrating its benefits and contribution to the restoration of native habitat 4) the importance of the stormwater BMP rain gardens in helping to reduce nonpoint source pollution 5) other best practices the Town and its residents can follow to protect and preserve Bare Hill Pond and its watershed.

Step 2: Target Audience

Target audiences that need to be reached to meet the goals and objectives identified above.

The target audiences include: 1) All residents and Town officials so that they understand the benefits of the on-going activities and the importance of watershed protection. 2) All abutters to the Pond and the watershed to understand the unique role they can play in avoiding contributing to non-point source pollution. 3) Visitors to Bare Hill Pond, a Great Pond, so that they follow best practices when boating, fishing and swimming.

Step 3: Outreach Products and Distribution

The outreach product(s), activities and distribution form(s) that will be used for each.

1. The Committee regularly attends Town events with an information table to share materials that (a) inform residents about watershed protection including:

   a. The Committee maintains a BHPWMC website with our strategy, planning, reports and watershed information.
   b. A webpage and handouts on Information on Healthy Lawns for Healthy Families that explains why fertilizers should be avoided in the watershed.
   c. haring and discussing each year's annual report to the Conservation Commission on its website

2. Conducting regular annual events with our wetlands expert who provides a tour of the Pond showing how the drawdown has controlled invasive species and restored native habitat.

3. Providing written and oral comments to other Town Boards making decisions regarding development in the watershed that could put Bare Hill Pond at risk, such as:

   a. Comments on Notices of Intent at the Conservation Commission in the watershed

   b. Comments on applications for Zoning variances in the watershed that could increase non-point source pollution,

   c. Comments to the Planning Board on removal of forests in the watershed that could impact storm water run off under the Town's erosion control bylaw.

4. Providing an Annual Report to Town meeting in writing that is distributed to all residents that provides an update on activities and why they are important to watershed protection.

5. Sponsoring an award each year at the annual High School Science Fair to encourage students to study watershed protection.

6. Write or contribute to regular articles in the Harvard Press about protection of the Bare Hill Watershed.

Step 4: Evaluate Information/Education Program

The Bare Hill Pond Watershed Management Committee meets monthly. It maintains a schedule of activities which it conducts in each month of the year to fulfill each of its commitments. It reviews and evaluates its performance during the prior month and what needs to be accomplished in the next 3 months at each meeting. This activities schedule is also reviewed at each Monthly meeting to ensure that all activities are performed as planned.

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.

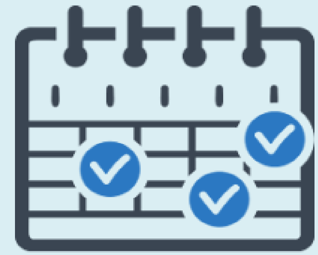


Table FG-1: Implementation Schedule and Interim Measurable Milestones

Structural & Non-Structural BMPs						
BIORETENTION AND RAIN GARDENS *Town Center, Schools, Pond Road, Route 111,*	Completion of Construction of Rain Gardens					
	7/27/2010					
Pumped Winter drawdown In Place *Bare Hill Pond*	Complete construction and test Pump House	Complete Demonstration Study	Replace Obsolete VFD Drive for Pump engine			
	7/15/2006	6/30/2007	7/30/2024			
Invasive Species Removal at Town Beach and other sites *Bare Hill Pond*	Town Beach Removal	Town Beach Removal completion	Adjacent to Beach Areas Needing Removal	Other Selected Site Removal by Residents	Other Selected Site Removal by Residents	Other Selected Site Removal by Residents
	6/30/2024	8/15/2024	6/30/2025	8/15/2025	8/15/26	8/15/27

Public Education & Outreach						
Attend Public Meetings	Spring Town Meeting	Fall Town Meeting	Spring Town Meeting	Fall Town Meeting	Spring Town Meeting	Fall Town Meeting
	4/15/2024	10/15/2024	4/15/2025	10/15/2025	4/15/2026	10/15/2026
Attend ZBA, Conservation and Planning Board	As needed when development is in Watershed					
	Throughout each year					
Pond Tour with Watershed Expert	Annual each summer					
	July					
Science Fair	Annual Award for Student Watershed Projects					
	March					
Send Watershed Residents Best Practice Information	Fall Mailing each year	Winter Mailing each year				
	September	January				

Monitoring	
Annual Report to Conservation Commission	Every Year
	August
Frog Counts	Every Year
	March, April, May and July
Pond Monitoring by Watershed Expert to document DO	Every Year
	March, April, May and July
Pond Monitoring by Watershed Expert to document DO, temp phosphorus, native and non-native plants	Every Year
	March, April, May and July
Reptile Count	Every Year
	March, April, May and July

Scheduling and milestone information:

The majority of the capital investment has been achieved leading to the operational stage of watershed management on Bare Hill Pond. The key unmet needs in the watershed are the increased risk of in-lake phosphorus loading due to higher temperatures and the continued control of invasive species. The importance of reliable consistent deep drawdowns to maintain resiliency and avoid hazardous algal blooms as well as control invasive species has been reinforced following recent years where the pump had mechanical issues. The pump controls are being upgraded and replaced in 2024 to restore the high level of performance and reliability experienced in the first ten years. The electronic control system was older than its expected useful life and thus needed to be replaced. The other learning from the initial 15 years is that there are several areas of the Pond where the drawdown is not able to control the invasive species. They tend to be 1 acre or less and appear to be best managed by using divers with suction hoses. That will be the next major new activity to schedule in addition to the existing ongoing educational, operational and monitoring activities.

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 Bare Hill Pond.

Indirect Indicators of Load Reduction

The Board of Health conducts regular testing of water for hazardous algal blooms. They use both laboratory testing and the optical testing device furnished by the EPA. The occurrences will be evaluated in light of the success of the prior winter drawdown, and the phosphorus and measurements of anoxic conditions in the annual assessment described in Project Specific Indicators.

Project-Specific Indicators

The drawdown project has detailed watershed monitoring requirements that include: 1) Identification and measurement of quantity of invasive and native plants at designated transects in the Pond. 2) measurements of phosphorus, DO2, temperature, and Secchi readings at designated times and locations in the Pond 3) Tracking of fish counts at multiple fishing derbies each year. 4) Evaluation of downstream wetlands impacts, if any. 5) Frog counts to ensure species continuity and health. 6) Turtle counts to ensure species continuity and health. 7) Mussel surveys to ensure continuity and observed reproduction. These are required under the Order of Conditions for the deep drawdown and reviewed annually by the Conservation Commission.

TMDL Criteria

The TMDL goals were the Section 319 Project goals to reduce invasive species and to reduce phosphorus below 0.030 mg/l which was achieved after initiating deep drawdowns.

Direct Measurements

Direct measurements are taken annually under the guidelines of the QAPP approved in the first 319 grant and are reported annually to the Conservation Commission. As detailed in the 2023 ARC Annual report, there are specific sites for measuring the relative presence of plant species, for measuring phosphorus, dissolved oxygen and Secci disk readings.

Adaptive Management

This Watershed Management Plan is an example of when it needs to be revised. The watershed strategy followed to date is achieving the TMDL goals, it was not incorporated in the Watershed Management Plan. Even with the successes achieved so far, there are areas of the Pond that are too deep or remain wet and allow for persistence of invasive species, such as the Town swimming area over 6.5 feet. The plan includes the prior actions to protect the pond, such as the rain gardens for stormwater control and the pumped drawdown , but now it will also include a plan to use new strategies to control invasive species in small spot locations in the pond to seek to achieve the TMDL goals. In addition, the strategy will incorporate phosphorus management to reduce the risk of hazardous algal blooms due to climate change.

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Water Quality Assessment Reports

"*Nashua River Watershed 2003 Water Quality Assessment Report*"

TMDL

"*Bare Hill Pond, Harvard, MA. (MA81007) TMDL* "

1987 Whitman and Howard Report

1998 ENSR Water Quality and Aquatic Plant Evaluation

2002 ENSR Wildlife, Habitat and Vegetative Assessment

Annual Updates and Reports to Conservation Commission (see 2023 ARC Report and 2023 Committee report for a cumulative update)

Chronology of Pond Management from early 1800s to 2000

2005-06 Watershed Survey and Plan

Appendices

Appendix A – Pollutant Load Export Rates (PLERs)

Land Use & Cover[1]	PLERs (lb/acre/year)		
	(TP)	(TSS)	(TN)
AGRICULTURE, HSG A	0.45	7.14	2.6
AGRICULTURE, HSG B	0.45	29.4	2.6
AGRICULTURE, HSG C	0.45	59.8	2.6
AGRICULTURE, HSG D	0.45	91	2.6
AGRICULTURE, IMPERVIOUS	1.52	650	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	15.1
FOREST, HSG A	0.12	7.14	0.5
FOREST, HSG B	0.12	29.4	0.5
FOREST, HSG C	0.12	59.8	0.5
FOREST, HSG D	0.12	91	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	1.34	1,480	10.5
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	15.1
LOW DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.3
LOW DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.2
LOW DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.4
LOW DENSITY RESIDENTIAL, HSG D	0.37	91	3.7
LOW DENSITY RESIDENTIAL, IMPERVIOUS	1.52	439	14.1
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			