WATERSHED-BASED PLAN

Bare Hill Pond

HARVARD, MA

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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 2,427 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 Bare Hill Pond DEP, DWM TMDL Report MA81007-1999-001 July, 1999 Report (the "1999 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 (the "Committee" or "BHPWMC") engaged Whitman and Howard in 1987 and ENSR 1998 to consider its options. Atter the 1999 TDML Report, the Committee asked ENSR for a report in 2002 to develop a plan. The Committee 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 1999 TDML Report. Informing its decisions were several reports including the prior1998 Bare Hill Pond Water Quality and Aquatic Plant Evaluation report by ENSR, the 2002 Wildlife, Habitat and Vegetative Assessment of Bare Hill Pond, with Management Implications by ENSR, and the 2006 Bare Hill Pond Watershed Survey (Nestler and Flaherty). The strategy was to begin to use winter drawdowns to reduce phosphorus by increasing turnover in the Pond, and to control eutrophication and 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 seed bearing water chestnut plants.

This work was planned, and then put in operation using practices in the newly issued Final Generic Environmental Impact Report on Eutrophication and Aquatic Plant Management in Massachusetts (the "GEIR") and using specific habitat assessments and guidelines based on two studies referenced above by ENSR for the BHPWMC in 1998 and 2002. 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 management, 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 up to 3.5 feet. In 2005, the BHPWMC applied for a Section 319 grant, because it became evident that while the initial drawdowns were improving the Pond and its habitat, a 3.5-foot winter drawdown was not sufficient to achieve the 1999 TMDL goals. With the award of the Section 319 grant in 2006, the Committee (largely through volunteer labor) constructed a pump house to conduct deep winter drawdowns under careful protocols established under the oversight of the Conservation Commission. Starting at 5 feet followed by 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 2001, with over 20 years of monitoring data contained in assessment reports submitted to the Conservation Commission since 2002[1]. Bare Hill Pond may have one of the most comprehensive longitudinal collections of data of any lake or Pond in the Commonwealth for this strategy.

Key learnings included that 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. As a result, taking a year off could cause a reversal when followed by a climate related or mechanical related issue. Second, the impact of each drawdown is not dramatic but incremental at best. Each drawdown builds on prior years. This helps assure avoidance of harm as benefits are quantified. Over time, data demonstrates there is a significant return of native species that in the presence of drawdowns can out compete invasive milfoil and fanwort 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 indicates that properly selected timing and the controlled rate (less than 2" per day) of the winter drawdown does not appear to be harmful to their populations or habitats. Finally, the 6.5-foot depth of the drawdown which essentially leaves in place the original pond prior to construction of the dam provides adequate habitat for overwintering of in-lake species as fish populations have continued to thrive as well as other invertebrates.

Drawdowns do not control seed reproducing invasive species like water chestnut. Water chestnut plants were historically being marginally controlled by containing them using hand pulls to keep them within 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

[1] See reports listed on the Committee webpage here.

eradicated from Bare Hill Pond and native species have returned.[2] 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 awarded in 2010 and funding from the grant 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 by Horsely Whitten and identified the sites that should have rain gardens[3]. In the initial work conducted by Horsley Whitten in preparing its proposal for controlling storm water entering Bare Hill Pond, it recommended limiting the proposed interventions to six sites in Town center. Other streams that enter the Pond were found to have existing wetlands that were not likely to be further improved by implementing rain garden controls. Notably, the largest contributor to phosphorus in the water column is from Pond bottom sediment or in-lake loading.[4]

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 phosphorus 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 harmful algal blooms. Cyanobacteria are monitored by the Town's Board of Health under a Cyanobacteria policy and access to the Pond is subject to advisories from the Board of Health. In those years, anoxic conditions rose from the 14-foot level to 10-12 feet in depth. Significantly lower oxygen levels and significantly higher phosphorus levels were found at a number of locations in late July in several recent summers, suggesting a higher risk. In the winters immediately prior to these expanded, anoxic conditions, pump mechanical issues and excess rain in December made it difficult to have successful drawdowns. The result was higher potential levels of phosphorous in the water column in the Spring potentially 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 two summers the drawdowns achieved the deeper depth goal, and despite significant heat and anoxic conditions, there were no algal blooms likely due to the resilience 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. When the pump did not operate in the 2023-24 winter and phosphorus was not reduced, an algal bloom occurred again in the Summer of 2024.

Lastly, the deep drawdowns do not routinely 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, where the drawdown has limited or little effect. These areas

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[2] See this video report on the successful water chestnut eradication.
[3] See Bare Hill Pond Stormwater Management Assessment Final (Horsley Whitten Group) (2008).
[4] See Section 4 A, *infra*.

range from less than half an acre to 1-3 acres. The BHPWMC engaged and may continue to engage diver assisted suction hose (DASH) contractors to remove milfoil and fanwort selectively from the smaller areas that remain unaddressed. The plan is also 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 as a template for their permits and engage the contractor in areas that they control.

Throughout all of these activities, the BHPWMC uses its wetlands consultants to evaluate the monitoring data and to perform professional monitoring and then engages in outreach and information sharing at meetings, in the local paper, in mailings and at annual pond tours with our 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 BHPWMC is a Town Committee appointed by the Select Board. It was formed by the Town in 1959 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 regulatory oversight of the Conservation Commission where the Committee provides regular annual updates. These meetings are open to and attended by interested members of the community and available on YouTube through local cable channel access. The Town's 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 1999 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 since 2003 (see 2024 ARC Report and 2024 Committee report for a cumulative update)
- Chronology of Pond Management from early 1800s to 2000
- 2005-06 Watershed Survey and Plan

Bare Hill Pond Challenges and Summary of Completed Work

The primary challenge for Bare Hill Pond is eutrophication, invasive aquatic species and phosphorus loading (primarily from internal loading). The executive summary in the 1999 TMDL Report provides as follows:

> Bare Hill Pond is listed on the Massachusetts 303d list for Nuisance Aquatic Plants and lake water quality may be threatened by high phosphorus loadings. This report, based on the Whitman and Howard (1987) Diagnostic/ Feasibility (D/F) study concludes that the excessive macrophyte growth in the pond is due to both natural conditions associated with flooded shallow areas after the lake was dammed and anthropogenic nutrient enrichment from the pond's watershed. Current plant harvesting operations and winter drawdowns may be sufficient to control macrophytes without the need for additional measures. The D/F study recommends watershed management to control nutrients and sedimentation and also recommended water level manipulation and optimization of plant harvesting to control plant growth. The proposed control effort is predicted to reduce total phosphorus concentrations from 0.044 mg/l to 0.030 mg/l. Because of the limited data available on discrete sources of nutrients within the watershed, a locally organized watershed survey is recommended to target reductions in nonpoint source nutrients and sediments. In many cases the State has limited authority to regulate nonpoint source pollution and thus successful implementation of this TMDL will require cooperative support from the public including lake and watershed associations, local officials and municipal governments in the form of education, funding and local enforcement. Funding support to aid in implementation of this TMDL is available under various state programs including section 319 and the State Revolving Fund Program (SRF) and the Department of Environmental Management's Lakes and Pond fund.

Based on this finding and studies conducted on behalf of the Bare Hill Pond Watershed Management Committee ("Committee") for the Town, substantial progress was made in developing a watershed strategy for Bare Hill Pond. Bare Hill Pond, its habitat and its protection, are overseen by the Committee, an appointed Board in the Town of Harvard. In 2003, the Committee adopted a new strategy based on the watershed reports listed above in the Data Sources, 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 plan had a short-term strategy to achieve the TDM goals, a medium-term strategy to achieve overall reduction of non-point source pollution from controllable sources and long-term strategy to educate and enhance residents to use best practices in the watershed.

Because of the extensive knowledge identified through studies of the watershed, and because of the availability of Section 319 funding, substantial progress has been made in identifying and then addressing many of the short-term and medium- and long-term goals since 2001. The section will discuss the challenges identified, and the activities undertaken to address these challenges since 2001.

Short-Term Strategy – Achieving the TDML Goals

In 2002, based on a significant increase in the growth of fanwort and milfoil, the Committee, in reliance on the data in the TMDL Study and Whitman and Howard reports, 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 seek to reduce eutrophication. To obtain advice on best options for proceeding and 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 initial 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 3.5foot 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 and protocol 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 purpose of this grant was 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 to allow native plants to repopulate Bare Hill Pond. Also, a Watershed Survey or watershed management strategy plan was prepared in 2006 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 Quality Assurance Project Plan ("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 [2024 ARC In Lake Water Quality Assessment and Annual Report] (the "ARC Annual Report"):

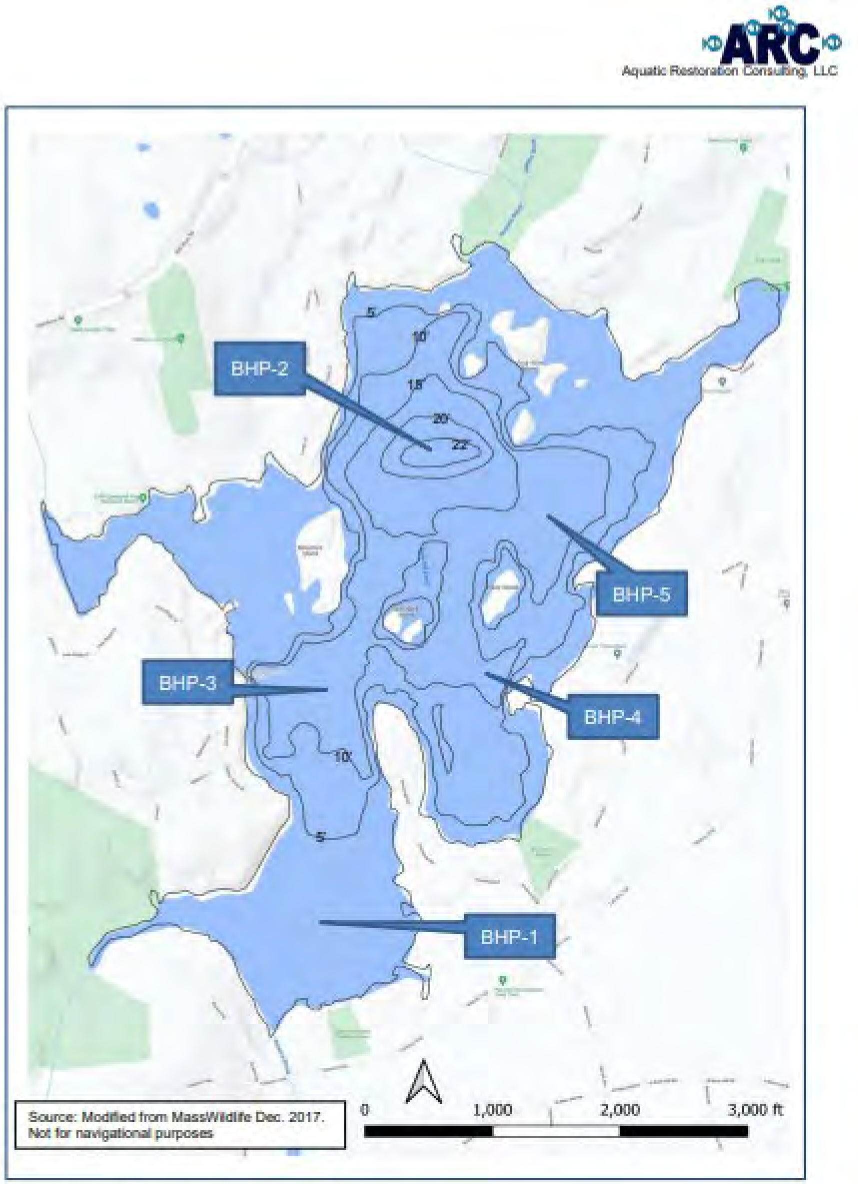


Figure 4. Bare Hill Pond Monitoring Stations.

The following table shows the drawdown history since 2001.

Drawdown History:

Table 1. History of Bare Hill Pond Winter Drawdowns.

Winter Season	Water Level Reduction and Summary of Following Growing Season Observations
2002-03	1.5 Feet
2003-04	3.5' gravity drawdown
2004-05	3.5' gravity drawdown
2005-06	3.5' gravity drawdown. These first few created evidence of efficacy in drawdown zone and no evidence of substantial issues
2006-07	5' gravity and pump drawdown. Some increase in efficacy
2007-08	5' gravity and pump drawdown. Good freeze and improvement
2008-09	3.5' gravity drawdown. Per request to see if a year off pumping would work - limited efficacy and rebound in plants
2009-10	6' gravity and pump drawdown. Planning started for beach excavation and the storm water rain gardens
2010-11	6.5' gravity and pump drawdown. Continued incremental efficacy and no harm detected
2011-12	7' gravity and pump drawdown. More efficacy and depth needed for the beach excavation project
2012-13	6' gravity and pump drawdown. Backed off partway through process to see if efficacy could be maintained
2013-14	No drawdown. Year off to see if lower frequency worked - phosphorous stable, some re-emergence in spots
2014-15	5.5' drawdown. Heavy snowfall runoff - phosphorous increase and increased observance of invasives by residents in 5 – 8 foot zone but overall reduction in plant volume and at transect sites
2015-16	6.0' drawdown. Very mild winter with an extended warm, dry and sunny growing season following
2016-17	5.75' drawdown. Very mild winter, even warmer than previous year. Wet spring and summer; water level higher than past years
2017-18	6' drawdown. Cold long winter with freezing temperatures into April. Period of hot humid weather leading to a pattern of extended wet weather. Water levels remained high throughout the summer.
2018-19	4.5' drawdown. While 6' was the goal, it was difficult to achieve the desired drawdown depth due to precipitation. The early portion of the summer was wet and overcast but come July it was warm and dry.
2019-20	6.0' drawdown. Warm November and March. Very low precipitation/snow cover
2020-21	Attempted 6.5'. Equipment issues prevented holding that depth beyond November. Lake was about 3.0' down during a short period of freezing
2021-22	6.5' drawdown. This season was typical in terms of temperatures and precipitation for most months except November which was below average. Snowpack was slightly below normal.
2022-23	7.5' due to operator error; Corrective actions were taken as discussed with the Conservation Commission. Lake refilled to approximately 4 feet prior to the freeze in January. The winter was warmer & wetter than usual.
2023-24	2.5' Gravity only due to pump mechanical issues. Very warm winter with unsustained freezing temperatures

The first pumped drawdown of 5 feet was in 2006-07 following the construction of the pumping station under the Section 319 grant. The depth of the deep drawdown was increased incrementally each year as monitoring data was reviewed and as it became clear that additional depth 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.

Phosphorous Short-Term Goal and Challenge:

The following data in the 2024 ARC Annual Report shows the reduction in phosphorus and the impact of performing the drawdowns over since 2001:

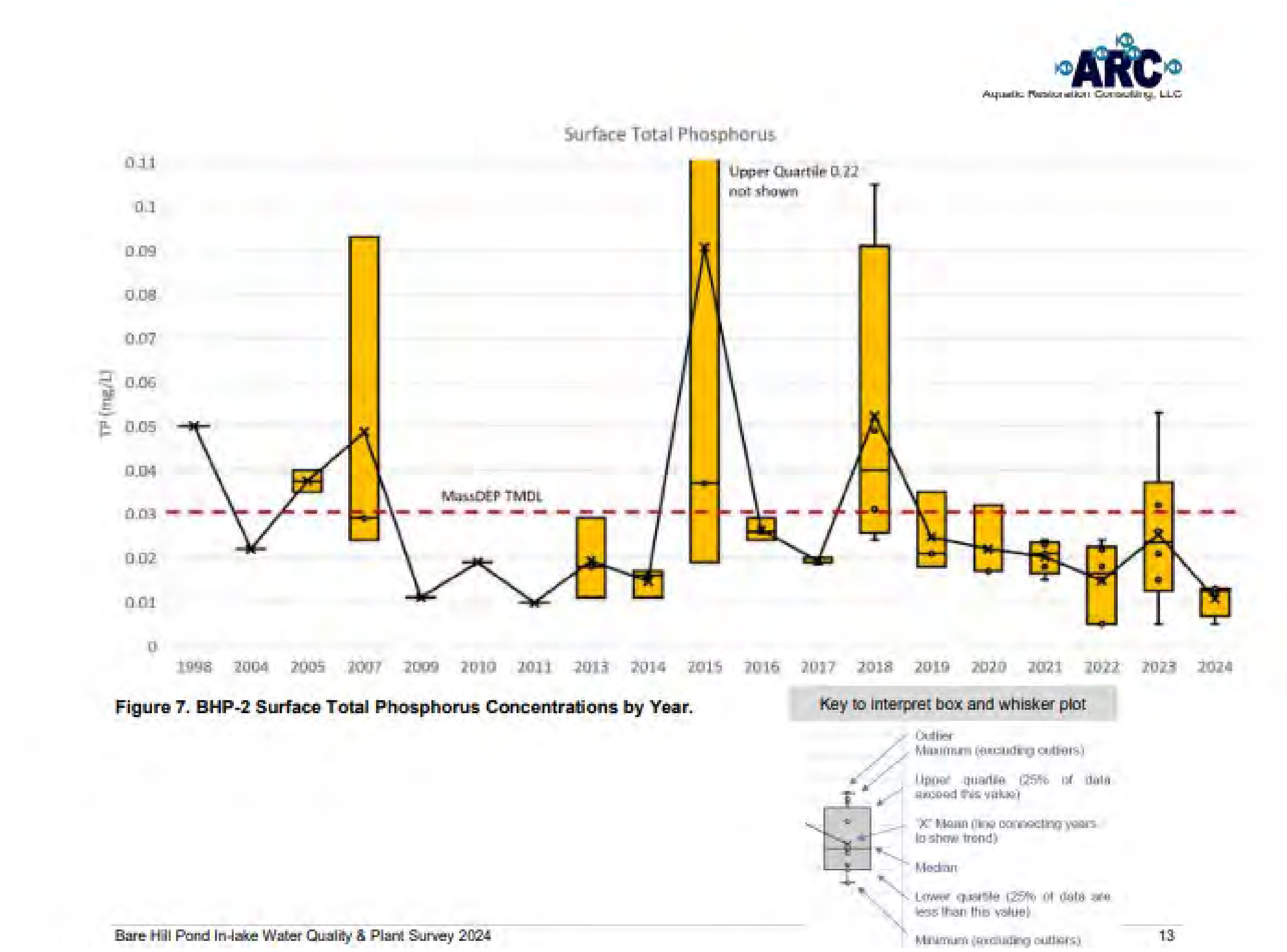
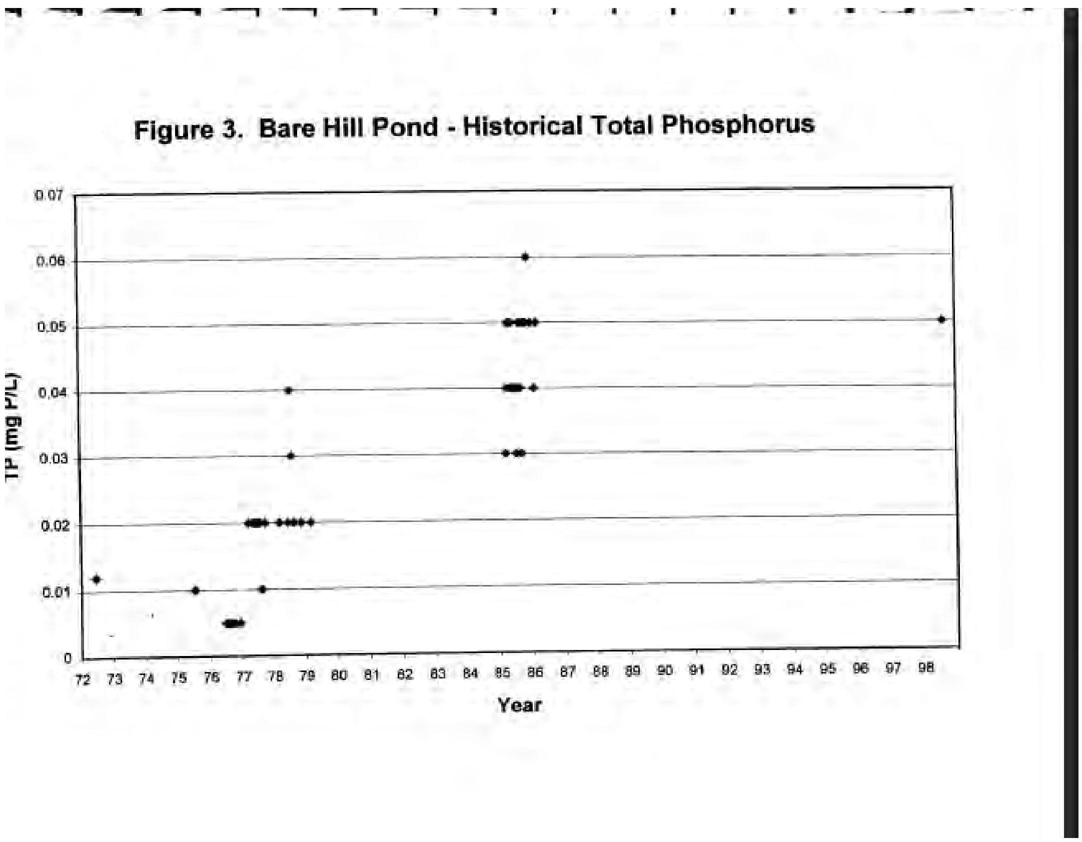


Figure 7. BHP-2 Surface Total Phosphorus Concentrations by Year.

Notes: The impact was initially incremental.   As depth increased, a significant difference (high levels of phosphorus) was observed following years without a deep drawdown (2008-09 (gravity only 3.5 ft., 2013-14 no draw down and 2015 partial drawdown). Variation also occurred due to anoxic conditions and in-lake loading during hot summers (2018). Most years have achieved reductions below 0.30 TDML goal.

Prior to the 1999 TDML Report, historical phosphorous measurements were reported to the Town by ENSR in the 1998 ENSR Report. The 0.05 readings were observed as early as 1985, as shown in this graph:



When MassDEP 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 short-term phosphorous goal has been largely achieved through the use of deeper drawdowns, however, with climate change, and increased temperatures and drought, it is possible that anoxic conditions in late summer could trigger algal blooms. In years following a drawdown, algal blooms have been avoided, however, it is also possible that drawdowns alone may not be sufficient to control phosphorous should anoxic conditions become more prevalent due to climate change in the future.

Invasive Milfoil and Fanwort Short-Term Challenge:

As noted in the 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 of milfoil and fanwort, 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.

Weather is a major factor. Drawdowns have limited effect on invasive species when the winters are warm and wet and the freeze is limited in duration. That said, phosphorous is also reduced in those years when the draw down is successful from a depth perspective.

Over time, with the multiple successful drawdowns and freezes, Bare Hill Pond had until 2024 shifted from a heavy dominance of invasive milfoil and fanwort to a significant level of control of the target invasive species and a repopulation of native species.

The 2023 ARC Annual Report plant survey shows the variation of significant native and non-native plant species since 1998:

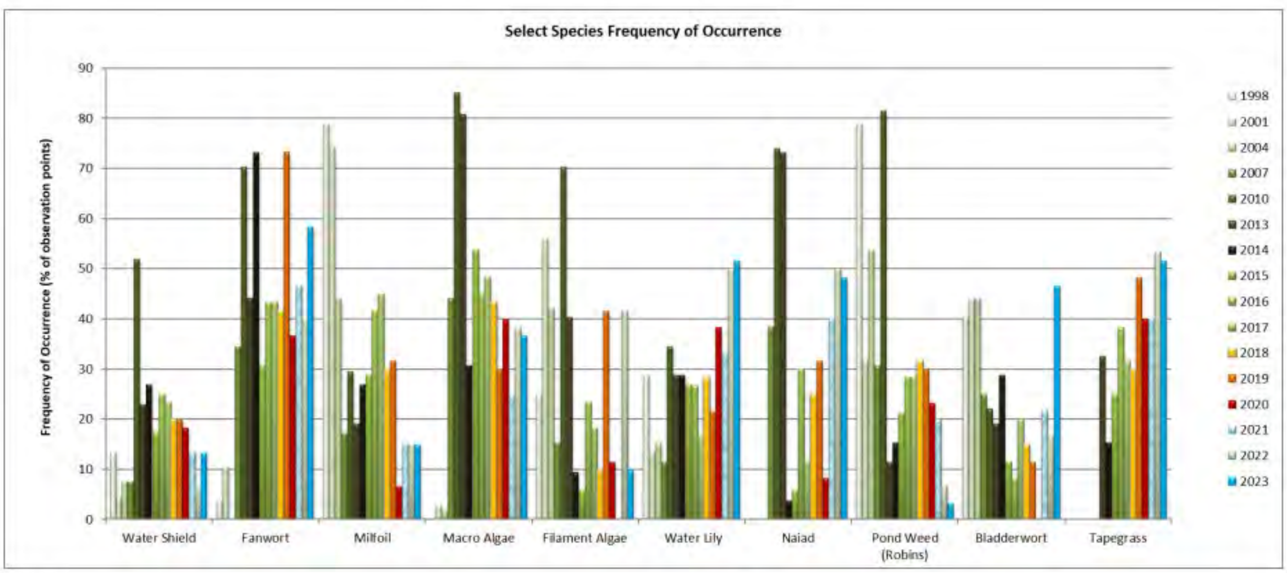


Figure 10. Bare Hill Pond Select Plant Species Frequency of Occurrence

Without a successful freeze and drawn in 2023-24, there was a substantial loss of progress, as noted in the 2024 ARC Annual Report:

> The aquatic plant coverage and biomass substantially increased since 2023. While the two native species (bladderwort and tapegrass) that increased abundance in the last couple of years remained similar in 2024, two non-natives, fanwort and milfoil abundance increased

dramatically**. Fanwort frequency increased by 33% from 2023 and 86% from 2022.** Only five observation locations did not contain fanwort in 2024. Fanwort was observed actively growing throughout the drawdown zone. Milfoil observations increased by 35% over last year. Coincident with these increases was a sharp reduction in the frequency and abundance of macro-algae (Chara and Nitella), which were the species that colonized the drawdown zone after several years of successful drawdowns. Frequency of these macroalgae decreased by 30% since last year. This species community shift is the reciprocal of what was observed when the extended drawdown was initiated. While it took several years for the plant community to shift away from milfoil and fanwort to Chara, Nitella and seed producers, the recolonization of fanwort and milfoil due to a lack of drawdown was rapid. These plants have regained dominance in the drawdown zone. Robbins pondweed (Potamogeton robbinsii) abundance was low again in 2024. The decline in this beneficial species is unexplained but is likely related to increased growth of fanwort outside the drawdown zone.

The short-term goal of controlling milfoil and fanwort has been substantially achieved when drawdowns are repeated annually to maintain control. Missed years, partial, incomplete drawdowns or the absence of freezes have caused setbacks.

Habitat Monitoring and Assessments:

In conjunction with the performance and measurement of the drawdown on plant species and to reduce phosphorus, a significant watershed monitoring and habitat assessment was undertaken and implemented each year to identify and monitor for efficacy and to identify any harmful impacts. This is reviewed annually with the Conservation Commission and each drawdown under its Order of Conditions must have an annual review and approval by the Conservation Commission notwithstanding any prior approved permits to ensure it is having a beneficial impact.

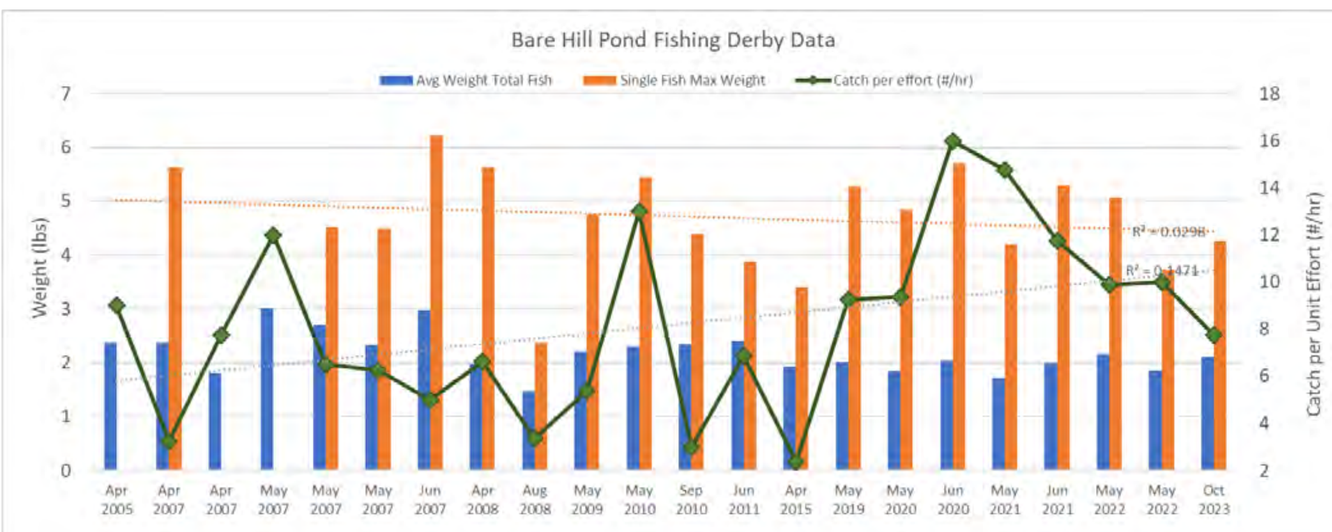
The drawdowns in the early years were 3.5 feet or less and then only increased incrementally with extensive habitat monitoring to ensure harm to the habitat was avoided and that efficacy was achieved. Monitoring revealed that native plants outcompeted the invasive species (absent an interruption of the drawdown) and repopulated the Pond over time.

The use of the Town's harvester was limited in 2003 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 marked

and pulled when they appear. Fish, amphibian, reptile, and invertebrate populations are monitored each year and continue to be found to be stable and healthy. See a picture from a turtle count and from a mussel check.

Fish populations are also stable and thriving. Amphibian and reptile counts were stable. Refill data measured annually show that the water is restored prior to spawning.   Blue herons and Eagles returned and now thrive at Bare Hill Pond suggesting that food sources were plentiful, and otter, beaver, mink, and fox are routinely observed.

Fishing derbies are a good source of fish population data and show similar weights of fish caught year to year. Observations from fishing clubs are very positive on the health of the fish population.



The monitoring of native and non-native plant species is conducted annually at designated transects in the QAPP as shown in the Table on page 13.

It is also important to note there are multiple acres of extensive downstream wetlands at the outflow of the Pond and then continuing throughout much of the Bowers brook watershed until it reaches Ayer over approximately 4 miles. These wetlands were formed by the existing roads; Route 110 (north of the Pond) and Route 2 (further north) in particular.   This is believed to provide significant protection against rapid downstream stream flow during the drawing down of the Pond (which in any event does not exceed 2" per day) and further migration downstream of excess phosphorus in the water impacting the downstream watershed negatively.   In the 2002 ENSR Report, the wetlands were specifically identified as a means for protecting the downstream watershed from excessive phosphorus and flooding, and noted:

> Wetland Functions
>
> The wetlands identified on the site provide significant wetland functions and benefits. The primary wetland functions and benefits are listed below with comments on specific relationships at Bare Hill Pond and related wetlands.
>
> Flood Storage and Flood Control Depressed areas that normally harbor wetlands provide temporary storage capacity for runoff that might otherwise cause flooding. Activities that reduce this function are considered deleterious, while activities that increase this function are beneficial. At Bare Hill Pond, the entire lake is a flood storage facility, with additional capacity available in contiguous wetlands upgradient of the lake and in the downstream wetland through which the outlet (Bowers Brook) flows.
>
> Ground Water and Water Quality Wetlands can act as treatment cells for water passing through them and may help recharge groundwater beneath the system if soil permeability is adequate. Emergent wetlands with a variety of habitat types can provide excellent treatment of runoff if detention time is sufficient. Activities that enhance habitat types (and associated treatment potential) or detention are therefore considered beneficial. A range of habitat types is present at Bare Hill Pond, and treatment of runoff in adjacent wetlands may be significant. Recharge appears limited, based on muck accumulations and resultant low permeability. [5]

Annual reports to the Conservation Commission include observations on the impact on the downstream and adjacent wetlands to Bare Hill Pond and they appear to be thriving and healthy.

This is also consistent with the commentary in the 2025 draft Massachusetts Guide to Algae and Aquatic Plant Management (the "2025 Guide"), which states:

> Constructed stormwater wetlands are wetland systems that maximize the removal of pollutants from stormwater runoff through vegetative filtration, nutrient uptake, soil binding, bacterial decomposition, and enhanced settling. Constructed stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Much of the effectiveness of the treatment is related to microbial action; the plants act more as the substrate than the active pollutant removers, but removal rates are higher in the presence of plants.[6]

Below are maps and photos of these wetlands.

---

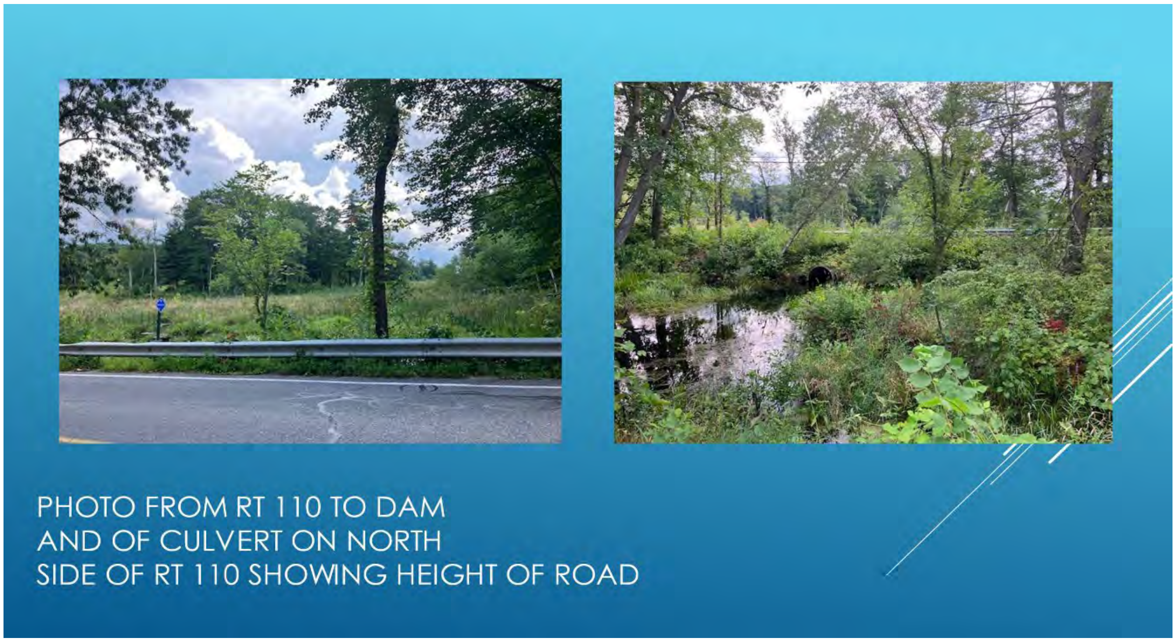
[5] 2002 ENSR Report at 18.
[6] 2025 Guide at 5-39.

These wetlands 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:

Note that even with the higher flow of water below the dam, there is little evidence of channeling and good evidence of dispersal of the water. There is a large impoundment created by Rt 110 in the distance approximately at tree line where the water is held back by the road during the drawdown and the outflow is regulated by the existing culvert which is well above the height of the floor of the wetland. This allows for a slower movement of the water.   The roads and culverts perform similar function intermittently over the approximately 4 miles of wetlands.

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 and refill are maintained.

The Short-Term Goal of assuring that the project was properly monitored has been achieved and is subject to annual review and approval by the Conservation Commission.

In summary, the drawdown project has been effective in reducing eutrophication and controlling invasive species and allowed for the improvement of the habitat and the Bare Hill Pond Watershed as a short-term goal. More actions may be necessary as a result of climate change as freezing may become less reliable and anoxic conditions more common in summer months.

Medium Term Goal: Reducing Non-Point Source Pollution from Higher Risk Locations in Town Center

While the initial years of the drawdown project helped to address the short-term risk of eutrophication and annual in-lake loading of phosphorus, there were several stormwater inputs to Bare Hill Pond that could also introduce over time more phosphorus in the Pond and put this work at risk.   A second 319 Grant was sought in 2010 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.

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.   These rain gardens were built and are maintained and tested to continue to ensure their performance under a QAPP mandated maintenance plan. Annual reports of maintenance are required to be submitted to the Conservation Commission by the Department of Public Works.

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

Legend

- Drainage Areas
- Streams
- Proposed BMP Locations

N

400 Feet

Horsley Witten Group

Drainage Areas and BMP Locations
Bare Hill Pond
Harvard, MA

4/13/08 mw

Figure 4-1

Here are photos of the major BMP sites that are in operation:

DA4 on Map

DA3 on Map

DA3 on MAP

DA2 on MAP

As Peter Mitchell, from DEP, noted following a review of the project, "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.

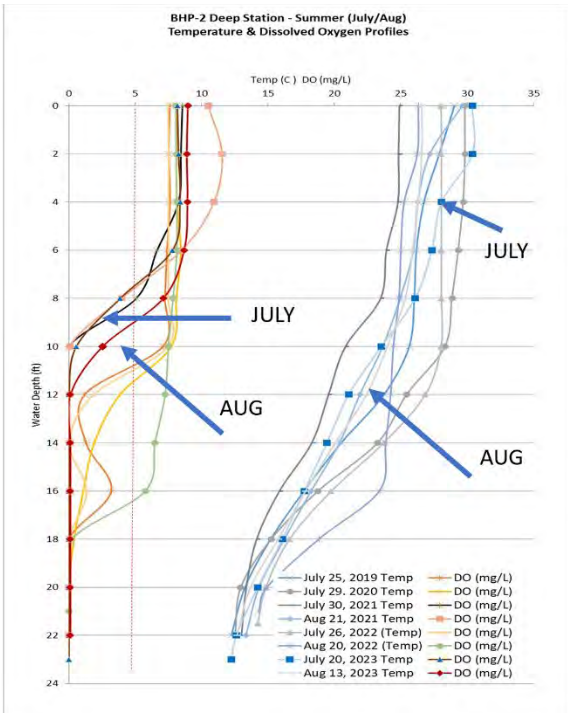
Long Term Strategy

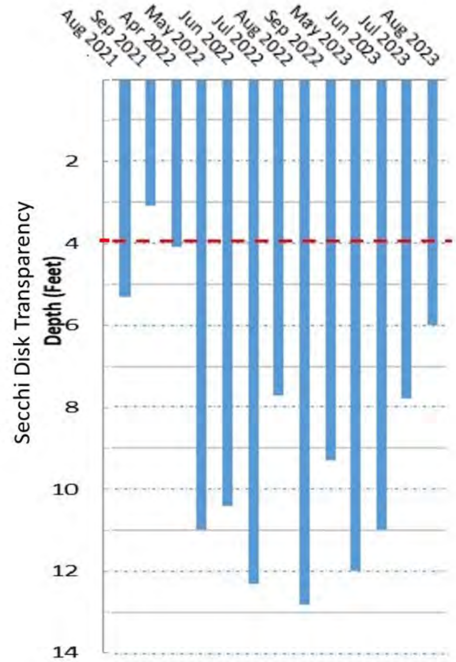
Risk of In-Lake Loading:

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 substantially enlarged over sheep pasture in the 1800s by construction of the dam. This level of in-lake loading is noted in the table of TMDL Allocations shown in Element B of the Water Quality Section at page 49, below. This is further supported by the recent observation of algal blooms associated with temperature and not stormwater.

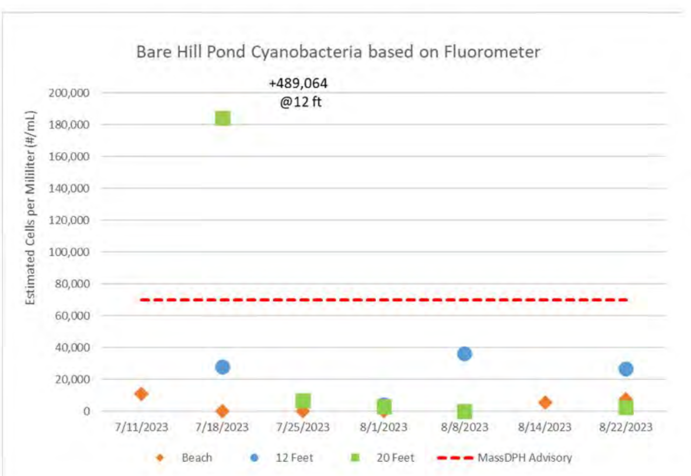
While the winter drawdowns have worked effectively to address and reduce the phosphorus and invasive species challenges in Bare Hill Pond, there are still problem areas that remain to be addressed. Climate change and droughts have led to temperature increases in Bare Hill Pond. Annual monitoring has detected a significant expansion in the anoxic zones in Bare Hill Pond. During 2020 and 2021, the anoxic zones expanded into the sunlit areas of the Pond from 14 foot or greater depths to as high as 12 feet. This allows for cyanobacteria blooms (cyanobacteria is normally present in the deepest zones in natural quantities) to bloom and migrate to sunlit areas of the Pond. Temperatures are higher due to climate change but also due to droughts when the spring flow declines and does not cool the Pond. 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. Oxygen declined, and as a result, anerobic biology triggered release of phosphorus across a much larger area of the Pond. Anoxic conditions were found at 12 feet which appear to have triggered cyanobacteria algal blooms. In those summers the preceding winter drawdowns were also not fully achieved due to excess rainfall in December and a pump malfunction which to some extent may have impacted the phosphorus reduction in those years. In years prior, and in the years since, there were no hazardous algal blooms, suggesting the drawdowns provide a level of resiliency to address climate change.

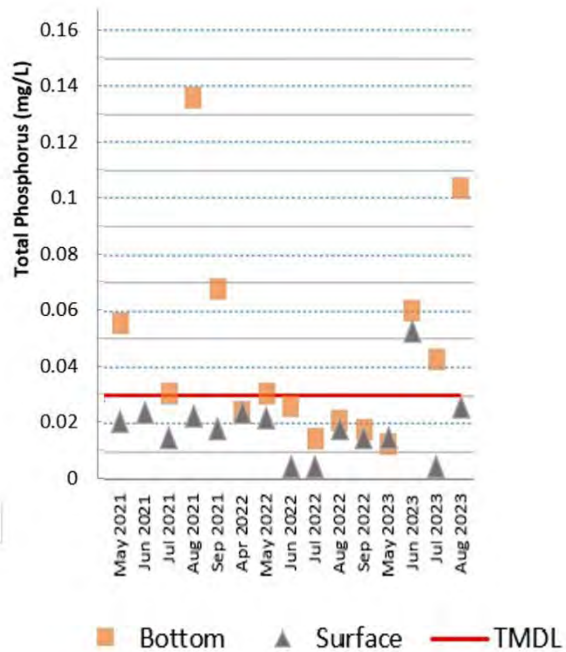
The following data from the 2023 ARC Annual Report and prior annual reports show the impact of increased temperatures and anoxic zone expansion over the last few years. One can also see the impact of phosphorus release in the sample sites in the deeper zones.





Note: Red Line = low visibility indicator of algal bloom and hazardous visibility for swimming per Harvard Board of Health





Algal blooms have not occurred on Bare Hill Pond following storm events further supporting the data in the TDML Allocation Table B-2 in the Water Quality section 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 in adding resiliency not originally envisioned when they were initiated in 2003.

Climate Change Risk:

There remains eutrophication risk as a result of heat caused anoxic conditions in the Pond should anoxic conditions become more prevalent with increases in temperature and less regular rainfall in the summer. In addition, there are spot areas (i.e., the deep part of the Town Beach swimming areas) of the Pond where temperature increase due to climate change, stream and spring flow do not allow for adequate freezing and control of invasive milfoil and fanwort even with a deep winter drawdown.

Development Risk:

In addition, during the past 25 years, the Committee has submitted comments on development in the watershed to help assure permitting that requires best practices and protects the watershed health. Under the Town By-laws, the Conservation Commission, the Planning Board and the Zoning Board of Appeals seeks Committee comments on all development in the watershed seeking their review to protect the watershed and the Pond. The Committee has a policy of restricting new development on the Pond, encouraging replanting of native shoreline plants and trees, limiting the use of phosphorus fertilizers to those authorized under EPA guidelines and ensuring that no new stormwater risk is created by any development in the watershed. Plans are regularly adjusted to incorporate best practices and to protect the Pond.

Over the past 25 years, the majority of homes around the Pond (approximately 100 homes) have been sold or upgraded reducing the risk of septic nutrient loading. A review of the property records on the Town website reveals that 92 homes are post Title V being effective and applicable to their renovation or sale and would have had to have upgraded their septic systems. 15 summer camps/cabins with summer occupancy only have not been sold but may have voluntarily upgraded. Similarly, 7 year-round homes have not been sold since the adoption of Title V and may not have septic upgrades.

The Committee offers regular educational and community activities to inform the community and its residents of its activities and plans. These include Pond tours with our ARC consultants, poster sessions at Town Meeting, regular articles in the local press and community talks at the Library and the Council on Aging,

Invasive Water Chestnut Challenge

Invasive water chestnut plants were also identified as a goal for removal in the 1999 TMDL. Below 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 in mid-summer. A video documentary discussing this successful project can be found here.

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.

Drawdown Limitations:

Lastly, it is increasingly evident that there are site specific areas during a drawdown 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 was 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. A demonstration project was conducted in 2024 at the Town beach and will be evaluated during monitoring in 2025.

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)

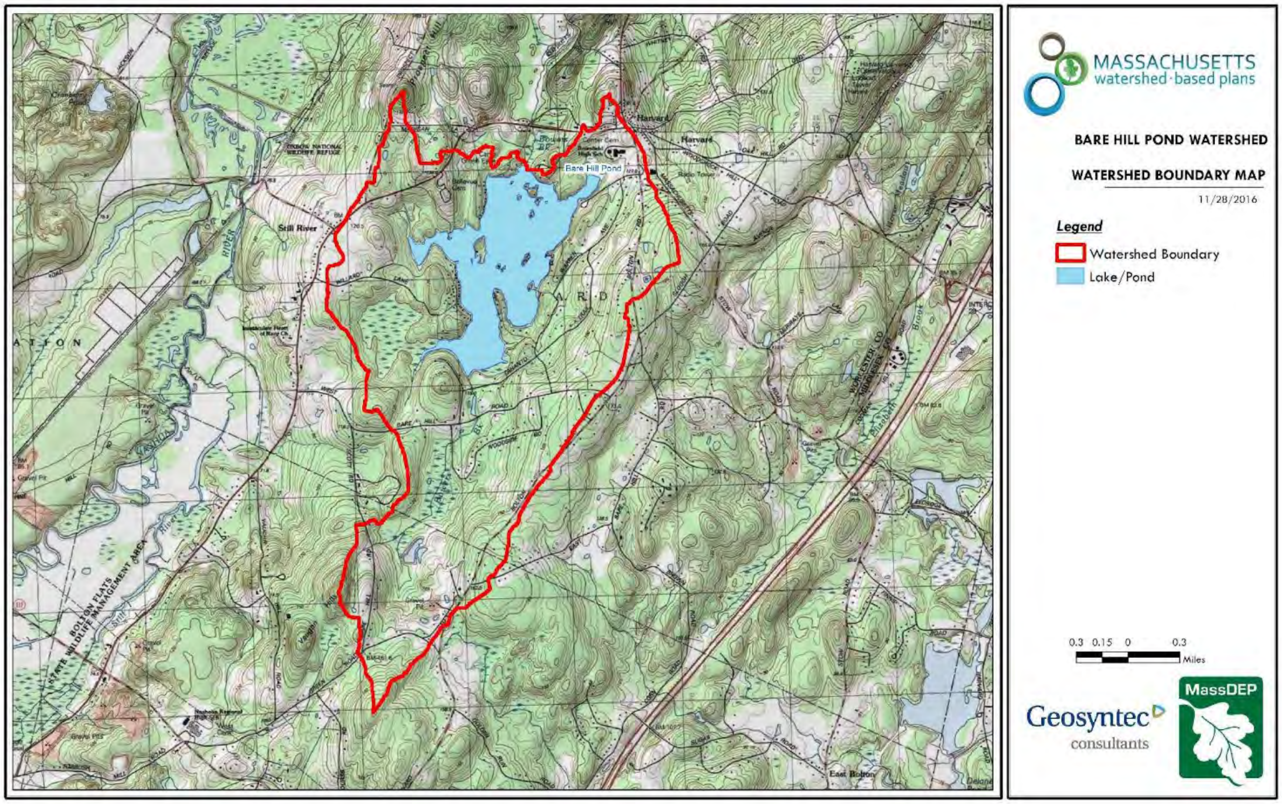


Figure A-1: Watershed Boundary Map (MassGIS, 1999; MassGIS, 2001; USGS, 2016)

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

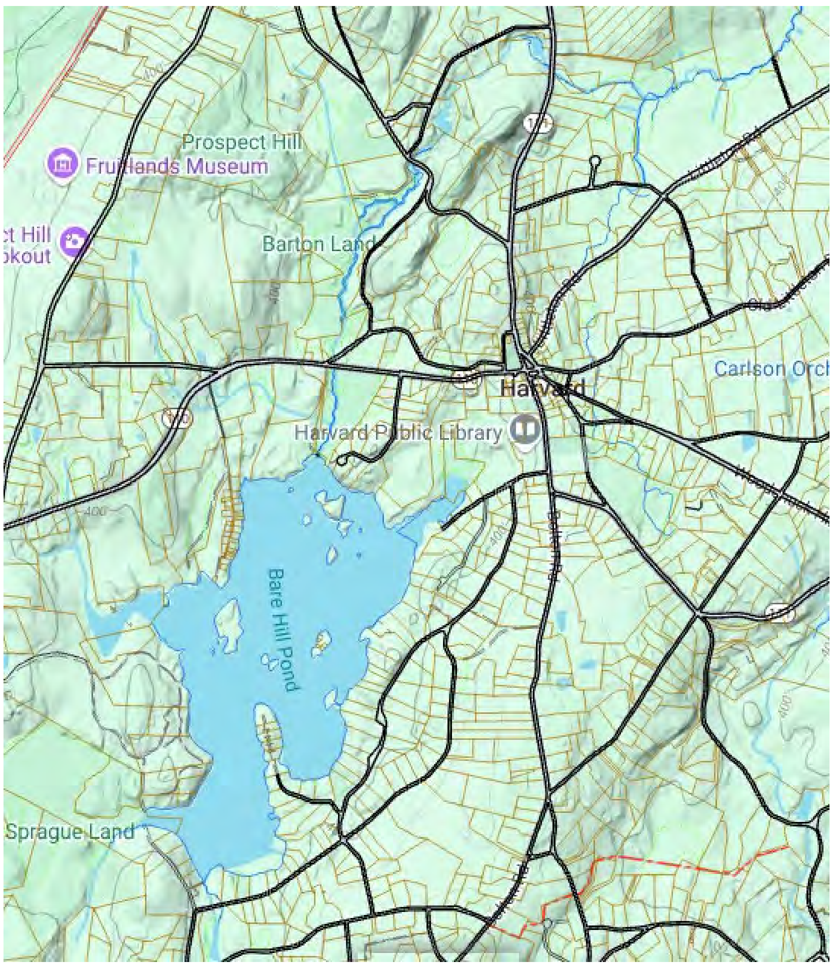
General watershed information:

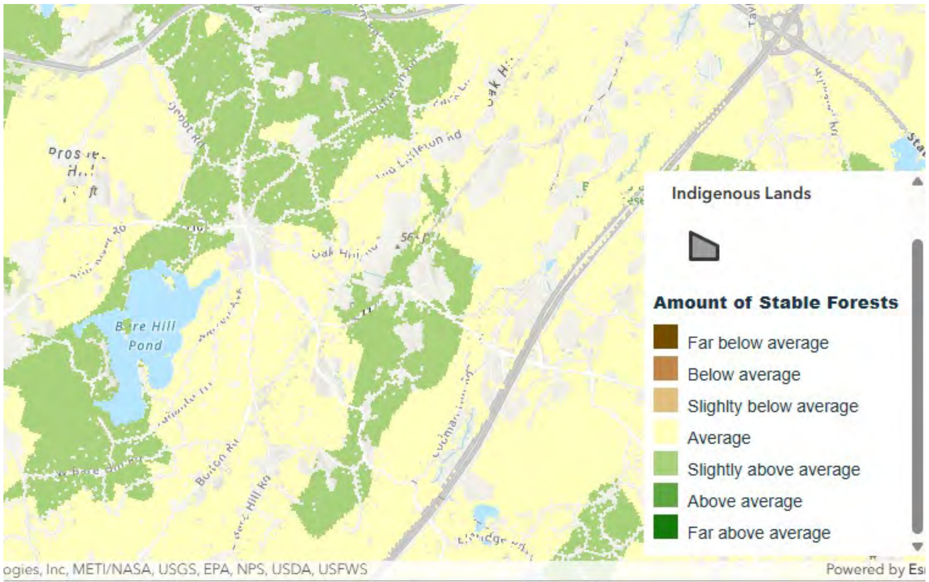
Bare Hill Pond is one of Harvard's primary visual, recreational, and natural resources. A natural lake has existed on the site since the retreat of the glacier at the close of the last Ice Age. During colonial times, the natural pond was only about 200 acres in size. In 1838, a dam was built that flooded the surrounding pasturelands and increased its size to 300 acres. Bare Hill Pond averages about 10 feet in depth. The original 200-acre pond forms a deeper basin with an average depth of 13 feet, while the 121 acres of flooded flats average only 4.5 feet. Soundings made in August 1977 show the deepest part of the pond to be 24 feet, at a point west of Whitney's Island. Bare Hill Pond is designated by the Commonwealth as a "Great Pond," which gives the general public access to its waters for recreation. This history creates a nutrient rich 121 acre zone that is easily accessible to sunlight.

The pond has two beaches, one located along the northern shore at the Green Eyrie Girl Scout Camp, and a Town-owned beach off Pond Road. DEP owns an undeveloped parcel on Warren Avenue and the south end of the Pond. Public access to the beaches is restricted, but the general public can launch boats at the Town beach and gain pond access through multiple Harvard conservation land sites with trails that are located around the Pond. There is development of homes on the Pond there is extensive preservation of conservation land around the Pond as well.

Recreational activities on the pond include swimming, boating, sailing, canoeing, kayaking, rowing, fishing, water skiing, ice-skating, and ice fishing. Residents heavily use the Town beach in summer months; it is the center of recreational and social activity for families with young children. A beach program that includes lifeguard training and staffing, swimming, and boating lessons operates under the aegis of Harvard's Park and Recreation Committee.

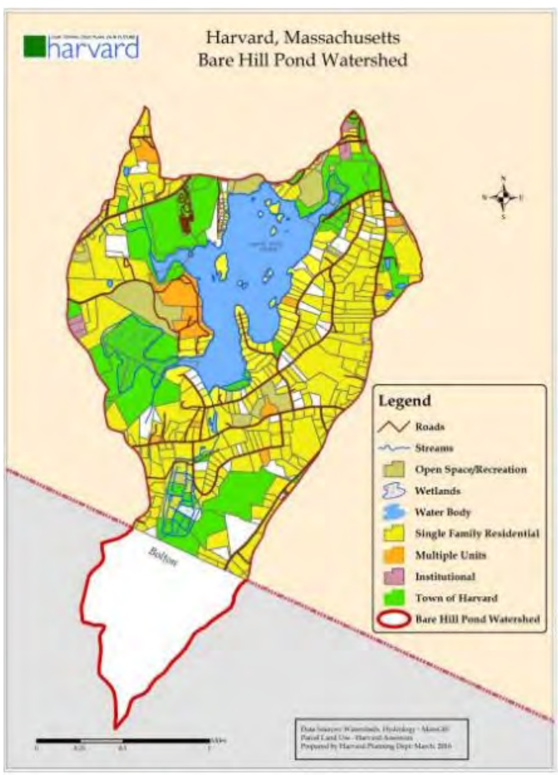
Within the Nashua River watershed, Harvard's major stream, Bowers Brook, flows across the length of Harvard from south to north. It rises in the two ponds at Bowers Springs Conservation Area straddling Bolton and Harvard. From there it threads in several channels through an extensive area of forest and then red maple swamp and hummocked shrub swamp before it flows into the south end of Bare Hill Pond. There is limited development adjacent to Bowers Brook. It flows out of Bare Hill Pond through a series of wetlands until it reaches Ayer. Here is a map that shows the watershed which while developed in many locations, it is heavily forested in most of the Bare Hill Pond Watershed and the greatest development is in Town Center, north of the Pond where there is a concentration of impervious surface parking lots and roads. These roads capture the storm water and direct it to the series of rain gardens where previously the outflow ran untreated into the Pond. Much of the area surrounding the Pond itself and the hills surrounding the outer reaches of the Pond's watershed is forested and streams coming into the Pond other than Bowers's Brook run through forests or wetlands over much of their length. The





Nature Conservancy Forest Mapping tool shows that the forest cover is average to above average in quality:

Much of the land around Bare Hill Pond is protected conservation land or protected under Chapter 61A and 61B of Mass General Laws so there is limited potential for further development other than renovations subject to the Wetlands Protection Act. This map shows the area under protection:



Map 4.2 – Bare Hill Pond Watershed

This map does not include Chapter 61A and 61B deeded properties that are conservation restricted properties in the watershed.

Bare Hill Pond is connected to the water table by many springs, and the refill of the Pond is primarily from spring flow until it approaches the last 2 feet of refill. Monitoring refill data over 20 years indicates about the same rate of refill in years with rain and without rain until water table height is reached. Rainfall and snow melt then drive the rest of the refill.

There is a risk of salt contamination from the runoff from State Route 111 which is maintained by the Commonwealth. While the Town avoids the use of salt on the roads adjacent to the Pond, the Commonwealth to our knowledge does not.

In each of the monitoring studies by ENSR and ARC, no endangered or threatened species have been identified, although vernal pools in the watershed are common and the Conservation Commission actively seeks to ensure they are protected and provide important habitat for amphibians and reptiles.

MassDEP Water Quality Assessment Report and TMDL Review

The following reports are available:

- Annual Water Quality Assessments by ARC as part of each Annual Report to the Conservation Commission
- BARE HILL POND WATER QUALITY AND AQUATIC PLANT EVALUATION 1998 ENSR
- Bare Hill Pond, Harvard, MA. (MA81007) TMDL
- DIAGNOSTIC FEASIBILITY STUDY BARE HILL POND HARVARD, MASSACHUSETTS
- WILDLIFE, HABITAT AND VEGETATIVE ASSESSMENT OF BARE HILL POND, WITH MANAGEMENT IMPLICATIONS 2002 ENSR
- 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.

Nashua River Watershed 2003 Water Quality Assessment Report (MA81007 - Bare Hill Pond)

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:

The following Reports that supplement 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 2022 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 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	Bare Hill Pond, Harvard, MA. (MA81007) TMDL

	(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. Wellesley, MA.	
Bacteria	Class B Standards • Primary contact recreation: For E. coli, geometric mean of samples collected within any 90-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 90-day or smaller period shall not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL.o Waters adjacent to any public or semi-public beach, at a location used for bathing and swimming purposes or waters impacted by combined sewer overflows (CSO) or publicly owned treatment works (POTW) discharges: For E. coli, geometric mean of samples collected within any 30-day or smaller period shall not exceed 126 cfu/100 mL, and no more than 10% of all such samples shall exceed 410 cfu/100 mL. For enterococci, geometric mean of all samples collected within any 30-day or smaller period shall	Massachusetts Surface Water Quality Standards (MassDEP, 2022)

	not exceed 35 cfu/100 mL, and no more than 10% of all such samples shall exceed 130 cfu/100 mL	
Invasive Non-Native Plants	Continued Control of Non-Native Milfoil, Fanwort and Water Chestnut Plants Goal is to maintain control and reduction of non-native invasive species based on measurements of plant prevalence and density at the designated transects in the protocol for reporting to the Conservation Commission Annually Continue Monitoring to confirm successful 0removal and control of invasive water chestnuts	See, Methodology in the 2024 ARC Annual Report Volunteer reporting and marking of any observed water chestnut plants. Pull and mark location with a float to confirm no regrowth
Cyanobacteria	Cyanobacteria shall not not exceed the standard established by the Harvard Board of Health No Water Contact: Fluorometer analysis equivalent to and/or cell counts of 70,001 - 1,000,000 c/mL No On Water Activities: Fluorometer analysis equivalent to and/or cell counts in excess of 1,000,001 c/mL	Bare Hill Pond Town Beach Algal Bloom Procedure Prepared by the Harvard Board of Health Updated: September 10, 2024

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

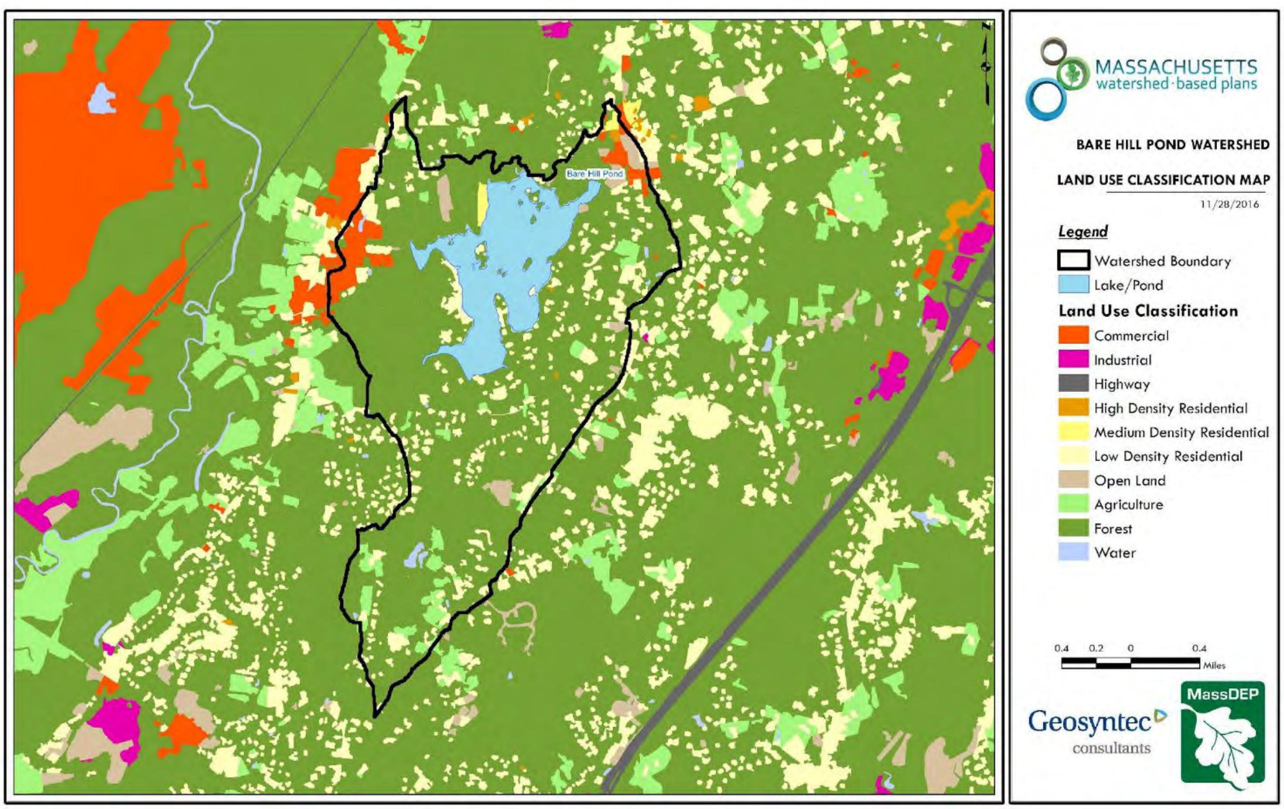


Figure A-2: Watershed Land Use Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

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.[7] 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 was 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.

[7] The Sutherland equations are a set of empirical equations used to calculate the percentage of directly connected impervious areas (DCIA) in urban watersheds. The equations were developed by R.C. Sutherland in 1995 and are based on USGS data. The EPA uses the equations to estimate DCIA based on land use types.

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.

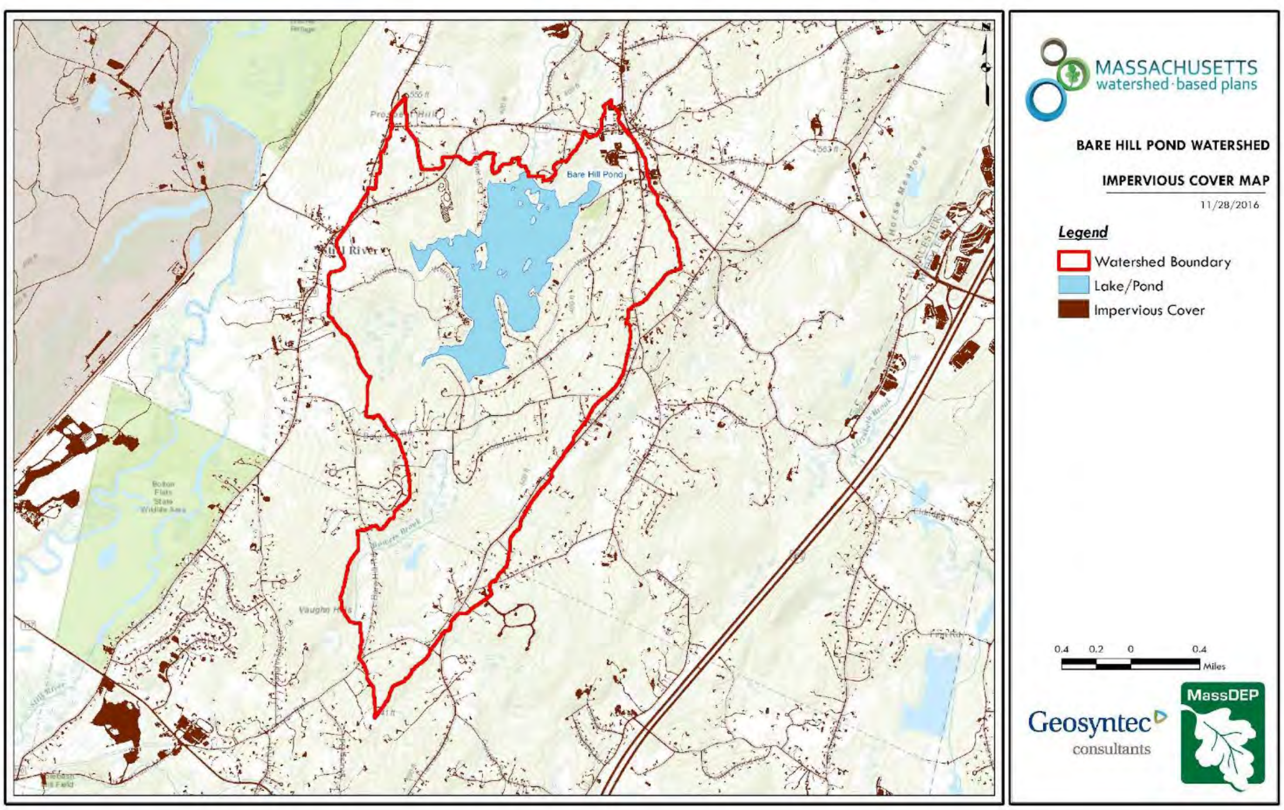


Figure A-3: Watershed Impervious Surface Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

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

Land use information:

See the information from the Horsley Whitten Final Report at pages 19-21, above, 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 2024 ARC Bare Hill Pond In-Lake Water Quality and Plant Survey . The primary source of phosphorus based on the reports and studies to date is from in-lake loading from the Pond sediment. The secondary source for phosphorous is from stormwater inflows although this is believed to be well controlled after the installation and maintenance of the rain gardens.

The reason for this conclusion is that the phosphorous readings in Bare Hill Pond vary with temperature and anoxic conditions and not with rainfall and stormwater. The physical characteristics of the man made expansion of Bare Hill Pond on former grazing land, surrounded by deforested hills in the 1700s to mid-1800s made this a very fertile Pond bottom.

As shown in the following graphs, as temperature increases, dissolved oxygen increases, and this in turn leads to anerobic release of phosphorus from the pond sediment. Note the difference between Spring and Summer:

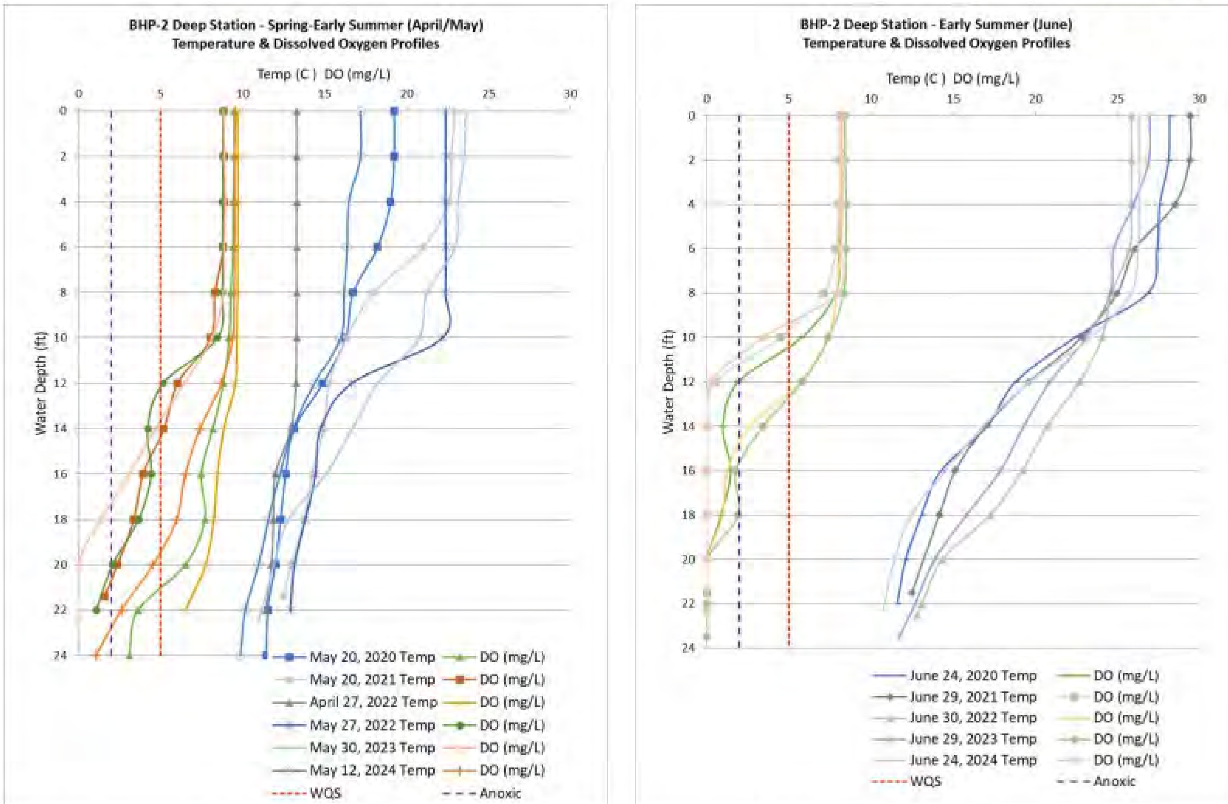
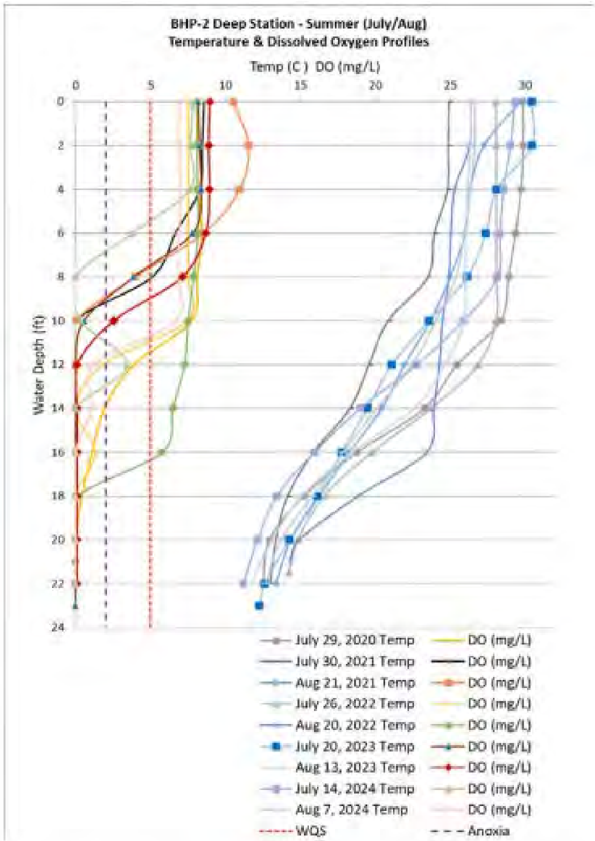


Figure 5. Temperature & Dissolved Oxygen Profiles at BHP-2 during Spring & Early Summer for 2020-2024

Note also that the crossing of the dotted black line (anoxic condition) occurs at a shallower depth in the summer when the temperature is high in Summer compared to Spring.

Note how in August it becomes even more extreme over the dotted black line at 10 feet and then subsides with cooler temperatures in Sept/Oct.



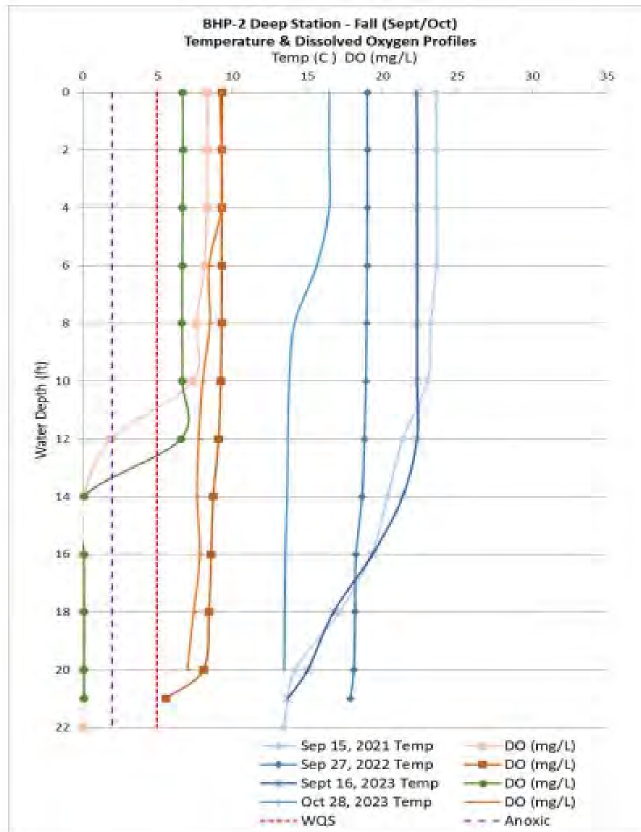
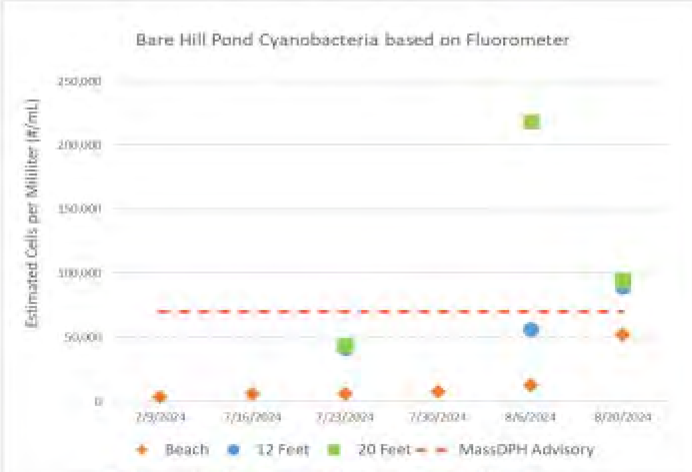


Figure 6. Temperature & Dissolved Oxygen Profiles at BHP-2 during Summer and Fall for 2020-2024.

These profiles tracked with the Cyanobacteria testing and the secchi disk readings, shown below:



Data provided by Town of Harvard Board of Health

Figure 8. Estimate Cyanobacteria Cells.

Figure 9. Bare Hill Pond (BHP-2) Secchi Disk Transparency.

During each of the Algal Bloom years, there was a drought and very low input from the streams in July/August along with higher temperatures. The blooms were not triggered by the few infrequent storm events. As discussed in the 2024 ARC Annual Report , higher temperatures increase biological activity (e.g., encourage algae growth). In addition, they increase the likelihood of internal phosphorus loading by strengthening thermal stratification, which can promote more frequent, prolonged, or intense anoxic conditions at the sediment-water interface.

This suggests that in-lake phosphorus loading is occurring from these 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. Together this indicates that control of in-lake loading is an important objective. The drawdown builds resiliency into the phosphorus level by lowering phosphorus before the summer to create 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	1742 lbs/yr when there is peak in-lake loading	1127 lbs/yr	615 lbs/yr
Total Nitrogen	2776 lbs/yr	2776	No increase
Total Suspended Solids	74 ton/yr	74	No increase
Bacteria	*MSWQS for bacteria are concentration standards (e.g., colonies of fecal coliform bacteria*	Class B. **Class B Standards** • Primary contact recreation: For E. coli, geometric mean of samples	

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

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

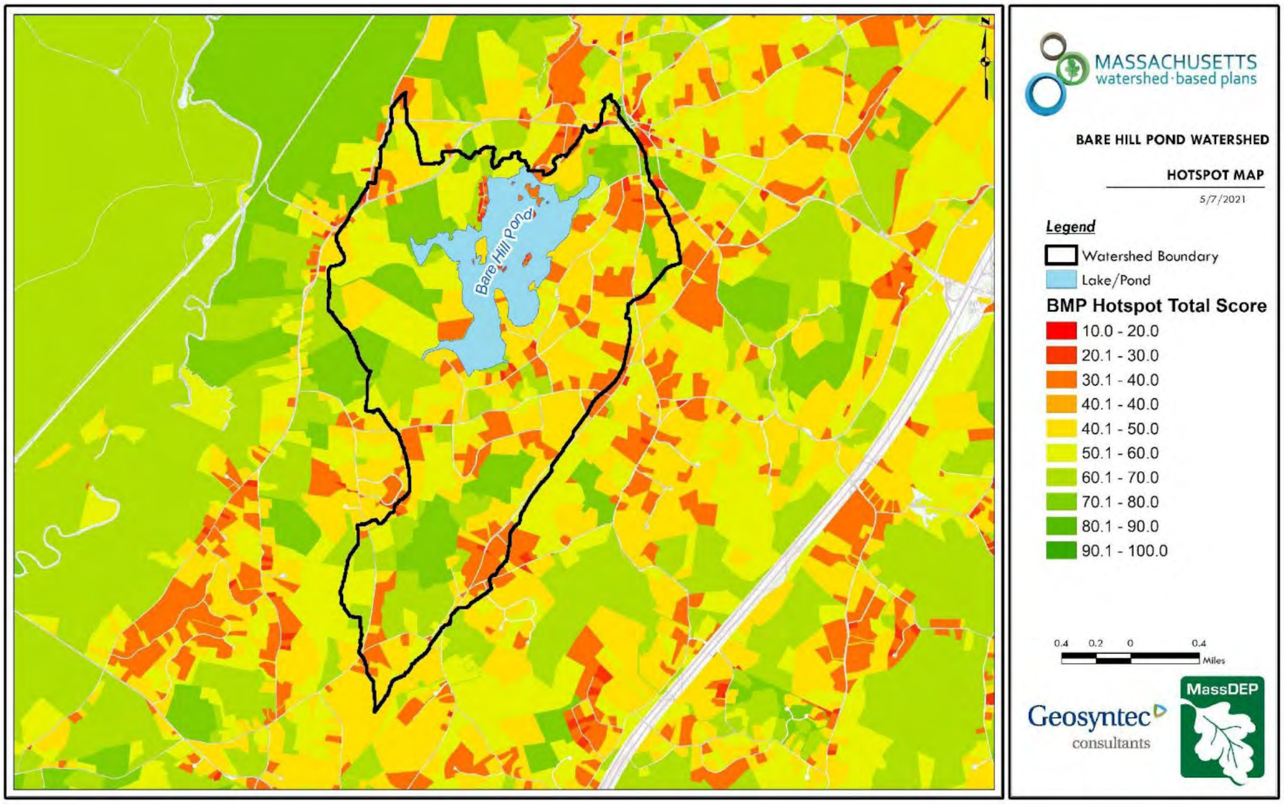


Figure C-1: BMP Hotspot Map (MassGIS (2015a), MassGIS (2015b), MassGIS (2017a), MassGIS (2017b), MassGIS (2020), MA Department of Revenue Division of Local Services (2016), MassGIS (2005), ArcGIS (2020), MassGIS (2009b), MassGIS (2012), ArcGIS (2020b))

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

Proposed Management Measures:

As discussed in Element A above at pages 18- 22, above, the Town has implemented storm water treatment rain gardens designed by Horsley and Whitten to capture the Town Center impervious paved areas and road runoff and remove phosphorus before the water enters the Pond. The BMPs were designed to remove the maximum amount of phosphorus (approximately 50%) and pursuant to a QAPP referenced above, are tested for performance on 3-year schedule. In addition, they are cleaned out pursuant to the maintenance plan annually and a report confirming such maintenance is required to be filed annually by the Dept. of Public Works with the Conservation Commission annually. The Department of Public Works also engages a street sweeping contractor annually to remove sand from the roadways in Town and minimizes use of salt on roads it controls close to Bare Hill Pond.

In addition to the BMPs, over the past 20 years, additional management measures have already been implemented that involve engagement with residents in the watershed, educational programs, comments on all new permitting and construction in the watershed on best practices to protect the watershed before the Planning Board under a Stormwater Control By-Law, a Zoning Board of Appeals By-law requiring all construction protect the Pond, and the Conservation Commission for activities in the watershed by residents. Over the past

25, these activities have encouraged and resulted in increased forest on the pond shores and slopes, the construction of rain gardens and planting of native species along the Pond shoreline which have substantially reduced the number of shoreline abutters with lawns and impervious surfaces in the buffer zone around the Pond. These activities will continue and help build further resilience into the watershed. Measurement of their impact on phosphorus is too attenuated to estimate. Measurement of their occurrence can be documented by photographic changes of the shorelines, and tracking ecological restoration as properties are maintained under the permitting process. Fertilizer reduction is a part of the on-going education efforts and for many years a condition restricting the use of phosphorus fertilizers was requested by the Committee to include in all permits. The Conservation Commission implemented these requested phosphorus restrictions in Orders of Conditions until about 2012. At the time, DEP informed that Conservation Commission could not include those restrictions. That said educational efforts have continued and the restrictions requested now ask that the fertilizers are used only in accordance with their labelling requirement.

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	CONTINUED OPERATION AND MAINTENCED OF THE TOWN CENTER 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(previously expended under 319 Grant Program project) Operating Cost: $4000/year

Additional BMPs – Invasive Species and Phosphorous Reduction

BMP TYPE	Operation and Monitoring of Annual Pumped Winter drawdown
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 (previously expended under319 program) Annual Operating Costs: $30-35,000 per year

BMP TYPE	Invasive Species Removal and Phosphorus Control in water column.
BMP LOCATION	Bare Hill Pond
DESCRIPTION	Removal of invasive fanwort and milfoil 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 Provide Technical Assistance to residents on the Pond shoreline in contracting and permitting the engagement of a diver assiste suction harvesting contractor.
ESTIMATED POLLUTANT LOAD REDUCTIONS	1-3 acres per year
ESTIMATED COST ($)	30,000 per year in operating costs. Diver Assisted Suction Hose Harvesting: $100,000 per contract when needed for Town beach and Conservation land shorelines.

Additional BMPs - Private Installation of Rain Gardens and Shoreline Restoration

BMP TYPE	Request construction of Bioretention Rain Gardens and native shoreline plantings to limit identified impervious surface runoff and
BMP LOCATION	Bare Hill Pond
DESCRIPTION	
ESTIMATED RESTORATION ACTIVITIES	Reduction and capture of stormwater from home roofs and impervious surfaces adjacent to the Pond
Actual COST ($)	$0 – part of residential improvement costs associated with permitting activities in the watershed

BMP TYPE	Invasive Species and Phosphorus Control in water column.
BMP LOCATION	Shoreline of Bare Hill Pond

DESCRIPTION	The Bare Hill Pond Committee under the Town By-laws is requested to comment on regulated activities by landowners in the watershed before the Planning Board, the Zoning Board of Appeals and the Conservation Commission. This occurs most frequently when a home is maintained, or a well or septic system needs to be upgraded in the watershed. Permits are conditioned on incorporating rain gardens and other native plantings to reduce run-off.
Measurement and Goal	Record the number of rain gardens or shoreline buffer zone plantings sites each year. Goal: 3 per year.
ESTIMATED COST ($)	$0 Volunteers provide comments to the Town Boards.

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	$4000/ year

Pumped Winter drawdown	Bare Hill Pond	$100-150,000 every 15 years	$7500	BHPWMC and DPW perform activities under Conservation Commission annual review and Order of Condition	Consultant Assessment and Monitoring by Aquatic Restoration Consulting, LLC (Wendy Gendron)	$13,000 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 Wetlands 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
Additional Monitoring of Phosphorus in input Streams and output into downstream wetlands	Bowers and Clapps Brook Streams At Dam outflow and at Route 110 Culvert	$0	$7500/year	BHPWMC would conducts with Wetlands Consultant	Aquatic Restoration Consulting, LLC	$7500/ year for 3 years and then every 3 years
					Total Funding Needed:	**$123,000**
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.

Specific topics to be included are: 1) education about maintaining shoreline native plants and forest protection; 2) education about the causes of algal blooms and what the community might do to further reduce algal bloom risk; and 3) education about the role of watershed and storm water management.

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. sharing 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 runoff 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. The number of events and a summary of each activity will be recorded to help with ensuring evaluation of the program. Two mailings each year are planned for watershed residents to provide information and a reminder of detailed information of the Committee website. This reaches all property owners abutting the pond. At least 2 articles per year in the Harvard Press on best practices, where to look for more information, and what each of us can do to protect the watershed. This reaches a majority of the community that receives the Harvard Press. Pond tours with Committee wetlands expert to allow persons interested in learning more and how they can help to ask questions and see what is described in the educational materials. These tours occur once per summer and usually involve about 10 people. At least one community forum and presentation of the Committee's watershed management strategy and plan to engage community members, answer questions and share best practices. These forums usually attract about 75-100 persons and are recorded and available on the cable channel website. Here is a video link to a recent presentation at the Council on Aging.

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.

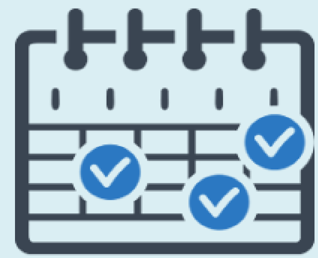


Table FG-1: Implementation Schedule and Interim Measurable Milestones

Structural & Non-Structural BMPs						
BMP	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Milestone 6**
BIORETENTION AND RAIN GARDENS *Town Center, Schools, Pond Road, Route 111,*	Completed Construction of Rain Gardens in 2010	Annual Operation and Maintenance Annual Count of Private Intallation of Rain Gardens and Shoreline Plantings 2026	Annual Operation and Maintenance Annual Count of Private Intallation of Rain Gardens and Shoreline Plantings 2027	Annual Operation and Maintenance Annual Count of Private Intallation of Rain Gardens and Shoreline Plantings 2028	Annual Operation and Maintenance Annual Count of Private Intallation of Rain Gardens and Shoreline Plantings 2029	Annual Operation and Maintenance Annual Count of Private Intallation of Rain Gardens and Shoreline Plantings 21030
Pumped Winter drawdown In Place *Bare Hill Pond*	Complete construction and test Pump House 2006	Complete Demonstration Study 2007	Replaced Obsolete VFD Drive for Pump engine 8/2024	Annual Operation and Maintenance 2025	Annual Operation and Maintenance 2026	Annual Operation and Maintenance 2027

Invasive Species Removal at Town Beach and other sites *Bare Hill Pond*	Town Beach Removal Complete	Town Beach Removal completed	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	Pending 319 Grant if needed Fall 2025	2025	2026	2027

Public Education & Outreach						
BMP	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Milestone 6**
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 Consultant	Annual each summer					
	July					
Science Fair	Annual Award for Student Watershed Projects March each Year					
Send Watershed Residents Best Practice Information	Fall and Winter Mailing each year September/January					

BMP	Milestone 1	Milestone 2	Milestone 3	Milestone 4	Milestone 5	Milestone 6
Annual Report to Conservation Commission	Every Year					
	August					
Frog Counts	Every Year					
	March, April, May and July					
Pond Monitoring by Watershed Consultant to document DO	Every Year					
	March, April, May and July					
Pond Monitoring by Watershed Consultant to document DO, temp phosphorus, native and non-native plants	Every Year					
	March, April, May and July					
Downstream wetland phosphorus monitoring by Watershed Consultant	November during active drawdown					
Reptile Count	Every Year					
Mussel Survey	Every November prior to Freeze					

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 milfoil and fanwort 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 were 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 may not be 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 may be the next major new activity to schedule in addition to the existing ongoing educational, operational and monitoring activities.

The other potential project would be to consider whether drawdowns are at their limit of effectiveness in light of climate change and whether alum should be considered as a second method of phosphorus control. The next year or two may provide data supporting that additional management technique. The failure of the pump in recent years leading to incomplete drawdowns makes it hard to know if the drawdown alone will be sufficient. In the years where the drawdown was not complete, algal blooms occurred; in other years when the drawdown was complete algal blooms did not occur. If algal blooms occur when the drawdown is complete, then this additional project should be considered.

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. If algal blooms continue to occur in the presence of drawdowns, then it would indicate a need for further reduction in phosphorus and that the load is not being reduced as it was in prior years or that the load is higher due to higher temperatures. In 2024 after 2 years of incomplete drawdowns, there was a 30 percent increase in the pond at the measured transects of invasive milfoil and fanwort. This indicated a load increase had not been addressed or that the absence of freezing and drying of the plants allowed for them to rapidly repopulate and outcompete the native species in 2024. Absence of algal blooms correlates over the past 10 years with lower phosphorous and higher oxygen readings in July.

Project-Specific Indicators

The drawdown project has detailed watershed monitoring requirements that include (followed by an excerpt from the 2024 ARC Report where more detail is needed:

1) Identification and measurement of quantity of invasive and native plants at designated transects in the Pond,

ARC
Aquatic Restoration Consulting, LLC

In-lake Plant Survey

ARC conducted a plant survey on August 7, 2024. We used the same methods employed during the previous surveys conducted since 1998. ARC mapped pond aquatic vegetation along the five transects (A through E) established in 1998. We also repeated the eight points added in 2016 (F through I). Each transect was divided into a series of observation points and were located using Global Positioning System (GPS). A total of 60 points were assessed during the survey.

The plant survey focused on macroscopic fully submerged (e.g., milfoil), floating-leaved (e.g., pond lily), and/or free-floating plants (e.g., duckweed). At each transect point, we recorded the percent cover of all plants, the percent biovolume (as measured by the amount of the water column filled with plants) using a semi-quantitative (0-4) ranking system. Species observed in each transect were identified and assigned a relative density based on all species present (Table 4). Water depth was also recorded at each transect point. These data are presented in Table 5.

Table 4. Plant Survey Categories

Rank	Cover & Biovolume	Density Category	Description
0	No plants		
1	1-25%	Trace	Single to a few plants
2	26-50%	Sparse	Multiple plants but not abundant, about a handful
3	51-75%	Moderate	Numerous plants but not dominate, about a plant rake full
4	76-100%	Dense	Very abundant, more than a rake full

2) measurements of phosphorus, DO, temperature, and Secchi readings at designated times and locations in the Pond.

In-Lake Sampling

In-lake sampling was conducted at five stations (Figure 4) on May 12, June 24, July 14 and August 7, 2024 (September & October sampling not yet scheduled). ARC used the same sampling methods as prior surveys for data collection consistency (see prior reports for methodology). In-situ water depth profile measurements of temperature, dissolved oxygen (DO), and specific conductivity were recorded at all five locations. ARC collected samples for total phosphorus (TP), dissolved phosphorus (DP) and total suspended solids (TSS) at the surface and approximately 0.5 feet above the sediment water interface (bottom) at BHP-2, at the surface at BHP-1 and TP at the bottom at stations BHP-3, 4 & 5.

Five sample locations (Figure 4):

- BHP-1 shallow basin in the south
- BHP-2 deep hole in the north/main basin BHP-2
- BHP-3 between BH-1 & BHP-2 south of Ministers Island
- BHP-4 south of Sheep, east of Spectacle Islands
- BHP-5 southeast of BHP-1 between Sheep and Four Acre Islands

The temperature and DO profiles showed signs of thermal stratification in May, with a stronger stratification evident in June, July and August. DO concentrations in the hypolimnion have declined substantially since 2010. The hypoxic (low oxygen) layer is expanding and resulting in less desirable habitat for aquatic biota. Waters below ten feet were historically below the 5.0 mg/L threshold considered to support aquatic life, but data recorded since 2022 suggest that supportive waters are limited to about eight feet (a loss of a two-foot layer). Further loss of oxygen facilitates the release of phosphorus from sediments, resulting in ideal conditions (warm water and plenty of phosphorus) for cyanobacteria blooms. The lake was anoxic (<2 mg/L oxygen) at a depth of seven feet in July 2024, with slight recovery in August to 11.5 feet vs 12-14 feet in the past (Table 2, Figures 5 & 6). DO at the added stations also exhibited anoxia at ten to 12 feet in June/July 2024. These conditions allow phosphorus release from iron in the sediments. The lake typically regains oxygen in the hypolimnion after mid-September when fall turnover (mixing) occurs.

Table 2 provides depth profile data through August 7, 2024. Figures 5 & 6 provide a graphical representation of temperature and DO data for the deep station (BHP-2) in comparison with the last five years.

Lake pH ranges from slightly acidic [<7 standard units (SU)] to basic (>7 SU). Higher pH values (>8.0 SU) are likely due to primary productivity when plants (macrophytes and/or phytoplankton) are photosynthesizing. During this process, carbon dioxide is removed from the water raising the pH of water. Lake water pH is typically the highest in the afternoon.

Specific conductivity in 2024 was similar to prior years, between 150 and lower 200 microsiemens per centimeter (µs/cm), just over the desirable range threshold (<200 µs/cm). Values above 200 us/cm can be indicative of elevated dissolved pollutants and high productivity. It is common to have increased conductivity near the water-sediment interface where suspended solids increase conductivity. Surface and mid-depth values were comparable between stations.

Turbidity is measured in-situ with a probe. The probe sends a beam of light and the amount of light that is reflected back is used to calculate particle density in the water. The more light reflected, the more particles there are in the water. Turbidity was variable between July and August. It is not known if the elevated turbidity measurements were caused by phytoplankton, suspended solids and/or bubbles generated by boat traffic

Table 3 provides the results of phosphorus, TSS and water clarity (measured by Secchi disk transparency) during 2024. A comparison of phosphorus concentrations in the main basin (BHP-2) over time is illustrated graphically in Figure 7. Overall TP was low in 2024 at all locations on all dates. TP surface concentrations were below the Massachusetts Department of Environmental Protection (MassDEP) target concentration of 0.030 mg/L[3] at the surface during in 2024.

Bottom water samples exceeded MassDEP's threshold at BHP-2 in May, but all other samples were below 0.03 mg/L. This elevated value can be the result of suspended solids or phosphorus being released and/or accumulating in the hypolimnion. DP, the dissolved fraction of phosphorus, was detected in May and August suggesting that there is phosphorus readily available for algal uptake in both the surface and bottom waters. It should be noted that algal blooms were observed in 2020 and 2021, when TP values were generally below the MassDEP threshold suggesting that the threshold isn't low enough to be protective against blooms or the algae are obtaining their nutrients from bottom waters where TP and DP concentrations are greater.

The Town of Harvard Board of Health (BOH) fluorometer readings and estimated cyanobacteria cell counts were generally below the 70,000 cells/mL advisory threshold in 2024, except the samples collected at 12 and 20 feet in August (Figure 8). These data are similar to those collected in 2023, except that the higher reading occurred in July 2023 vs August in 2024.Values at the beach were consistently below the advisory threshold.

TSS numbers were at or less than detection at all surface water samples. The highest TSS was recorded in the bottom sample in August.

Secchi disk transparency (SDT) in 2024 was much improved from 2021 due to the absence of an algal bloom. SDT ranged from 9.6 to 12.3 feet (range in 2021 was 3.0 to 12.4 feet). The lowest values were recorded in June. Clarity was above the MassDEP State Water Quality Standard of four feet for swimming during all monitoring events (through August 2024; Figure 9). Water clarity was greatest in August.

3) Tracking of fish counts at multiple fishing derbies each year.

A number of fishing clubs hold derbies on the Pond each year and a condition of access is that they record all fish caught, species, weight, size and send it to the Committee. The numbers are tracked year to year and trends are observed. Bare Hill Pond has a non-stocked fish population and it is thriving.

4) Evaluation of downstream wetlands impacts, if any.
The vegetative assessment protocol was established in 2002 by ENSR. It was conducted with for over 15 years with almost no significant changes noted, and now is conducted with a visual inspection that if changes are detected, the full monitoring is performed.

Vegetative Assessment of Riparian Wetlands and Forests

The majority of the lakeshore does not support emergent vegetation due to exposure to wave action and absence of suitable habitat. Coves and shallow water environments along the lake margin support stands of emergent vegetation. Emergent wetland habitat is best represented in the southern section of the lake at the end of Bowers Road, in the shallow cove west of Minister's Island, and in the shallow water habitat north of the town beach (Figure 2). Aquatic macrophytes were common to abundant in shallow water habitat observed from the lakeshore. Aquatic macrophytes recorded in the field surveys performed by ENSR included such species as variable-leaf milfoil (*Myriophyllum heterophyllum*), yellow water-lily (*Nuphar variegata*), white water-lily (*Nymphaea odorata*), bladderworts (*Utricularia* spp.), pondweeds (*Potamogeton* spp.), and grass-leaf arrowhead (*Sagittaria graminea*). Results of a comprehensive survey on the distribution of aquatic macrophytes in Bare Hill Pond are in Appendix A.

The representative vegetative sample plots set by ENSR (Figure 2) include two plots in the emergent wetland community north of the town beach (Figure 6), contiguous with the lake. Plant cover estimates recorded in the lake sample plots are presented in Appendix B. Dominant species recorded in the vegetation sample plots established in the emergent wetland community include cattail (*Typha latifolia* and *T. angustifolia*), purple loosestrife (*Lythrum salicaria*), Canada bluejoint (*Calamagrostis canadensis*), and wool-grass (*Scirpus cyperinus*). Dominant species in the emergent communities are tolerant of water level fluctuations and extended periods of exposure. The recorded emergent species will not be adversely impacted by the increased water level adjustments proposed to control nuisance vegetation in the lake.

A second set of vegetation sample plots was located in the broad scrub-shrub/emergent wetland community adjacent to Bowers Brook north of (downstream of) the dam (Figures 7 and 8). Dominant plants recorded in the downstream vegetation sample plots include shrubs, such as sweet pepperbush (*Clethra alnifolia*), black alder (*Ilex verticillata*), arrowwood (*Viburnum dentatum*), swamp azalea (*Rhododendron viscosum*), swamp rose (*Rosa palustris*), and highbush blueberry (*Vaccinium corymbosum*). Canopy cover in the scrub-shrub wetland is relatively light. Canopy dominants recorded in the field survey include red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), white ash (*Fraxinus americana*), and white pine (*Pinus strobus*) along the transitional borders. Standing deadwood and windfalls are common in the scrub-shrub wetland. Herbaceous dominants include burreed (*Sparganium* sp.), tussock sedge (*Carex stricta*), wool-grass, Canada bluejoint, cattail, marsh fern (*Thelypteris palustris*), cinnamon fern (*Osmunda cinnamomea*), and royal fern (*Osmunda regalis*). Plant cover estimates recorded in the downstream sample plots established in scrub-shrub wetland habitat are in Appendix B.

5) Frog counts to ensure species continuity and health.
Trained volunteers learn frog calls from a recording and do counts timed to coincide with the seasonal variation in mating calls. They count calls in a defined time limit after remaining still for two minutes. Here is the 2024 data sheet:

Date	Location	Bull	Green	Wood	Spring Peeper	Gray tree	American toad	Pickerel	Comment	time
4/22/2023	tennis courts				17					7:30
4/22/2024	clapp's brook				0				Cool evening no frogs	7:44
4/26/2024	bowers rd(cove drive)				0				not done - too few frogs	7:30
5/10/2024	tennis courts				8				Little to no frogs	7:45
5/18/2024	tennis courts	1			18				Warm night	7:30
5/18/2024	clapp's brook				Chorus		2	12		8:20
5/18/2024	bowers rd(cove drive)	12			Chorus			87	Dark clouds	9:12
6/14/2023	tennis courts								ESTIMATE	8:43
6/14/2021	clapp's brook	12	120					28		9:04
6/14/2023	bowers rd(cove drive)				192			60		9:34
7/17/2024	tennis courts				10		2		Bit cool	8:22
7/22/2024	clapp's brook	8	17						Way too many bugs	9:16
7/29/2024	bowers rd(cove drive)	7	7					8	light rain	9:00

6) Turtle counts to ensure species continuity and health.

A volunteer quietly paddles the pond at the same time each year in August photographing and counting turtles in fixed time period. Here is the 2024 report:

2024 Bare Hill Pond Turtle Report

Day/Date/Time: Thurs, Aug 8th, 2024 between 12:30-1:45 PM

Weather- overcast to partly cloudy, steady breeze, 75F.

Method – same as previous years.

Track and Observations: Like 2023, I started from the shoreline across from the Town beach to just beyond the Girl Scout's beach, including a couple of island shorelines. I counted 47 turtles, 46 American Painted and 1 possible Blanding's Turtle (See photo). All turtles appeared healthy and distributed in size/age.

The annual counting table is here updated.

Year	Painted Turtles Counted
2017	34
2018	64
2021	26
2022	39
2023	83
2024	47

7) Mussel surveys to ensure continuity and observed reproduction.
In November, when the Pond is lowered to 5 feet, it is then possible to observe Mussels in the areas beyond the 6.5 ft drawdown zone. Typically they are quite numerous and juvenile mussels are also present showing that they are reproducing. Mussel shells are often found in the drawdown zone but after multiple years of draw downs they are mostly in areas deeper than the drawdown and the observer takers a photo and notes whether the density is similar to prior years. No changes have been observed in the density outside the drawdown zone. The common mussel found in Bare Hill Pond, according to a mussel biologist consulted lives across the entire pond bottom.

These seven activities are required under the Order of Conditions for the deep drawdown and reviewed annually by the Town of Harvard Conservation Commission.

TMDL Criteria

The TMDL goals were the Section 319 Project goals identified in Element B 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 in 2006 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 Secchi disk readings. Additional measurements of down stream flow to confirm that the downstream wetlands are capturing any excess phosphorus should be designed and implemented.

Adaptive Management

The Bare Hill Pond Watershed Management Committee was created to protect and preserve the Pond and its watershed. It has been very proactive is adopting strategies to help Bare Hill Pond and will continue to do so in the future. The inclusion of specific action items in this Watershed Management Plan will add an additional checklist to adhere to in these activities. This adds to the existing commitments made to the Conservation Commission in the Order of Conditions to conduct the necessary monitoring for the drawdown. These monitoring activities trigger consideration of other strategies that will likely trigger more adaptive activities in the future. In addition, to ensure that the Committee does not miss its obligations, there is an annual workplan and checklist that has been used for a number of years and is reviewed monthly to ensure that all action items are assigned to the appropriate person or department and that the work is completed. The annual workplan and checklist is revised as activities and priorities change. The comprehensive monitoring and review process at the Conservation Commission along with the advice of our wetlands consultant, ARC, will assure that we identify actions that are not working as intended and cause us to adapt and change the approach in the future, as appropriate.

The watershed strategy first and foremost is focused on continued achievement of the TMDL goals. 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 use of DASH divers is an example of an adaptation to the plan to address this issue. While the plan includes the prior actions to protect the pond, such as the rain gardens for stormwater control and the pumped drawdown, 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, and depending on future results from monitoring may also need to consider the use of Alum as a further strategy to control phosphorus from temperature induced in-lake loading.

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Water Quality Assessment Reports

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

TMDL

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1987 Whitman and Howard Report

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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			