HALFMOON LAKE

WATERSHED-BASED MANAGEMENT PLAN

PREPARED BY FB ENVIRONMENTAL ASSOCIATES
in cooperation with the Halfmoon Lake Association

NOVEMBER 2024 | **DRAFT**

Photo Credit: FBE

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ACRONYM	DEFINITION
AC	Assimilative Capacity
AIPC	Aquatic Invasive Plant Control, Prevention and Research Grants
ACEP	Agricultural Conservation Easement Program
ALI	Aquatic Life Integrity
ARM	Aquatic Resource Mitigation Fund
BCCD	Belknap County Conservation District
BMP	Best Management Practice
CAGR	Compound Annual Growth Rate
CHL-A	Chlorophyll-a
CNMP	Comprehensive Nutrient Management Plan
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWP	Center for Watershed Protection
CWSRF	Clean Water State Revolving Fund
DO	Dissolved Oxygen
DPW	Department of Public Works
EMD	Environmental Monitoring Database
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESRI	Environmental Systems Research Institute
FBE	FB Environmental Associates
FT	Feet
HAB	Harmful Algal Bloom
HMLA	Halfmoon Lake Association
ILFP	In-Lieu Fee Program
KG	Kilogram
LCHIP	Land and Community Heritage Investment Program
LID	Low Impact Development
LLMP	Lay Lakes Monitoring Program
LLRM	Lake Loading Response Model
LRCT	Lakes Region Conservation Trust
LRPC	Lakes Region Planning Commission
LWCF	Land and Water Conservation Fund
M	Meter
NAWCA	North American Wetlands Conservation Act
NERFG	New England Forest and River Grant
NCEI	National Centers for Environmental Information
NFWF	National Fish and Wildlife Foundation
NH GRANIT	New Hampshire Geographically Referenced Analysis and Information Transfer System
NHACC	New Hampshire Association of Conservation Commissions
NHD	National Hydrography Dataset
NHDES	New Hampshire Department of Environmental Services
NHDOT	New Hampshire Department of Transportation
NHFG	New Hampshire Fish and Game Department
NHLCD	New Hampshire Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source Pollution

ACRONYM	DEFINITION
NRCS	Natural Resources Conservation Service
NRI	Natural Resources Inventory
NWI	National Wetlands Inventory
PCR	Primary Contact Recreation
PCS	Potential Contamination Source
ppb, ppm	parts per billion, parts per million
RCCP	Regional Conservation Partnership Program
RCRA	Resource Conservation and Recovery Act
SCC	State Conservation Committee
SDT	Secchi Disk Transparency
TP	Total Phosphorus
UNH	University of New Hampshire
USLE	Universal Soil Loss Equation
VLAP	Volunteer Lake Assessment Program
WMP	Watershed-Based Management Plan
YR	Year

DEFINITIONS

Adaptive management approach recognizes that the entire watershed cannot be restored with a single restoration action or within a short time frame. The approach provides an iterative process to evaluate restoration successes and challenges to inform the next set of restoration actions.

Anoxia is a condition of low dissolved oxygen.

Assimilative Capacity is a lake's capacity to receive and process nutrients (phosphorus) without impairing water quality or harming aquatic life.

Best Management Practices (BMPs) are conservation practices designed to minimize discharge of NPS pollution from developed land to lakes and streams. Management plans should include both non-structural (non-engineered) and structural (engineered) BMPs for existing and new development to ensure long-term restoration success.

Build-out analysis combines projected population estimates, current zoning restrictions, and a host of additional development constraints (conservation lands, steep slope and wetland regulations, existing buildings, soils with low development suitability, and unbuildable parcels) to determine the extent of buildable areas in the watershed.

Chlorophyll-a (Chl-a) is a measurement of the green pigment found in all plants, including microscopic plants such as algae. Measured in parts per billion or ppb, it is used as an estimate of algal biomass; the higher the Chl-a value, the higher the number of algae in the lake.

Clean Water Act (CWA) requires states to establish water quality standards and conduct assessments to ensure that surface waters are clean enough to support human and ecological needs.

Cyanobacteria are photosynthetic bacteria that can grow prolifically as blooms when enough nutrients are available. Some cyanobacteria can fix nitrogen and/or produce microcystin, which is highly toxic to humans and other life forms.

Dissolved Oxygen (DO) is a measure of the amount of oxygen dissolved in water. Low oxygen can directly kill or stress organisms and stimulate release phosphorus from bottom sediments.

Epilimnion is the top layer of lake water directly affected by seasonal air temperature and wind. This layer is well-oxygenated by wind and wave action.

Eutrophication is the process by which lakes become more productive over time (oligotrophic to mesotrophic to eutrophic). Lakes naturally become more productive or "age" over thousands of years. In recent geologic time, however, humans have enhanced the rate of enrichment and lake productivity, speeding up this natural process to tens or hundreds of years.

Fall turnover is the process of complete lake mixing when cooling surface waters become denser and sink, especially during high winds, forcing warmer, less-dense water to the surface. This process is critical for the natural exchange of oxygen and nutrients between surface and bottom layers in the lake.

Flushing rate (also called retention time) is the amount of time water spends in a waterbody. It is calculated by dividing the flow in or out by the volume of the waterbody.

Full build-out refers to the time and circumstances in which, based on a set of restrictions (e.g., environmental constraints and current zoning), no more building growth can occur, or the point at which lots have been subdivided to the minimum size allowed.

Hypolimnion is the bottom-most layer of the lake that experiences periods of low oxygen during stratification and is devoid of sunlight for photosynthesis.

Impervious surfaces refer to any surface that will not allow water to soak into the ground. Examples include paved roads, driveways, parking lots, and roofs.

Internal Phosphorus Loading is the process whereby phosphorus bound to lake bottom sediments is released back into the water column during periods of anoxia. The phosphorus can be used as fuel for plant and algae growth, creating a positive feedback to eutrophication.

Low Impact Development (LID) is an alternative approach to conventional site planning, design, and development that reduces the impacts of stormwater by working with natural hydrology and minimizing land disturbance by treating stormwater close to the source, and preserving natural drainage systems and open space, among other techniques.

Nonpoint Source (NPS) Pollution comes from diffuse sources throughout a watershed, such as stormwater runoff, seepage from septic systems, and gravel road erosion. One of the major constituents of NPS pollution is sediment, which contains a mixture of nutrients (like phosphorus) and inorganic and organic material that stimulate plant and algae growth.

Non-structural BMPs, which do not require extensive engineering or construction efforts, can help reduce stormwater runoff and associated pollutants through operational actions, such as land use planning strategies, municipal maintenance practices, and targeted education and training.

Oligotrophic lakes are less productive or have fewer nutrients (i.e., low levels of phosphorus and chlorophyll-a), deep Secchi Disk Transparency readings (8.0 m or greater), and high dissolved oxygen levels throughout the water column. In contrast, **eutrophic** lakes have more nutrients and are therefore more productive and exhibit algal blooms more frequently than oligotrophic lakes. **Mesotrophic** lakes fall in-between with an intermediate level of productivity.

pH is the standard measure of the acidity or alkalinity of a solution on a scale of 0 (acidic) to 14 (basic).

Riparian refers to wildlife habitat found along the banks of a lake, river, or stream. Not only are these areas ecologically diverse, but they are also critical to protecting water quality by preventing erosion and filtering polluted stormwater runoff.

Secchi Disk Transparency (SDT) is a vertical measure of the transparency of water (ability of light to penetrate water) obtained by lowering a black and white disk into the water until it is no longer visible. Transparency is an indirect measure of algal productivity and is measured in meters (m).

Structural BMPs, or engineered Best Management Practices, are often at the forefront of most watershed restoration projects and help reduce stormwater runoff and associated pollutants.

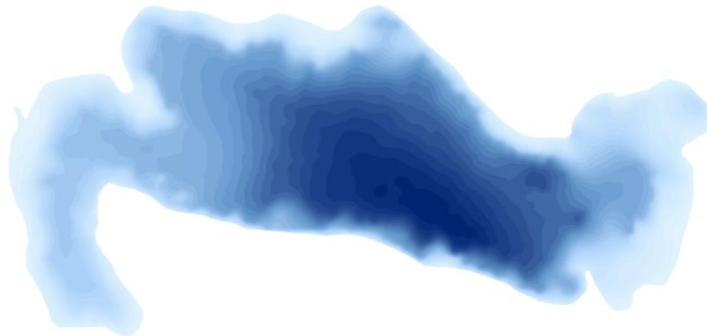
Thermal stratification is the process whereby warming surface temperatures in summer create a temperature and density differential that separates the water column into distinct, non-mixable layers.

Thermocline or **metalimnion** is the markedly cooler, dynamic middle layer of rapidly changing water temperature. The top of this layer is distinguished by at least a degree Celsius drop per meter of depth.

Total Phosphorus (TP) is one of the major nutrients needed for plant growth. It is generally present in small amounts (measured in parts per billion (ppb)) and limits plant growth in lakes. In general, as the amount of TP increases, the number of algae also increases.

Trophic State is the degree of eutrophication of a lake and is designated as oligotrophic, mesotrophic, or eutrophic.

EXECUTIVE SUMMARY



Halfmoon Lake is a 288-acre lake with a 3,829-acre watershed located within the towns of Alton and Barnstead in the Lakes Region of New Hampshire. Development is scattered throughout the watershed, with most of the development along the shores or just to the east of Halfmoon Lake. Halfmoon Lake is fed by tributaries such as the Route 28 inlet, the Public Beach inlet, Fern Hill Inlet, Horse Farm inlet, and Dugan's inlet. From the outlet of Halfmoon Lake, water flows south into Locke Lake, then continues down Webster Stream to the Suncook River. The Suncook River discharges into the Merrimack River on the border of Pembroke and Allenstown, NH.

The Problem

According to the 2022 Data Summary of the New Hampshire Volunteer Lake Assessment Program (VLAP) Individual Lake Report for Halfmoon Lake, the lake has total phosphorus and chlorophyll-a levels higher than the NH Department of Environmental Services (NHDES) threshold for oligotrophic lakes, though concentrations of each parameter appear to be improving. NHDES designated Halfmoon Lake as a Class B water, impaired for Aquatic Life Integrity due to elevated total phosphorus and chlorophyll-a, low pH, and low dissolved oxygen saturation. Halfmoon Lake is also listed as impaired for Primary Contact Recreation due to the presence of cyanobacteria hepatotoxic microcystins. Multiple inlets, including the Fern Hill Inlet, Dugan's Inlet, and an unnamed brook north of Crescent Beach (Route 28 Inlet) are identified as impaired for Aquatic Life Integrity due to low pH. The 1978 NHDES Lake Trophic Survey Report assessed the lake as oligotrophic, noting aquatic weeds were common along the shoreline. By the next assessment in 1992, the lake was reclassified as mesotrophic due to depleted dissolved oxygen in bottom waters. It was noted that aquatic plants were less abundant, though reports of nuisance filamentous algae in bottom waters were more frequent.

Three cyanobacteria blooms have been reported in the past 15 years at Halfmoon Lake, leading to warnings issued by the NHDES for a cumulative 30 days. The first advisory was issued in 2011 (9 days), followed by 2018 (14 days) and 2019 (7 days). The deep spot of Halfmoon lake is known to experience anoxia, which can trigger the release of phosphorus from bottom sediments and be mixed up into the water column for use by phytoplankton such as cyanobacteria. This phenomenon known as internal loading is already evident in Halfmoon Lake, though it is not the greatest source of phosphorus to the lake system. Enhanced loading of phosphorus to surface waters, whether from internal or external sources, particularly when compounded by the impacts from climate change, can stimulate excessive plant, algae, and cyanobacteria growth and degrade water quality.

Cyanobacteria blooms are typically spurred by a combination of warming waters and excessive nutrients, in particular phosphorus, to surface waters. Sources of phosphorus in the watershed impacting the lake's water quality include stormwater runoff from developed areas, shoreline erosion, erosion from construction activities or other disturbed ground particularly along roads, excessive fertilizer application, failed or improperly functioning septic systems, leaky sewer lines, unmitigated agricultural activities, and pet, livestock, and wildlife waste. Nine-teen (19) problem sites were identified in the watershed during a field survey. The greatest and most consistent issues identified were erosion at the two boat ramps, road shoulder and ditch erosion on steeply sloping roads, unpaved road erosion, and buffer clearing. Additionally, 56 shorefront properties were identified as having some impact to water quality due to evidence of erosion and lack of vegetated buffer. The model results revealed changes in phosphorus loading and in-lake phosphorus concentrations over time from pre-development through future conditions, showing that the water quality of Halfmoon Lake is threatened by current development activities in the watershed and will degrade further with continued development in the future, especially when compounded by the effects of ongoing climate change.

Finally, a build-up of legacy phosphorus in bottom sediments can be released back into the water column under low oxygen conditions, typically experienced in late summer – a phenomenon known as internal phosphorus loading. The model showed that internal phosphorus loading to Halfmoon Lake is significant at 9% of the total phosphorus load. It is likely that the internal load will need to be addressed to fully restore the excellent water quality of Halfmoon Lake.

The Goal

The goal of the Halfmoon Lake WMP is to improve the water quality of Halfmoon such that it meets state water quality standards for the protection of Aquatic Life Integrity (ALI) and Primary Contact Recreation (PCR), and substantially reduce the likelihood of harmful cyanobacteria blooms in the lake. This goal will be achieved by accomplishing the following objectives. More detailed action items to achieve these objectives will be provided in the action plan of the WMP.

OBJECTIVE 1: Reduce phosphorus loading from existing development by 33% (45 kg/yr) to Halfmoon Lake to improve the average in-lake summer total phosphorus concentration to 8.1 ppb and annual chlorophyll-a concentration to 3.0 ppb.

OBJECTIVE 2: Mitigate (prevent or offset) phosphorus loading from future development by 3.2 kg/yr to Halfmoon Lake to maintain average summer in-lake total phosphorus concentration in the next 10 years.

The Solution

As a result of the recent cyanobacteria blooms, the Halfmoon Lake Association (HMLA) initiated a campaign to better understand and protect the water quality of Halfmoon Lake. Funding from the Water Quality Planning Grant from the NHDES with Clean Water Act Section 604(b) funds from the U.S. Environmental Protection Agency were secured to develop a WMP for Halfmoon Lake. As part of the development of the WMP, a build-out analysis, land-use model, water quality and assimilative capacity analysis, septic system inventory, shoreline survey, and watershed survey were conducted to identify and quantify the sources of phosphorus and other pollutants to the lake. Results from these analyses were used to determine recommended management strategies for the identified pollutant sources in the watershed. An Action Plan (Section 5) was developed in collaboration with a Watershed Management Plan Steering Committee comprised of key watershed stakeholders (see Acknowledgements). The following actions were recommended to meet the established water quality goal and objectives for Halfmoon Lake:

WATERSHED STRUCTURAL BEST MANAGEMENT PRACTICES (BMPs): Sources of phosphorus from watershed development should be addressed through installation of stormwater controls, stabilization techniques, buffer plantings, etc. for the following: stormwater infrastructure, the high priority sites (and the medium and low priority sites as opportunities arise) identified during the watershed survey, the high and medium impact shoreline properties identified during the shoreline survey, and any new or redevelopment projects in the watershed with high potential for soil erosion.

MONITORING: A long-term water quality monitoring plan is critical to evaluate the effectiveness of implementation efforts over time. HMLA, in concert with NHDES Volunteer Lake Assessment Program (VLAP), should continue the annual monitoring program and consider incorporating additional monitoring recommendations laid out in this plan.

EDUCATION AND OUTREACH: HMLA and other key watershed stakeholders should continue all aspects of their education and outreach strategies and consider developing new ones or improving existing ones to reach more watershed residents. Examples include providing educational materials to existing and new property owners, as well as renters, by distributing them at various locations and through a variety of means, such as websites, newsletters, social media, community events, or community gathering locations. Educational campaigns should include raising awareness of water quality concerns, septic system maintenance, fertilizer and pesticide use, pet waste disposal, waterfowl feeding, invasive aquatic species, boat pollution, shoreline buffer improvements, gravel road maintenance, and stormwater runoff controls.

OTHER ACTIONS: Additional strategies for reducing phosphorus loading to the lake include: revising local ordinances such as setting low impact development (LID) requirements on new construction; identifying and replacing malfunctioning septic systems; inspecting and remediating leaky sewer lines; using best practices for road maintenance and other activities including municipal operations such as infrastructure cleaning; conserving large or connective habitat corridor parcels; and improving agricultural practices. Future development should also be considered as a pollutant source and potential threat to water quality. Halfmoon Lake is at risk for greater water quality degradation from new development in the watershed unless climate change resiliency and LID strategies are incorporated to existing zoning standards.

The recommendations of this plan will be carried out largely by HMLA with assistance from a diverse stakeholder group, including representatives from the municipalities (e.g., select boards, planning boards), conservation commissions, state and federal agencies or organizations, nonprofits, land trusts, schools and community groups, local business leaders, and landowners. The cost of successfully implementing the plan is estimated at $0.6-$1.2 million over the next 10 or more years in addition to the dedication and commitment of volunteer time and support to manage plan implementation. However, many costs are still unknown or were roughly estimated and should be updated as information becomes available. This financial investment can be accomplished through a variety of funding mechanisms via both state and federal grants, as well as commitments from municipalities or donations from private residents. Of significant note, this plan meets the nine planning elements required by the EPA, and Halfmoon Lake is now eligible for federal watershed assistance grants.

Important Notes

The success of this plan is dependent on the continued effort of volunteers and a strong and diverse stakeholder group that should meet regularly to coordinate resources for implementation, review progress, and make any necessary adjustments to the plan to maintain relevant action items and interim milestones. A reduction in nutrient loading is no easy task, and because there are many diffuse sources of phosphorus reaching surface waters in the watershed, it will require an integrated and adaptive approach across many different parts of the watershed community to be successful. The recommendations in this plan are idealized and, in some cases, may be difficult to achieve given the physical and political realities of the community dealing with old infrastructure, lack of access to key lakefront areas, and limited funding and volunteer or staff capacity.

Finally, we all have a common responsibility to protect our lakes for future generations to enjoy. Private landowners arguably hold the most power in making significant impact to restoring and maintaining excellent water quality in our lakes; however, engaging private landowners as a single stakeholder group can be difficult and outreach efforts often have limited reach, especially to those individuals who may require the most education and awareness of important water quality protection actions. HMLA will continue to engage the public as much as possible so that private individuals can help review and implement the recommendations of this plan and protect the water quality of Halfmoon Lake long into the future.

Halfmoon Lake © FBE

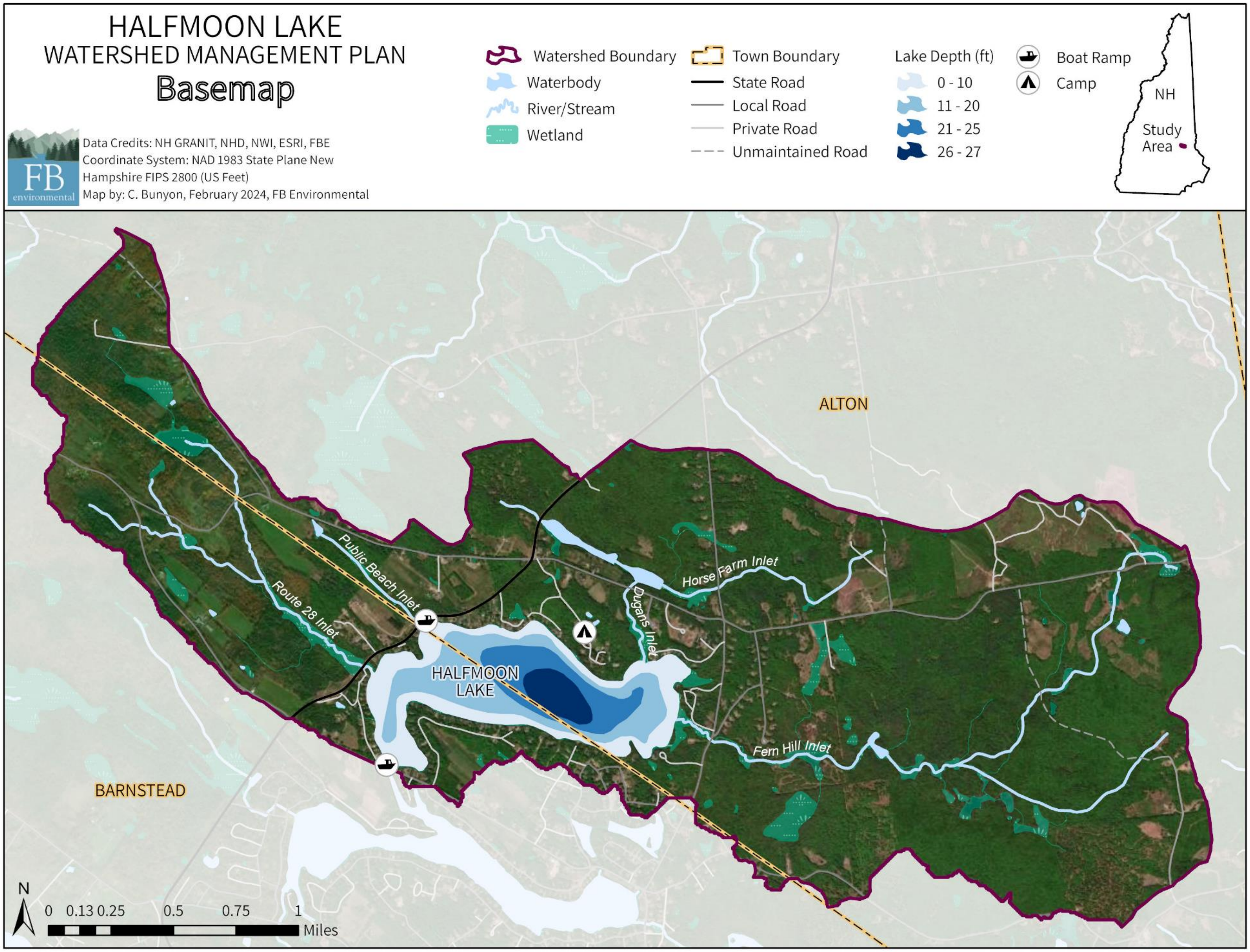


Figure 1. Halfmoon Lake watershed.

1 INTRODUCTION

1.1 WATERBODY DESCRIPTION AND LOCATION

Halfmoon Lake is a 288-acre (116.5 hectare) lake with a 3,829-acre (1,549.5 hectare) watershed in the towns of Alton (78%) and Barnstead (22%). It is a glacially formed lake, fed by tributaries that drain from the surrounding watershed, tributaries such as the Route 28 inlet, the Public Beach inlet, Fern Hill Inlet, Horse Farm inlet, and Dugan's inlet (Figure 1). From the outlet on the southern end of the lake, water flows south directly into Locke Lake, which is a 149 acres (60.3 hectare) mesotrophic lake, from which it drains into Webster Stream to the Suncook River. The Suncook River discharges in the Merrimack River on the Boarder of Pembroke and Allenstown, NH.

Precipitation and air temperature data for the surrounding region of Halfmoon Lake, were collected from 1994-2023 from Daymet (Figure 2). Annual air temperature (from average monthly data) generally ranges from 10 °F to 70 °F, with an average of 46 °F (Daymet). The area experiences moderate to high rainfall and snowfall, averaging 50.6 inches of precipitation annually.

The highest elevation in the watershed is located at Prospect Mountain (around 1,400 feet above sea level), which is in Alton on the Northeastern part of the watershed boundary. Halfmoon Lake and the direct shoreline area are approximately 640 feet above sea level. These elevation measurements were derived from digital elevation models provided by NH GRANIT.

The Halfmoon Lake watershed is situated within a temperate zone of converging weather patterns from the hot, wet southern regions and the cold, dry northern regions, which causes various natural phenomena such as heavy snowfalls, severe thunder and lightning storms, and occasional hurricane.

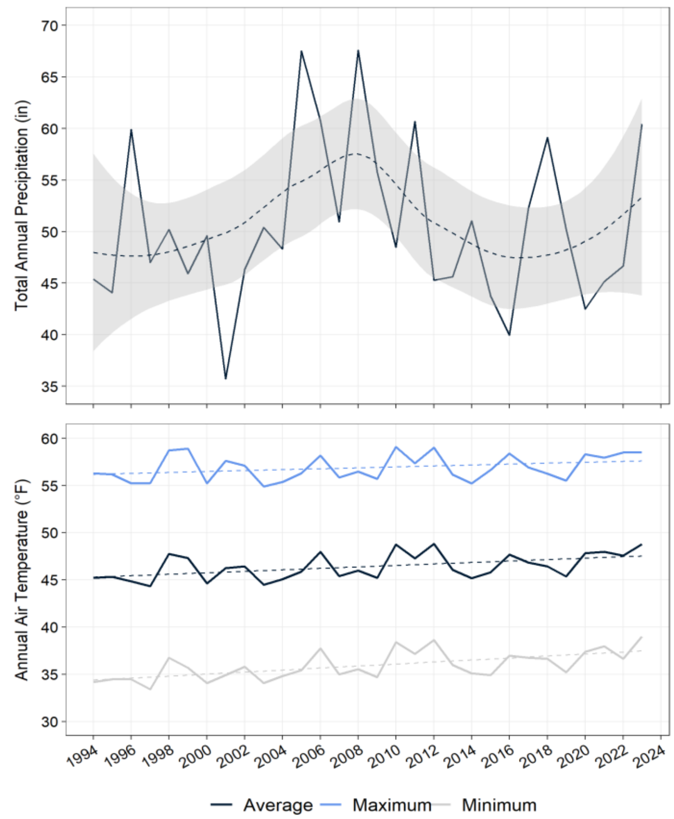


Figure 2. *Total annual precipitation and annual max, average, and min of monthly air temperature from 1994 - 2023 for the region. Data collected from Daymet.*

The watershed is characterized primarily by mixed forest that includes both conifers (e.g., white pine and eastern hemlock) and deciduous (e.g., beech, red oak, and maple) tree species. Fauna that enjoy these forested resources include land mammals (moose, deer, black bear, coyote, bobcats, fisher, fox, raccoon, weasel, porcupine, muskrat, mink, chipmunks, squirrels, snowshoe hares, and bats), water mammals (muskrat, otter, and beaver), land and water reptiles and amphibians (turtles, snakes, frogs, and salamanders), various insects, birds (herons, loons, gulls, geese, multiple species of ducks, wild turkeys, ruffed grouse, cormorants, bald eagles, and song birds)[1], and fish.

[1] Data from FBE field observations and Cornell Lab of Ornithology eBird database.

1.2 WATERSHED PROTECTION GROUPS

The Halfmoon Lake Association (HMLA) serves as the non-profit lake association for Halfmoon Lake with a mission to *"protect the interest of property owners through education and the continued monitoring of lake quality in order to enhance both property values and recreational opportunities."* HMLA oversees a loon nesting program, in addition to working closely with NHDES to monitor water quality and invasive weed control.

The Belknap County Conservation District (BCCD) is one of 10 county conservation districts in New Hampshire that operate as resource management agencies and a subdivision of local governments. BCCD's mission is to "*coordinate and implement programs for education and on-the-ground work regarding conservation, use, and development of soil, water, and related resources*." This organization works with farmers, forest owners, landowners, schools, and municipalities to help protect and conserve the area's natural resources through projects such as stream bed restoration, invasive species management, and pollinator plantings. Both Alton and Barnstead are part of Belknap County.

Lakes Region Conservation Trust (LRCT) is a non-profit organization "*dedicated to the permanent conservation, stewardship, and respectful use of lands that define the character of the Lakes Region and its quality of life*." Their vision is a "*future where conserved lands support thriving biodiversity, healthy watersheds, and vibrant human communities*." LRCT has conserved 162 properties totaling over 28,300 acres in the Lakes Region.

The New Hampshire Association of Conservation Commissions (NHACC) works to provide educational assistance to conservation commissions throughout New Hampshire (216 in total). As a non-profit organization, the NHACC's mission is to instill responsible use of the available natural resources by promoting conservation and serving as the communication link between conservation commissions, while providing technical support on the logistics of conservation commission meetings and document language. Conservation commissions in the Halfmoon Lake watershed include those of Alton and Barnstead.

Covering 31 communities, the Lakes Region Planning Commission (LRPC) is a valuable resource to the region. The LRPC aids communities with their local planning services in a targeted approach to protect the environment, while supporting local economies and cultural values.

The New Hampshire Department of Environmental Services (NHDES) works with local organizations to improve water quality in New Hampshire at the watershed level. NHDES works with communities to identify water resource goals and to develop and implement watershed-based management plans. This work is achieved by providing financial and technical assistance to local watershed management organizations and by investigating actual and potential water contamination problems, among other activities.

1.3 PURPOSE AND SCOPE

The purpose and overarching goal of the Halfmoon Lake Watershed-Based Management Plan (WMP) is to guide implementation efforts over the next 10 years (2025-2034) to improve the water quality of Halfmoon such that they meet state water quality standards for the protection of Aquatic Life Integrity (ALI) and Primary Contact Recreation (PCR), and substantially reduce the likelihood of harmful cyanobacteria blooms in the lake.

As part of the development of this plan, a **build-out analysis**, land-use model, water quality and **assimilative capacity** analysis, and shoreline and watershed surveys were conducted to better understand the sources of phosphorus and other pollutants to the lake (Sections 2 and 3). Results from these analyses were used to establish the water quality goal and objectives (Section 2.5), determine recommended management strategies for the identified pollutant sources (Section 4), and estimate pollutant load reductions and costs needed for remediation (Sections 5 and 6). Recommended management strategies involve using a combination of **structural and non-structural Best Management Practices** (BMPs), as well as an **adaptive management approach** that allows for regular updates to the plan (Section 4). An Action Plan (Section 5) with associated timeframes, responsible parties, and estimated costs was developed in collaboration with the **Watershed Management Plan Steering Committee** and the Technical Advisory Committee (Section 1.4). This plan meets the nine elements required by the United States Environmental Protection Agency (EPA) so that communities become eligible for federal watershed assistance grants (Section 1.5).

1.4 COMMUNITY INVOLVEMENT AND PLANNING

The plan was developed through the collaborative efforts of numerous meetings, public presentations, and conference calls between FB Environmental Associates (FBE), HMLA, NHDES, representatives from the towns of Alton and Barnstead, and private landowners (see Acknowledgments).

1.4.1 Plan Development Meetings

Several meetings were held over the duration of the plan development. The following list does not include routine annual meetings conducted separately by HMLA, except as they relate to the watershed plan development.

- **August 27, 2023:** FBE delivered a WMP development process presentation to HMLA.
- **December 11, 2023:** Halfmoon Lake WMP Kick-off meeting (Steering Committee meeting #1).
- **December 22, 2023**: HMLA and FBE met with NRCS to discuss outreach strategies to reach agricultural stakeholders.
- **March 28, 2024**: HMLA and FBE attended the Belknap County Natural Resource Assessment Local Working Group meeting held by NRCS.
- **April 26, 2024**: HMLA and FBE met to conduct the Watershed Survey.
- **May 31, 2024**: HMLA and FBE met to discuss the septic system inventory.
- **June 12, 2024**: HMLA and FBE met to conduct the Shoreline Survey.
- **July 13, 2024**: HMLA annual meeting #1. FBE presented the results of the water quality analysis.
- **August 5, 2024**: Steering Committee Meeting #2: Discussion of the watershed & shoreline survey results and the Action Plan
- **August 22, 2024**: Steering Committee Meeting #3: Review of the build-out analysis, lake model, and setting water quality goal.
- **August 25, 2024**: Halfmoon Lake Annual Meeting #2. FBE presented on the status of the WMP development and the water quality goals.
- **November 15, 2024**: Halfmoon Lake WMP Draft public presentation.

1.4.2 Draft WMP Public Presentation and Review Period

A final public presentation was held virtually on November 15th, 2024, to summarize the analyses and recommendations detailed in the plan. The presentation was attended by members of Steering Committee and community. A portion of the presentation was dedicated to receiving public feedback on the plan. The presentation was followed by a 30-day review period where the public had additional time to digest the material, read the draft WMP, and provide comments and recommendations for edits. All feedback that was submitted to the Steering Committee, HMLA, and ultimately FBE was thoughtfully considered when developing the final MWP for Halfmoon Lake.

1.5 INCORPORATING EPA'S NINE ELEMENTS

EPA guidance lists nine components that are required within a WMP to restore waters impaired or likely to be impaired by **nonpoint source (NPS) pollution**. These guidelines highlight important steps in restoring and protecting water quality for any waterbody affected by human activities. The nine required elements found within this plan are as follows:

- **A. IDENTIFY CAUSES AND SOURCES: Sections 2 and 3** highlight known sources of NPS pollution to Halfmoon Lake and describe the results of the watershed survey and other assessments conducted in the watershed. These sources of pollutants must be controlled to achieve load reductions estimated in this plan, as discussed in item (B) below.
- **B. ESTIMATE PHOSPHORUS LOAD REDUCTIONS EXPECTED FROM MANAGEMENT MEASURES: Sections 2 and 5** describe the calculation of pollutant load to Halfmoon Lake and the amount of reduction needed to meet the water quality goal, respectively.
- **C. DESCRIPTION OF MANAGEMENT MEASURES: Sections 4 and 5** identify ways to achieve the estimated phosphorus load reduction and reach water quality targets. The Action Plan focuses on several major topic areas that address NPS pollution. Management options in the Action Plan focus on non-structural BMPs integral to the implementation of structural BMPs.
- **D. ESTIMATE OF TECHNICAL AND FINANCIAL ASSISTANCE: Sections 5 and 6** includes a description of the associated costs, sources of funding, and primary authorities responsible for implementation. Sources of funding need to be diverse and should include local, state, and federal granting agencies, local groups, private donations, and landowner contributions for implementation of the Action Plan.
- **E. EDUCATION & OUTREACH: Section 4** describes how the educational component of the plan is already being or will be implemented to enhance public understanding of the project.
- **F. SCHEDULE FOR ADDRESSING PHOSPHORUS REDUCTIONS: Section 5** provides a list of action items and recommendations to reduce the phosphorus load to Halfmoon Lake. Each item has a set schedule that defines when the action should begin and/or end or run through (if an ongoing activity). The schedule should be adjusted by the HMLA on an annual basis (see Section 4 on Adaptive Management).
- **G. DESCRIPTION OF INTERIM MEASURABLE MILESTONES: Section 6** outlines indicators along with milestones of implementation success that should be tracked annually.
- **H. SET OF CRITERIA: Sections 2 and 6** can be used to determine whether loading reductions are being achieved over time, substantial progress is being made towards water quality objectives, and if not, criteria for determining whether this plan needs to be revised.
- **I. MONITORING COMPONENT: Section 6** describes the long-term water quality monitoring strategy for Halfmoon Lake, the results of which can be used to evaluate the effectiveness of implementation efforts over time as measured against the criteria in (H) above. The success of this plan cannot be evaluated without ongoing monitoring and assessment and careful tracking of load reductions following successful BMP implementation projects.

2 ASSESSMENT OF WATER QUALITY

This section provides an overview of the past, current, and future state of water quality based on the water quality assessment and watershed modeling, which identified pollutants of concern and informed the established water quality goal and objectives for Halfmoon Lake.

2.1 WATER QUALITY SUMMARY

2.1.1 Water Quality Standards & Impairment Status

2.1.1.1 Designated Uses & Water Quality Criteria

The **Clean Water Act** (CWA) requires states to determine designated uses for all surface waters within the state's jurisdiction. Designated uses are the desirable activities and services that surface waters should be able to support and include uses for ALI, fish consumption, shellfish consumption, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating and fishing), and wildlife. Surface waters can have multiple designated uses. **Primary Contact Recreation (PCR) and ALI are the two major uses for lakes – ALI being the focus of this plan.** In New Hampshire, all surface waters are also legislatively classified as Class A or Class B, most of which are Class B (Env-Wq 1700). Halfmoon **Lake is classified as Class B waters in the State of New Hampshire,** impaired for Aquatic Life Integrity due to elevated total phosphorus and chlorophyll-a, low pH, and low dissolved oxygen saturation. Halfmoon Lake is also listed as impaired for Primary Contact Recreation due to the presence of cyanobacteria hepatotoxic microcystins. Additionally, from 1974 to 2010, NHDES conducted surveys of lakes to determine **trophic state** (**oligotrophic**, **mesotrophic**, or **eutrophic**). The trophic surveys evaluated physical lake features, as well as chemical and biological indicators. For Halfmoon Lake, the trophic state was determined to be oligotrophic in 1978, noting aquatic weeds were common along the shoreline**.** By the next assessment in 1992, the lake was re-classified as mesotrophic due to depleted dissolved oxygen in bottom waters. During this last assessment, it was noted that aquatic plants were less abundant, though reports of nuisance filamentous algae in bottom waters were more frequent. Additionally, multiple inflows to the lake are classified as impaired for low pH and may affect the water quality of the lake itself (Table 1).

Table 1. *NHDES assessment of the inlets to Halfmoon Lake and their associated water quality rating as reported on the NHDES 2020/2022 Watershed Report Cards (NHDES, 2022b).*

Assessment Unit Name	AUID	Water Quality
Route 28 Inlet	HALALT28	Impaired for ALI due to low pH
Fern Hill Inlet	HALALTF	Impaired for ALI due to low pH
Dugans Inlet	HALALTD3	Impaired for ALI due to low pH
Horse Farm Inlet	HALALTH	Impaired for ALI due to low pH

Water quality criteria are then developed to protect designated uses, serving as a "yardstick" for identifying water quality exceedances and for determining the effectiveness of state regulatory pollution control and prevention programs. Depending on the designated use and type of waterbody, water quality criteria can become more or less strict if the waterbody is classified as either Class A or B or as oligotrophic, mesotrophic, or eutrophic. To determine if a waterbody is meeting its designated uses, water quality criteria for various parameters (e.g., **chlorophyll-a**, **total phosphorus**, **dissolved oxygen**, **pH**, and toxics) are applied to the water quality data. If a waterbody meets or is better than the water quality criteria, the designated use is supported. The waterbody is considered impaired for the designated use if it does not meet water quality criteria. Water quality criteria for each classification and designated use in New Hampshire can be found in RSA 485 A:8, IV and in the state's surface water quality regulations.

2.1.1.2 Antidegradation Provisions

The Antidegradation Provision (Env-Wq 1708) in New Hampshire's water quality regulations serves to protect or improve the quality of the state's waters. The provision outlines limitations or reductions for future pollutant loading. Certain development projects (e.g., projects that require Alteration of Terrain Permit or 401 Water Quality Certification) may be subject to an Antidegradation Review to ensure compliance with the state's water quality regulations. The Antidegradation

Provision is often invoked during the permit review process for projects adjacent to waters that are designated impaired, high quality, or outstanding resource waters. While NHDES has not formally designated high-quality waters, unimpaired waters are treated as high quality with respect to issuance of water quality certificates. Antidegradation requires that a permitted activity cannot use more than 20% of the remaining assimilative capacity of a high-quality water. This is on a parameter-by-parameter basis. For impaired waters, antidegradation requires that permitted activities discharge no additional loading of the impaired parameter.

2.1.2 Water Quality Data Collection

New Hampshire VLAP has been monitoring Halfmoon Lake every year since 1989. NHDES, the NH Department of Health and Human Services, and volunteers from HMLA have also monitored and assessed the lake over the years.

Water quality data were obtained for this plan from the NHDES Environmental Monitoring Database (EMD) and directly from Bob Craycraft of UNH LLMP. Twenty-six (26) water quality stations were identified in the watershed with varying amounts of water quality data. A descriptive overview of available water quality data in the watershed is as follows for a subset of sites shown in Figure 3:

- **HALALTD (Halfmoon Lake Deep Spot):** variable depth grab samples (from the **epilimnion**, **metalimnion**, and/or **hypolimnion**) were collected from 1989-2024 (with only a few minor gaps) for numerous parameters, but most consistently for temperature, dissolved oxygen, Secchi disk transparency, chlorophyll-a, total phosphorus, pH, and specific conductance.
- **HALALT28 (Halfmoon Lake-Rt 28 Inlet):** variable parameters from 1989-2024, including pH, total phosphorus, and specific conductivity every year since 1989, turbidity every year since 1997, and chloride every year since 2010 (except 2013).
- **HALALTF (Halfmoon Lake-Fern Hill Inlet):** variable parameters from 1989-2024, including pH, total phosphorus, and specific conductivity every year since 1989, turbidity every year since 1997, and chloride every year since 2011 (except 2013).
- **HALALTH (Halfmoon Lake-Horse Farm Inlet):** variable parameters from 1991-2024, including pH, total phosphorus, and specific conductivity every year since 1991, turbidity every year since 1997, and chloride every year since 2010 (except 2013).

These four sites listed above are the most active sites for water temperature, dissolved oxygen, total phosphorus, and chloride by the NH VLAP program. HALALTC (Halfmoon Lake-Crescent Beach), HALALTD1 (Halfmoon Lake-Dalton Beach), HALALTD3 (Dugans Inlet) were routinely monitored for pH, total phosphorus, specific conductance, turbidity, and *E. coli* generally from the early 1990s to early-mid 2010s with a few data gaps.

Many other sites have recently been sampled for *E. coli*, including HALALTB (Halfmoon Lake-Boys Camp) from 1991-1995, 2002-2019, and 2021-2024, HALALTHWB (Halfmoon Lake-Hollywood Beach) in 1991, from 2005-2006, 2008-2019, and 2021-2024, HALALPUB (Halfmoon Lake-Public Beach) from 1991-1995, 1998, 2003-2019, and 2021-2024, and HALALTR (Halfmoon Lake-Rustic Shores) from 1991-1995, 1998, 2002-2019, and 2021-2024.

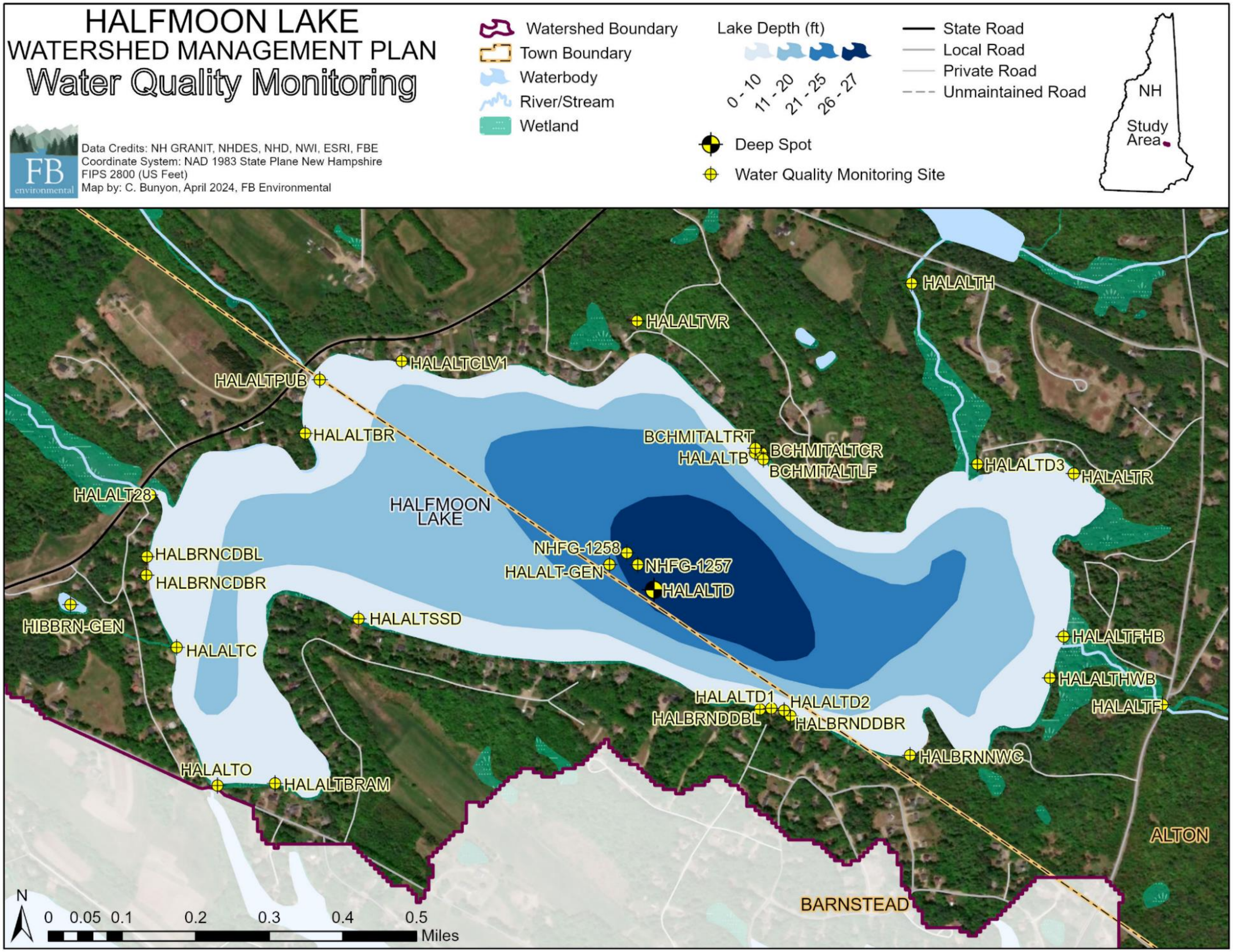


Figure 3. *Map of water quality sampling sites within the Halfmoon Lake watershed and the bathymetry of Halfmoon Lake.*

Table 2. *Matching site ID and site description by site type. Refer to Figure 3 for location.*

Site ID	Site Description	Site Type
HALALT28	HALFMOON LAKE-RT 28 INLET	RIVER/STREAM
HALALTB	HALFMOON LAKE-BOYS CAMP	LAKE/POND
HALALTBR	HALFMOON LAKE-BOAT RAMP	LAKE/POND
HALALTBRAM	HALFMOON LAKE-BRAMANTE	LAKE/POND
HALALTC	HALFMOON LAKE-CRESCENT BEACH	LAKE/POND
HALALTCLV1	HALFMOON LAKE-CULVERT 1	CULVERT
HALALTD	HALFMOON LAKE-DEEP SPOT	LAKE/POND
HALALTD1	HALFMOON LAKE-DALTON BEACH	LAKE/POND
HALALTD3	HALFMOON LAKE-DUGANS INLET	RIVER/STREAM
HALALTF	HALFMOON LAKE-FERN HILL INLET	RIVER/STREAM
HALALTFHB	HALF MOON LAKE-FERN HILL BEACH	LAKE/POND
HALALT-GEN	HALFMOON LAKE-GENERIC	LAKE/POND
HALALTH	HALFMOON LAKE-HORSE FARM INLET	RIVER/STREAM
HALALTHWB	HALFMOON LAKE-HOLLYWOOD BEACH	LAKE/POND
HALALTO	HALFMOON LAKE-OUTLET	RIVER/STREAM
HALALTPUB	HALFMOON LAKE-PUBLIC BEACH	LAKE/POND
HALALTR	HALFMOON LAKE-RUSTIC SHORES	LAKE/POND
HALALTSSD	HALFMOON LAKE-S SHORE DRIVE	LAKE/POND
HALALTVR	HALFMOON LAKE-VARNEY RD	RIVER/STREAM
HALBRNCDBL	CRESCENT DRIVE BEACH LEFT	LAKE/POND
HALBRNCDBR	CRESCENT DRIVE BEACH RIGHT	LAKE/POND
HALBRNCDCR	CRESCENT DRIVE BEACH CENTER	LAKE/POND
HALBRNDDBCR	DALTON DRIVE BEACH - CENTER	LAKE/POND
HALBRNDDBL	DALTON DRIVE BEACH - LEFT	LAKE/POND
HALBRNDDBR	DALTON DRIVE BEACH - RIGHT	LAKE/POND
HALBRNNWC	NEW CASTLE BEACH	LAKE/POND

2.1.3 Trophic State Indicator Parameters

Total phosphorus, chlorophyll-a, and Secchi disk transparency are trophic state indicators, or indicators of biological productivity in lake ecosystems. The combination of these parameters helps determine the extent and effect of **eutrophication** in lakes and helps signal changes in lake water quality over time. For example, changes in Secchi disk transparency may be due to a change in the amount and composition of algae communities (typically because of greater total phosphorus availability) or the amount of dissolved or particulate materials in a lake. Such changes are likely the result of human disturbance or other impacts to the lake's watershed.

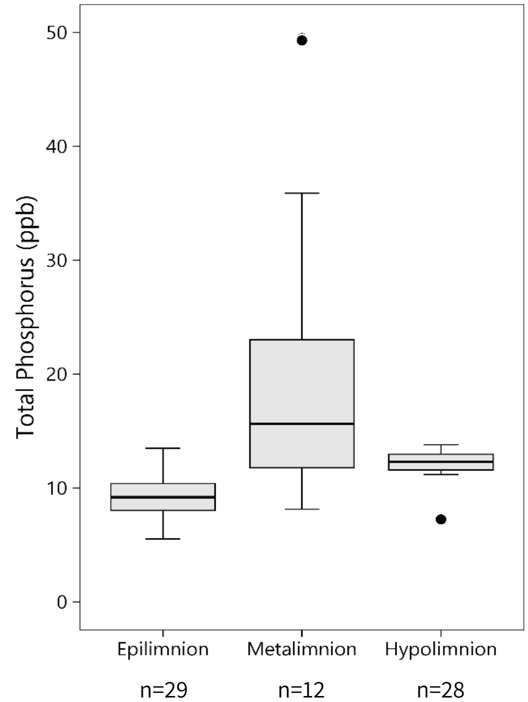


Figure 4. *Boxplots showing median total phosphorus concentration in the epilimnion, metalimnion, and hypolimnion of the deep spot of Halfmoon Lake (HALALTD) from the past 10 years, 2014-2023.*

At Halfmoon Lake from 2014-2023, higher total phosphorus concentrations were most often measured in the metalimnion and hypolimnion compared to the epilimnion, indicating some amount of internal phosphorus loading is occurring (Figure 4). Phosphorus concentrations are also more variable in the metalimnion than the epilimnion and hypolimnion. While the cause of elevated meta- and hypolimnion turbidity at Halfmoon Lake is unknown, it suggests the possibility that cyanobacteria may be taking advantage of this additional phosphorus source and transporting it to other areas of the water column, resulting in the observed cyanobacteria blooms.

For the available time period, 1978-2023, no statistically significant trends were found for median epilimnetic total phosphorus, chlorophyll-a, or Secchi disk transparency at the deep spot of Halfmoon Lake (HALALDT) (

Figure 5). The 2022 Data Summary of the NH VLAP Individual Lake Report for Halfmoon Lake found stable trends for total phosphorus and Secchi disk transparency, and improving trends in chlorophyll-a, though higher concentrations of chlorophyll-a were observed in 2023.

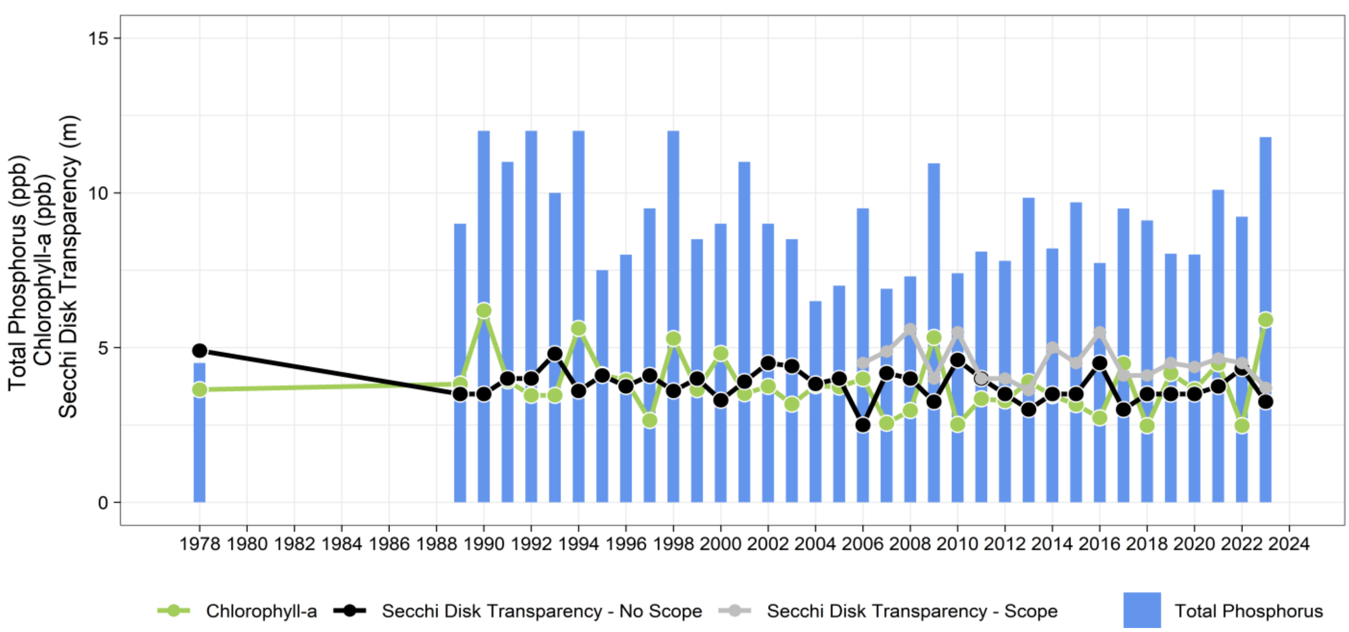


Figure 5. Median epilimnion grab samples (0-3 meters) total phosphorus, median composite epilimnion (0-5 meters) chlorophyll-a, and median water clarity (Secchi Disk depth for scope and no scope methods) measured at Halfmoon Lake largely in June-September from 1978-2023 for the deep spot station (HALALTD). No statistically significant trends were detected from the Mann-Kendall nonparametric trend test using rkt package in R Studio.

2.1.4 Dissolved Oxygen & Water Temperature

A common occurrence in New Hampshire's lakes is the depletion of dissolved oxygen in the deepest part of lakes throughout the summer months. This occurs when thermal stratification prevents warmer (less dense), oxygenated surface waters from mixing with cooler (denser), oxygen-depleted bottom waters in the lake. Chemical and biological processes occurring in bottom waters deplete the available oxygen throughout the summer, and because these waters are colder and denser, the oxygen cannot be replenished through mixing with surface waters. Dissolved oxygen levels below 5 ppm (and water temperature above 24 °C) can stress and reduce habitat for cold-water fish and other sensitive aquatic organisms. In addition, anoxia (low dissolved oxygen) at lake bottom can result in the release of sediment-bound phosphorus (otherwise known as internal phosphorus loading), which can become a readily available nutrient source for algae and cyanobacteria. While thermal stratification and depletion of oxygen in bottom waters is a natural phenomenon in dimictic lakes such as Halfmoon Lake, it is important to track these parameters to make sure the extent and duration of low oxygen does not change drastically because of human disturbance in the watershed resulting in excess phosphorus loading.

Figure 6 shows temperature and dissolved oxygen profiles for Halfmoon Lake averaged across sampling dates (1989-2022) during thermal stratification largely in summer (between spring and fall turnover). The change in temperature, seen most dramatically between 5 and 7 m, indicates thermal stratification in the water column. The average dissolved oxygen of <2 ppm at 7-9 m depth indicates the possibility of **internal phosphorus loading** under anoxic conditions. Historic recording of temperature and dissolved oxygen profiles includes multiple water column profiles per sampling season which provide insight to seasonal changes in the lake. Additional profiles in the early autumn months (September and October) can provide additional insight into the possible internal loading in Halfmoon Lake.

Lake Stratification and Mixing

Halfmoon Lake is a dimictic lake, undergoing two cycles of stratification and mixing annually. Stratification takes place during summer, as surface waters warm, forming a thermal barrier due to differences in water densities. Additionally, winter months see stratification when the lake freezes over, with colder surface waters sitting atop warmer bottom waters. Dimictic lakes undergo both "fall turnover" and "spring turnover," characterized by the loss of these temperature gradients which enable water mixing once again.

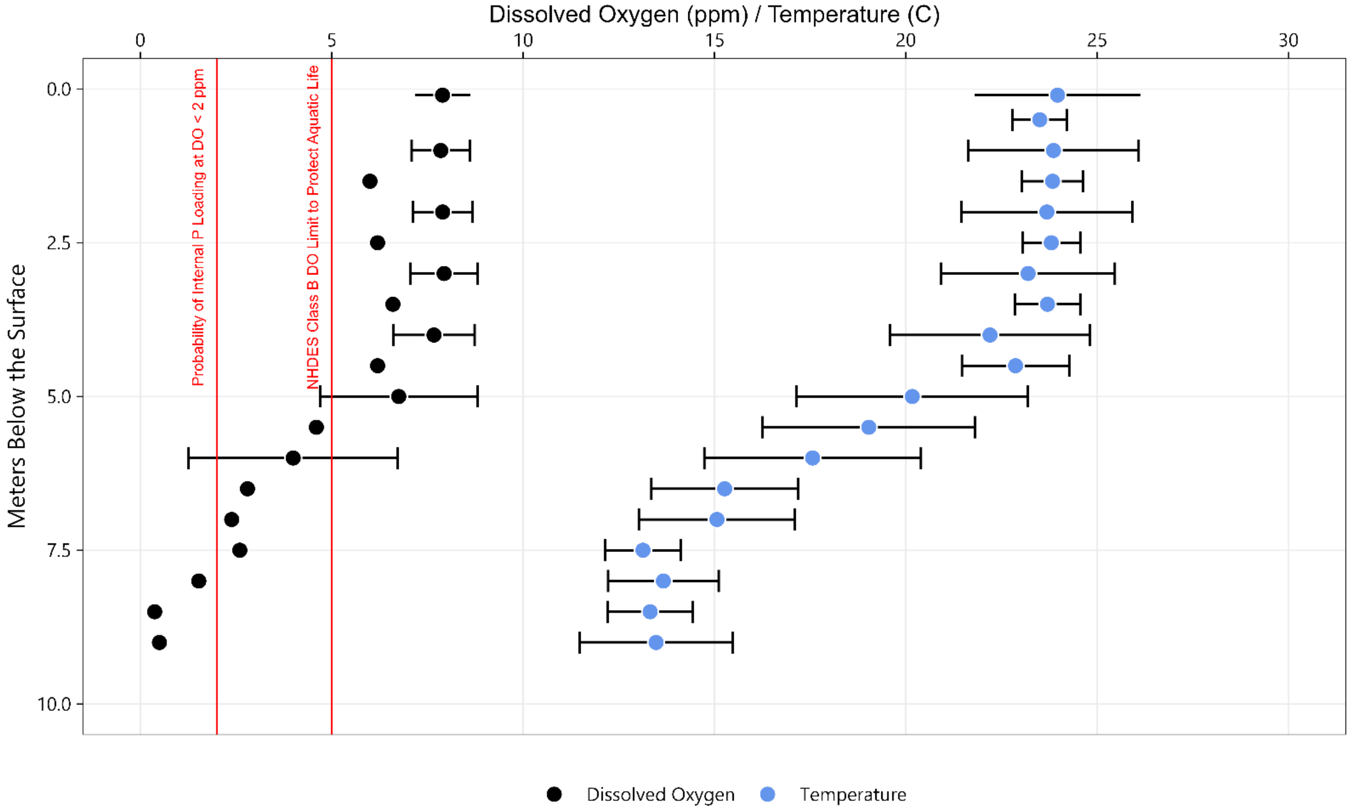


Figure 6. *Dissolved oxygen (black) and water temperature (blue) depth profiles for the deep spot of Halfmoon Lake (HALALTD). Dots represent average values across sampling dates for each respective depth. Error bars represent standard deviation. Data represents profiles collected from 2014 to 2023 (n=20).*

2.1.5 Phytoplankton (Cyanobacteria) and Zooplankton

Nutrients such as phosphorus and nitrogen, as well as algae and cyanobacteria, naturally occur in the environment, including lakes and tributaries and their contributing watersheds, and are essential to lake health. Under natural conditions, algae and cyanobacteria concentrations are regulated by limited nutrient inputs and lake mixing processes that keep them from growing too rapidly. However, human related disturbances, such as erosion, overapplied fertilizers, polluted stormwater runoff, excessive domesticated animal waste, and inadequately treated wastewater, can dramatically increase the amount of nutrients entering lakes and their tributaries. Excess nutrient loading to human-disturbed lake systems, in combination with a warming climate, has fueled the increasing prevalence of Harmful Algal Blooms (HABs) or the rapid growth of algae and cyanobacteria in lakes across the United States.

Cyanobacteria are small photosynthesizing, sometimes nitrogen-fixing, single-celled bacteria that grow in colonies in freshwater systems. Cyanobacteria blooms can (but not always) produce microcystins and other toxins that pose a serious health risk to humans, pets, livestock, and wildlife, such as neurological, liver, kidney, and reproductive organ damage, gastrointestinal pain or illness, vomiting, eye, ear, and skin irritation, mouth blistering, tumor growth, seizure, or death. Blooms can form dense mats or surface scum that can occur within the water column or along the shoreline. Dried scum along the shoreline can harbor high concentrations of microcystins that can re-enter a waterbody months later. There are several different species of cyanobacteria, such as:

- ***Anabaena/Dolichospermum***: typically observed as filaments, associated with microcystins, anatoxins, saxitoxins, and cylindrospermopsin, *documented in Halfmoon Lake in 2019.*
- ***Microcystis***: typically observed as variations of small-celled colonies, associated with microcystins and anatoxins.
- ***Aphanizomenon***: Typically forms rafts of filaments, associated anatoxin-a, anatoxin-a (S), saxitoxins, and possibly microcystins.

- ***Woronichinia***: Typically forms dense colonies, associated with microcystins.
- ***Planktothrix/Oscillatoria***: typically observed as filaments, associated with microcystins and cylindrospermopsin, can maintain high growth rate at relatively low light intensities when it forms metalimnetic blooms (NHDES, 2020), *documented in Halfmoon lake in 2011 and 2018.*

Cyanobacteria are becoming more prevalent in low-nutrient lake systems likely due to climate change warming effects (e.g., warmer water temperatures, prolonged thermal stratification, increased stability, reduced mixing, and lower flushing rates at critical low-flow periods that allow for longer residence times) that allow cyanobacteria to thrive and outcompete other phytoplankton species (Przytulska, Bartosiewicz, & Vincent, 2017; Paerl, 2018; Favot, et al., 2019). Many cyanobacteria can regulate their buoyancy and travel vertically in the water column to maximize their capture of both sunlight and sediment phosphorus (even during stratification and/or under anoxic conditions) for growth. In addition, some cyanobacteria can also fix atmospheric nitrogen, if enough light, phosphorus, iron, and molybdenum are available for the energy-taxing process. Some taxa are also able to store excess nitrogen and phosphorus intra-cellularly for later use under more favorable conditions. Because of these traits and as climate warming increases the prevalence and dominance of cyanobacteria, cyanobacteria are one of the major factors driving positive feedbacks with lake eutrophication and may be both accelerating eutrophication in low-nutrient lakes and preventing complete recovery of lakes from eutrophic states (Dolman, et al., 2012; Cottingham, Ewing, Greer, Carey, & Weathers, 2015). A better understanding of cyanobacteria's role in nutrient feedbacks will be needed for better and more effective lake restoration strategies.

Bloom History

Halfmoon Lake has had four officially reported NHDES cyanobacteria bloom advisories, the first of which was issued in 2011 (Table 3). The 2011 advisory lasted for nine days and was dominated by the taxon *Oscillatoria*, with a cell count of 859,833. The next advisory was issued in 2018 and was dominated by *Oscillatoria* and *Planktothrix*. The bloom had a cell count of 1,450,000 and lasted for fourteen days. One year later in 2019, an advisory was issued for seven days. The bloom was dominated by *Dolichospermum* (formerly *Anabaena*) with a cell count of 137,000 cells/mL. *Oscillatoria* and *Planktothrix* can form benthic mats, and *Dolichospermum* are potentially a toxin producing species. No cyanobacteria bloom advisories were issued by NHDES from 2020-2023. In 2024, a cyanobacteria bloom occurred on the western side of the lake near the public boat ramp and advisory was issued. The advisory lasted 6 days and consisted primarily of *Dolichospermum, Woronichinia, and Planktothrix.*

Table 3. *Cyanobacteria advisories issued by NHDES for HalfmoonLake (NHDES, 2022c).*

Advisory Date	Duration (days)	Dominant Taxa	Illness Reported	Total Cell Concentration (cells/mL)
2011	9	*Oscillatoria*	None	859,833
2018	14	*Planktothrix*	None	1,450,000
2019	7	*Dolichospermum/Anabaena*	None	137,000
2024	6	*Dolichospermum, Woronichinia, Planktothrix*	None	1,050,000

Phytoplankton/Zooplankton Results

The 2022 Data Summary of the NH VLAP Individual Lake Report for Halfmoon Lake shows phytoplankton population (relative percent cell count per taxa) for 2014, 2016, 2018, and 2021. In 2021, golden-browns dominated over other taxa after cyanobacteria dominated in 2016 and 2018. However, in 2022, cyanobacteria were also observed at 8 meters in August, indicating their continued presence in Halfmoon Lake. This continuing shift from diatoms and golden-browns to cyanobacteria is also evident when analyzing older trophic surveys as well. Phytoplankton and zooplankton samples were collected and analyzed during the 1979 and 1992 NHDES Trophic Surveys of Halfmoon Lake. The dominant phytoplankton species were *Chrysosphaerella* (golden-brown), *Ceratium* (diatom), and *Asterionella* (diatom).

The dominant zooplankton species in the 1979 and 1992 surveys were *Nauplius* larvae (copepod), *Kellicottia* (rotifer), and *Gastropus* (rotifer). Copepods are small crustaceans that eat phytoplankton and provide an important food source to fish. Rotifers are small zooplankton whose population can respond quickly to environmental changes. *Daphnia* are among the most efficient grazers of phytoplankton but were not shown to be a dominant zooplankton in Halfmoon Lake. Maintaining a balance of phytoplankton and zooplankton are necessary components of a healthy lake ecosystem.

It is unlikely that cyanobacteria will be fully eradicated in the Halfmoon Lake watershed; some species of cyanobacteria can become dormant in sediment and then can jump-start cell reproduction once conditions are favorable (warm water temperatures and plenty of sunlight and nutrients). Given the historical occurrence of cyanobacteria blooms, the effects of climate change, and watershed activities, it is likely that blooms may be observed in the years to come, though year-to-year variability is expected (timing, extent, and severity of blooms). Despite this, conditions favorable for blooms can be substantially minimized by reducing nutrient-rich runoff from the landscape during warm, sunny spells. Water level and flow also helps to either flush out blooms or limit upstream nutrient sources to stymie growth.

2.1.6 Chloride & Specific Conductivity

Chloride pollution can cause harm to aquatic organisms and disrupt internal mixing processes when concentrations reach toxic levels. The State of New Hampshire sets a chronic threshold of 230 ppm for chloride (which roughly equates to 835 µS/cm for specific conductivity). Chloride concentrations in Halfmoon Lake are well below the chronic threshold, with both chloride and specific conductivity low, which is typical for a high-quality lake (most New Hampshire lakes are around 4 ppm or 40 µS/cm). However, both chloride and specific conductivity show statistically significant increasing trends over the record from 1978-2023 across all depth zones (Figure 7). Upon further investigation in the dataset, the frequency and timing of specific conductivity sampling became less irregular in 2010. For example, before 2010, the epilimnion samples for specific conductivity ranged from June to September and from one to 4 samples per year. After 2010, three samples were collected each year – one in June, July, and August (except in 2020). Even when the data is analyzed before and after this change of sampling approach, an increasing trend remains evident, and the timing of sample collection does not account for the oscillation of the yearly median data plotted in Figure 7.

The increasing trends indicate that chloride from winter salting practices for deicing roads and other surfaces in the watershed may be contaminating the lake. Another potential source of chloride and specific conductivity is sediment loading from eroding, unpaved roads throughout the watershed. The steep slopes located in some areas of the watershed may make the watershed more susceptible to soil loss and road erosion. Other sources of pollution that may increase chloride and specific conductivity levels include wastewater inputs from septic systems and fertilizers. While not an immediate concern for the health of the lake, chronic chloride toxicity will likely become an issue in the future without a proactive reduction in salt use in the watershed.

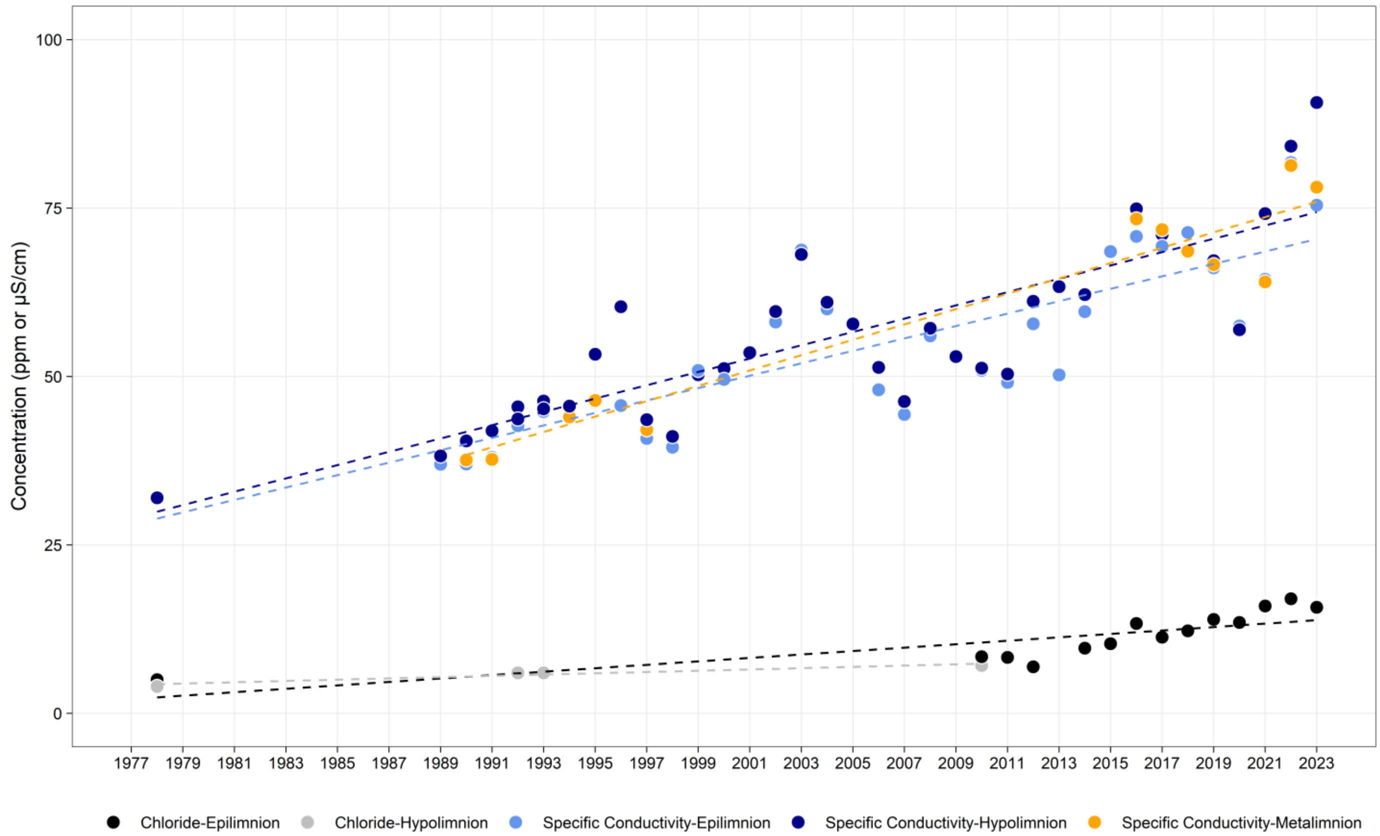


Figure 7. *Yearly median of monthly medians for chloride and specific conductivity in the deep spot of Halfmoon Lake (HALALTD). Dashed lines indicate a statistically significant increasing (degrading) trend.*

2.1.7 Turbidity

Turbidity is a measure of the cloudiness or murkiness of water, caused by the absorption or scattering of light by particulates in the water column. Various factors affect the turbidity of a lake or stream, such as algal and/or cyanobacterial colonies, organic matter, and sediment. High levels of turbidity can decrease water clarity, inhibiting photosynthesis and limiting the growth of aquatic plants, harm filter feeders, and damage the gills of fish. Turbid waters tend to be warmer and have lower levels of dissolved oxygen as suspended particles absorb sunlight and photosynthesis is decreased.

Turbidity values are low (<1NTU) at the deep spot of Halfmoon Lake (HALALTD); particularly in the epi- and metalimnions. The water quality standard in New Hampshire for turbidity in Class B waters is <10 NTU above naturally occurring levels, above which a violation occurs. Although a specific value for “natural” turbidity has not been set by the New Hampshire Department of Environmental Services, it is generally accepted that natural turbidity is low if less than 1 NTU[2]. The epilimnion and metalimnion of Halfmoon Lake show turbidity levels well below the NHDES threshold of 10 NTU (Figure 8). Turbidity is likely higher in the hypolimnion due to the ability of cyanobacteria to regulate their buoyancy using gas-vesicles. Cyanobacteria may descend into the hypolimnion during high light intensity conditions, or to take advantage of bio-available phosphorus at these depths. This phenomenon was observed in 2022 as noted in the Volunteer Lake Assessment Program Individual Lake Report for that year.

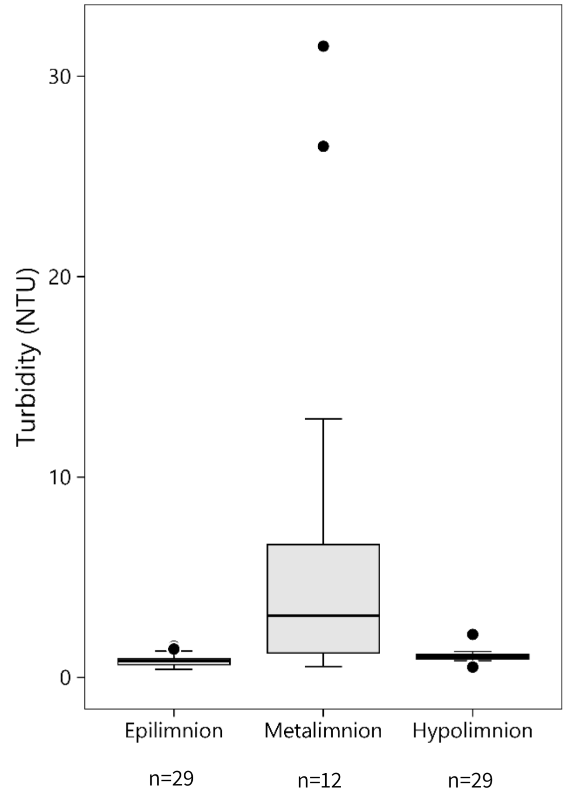


Figure 8. *Boxplots showing median turbidity in the epilimnion, metalimnion, and hypolimnion of the deep spot of Halfmoon Lake (HALALTD) for the past 10 years (2014-2023).*

2.1.8 pH

The pH of a water body describes how acidic or basic the water is, with lower values representing more acid conditions, and a value of 7 representing neutral. The habitable range of pH for aquatic organisms is near neutral, with NHDES setting the standard for Class B waterbodies to have a pH between 6.5 and 8.0 to protect aquatic life. Monitoring the pH of Halfmoon Lake is especially important as multiple inflows to the lake are classified as impaired for low pH and may affect the water quality of the lake itself.

Median pH in the epilimnion of Halfmoon Lake at the deep spot (HALALTD) has been stable from 1989-2023 and has generally been at the lower (more acidic) end of the acceptable range set by NHDES (Figure 9). Across the different depth zones, pH has generally been higher (less acidic) in the epilimnion than in the metalimnion or hypolimnion. Higher pH in the epilimnion is typically expected because of the greater amount of photosynthesis occurring in the photic zone which raises the pH, and increased respiration occurring in lower depth zones has an acidifying effect on the water. The pH may be lowest in the hypolimnion due to the settling of detritus and other organic matter on the bottom sediments, which leads to increased respiration when oxygen is present. Both the metalimnion and hypolimnion have median pH values that are below the NHDES guidelines for supporting aquatic life (state value, and sample range/number) (Figure 9). Low pH can have adverse effects on aquatic biota, and extremely low pH can promote the release of iron or even aluminum bound phosphorus (pH < 5.5) from the bottom sediments.

[2] In the 2020/2022 Consolidated Assessment and Listing Methodology (CALM), NHDES provides reference values aimed to represent natural turbidity that differ based on the month, derived from other streams. The reference values for streams in June, July, August, and September are 0.875, 0.831, 0.813, and 0.800 NTU, respectively (NHDES, 2022a).

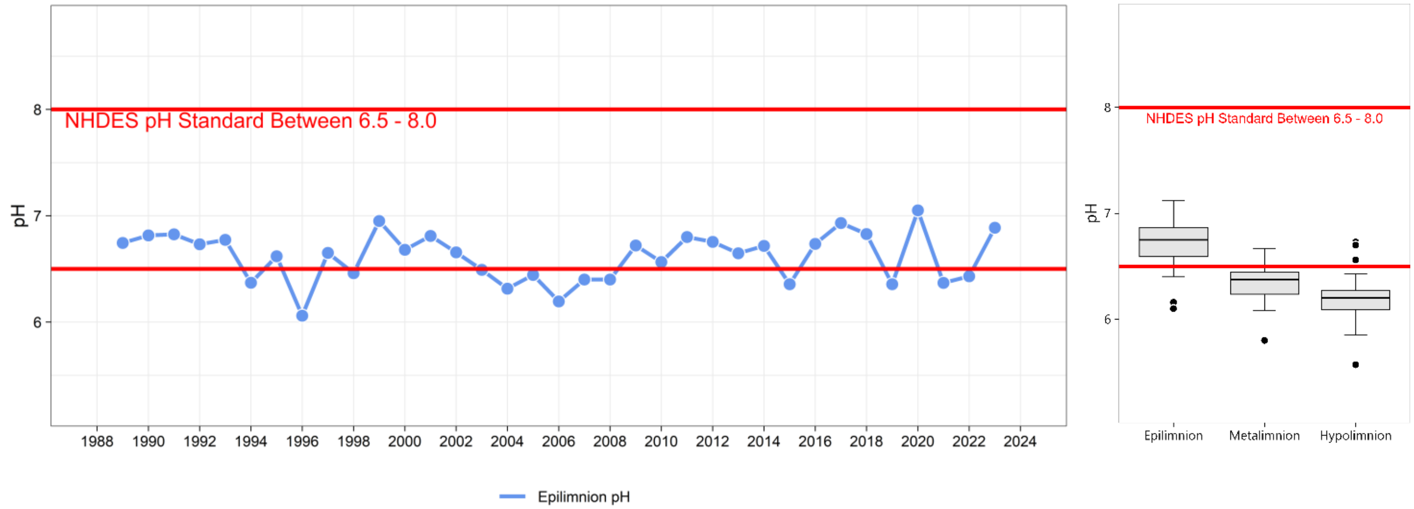


Figure 9. *(Left) Yearly median of monthly medians for epilimnion pH in the deep spot of Halfmoon Lake (HALALTD). (Right) Boxplots showing median pH in the epilimnion, metalimnion, and hypolimnion of the deep spot of Halfmoon Lake (HALALTD) for the past 10 years,*

2.1.9 Fish

Fish are an important natural resource for sustainable ecosystem food webs and provide recreational opportunities. Halfmoon Lake supports populations of warm water species including but not limited to smallmouth bass, largemouth bass, chain pickerel (Eastern), brown bullhead, white and yellow perch, black crappie, and bluegill (NHFG, 2023).

2.1.10 Invasive Species

The introduction of non-indigenous invasive aquatic plant species to New Hampshire's waterbodies has been on the rise. These invasive aquatic plants are responsible for habitat disruption, loss of native plant and animal communities, reduced property values, impaired fishing and degraded recreational experiences, and high removal costs. Once established, invasive species are difficult and costly to remove. There are multiple programs that help prevent the introduction of invasive species and monitor the lake, including the Lake Host Program and the Weed Watcher Program of which neither Halfmoon Lake is a part of. Unfortunately, Halfmoon Lake has reported Variable milfoil in its waters (NHDES, Lake Information Mapper).

2.1.11 Stream Water Quality Summary

2.1.11.1 Total Phosphorous & Turbidity

Total Phosphorus & Turbidity

The water quality of streams that contribute water, nutrients, contaminants, and more, to Halfmoon Lake can reveal areas throughout the watershed contributing disproportionate amounts of certain parameters. Stream health is also critical because they often abut wetlands and serve as the home to various aquatic biota and macroinvertebrates. Of the streams around Halfmoon Lake, only Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28) have been sampled in the past 10 years. Although various other sites have been sampled in the past, this analysis focuses on streams with recent data. A summary of data for these three inlets is available in Table 4.

Stream total phosphorus concentrations are relatively stable over time (1989 – present, Figure 10), with the Route 28 Inlet consistently having the highest total phosphorus concentration with a median of 58.4 ppb over the past ten years (Table 2). The Fern Hill Inlet historically had the lowest total phosphorus concentration, though levels have risen since 2013. However, statistically significant stable trends were found for total phosphorus and turbidity for the Fern Hill Inlet from 1989 (TP) or 1997 (turbidity) to present. The EPA's Ambient Water Quality Criteria Recommendations for Rivers and Streams recommends a reference total phosphorus level of 5 ppb for the sub-ecoregion containing the Halfmoon Lake watershed. All three stream inlets were above this reference threshold.

Turbidity is relatively low in the streams that feed Halfmoon Lake, with median values below 10 NTU for all streams over the past ten years. In 2022, a turbidity spike was observed at the Route 28 Inlet concurrent with a spike in total phosphorus (Figure 10). Turbidity is highly variable and often weather dependent. The timing and severity of storms is likely to have a large impact on turbidity readings due to the delivery and flushing of sediment and suspended particles through a stream. High turbidity is often caused by soil erosion and sediment loading associated with unpaved roads, agriculture, and residential development. Managing sources of turbidity often also addresses sources of phosphorus as phosphorus is adsorbed to soil particles that ultimately end up in streams. Low turbidity paired with high total phosphorus concentrations at the Route 28 Inlet suggest that sources of phosphorus other than soil erosion may be drivers of phosphorus loading to the stream. Although turbidity is generally low in the streams around Halfmoon Lake, the turbidity spike in 2022 serves as evidence that turbidity has the potential to increase in the absence of stormwater management and sediment control practices, especially as the frequency and severity of storm events have increased.

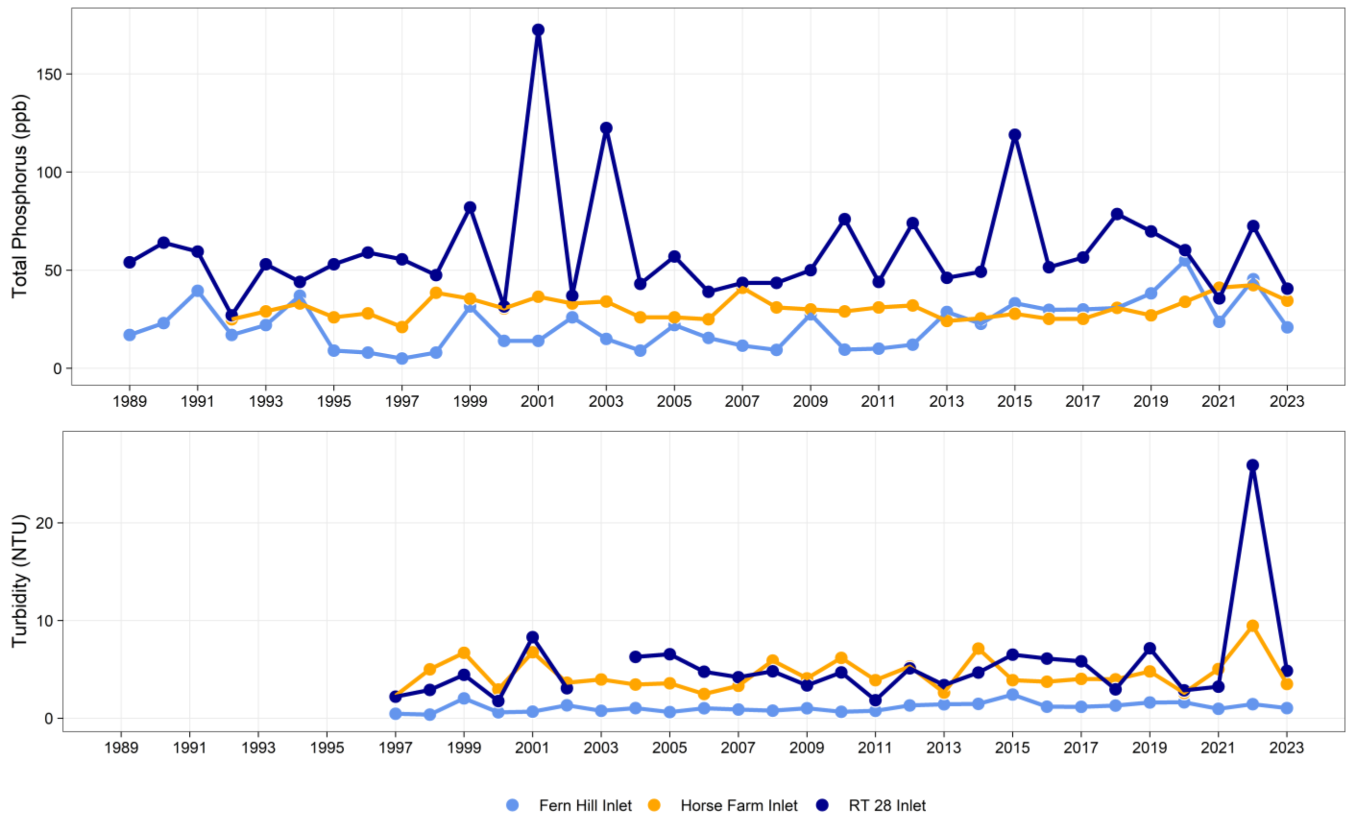


Figure 10. *[Top] Yearly median of monthly medians for total phosphorus at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). [Bottom] Yearly median of monthly medians for turbidity at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28).*

2.1.11.2 Chloride & Specific Conductivity

Specific conductivity is a measure of the water's ability to conduct an electrical current. In the context of streams, specific conductivity relates to the concentration of ionic compounds in the water. Inputs to streams that affect specific conductivity include various types of salts (road salt), ions bound in soil, and ions found in wastewater and agricultural runoff. Chloride and specific conductivity levels are not approaching the chronic toxicity threshold of 230 ppm for chloride (which roughly equates to 835 µS/cm for specific conductivity). However, statistically significant increasing trends were found for specific conductivity at Horse Farm Inlet and Route 28 Inlet from 1989-2023 (Figure 11, top). A statistically significant increasing trend for chloride can be observed at the Route 28 Inlet from 2013-2023 (Figure 11, bottom). Increasing trends in these parameters indicate that pollution from each respective sub-watershed is likely reaching the streams and ultimately Halfmoon Lake. The Fern Hill Inlet has had lower specific conductivity concentrations and chloride levels historically and in recent years compared to the Horse Farm Inlet and the RT 28 inlet (Figure 11).

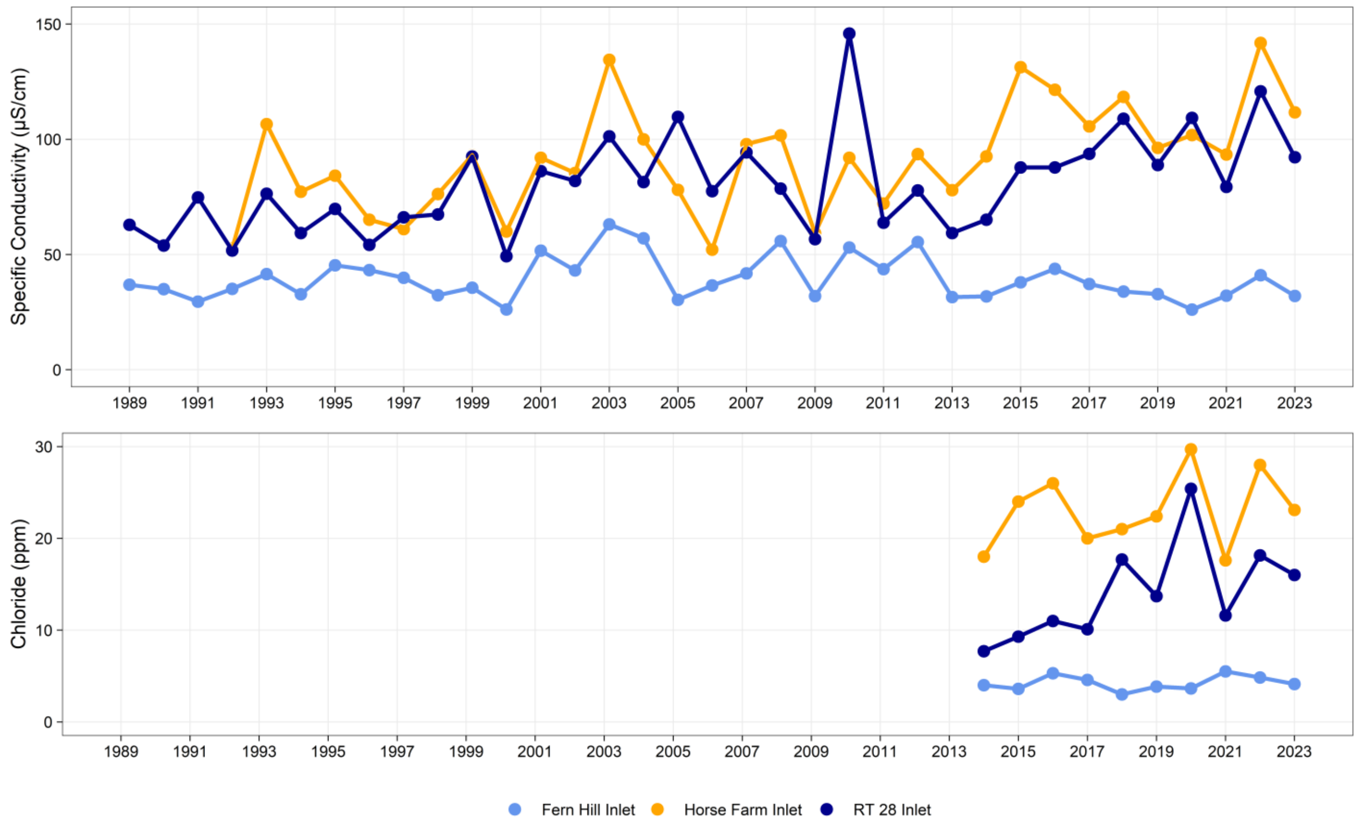


Figure 11. *[Top] Yearly median of monthly medians for specific conductivity at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). [Bottom] Yearly median of monthly medians for chloride at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). Statistically significant increasing trends were found for specific conductivity for the Horse Farm Inlet and Route 28 Inlet from 2013 to 2023 using a Mann-Kendall nonparametric trend test.*

2.1.11.3 pH

NHDES classified the Route 28 Inlet (HALALT28), Fern Hill Inlet (HALALTF), Dugans Inlet (HALALTD3), and Horse Farm Inlet [HALALTH] as impaired for low pH. Dugans Inlet and the Horse Farm Inlet are located along the same stream—only the Horse Farm Inlet has data within the past 10 years, so the Horse Farm Inlet will be used for this analysis. The pH at all three inlets appears to be consistently low (acidic) from 1989-2023, with the Horse Farm Inlet having the lowest pH (Figure 12). Over the past ten years, the Horse Farm Inlet has had a median pH of 6.3, less than the NHDES standard which is between 6.5 and 8.0 (Table 4). The Fern Hill Inlet and Route 28 Inlet have median pH values of 6.6 and 6.5, respectively, meaning they are nearing the bottom of the NHDES threshold, and any further decreases in pH may lead to adverse effects on the biologic community.

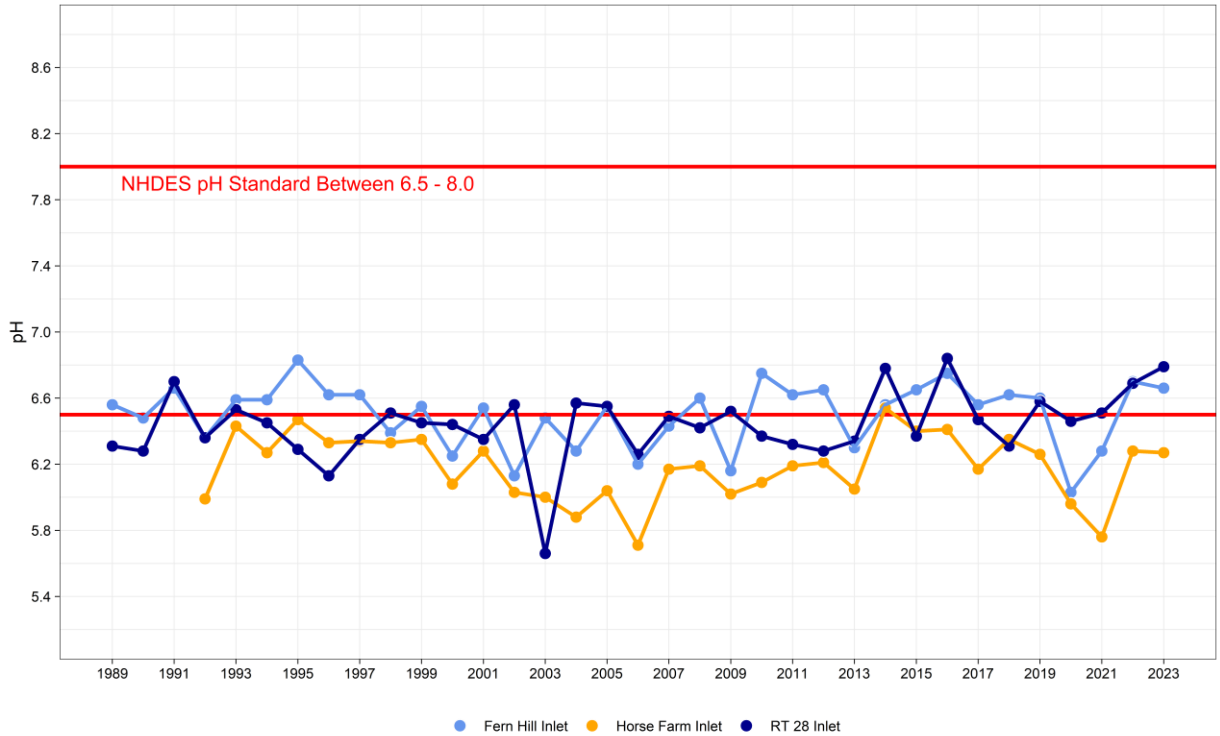


Figure 12. *Yearly median of monthly medians for pH at the Fern Hill Inlet (HALALTF), Horse Farm Inlet (HALALTH), and Route 28 Inlet (HALALT28). Values were converted to the concentration of hydrogen ions before being summarized and logarithmically transformed back to the pH scale.*

Table 4. *Median values of each water quality parameter for the three long-term stations. Existing water quality data summarized by day, then month, then year using the median statistic to create a recent data summary (2014-2023), historical data summary (1989-2013), and all data summary (1989-2023) Median pH values were determined by converting the value to the concentration of hydrogen ion before summarizing and logarithmically transforming back to the pH scale.*

Site	Parameter	Recent 10 Year Median	Historic Median	All Year Median
Halfmoon Lake – Fern Hill Inlet (HALALTF)	Total Phosphorus (ppb)	30.4	15.0	22.0
	Turbidity (NTU)	1.4	0.8	1.0
	Chloride (ppm)	4.1	-	4.1
	Specific Conductivity (µS/cm)	33.4	39.9	36.9
	pH	6.6	6.5	6.6
Halfmoon Lake – Horse Farm Inlet (HALALTH)	Total Phosphorus (ppb)	29.3	30.3	30.3
	Turbidity (NTU)	4.0	3.9	4.0
	Chloride (ppm)	22.8	-	22.8
	Specific Conductivity (µS/cm)	108.7	81.1	92.9
	pH	6.3	6.2	6.2
Halfmoon Lake – Route 28 Inlet (HALALT28)	Total Phosphorus (ppb)	58.4	53.0	53.0
	Turbidity (NTU)	5.3	4.3	4.7
	Chloride (ppm)	12.7	-	12.7
	Specific Conductivity (µS/cm)	90.5	74.8	78.6
	pH	6.5	6.4	6.4

2.2 ASSIMILATIVE CAPACITY

The assimilative capacity of a waterbody describes the amount of pollutant that can be added to a waterbody without causing a violation of the water quality criteria based on lake trophic designation. Halfmoon Lake is a borderline oligotrophic/mesotrophic waterbody; however, the mesotrophic designation was largely attributed to a degradation in dissolved oxygen in the bottom waters. For enhanced protection of water quality, the oligotrophic designation was selected for running the assimilative capacity analysis for Halfmoon Lake. For oligotrophic waterbodies, the water quality criteria are set at 8 ppb for total phosphorus and 3.3 ppb for chlorophyll-a, above which the waterbody is considered impaired. NHDES requires 10% of the difference between the best possible water quality and the water quality standard be kept in reserve; therefore, total phosphorus and chlorophyll-a must be at or below 7.2 ppb and 3.0 ppb, respectively, to achieve Tier 2 High Quality Water status by NHDES. Support determinations are based on the nutrient stressor (phosphorus) and response indicator (chlorophyll-a), with chlorophyll-a dictating the assessment if both chlorophyll-a and total phosphorus data are available and the assessments differ.

Results of the assimilative capacity analysis show that Halfmoon Lake is impaired for the oligotrophic class designation (

Table **7**). The existing median total phosphorus and chlorophyll-a concentrations exceed the assimilative capacity threshold, indicating that reductions in the total phosphorus load are likely needed to reduce the chlorophyll-a concentration to meet the 3.0 ppb threshold and reduce the risk of possible cyanobacteria blooms.

Table 5. *Aquatic life integrity (ALI) nutrient criteria ranges by trophic class in New Hampshire. TP = total phosphorus. Chl-a = chlorophyll-a, a surrogate measure for algae.*

Trophic State	TP (ppb)	Chl-a (ppb)
Oligotrophic	< 8.0	< 3.3
Mesotrophic	> 8.0 - 12.0	> 3.3 - 5.0
Eutrophic	> 12.0 - 28.0	> 5.0 - 11.0

Table 6. *Decision matrix for aquatic life integrity (ALI) assessment in New Hampshire. TP = total phosphorus. Chl-a = chlorophyll-a, a surrogate measure for algae concentration.*

Nutrient Assessments	TP Threshold Exceeded	TP Threshold NOT Exceeded	Insufficient Info for TP
Chl-a Threshold Exceeded	Impaired	Impaired	Impaired
Chl-a Threshold NOT Exceeded	Potential Non-support	Fully Supporting	Fully Supporting
Insufficient Info for Chl-a	Insufficient Info	Insufficient Info	Insufficient Info

Table 7. *Assimilative capacity (AC) analysis results for Halfmoon Lake (station HALALTD).*

Parameter	AC Threshold (ppb)	Existing Median WQ (ppb)*	Remaining AC (ppb)	Assessment Results
Total Phosphorus	7.2	9.2	-2.0	Impaired
Chlorophyll-a	3.0	3.6	-0.6	Impaired

** Existing water quality data truncated to May 24-Sept 15 in the previous 10 years (2014-2023) for composite, epilimnion, or upper samples (in order of priority on a given day). Data were summarized by day, then month, then year using median statistics.*

2.3 BEACHES E. COLI DATA SUMMARY

Beaches on Halfmoon Lake are regularly sampled for fecal contamination using the indicator bacteria *Escherichia coli (E. coli),* to protect the health of swimmers and other users of the beach. Long-term *E. coli* data exists for a few sites along the shoreline, with other sites only having available data from 2012-2018. Fecal contamination in lake beaches may occur from various sources, such as wildlife/waterfowl, recreation, and nearby failing septic systems. NHDES sets the water quality criteria for a designated beach on a Class B waterbody at a geometric mean of 47 MPN/100mL and a single sample criterion of 88 MPN/100mL for *E. coli*. All sites fell below the NHDES geomean standard for all years, except for the left side of Crescent Drive Beach (HALBRNCDBL) in 2018. Despite meeting the NHDES criteria, all long-term sampling sites (Public Beach, Rustic Shores, Boys Camp, and Hollywood Beach) and one other site (Dalton Drive Beach – Left) showed statistically significant increasing trends in *E. coli* levels from 1995 to present or 2012 to present, indicating that fecal contamination has increased slowly over time. Numerous single samples exceedances have occurred since sampling began, including at the Public Beach (2012, 2022), Crescent Drive Beach – Left (2013, 2015, 2017, 2018), Crescent Drive Beach – Right (2013, 2017, 2018), Crescent Drive Beach – Center (2019), New Castle Beach (2017, 2018), Dalton Drive Beach – Left (2017, 2018), and Dalton Drive Beach – Right (2017). Increasing *E. coli* levels can pose a health risk to lake users and are often caused by sources of contamination that also lead to elevated nutrient levels, such as nuisance waterfowl or underperforming/failing septic systems.

2.4 2024 WATER QUALITY SUMMARY

Water quality data for Halfmoon Lake and its tributaries were collected in 2024 by VLAP volunteers and FBE as part of routine VLAP monitoring and investigative monitoring to inform the watershed management planning effort. According to preliminary data from routine 2024 VLAP monitoring, the median epilimnion total phosphorus concentration for the year was 9.2 ppb, and the median composite (0-5 meters or 0-7 meters depth) chlorophyll-a concentration was 4.5 ppb. While the median epilimnion total phosphorus concentration aligned with the median concentration from 2014-2023, the median chlorophyll-a concentration was slightly higher (+0.9 ppb). Future monitoring will be useful in determining whether higher chlorophyll-a concentrations in 2024 were a result of typical variability observed across years in lakes, sampling variability from the specific dates chosen for monitoring, or reflective of worsening water quality.

Tributaries to Halfmoon Lake were observed to be comparable to previous years, with the Route 28 Inlet continuing to have the highest total phosphorus concentration (52 ppb), and Fern Hill having the lowest (27.1 ppb). All three streams that are regularly sampled had low pH, which is consistent with previous years.

Additional stratified grab samples were collected specifically in September at HALALTD throughout the season when internal loading and anoxia are typically at their peak. Sampling extended into the end of September to better characterize and understand internal phosphorus loading in the lake. Internal phosphorus loading can occur when dissolved oxygen is below 2mg/L. In this anoxic environment, phosphorus bound to lake bottom sediments is released back into the water column. Therefore, we compared total phosphorus concentrations at different depths throughout the season (Figure 13). As summer stratification strengthens in August through September, this prevents the mixing of water between layers to replenish dissolved oxygen in the hypolimnion, leading to a consistently anoxic hypolimnion and an increase in total phosphorus. Additional sources of phosphorus in the hypolimnion include sinking detritus or buoyancy-regulating cyanobacteria, which have been observed in Halfmoon Lake's hypolimnion in previous years. This occurrence will persist until air temperatures cool, stratification weakens, and the waters are mixed during fall turnover.

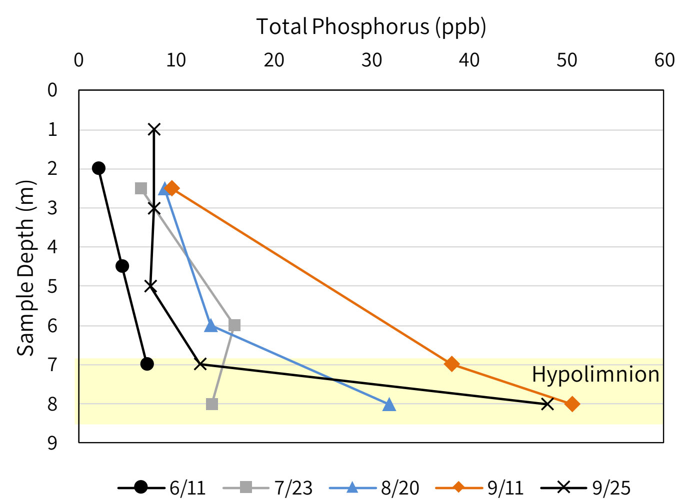


Figure 13. *Total phosphorus grab sample results collected from HALALTD at varying depths from June through September, 2024. The hypolimnion is highlighted in light yellow.*

Halfmoon Lake experienced one cyanobacteria bloom in 2024 beginning on 9/4, which featured a diverse mix of *Dolichospermum*, *Wornichinia*, and *Planktothrix* with a cell density of 1,050,000 cells/mL. After the bloom, FBE collected a screening-level phytoplankton tow at the deep spot of Halfmoon Lake to better understand the phytoplankton communities in the lake. The tow was taken through nearly the entire water column (0-8 meters) and captured all phytoplankton >80 µm. The phytoplankton in the sample were very diverse and were dominated by diatoms (primarily *Asterionella*) and golden-brown algae (primarily *Chrysosphaerella*). Cyanobacteria were common, with *Planktothrix*, *Dolichospermum*, and *Woronichinia* all being present. *Planktothrix* were the most common cyanobacteria. Other common phytoplankton include *Dinobryon* (golden-brown), *Fragilaria*, *Tabellaria*, and *Aulacoseira* (diatom), *Ceratium* (dinoflagellate), *Mallomonas* and *Synura* (synurophyte), *Staurastrum* (desmid), and *Mougeotia* (filamentous green). Zooplankton were also abundant in the sample, with *Daphnia* (cladoceran), a keystone predator in lakes, being most abundant. The zooplankton community was diverse, with *Calanoid* and *Cyclopoid* (copepod), Nauplius (copepod larvae), *Bosmina* (cladoceran), and *Keratella* and *Kellicottia* (rotifer) being common.

2.5 WATERSHED MODELING

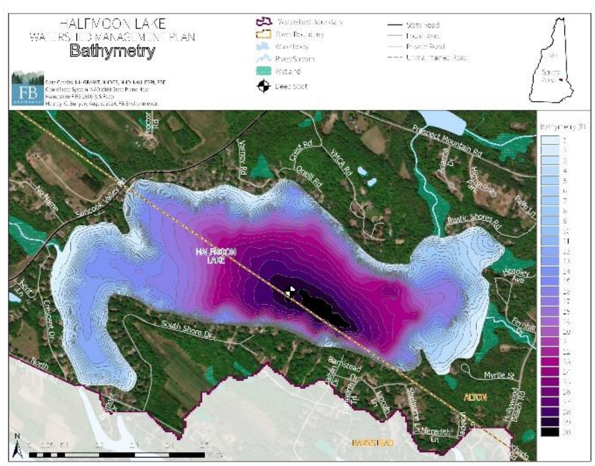
2.5.1 Lake Loading Response Model (LLRM)

Environmental modeling is the process of using mathematics to represent the natural world. Models are created to explain how a natural system works, to study cause and effect, or to make predictions under various scenarios. Environmental models range from very simple equations that can be solved with pen and paper, to highly complex computer software requiring teams of people to operate. Lake models, such as the Lake Loading Response Model (LLRM), can make predictions about phosphorus concentrations, chlorophyll-a concentrations, and water clarity under different pollutant loading scenarios. These types of models play a key role in the watershed planning process. EPA guidelines for watershed plans require that pollutant loads to a waterbody be estimated.

The LLRM is an Excel-based model that uses environmental data to develop a water and phosphorus loading budget for lakes and their tributaries (AECOM, 2009). Water and phosphorus loads (in the form of mass and concentration) are traced from various sources in the watershed through tributary basins and into the lake. The model incorporates data about watershed and sub-watershed boundaries, land cover, point sources (if applicable), septic systems, waterfowl, rainfall, volume and surface area, and internal phosphorus loading. These data are combined with coefficients, attenuation factors, and equations from scientific literature on lakes, rivers, and nutrient cycles to generate annual average predictions[3] of total phosphorus, chlorophyll-a, Secchi disk transparency, and algal bloom probability. The model can be used to identify current and future pollutant sources, estimate pollutant limits and water quality goals, and guide watershed improvement projects. A complete detailing of the methodology employed for the Halfmoon Lake LLRM is provided in the *Halfmoon Lake Loading Response Model Report* (FBE, 2024a).

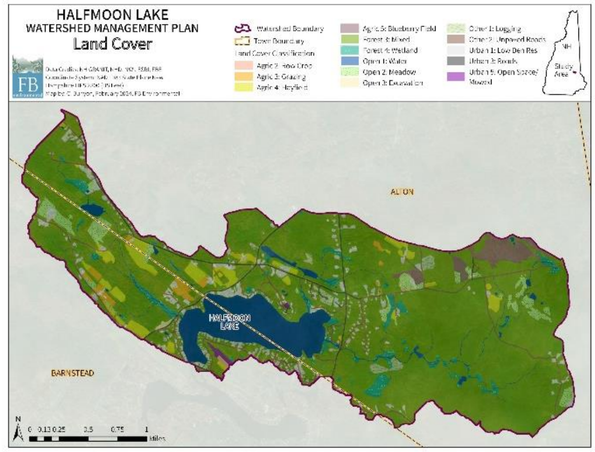
2.5.1.1 Lake Morphology & Flow Characteristics

The morphology (shape) and bathymetry (depth) of lakes and ponds are considered reliable predictors of water clarity and lake ecology. Large, deep lakes are typically clearer than small, shallow lakes as the differences in lake area, number and volume of upstream lakes, and **flushing rate** affect lake function and health.



The surface area of Halfmoon lake is 288.8 acres (4.3 miles of shoreline), with a maximum depth of 27 feet (8.2 m) and volume of approximately 5,192,372 m^3 (Appendix A, Map A-1). The **areal water load** is 31.1 ft/yr (9.482 m/yr), and the flushing rate is 2.13 times per year. The flushing rate of 2.13 means that the entire volume of Halfmoon Lake is replaced 2.13 times each year.

[3] The model cannot simulate short-term weather or loading events.



There are 10 identified dams in the watershed historically or currently controlling water flow, with one located at the outlet of the lake on the southern boundary of the watershed (NHDES, 2022d).

2.5.1.2 Land Cover

Characterizing land cover within a watershed on a spatial scale can highlight potential sources of NPS pollution that would otherwise go unnoticed in a field survey of the watershed. For instance, a watershed with large areas of developed land and minimal forestland will likely be more at risk for NPS pollution than a watershed with well-managed development and large tracts of undisturbed forest, particularly along headwater streams. Land cover is also the essential element in determining how much phosphorus is contributing to a surface water body via stormwater runoff and baseflow.

Current land cover in the Halfmoon Lake watershed was determined by FBE using a combination of published datasets on NH GRANIT and ESRI World Imagery from May 26, 2023, and Google Earth satellite imagery from October 10, 2020. For more details on methodology, see the *Halfmoon Lake Loading Response Model Report* (FBE, 2024a). Refer also to Appendix A, Map A-2. As of the 2023/2020 aerial imagery, development accounts for 9% (316 acres) of the watershed, while forested and natural areas account for 79% (2,803 acres). Wetlands and open water represent 5% (178 acres) of the watershed, not including the surface area of Halfmoon Lake. Agriculture represents 7% (244 acres).

Figure 14 shows a breakdown of land cover by major category for the entire watershed (not including lake area), as well as total phosphorus load by major land cover category (FBE, 2024a). Developed areas cover 9% of the watershed and contribute 52% of the total phosphorus watershed load to Halfmoon Lake.

Developed areas within the Halfmoon Lake watershed are characterized by **impervious surfaces**, including areas with asphalt, concrete, compact gravel, and rooftops that force rain and snow that would otherwise soak into the ground to run off as stormwater. Stormwater runoff carries pollutants to waterbodies that may be harmful to aquatic life, including sediments, nutrients, pathogens, pesticides, hydrocarbons, and metals.

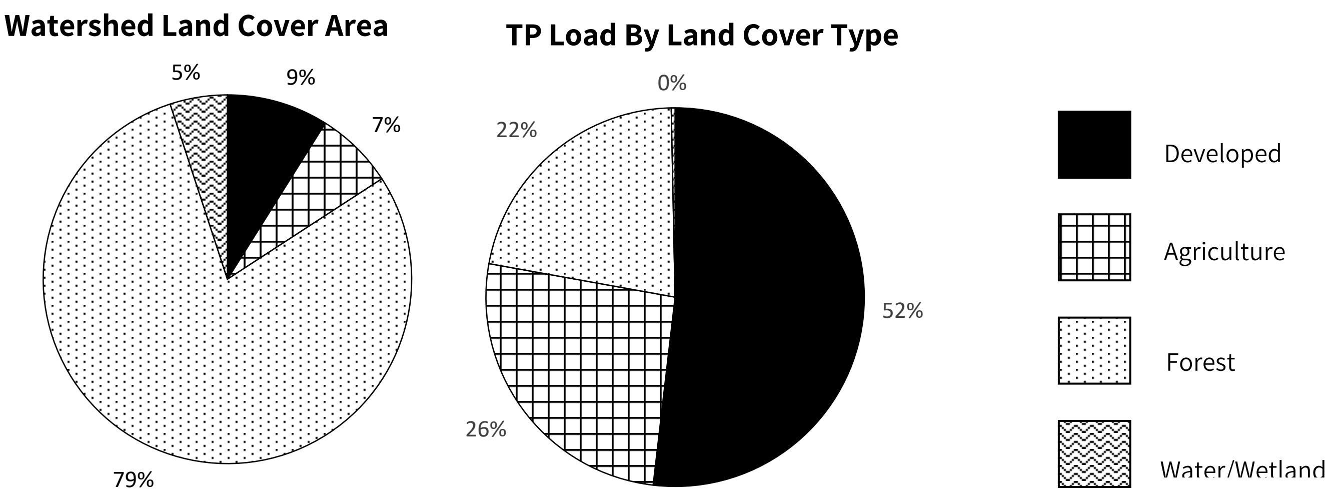


Figure 14. *Halfmoon Lake watershed land cover area by general category (developed, agriculture, forest, and water/wetlands) and total phosphorus (TP) watershed load by general land cover type. The water/wetlands category does*

not include the lake area. This shows that developed areas cover 9% of the watershed and contribute 52% of the TP watershed load to Halfmoon Lake.

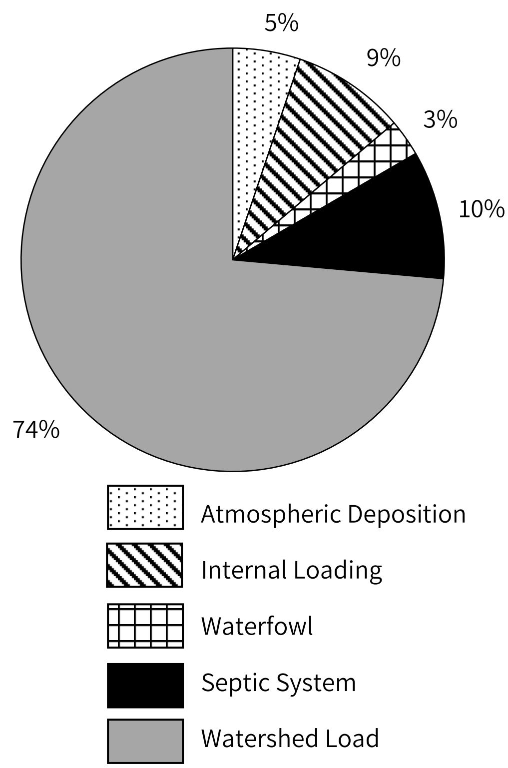


Figure 15. *Summary of total phosphorus loading by major source for Halfmoon Lake. Refer to Table 9 for breakdown.*

2.5.1.3 Internal Phosphorus Loading

Phosphorus that enters the lake and settles to the bottom can be re-released from sediment under anoxic conditions, providing a nutrient source for algae, cyanobacteria, and plants. Internal phosphorus loading can also result from wind-driven wave action or physical disturbance of the sediment (boat props, aquatic macrophyte management activities). Internal loading estimates were derived from dissolved oxygen and temperature profiles taken at the deep spot of Halfmoon Lake (to determine average annual duration and depth of anoxia defined as <2 ppm dissolved oxygen) and epilimnion/hypolimnion total phosphorus data taken at the deep spot of Halfmoon Lake (to determine average difference between surface (epilimnion) and bottom (hypolimnion) phosphorus concentrations). These estimates, along with anoxic volume and surface area, helped determine rate of release and mass of annual internal phosphorus load. The internal load estimate in any given year was highly variable and warrants further investigation.

2.5.1.4 LLRM Results

Overall, model predictions were in good agreement with observed data for total phosphorus, chlorophyll-a, and Secchi disk transparency (Table 8). It is important to note that the LLRM does not explicitly account for all the biogeochemical processes occurring within a waterbody that contribute to overall water quality and is less accurate at predicting chlorophyll-a and Secchi disk transparency. For example, chlorophyll-a is estimated strictly from nutrient loading, but other factors strongly affect algae growth, including transport of phosphorus from the sediment-water interface to the water column by cyanobacteria, low light from suspended sediment, grazing by zooplankton, presence of heterotrophic algae, and flushing effects from high flows. There were insufficient data available to evaluate the influence of these other factors on observed chlorophyll-a concentrations and Secchi disk transparency readings.

Watershed runoff combined with baseflow (74%) was the largest phosphorus loading contribution across all sources to Halfmoon Lake, followed by shorefront septic systems at 10% and internal loading at 9% (Table 9;Figure 15). Atmospheric deposition (5%) and waterfowl (3%) were relatively minor sources.

Development in the watershed is most concentrated around the shoreline where septic systems or holding tanks are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures (known or unknown), which leach untreated, nutrient-rich wastewater effluent to the lake. Note that 1) the estimate for the septic system load is only for those systems within 300 feet of the shoreline and potentially short-circuiting minimally treated effluent to the lake; and 2) the load from septic systems throughout the rest of the watershed is inherent to the coefficients used to generate the watershed load. Large swaths of agriculture in the upper watershed to the west of the lake, particularly in the Route 28 Inlet and Public Beach Inlet subwatersheds, may also be responsible for excess phosphorus loading to Halfmoon Lake and are accounted for in the Watershed Load of Figure 15. Internal loading, whereby low dissolved oxygen in bottom waters is causing a release of phosphorus from sediments, was estimated as a minor but important source of phosphorus to the lake. Watershed protection efforts should focus on reducing the watershed and septic system loads.

Normalizing for the size of a sub-watershed (i.e., accounting for its annual discharge and direct drainage area) better highlights sub-watersheds with elevated pollutant exports relative to their drainage area. Sub-watersheds with moderate-to-high phosphorus mass exported by area (> 0.20 kg/ha/yr) generally had more development or agriculture (i.e., the direct shoreline area to Halfmoon Lake and the Public Beach Inlet; Table 4, Figure 16). Drainage areas directly adjacent to waterbodies have direct connection to lakes and are usually targeted for development, thus increasing the possibility for phosphorus export. Agricultural areas, even far from the lake shoreline, can increase the potential for phosphorus export due to fertilizer use, soil disturbance, animal waste, and alteration to the landscape often associated with these land uses.

Once the model is calibrated for current in-lake phosphorus concentration, we can then manipulate land cover and other factor loadings to estimate pre-development loading scenarios (e.g., what in-lake phosphorus concentration was prior to human development or the best possible water quality for the lake). Refer to FBE (2024a) for details on methodology. Pre-development loading estimation showed that total phosphorus loading to Halfmoon Lake increased by 304%, from 61.6 kg/yr prior to European settlement to 248.6 kg/yr under current conditions (Table 9). These additional phosphorus sources are coming from development in the watershed (especially from the direct shoreline of Halfmoon Lake and agricultural areas in the Public Beach Inlet, Route 28 Inlet, and Fern Hill subwatersheds), septic systems, internal loading, and atmospheric dust. Water quality prior to settlement was predicted to be excellent with extremely low phosphorus and chlorophyll-a concentrations and high water clarity (Table 8).

We can also manipulate land cover and other factors to estimate future loading scenarios (e.g., what in-lake phosphorus concentration might be at full build-out under current zoning constraints or the worst possible water quality for the lake). Refer to FBE (2024a) and the *Halfmoon Lake Watershed Build-out Analysis* (FBE, 2024b) for details on methodology. Note: the future scenario did not assume a 10% increase in precipitation over the next century (NOAA, 2013), which would have resulted in a lower predicted in-lake phosphorus concentration; this is because the model does not consider the rate and distribution of the projected increase in precipitation. Climate change models predict more intense and less frequent rain events that may exacerbate erosion of phosphorus-laden sediment to surface waters and therefore could increase in-lake phosphorus concentration (despite dilution and flushing impacts that the model assumes).

Future loading estimation showed that total phosphorus loading to Halfmoon Lake may increase by 114%, from 248.6 kg/yr under current conditions to 532.4 kg/yr at full build-out (estimated by 2065) under current zoning for the Halfmoon Lake watershed (Table 9). Additional phosphorus will be generated from more development in the watershed, enhanced internal loading, greater atmospheric dust, and more septic systems (Table 9). The model predicted higher (worse) phosphorus (25.5 ppb), higher (worse) chlorophyll-a (10.2 ppb), and lower (worse) water clarity (1.9 m) compared to current conditions for Halfmoon Lake (Table 8). The number of bloom days may increase from a modeled average of 18 days currently to a modeled average of 215 days at full build-out (Table 8). Bloom Days represent average annual probability of chlorophyll-a exceeding 8 ppb.

Table 8. *In-lake water quality predictions for Halfmoon Lake. TP = total phosphorus. Chl-a = chlorophyll-a. SDT = Secchi disk transparency. Bloom Days represent average annual probability of chlorophyll-a exceeding 8 ppb.*

Model Scenario	Median TP (ppb)	Predicted Median TP (ppb)	Mean Chl-a (ppb)	Predicted Mean Chl-a (ppb)	Mean SDT (m)	Predicted Mean SDT (m)	Bloom Days
Pre-Develop.	--	3.0	--	0.5	--	10.0	0
Current (2023)	9.0 (11.8)	11.9	3.7	3.9	4.4	3.5	18
Future (2065)	--	25.5	--	10.2	--	1.9	215

**Mean TP concentration (first value) represents current in-lake epilimnion TP from observed data. Median TP concentration (second value in parentheses) represents 20% greater than the observed mean value as the value used to calibrate the model. Most lake data are collected in summer when TP concentrations are typically lower than annual average concentrations for which the model predicts.*

Table 9. *Total phosphorus (TP) and water loading summary by source for Halfmoon Lake.*

SOURCE	PRE-DEVELOPMENT			CURRENT (2023)			FUTURE (2065)		
	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)
ATMOSPHERIC	8.2	13%	1,457,756	12.9	5%	1,457,756	29.2	5%	1,457,756
INTERNAL	0.0	0%	0	21.5	9%	0	46.0	9%	0
WATERFOWL	7.0	11%	0	7.0	3%	0	7.0	1%	0
SEPTIC SYSTEM	0.0	0%	0	24.3	10%	19,272	28.1	5%	23,925
WATERSHED LOAD	46.5	75%	9,628,952	182.9	74%	9,603,959	422.2	79%	9,575,111
TOTAL LOAD TO LAKE	**61.6**	**100%**	**11,086,708**	**248.6**	**100%**	**11,080,986**	**532.4**	**100%**	**11,056,792**

Table 10. *Summary of land area, water flow, and total phosphorus (TP) concentration and loading by sub-watershed for Halfmoon Lake. Land area does not include the area of the lake.*

Sub-Watershed	Land Area (ha)	Pre-Development Watershed Loads				Current (2023) Watershed Loads					Future (2065) Watershed Loads			
		Water Flow (m^3/year)	Calc. P Conc. (mg/L)	P mass (kg/year)	P mass by area (kg/ha/year)	Water Flow (m^3/year)	Calc. P Conc. (mg/L)	Measured P Conc. (mg/L)	P mass (kg/year)	P mass by area (kg/ha/year)	Water Flow (m^3/year)	Calc. P Conc. (mg/L)	P mass (kg/year)	P mass by area (kg/ha/year)
Halfmoon Lake Direct Drainage	209.3	1,479,594	0.004	6.3	0.03	1,466,731	0.037	--	53.9	0.26	1,461,956	0.047	68.7	0.33
Dugans and Horse Farm Inlet	252.8	1,679,687	0.005	7.6	0.03	1,670,411	0.017	0.029	28.3	0.11	1,644,436	0.043	71.1	0.28
Fern Hill Inlet	643.2	4,275,653	0.005	20.7	0.03	4,278,654	0.011	0.030	47.1	0.07	4,301,272	0.040	170.9	0.27
Public Beach Inlet	44.9	316,512	0.005	1.7	0.04	314,928	0.039	--	12.4	0.28	303,838	0.098	29.6	0.66
Route 28 Inlet	283.2	1,877,505	0.005	10.3	0.04	1,873,236	0.022	0.058	41.1	0.15	1,863,608	0.044	81.8	0.29

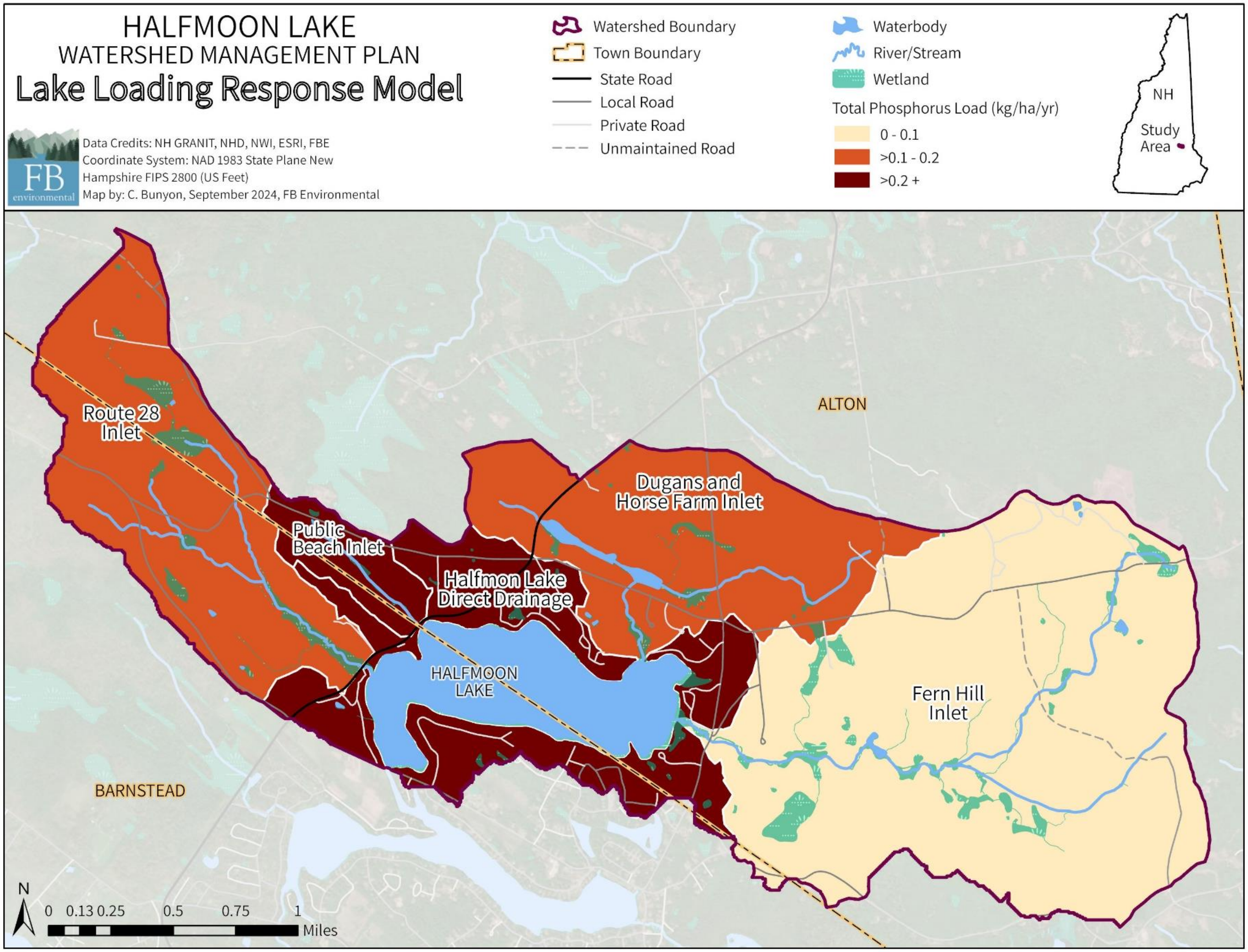


Figure 16. *Map of current total phosphorus load per unit area (kg/ha/yr) for each sub-watershed in the Halfmoon Lake watershed. Higher phosphorus loads per unit area are concentrated in the more developed direct shoreline area.*

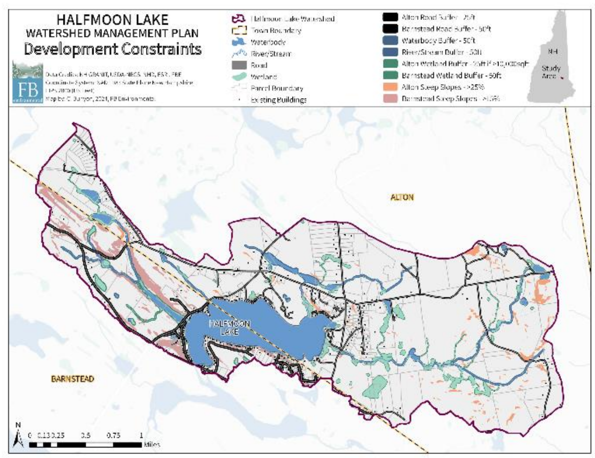
2.5.2 Build-out Analysis

A full build-out analysis was completed for the Halfmoon Lake watershed for the municipalities of Alton and Barnstead (FBE, 2024b). A build-out analysis identifies areas with development potential and projects future development based on a set of conditions (e.g., zoning regulations, environmental constraints) and assumptions (e.g., population growth rate). A build-out analysis shows what land is available for development, how much development can occur, and at what densities. "Full Build-out" is a theoretical condition representing the moment in time when all available land suitable for residential, commercial, and industrial uses has been developed to the maximum capacity permitted by local ordinances and zoning standards. Local ordinances and zoning standards are subject to change, and the analysis requires simplifying assumptions; therefore, the results of the build-out analysis should be viewed as planning-level estimates only for potential future outcomes from development trends.

FULL BUILD-OUT is a theoretical condition representing the moment in time when all available land suitable for residential, commercial, and industrial uses has been developed to the maximum capacity permitted by current local ordinances and current zoning standards.

To determine where development may occur within the study area, the build-out analysis first subtracts land unavailable for development due to physical constraints, including environmental restrictions (e.g., wetlands, conserved lands, hydric soils), zoning restrictions (e.g., shoreland zoning, street Right-of-Ways (ROWs), and building setbacks), and practical design considerations (e.g., lot layout inefficiencies) (Appendix A, Map A-5). Existing buildings also reduce the capacity for new development.

The build-out analysis showed that 79% (2,701 acres) of the watershed is buildable under current zoning regulations (Appendix A, Map A-6). FBE identified 416 existing principal buildings within the watershed, and the build-out analysis projected that an additional 762 buildings could be constructed in the future resulting in a total of 1,178 buildings in the watershed. Currently, existing buildings are the densest along the shoreline of Halfmoon Lake, so most of the projected buildings fall outside the direct shoreline area in expansive forested or agricultural areas of Alton and Barnstead, respectively. All zones within the study area have a current minimum lot size of 2 acres. With more of the watershed area in Alton than Barnstead, more projected buildings can be found in the Alton portion. Additional roadways would need to be built throughout the watershed for these projected buildings to be accessible.



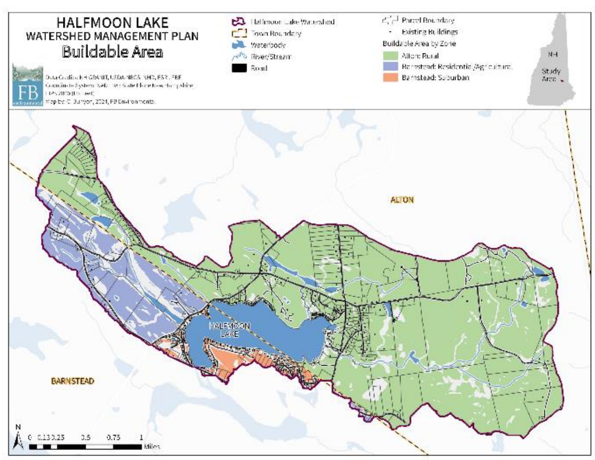


Table 11. *Amount of buildable land and projected buildings in the Halfmoon Lake watershed, in Alton and Barnstead, NH .*

Zone	Total Area (Acres)	Buildable Area (Acres)	Percent Buildable Area	Total No. Existing Buildings	Total No. Projected Buildings	Total No. Buildings	Percent Increase
Alton							
Rural	*2,740*	*2,283*	*83%*	*231*	*627*	*858*	*271%*
Barnstead							
Residential-Agricultural	*531*	*343*	*65%*	*25*	*95*	*120*	*380%*
Suburban District	*154*	*75*	*48%*	*160*	*40*	*200*	*25%*
Total	**3,425**	**2,701**	**79%**	**416**	**762**	**1,178**	

Four iterations of the TimeScope Analysis were run using compound annual growth rates (CAGR) for 10-, 20-, 30- and 50-year periods from 2010-2020 (0.94%), 2000-2020 (2.57%), 1990-2020 (2.67%), and 1970-2020 (2.76%), respectively (Table 12). Full build-out is projected to occur in 2135 at the 10-year CAGR, 2065 at the 20-year CAGR, 2063 at the 30-year CAGR, and 2062 for the 50-year CAGR (Figure 17).

Note that the growth rates used in the TimeScope Analysis are based on town-wide census statistics but have been applied here to a portion of the municipalities. If areas closer to the lake within each municipality develop faster than more inland areas, watershed full buildout conditions may occur sooner. Also note that the population growth rate in these municipalities is decreasing, so the 10 or 20-year estimate is likely more accurate than the 50-year estimate. Using census data to project population increase and/or development has inherent limitations. For instance, the building rate may increase at a different rate than population, due to factors such as commercial versus residential development and number of people per household. Many projected buildings would also require the development of new roadways which is a factor that would affect the rate of development. As such, the TimeScope Analysis might over or underestimate the time required for the study area to reach full build-out. Numerous social and economic factors influence population change and development rates, including policies adopted by federal, state, and local governments. The relationships among the various factors may be complex and therefore difficult to model.

Table 12. *US Census Bureau population and growth rates for the towns of Alton and Barnstead, NH, 1970-2020. Population estimates obtained from the NH Office of Strategic Initiatives.*

	Compound Annual Growth Rate			
Town	**50 yr. Avg. 1970-2020**	**30 yr. Avg. 1990-2020**	**20 yr. Avg. 2000-2020**	**10 yr. Avg. 2010-2020**
Alton	2.58%	2.23%	1.97%	1.36%
Barnstead	3.00%	1.55%	1.18%	0.68%
Towns Combined	**2.76%**	**2.67%**	**2.57%**	**0.94%**

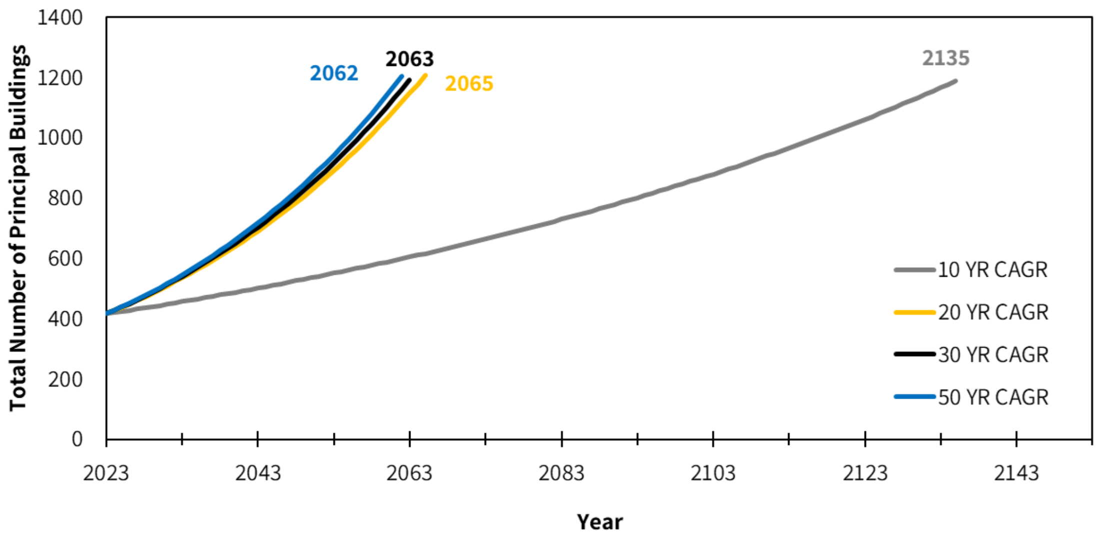


Figure 17. *Full build-out time projections of the Halfmoon Lake Watershed in Alton and Barnstead, NH (based on compound annual growth rates reported in Table 12).*

2.6 WATER QUALITY GOAL & OBJECTIVES

The model results revealed changes in total phosphorus loading and in-lake total phosphorus concentrations over time from pre-development through future conditions, showing that the water quality of Halfmoon Lake is threatened by current development activities in the watershed and will degrade further with continued development in the future. We can use these results to make informed management decisions and set an appropriate water quality goal for Halfmoon Lake. In-lake chlorophyll-a and total phosphorus concentrations indicate that the lake is currently in mesotrophic standing. To improve the water quality with the goal of approaching an oligotrophic standing, strong objectives must be established to protect and improve the water quality of Halfmoon Lake over the long term, especially given that the lake has experienced cyanobacteria blooms in the past and is threatened by new development.

We recommended that the annual average total phosphorus concentration for Halfmoon Lake be reduced from a predicted 11.9 ppb to 8.1 ppb, slightly on the mesotrophic side of the oligotrophic-phosphorus-plus-20% water quality criterion to represent annual average conditions. This equates to a 33% (45 kg/yr) reduction in the total phosphorus load to Halfmoon Lake. This reduction would put the chlorophyll-a predicted values into oligotrophic attainment at 3.0 ppb. It is important to note that meeting an oligotrophic water quality criterion for chlorophyll-a in Halfmoon Lake may not be enough to prevent cyanobacteria blooms due to external factors such as climate change. More data and evaluation of changes in Halfmoon Lake's water quality response to stressors would be needed to adjust this recommended goal any more stringently.

The goal of the Halfmoon Lake WMP is to improve the water quality of Halfmoon Lake such that it meets state water quality standards for the protection of Aquatic Life Integrity (ALI) and Primary Contact Recreation (PCR), and substantially reduce the likelihood of harmful cyanobacteria blooms in the lake. This goal will be achieved by accomplishing the following objectives. More detailed action items to achieve these objectives will be provided in the action plan of the WMP.

> **Objective 1:** Reduce phosphorus loading from existing development by 33% (45 kg/yr) to Halfmoon Lake to improve the average in-lake summer or annual total phosphorus concentration to 8.1 ppb and annual chlorophyll-a concentration to 3.0 ppb.
>
> **Objective 2:** Mitigate (prevent or offset) phosphorus loading from future development by 3.2 kg/yr to Halfmoon Lake to maintain average summer in-lake total phosphorus concentration in the next 10 years.

Reality Check: The watershed survey identified 19 sites impacting the lake. Remediating these sites could prevent up to 23.4 kg/yr of phosphorus from entering Halfmoon Lake. Treating shoreline sites could reduce the phosphorus load to Halfmoon Lake by 1.16 kg/yr[4] for the two high impact sites (disturbance score 11+), 5.78 kg/yr[5] for the 20 medium impact sites (disturbance score between 9-10), and 4.92 kg/yr[6] for the 34 low impact sites (disturbance score between 7-8) identified from the shoreline survey. Upgrading the 97 shorefront septic systems older than 25 years is estimated to reduce the phosphorus load to Halfmoon Lake by 9.7 kg/yr. **In sum, treating existing pollutant sources identified as coming from the external watershed load could reduce the phosphorus load to Halfmoon Lake by 45 kg/yr, which meets 100% of Objective 1 for Halfmoon Lake.** Non-structural best management practices (BMPs) such as educating homeowners about septic system maintenance, fertilizer use, and residential stormwater management may be effective at reducing phosphorus loading to Halfmoon Lake and meet the water quality goal by preventing septic system failures, reducing the amount of fertilizer used on residential lawns, and encouraging stormwater management at the property-scale.

Objective 2 can be met through ordinance revisions that implement low impact development strategies and encourage cluster development with open space protection and/or through conservation of key parcels of forested and/or open land.

The interim goals for each objective allow flexibility in re-assessing water quality objectives following more data collection and expected increases in phosphorus loading from new development in the watershed over the next 10 or more years (Table 13). Understanding where water quality will be following watershed improvements compared to where water quality would have been following no action will help guide adaptive changes to interim goals (e.g., goals are on track or goals are

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[4] Based on PLET model bank stabilization estimate for fine sandy loams, using 200 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.
[5] Based on PLET model bank stabilization estimate for fine sandy loams, using 100 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.
[6] Based on PLET model bank stabilization estimate for fine sandy loams, using 50 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

falling short). If the goals are not being met due to lack of funding or other resources for implementation projects versus due to increases in phosphorus loading from new development outpacing reductions in phosphorus loading from improvements to existing development, then this creates much different conditions from which to adjust interim goals. For each interim goal year, stakeholders should update the water quality data and model and assess if and why goals are or are not being met (refer to Section 6.5: Indicators to Measure Progress for environmental indicators). Stakeholders will then decide on how to adjust the next interim goals to better reflect water quality conditions and practical limitations to implementation.

Table 13. *Summary of water quality objectives for Halfmoon Lake. Interim goals/benchmarks are cumulative.*

Water Quality Objective	**Interim Goals/Benchmarks**		
	2026	**2029**	**2034**
1. Reduce phosphorus loading from existing development by 33% (45 kg/yr) to Halfmoon Lake to improve average in-lake summer or annual total phosphorus concentration to 8.1 ppb.			
	Achieve **7.25%** (11.25 kg/yr) reduction in TP loading to Halfmoon Lake.	Achieve **16.5%** (22.5 kg/yr) reduction in TP loading to Halfmoon Lake; re-evaluate water quality and track progress	Achieve **33%** (45 kg/yr) reduction in TP loading to Halfmoon Lake; re-evaluate water quality and track progress
2. Mitigate (prevent or offset) phosphorus loading from future development by 3.2 kg/yr to Halfmoon Lake to maintain average summer in-lake total phosphorus concentration in the next 10 years (2034).			
	Prevent or offset **0.8 kg/yr** in TP loading from new development to Halfmoon Lake.	Prevent or offset **1.6 kg/yr** in TP loading from new development to Halfmoon Lake; re-evaluate water quality and track progress	Prevent or offset **3.2 kg/yr** in TP loading from new development to Halfmoon Lake; re-evaluate water quality and track progress

3 POLLUTANT SOURCE IDENTIFICATION

This section describes sources of excess phosphorus to Halfmoon Lake. Sources of phosphorus to lakes include stormwater runoff, shoreline erosion, construction activities, illicit connections, failed or improperly functioning septic systems, leaky sewer lines, fabric softeners and detergents in greywater, fertilizers, and pet, livestock, and wildlife waste. These external sources of phosphorus to lakes can then circulate within lakes and settle on lake bottoms, contributing to internal phosphorus loads over time. Additional phosphorus sources can enter the lake from atmospheric deposition but are not addressed here because of limited local management options. Wildlife is mentioned as a potential source but largely for nuisance waterfowl such as geese or ducks that may be congregating in large groups because of human-related actions such as feeding or having easy shoreline access (i.e., lawns). Climate change is also not a direct source but can exacerbate the impact of the other phosphorus sources identified in this section and should be considered when striving to achieve the water quality objectives.

3.1 WATERSHED DEVELOPMENT

NPS pollution comes from many diffuse sources on the landscape and is more difficult to identify and control than point source pollution. NPS pollution can result from contaminants transported by overland runoff (e.g., agricultural runoff or runoff from suburban and rural areas), groundwater flow, or direct deposition of pollutants to receiving waters. Examples of NPS pollution that can contribute nutrients to surface waters via runoff, groundwater, and direct deposition include erosion from disturbed ground or along roads, stormwater runoff from developed areas, malfunctioning septic systems, excessive fertilizer application, unmitigated agricultural activities, pet waste, and wildlife waste.

3.1.1 Watershed Survey

A watershed survey of the Halfmoon Lake watershed was completed by technical staff from FBE. The objective of the watershed survey was to identify and characterize sites contributing NPS pollution and/or providing opportunities to mitigate NPS pollution in the watershed. Prior to the field work, FBE solicited input from HMLA, community members, and the Pilgrim Pines Camp about locations with known NPS pollution. FBE also analyzed aerial images and GIS data for land use/land cover, roads, municipal drainage system, public properties, waterbodies, and other features. This information enabled FBE to better plan for the survey (e.g., to target known or likely high-polluting sites, such as unpaved roads, beaches, highly impervious areas, etc.) and to inform recommended solutions.

Sediment accumulation of road due to erosion, uphill from the Barnstead Boat Ramp.

FBE conducted the watershed survey in April of 2024. For each location, field staff recorded site data and photographs on tablets. Information collected included location description and GPS coordinates; NPS problem description and measurements (e.g., gully dimensions); receiving waterbody; discharge type (direct or indirect/limited); and preliminary recommendations to mitigate the NPS problem. Field staff accessed sites from public and private roads and waterfront access points.

FBE identified 19 problem sites in the watershed (Figure 18). The main issues found were road and ditch erosion and buffer clearing. FBE estimated the potential pollutant removal that could be achieved by implementing recommendations. The BMP Matrix included as Appendix B summarizes the recommendations, load reduction estimates, and estimated costs for each site. The top five high priority sites (based on lowest impact-weighted cost per mass of phosphorus removed) are shown below. In addition to these specific sites, managers of both private and public roads should use best practices for road installation and maintenance for water quality protection.

Priority Site #1. 1-02: Boat Ramp and Road Shoulder – Barnstead

Location (latitude, longitude): 43.3873, -71.2400

Impact: High

Observations: The surface of the privately owned and steeply sloping boat ramp on North Barnstead Road contains a large amount of loose sediment which has been eroding directly into Halfmoon Lake. Looking uphill, the road shoulder of Crescent Road is eroding on both sides of the road, which directs stormwater runoff to the boat ramp. According to watershed residents, gullies form in the road shoulders on each side of North Barnstead Road during every large storm event. Watershed residents mentioned that these gullies are frequently repaired though the southern road shoulder gully continues to overtop the road and contributes stormwater flow to the boat ramp. The southern road shoulder is designed so that runoff from the road and nearby agricultural field flows down the road shoulder and into the stream that connects Halfmoon Lake to Locke Lake. However, an undersized culvert prevents water from moving downhill to the stream, so stormwater flows across the road and down the boat ramp into Halfmoon Lake. According to watershed residents, this site has been washing out for over 30 years.

The eroding road shoulder leading to the North Barnstead Rd boat ramp.

Recommendations: Regular road maintenance to maintain proper crowning to the southern road shoulder will also help decrease the amount of stormwater volume reaching the boat ramp. The road shoulder ditches should be armored with rip rap and check dams to slow stormwater movement and promote infiltration. The culvert on the south side of the road should be enlarged and inspected for blockages frequently to accommodate peak stormflow. Continue conversations with the boat ramp owners to repair the boat ramp. The repairs may include installing permeable pavers and subsurface stabilizers to prevent further erosion from the loose surface material while continuing to allow access to the lake. Engage with local farmers about agricultural BMPs such as a larger vegetated buffer between the fields and the road to prevent agricultural runoff from reaching the road and the nearby lakes.

Priority Site #2. 1-11: Public Boat Launch on Route 28 – Alton

Location (latitude, longitude): 43.3958, -71.2367

Impact: High

Observations: A gap in the shoreline buffer along Route 28 was observed at a site used as a boat launch. The sandy substrate showed evidence of erosion into Halfmoon Lake from the boat launch to mile marker 59. According to the Town of Alton tax forms, the property is town-owned and is used by Marine Patrol for boat access. Watershed residents specify that Marine Patrol does not often use this access point, and typically use the other boat ramp on Rt 28 in Barnstead. However, this site is frequently used by local fishermen.

Recommendations: Armor nearby road ditches with check dams and rip rap to reduce the amount and velocity of stormwater reaching the boat ramp area. Repair gullies in the launch area and consider adding subsurface interlocking stabilizers to create a well-defined boat ramp. Assess the use of the lot and enhance the shoreline buffer in sections where access is not necessary. Additionally, disconnecting or removing impervious (or compacted sand) surfaces where not needed can add space for additional stormwater controls and prevent erosion of the launch area. Consider defining an access point with a dock or wooden launch for canoes/kayaks to prevent erosion and vegetation trampling at the water's edge.

(Top) View of unpaved lot that serves as public access to Halfmoon Lake. (Bottom) View of the access point from the water as seen during the Shoreline Survey.

Priority Site #3. 1-06: Dalton Drive Beach Ramp – Barnstead

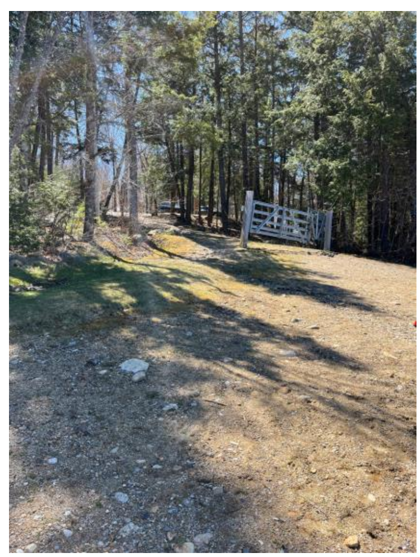
Location (latitude, longitude): 43.3882, -71.2248

Impact: High

Observations: Stormwater runoff begins on the very steep and unpaved/residential Dalton Road before leading down a steeply sloped paved parking lot and down to the beach area on Halfmoon Lake. On the east side of the road, there is a large gully leading through a slightly crushed culvert, under a driveway, and continuing down the road shoulder. Large gullies serve as a signal that erosion is occurring at the site as sediment has moved downslope along with stormwater. Under low flow, stormwater travels through this gully and continues through a culvert with a possibly buried outlet. Under high flow conditions, the stormwater flows within the ditch and across the road surface before continuing across the beach surface. On the beach, there are many signs of shoreline erosion, including small gullies and rills.

Unpaved parking lot and steeply sloping land adjacent to Dalton Drive Beach and Halfmoon Lake. There is forest between the beach and lot.

Recommendations: First, sweep the paved area for any loose debris. Then, install water bars and rubber razors approximately every 20 feet along the unpaved section of the road. Rubber razors direct stormwater away from the road surface and into ditches or forested areas, preventing stormwater from accumulating on the road. Install ditches on the road shoulder that are armored with rip rap or grass and check dams or coir logs. Check dams or coir logs may be used to slow stormwater movement and trap sediment while promoting retention for infiltration. Water bars may be installed on the beach in upslope areas to prevent runoff from the road from forming gullies on the beach. These will also direct stormwater into more vegetated areas. Leverage existing funding through the Locke Lake Association to implement stormwater controls at Dalton Drive Beach and ensure that improvements to lake access and recreation are completed in a lake-friendly manner that considers stormwater, vegetated buffers, and other best management practices.



(Left) Road shoulder erosion on the side of the parking lot to the beach area. (Middle) Road shoulder erosion leading down from the parking lot. (Right) Gullies lead down from the road onto the beach and ultimately into the lake.

<u>Priority Site #4</u>. 1-05: YMCA Road – Alton

Location (latitude, longitude): 43.3983, -71.2265

Impact: Medium

Observations: There are large amounts of road shoulder erosion and bare soil on both sides of YMCA road before the intersection of Crest Road. Stormwater follows road shoulder erosion channel into the forested area where it enters a wetland. The wetland flows under the road through a crushed, undersized, and clogging culvert to form a stream that ultimately outlets to Halfmoon Lake toward the end of Varney Road. Depending on the rainfall in the area, the blocked/undersized culvert can significantly impact the hydrology of the site, according to watershed residents. The road is currently maintained by local residents who have access to the proper machinery and equipment to keep the road drivable.


(Left) Culvert is slightly crushed. (Right) Bare soil and eroding road shoulder has caused a channelized path for stormwater.

Recommendations: Convert the erosion channel into a vegetated swale, complete with grass/vegetation and check dams. Consider amending soils with biochar (while avoiding nutrient amendments) to promote and stabilize vegetation growth if necessary. Create a small rain garden or a bioretention area or constructed wetland (depending on soil conditions) at the end of the channel before the stormwater enters the wetland with wetland plants that can tolerate high sun exposure. According to the USDA-NRCS soil survey, the soil in the area is sandy and very poorly drained (high water table). Constructed wetlands may be more suitable than bioretention in poorly drained areas. Assess which green stormwater infrastructure practice is suitable based on on-site soil conditions, which may require an engineer. Ensure the culvert is not filling with sediment and clean out the culvert as needed.

<u>Priority Site #5</u>. 1-12: Oneill Road – Alton

Location (latitude, longitude): 43.3962, -71.2274

Impact: Medium

Observations: Stormwater flows down Crest Road, turns the corner, and follows the steeply sloping O'Neill Road to erode a bare ditch leading to a road culvert that crosses the road and discharges to a wooded (possible wetland) area on private shoreline property. The backslope of the ditch was seeping shallow groundwater into the ditch at the time of the survey. Bare soil areas at the corner were eroding into the ditch.


(Left) Road shoulder erosion and bare soil on Crest Road at the intersection of O'Neill Road. Consider if the bare soil area is a suitable site for a rain garden. (Right) Eroding ditch looking west, downhill on O'Neill Road.

Recommendations: Remove plow berms and stabilize the ditch with rip rap and install check dams to slow stormwater movement and capture sediment. Alternatively, plant grass in bare soil areas to stabilize the soil. Consider amending soils with biochar (while avoiding nutrient amendments) to promote and stabilize vegetation growth if necessary. Consider if a rain garden is applicable on the corner of Crest and O'Neill Roads to capture stormwater from uphill on Crest Road. A rain garden would limit the amount of stormwater and sediment that travels downhill to Oneill Road. Consider installing a plunge pool at the culvert outlet at the discretion of the homeowner.

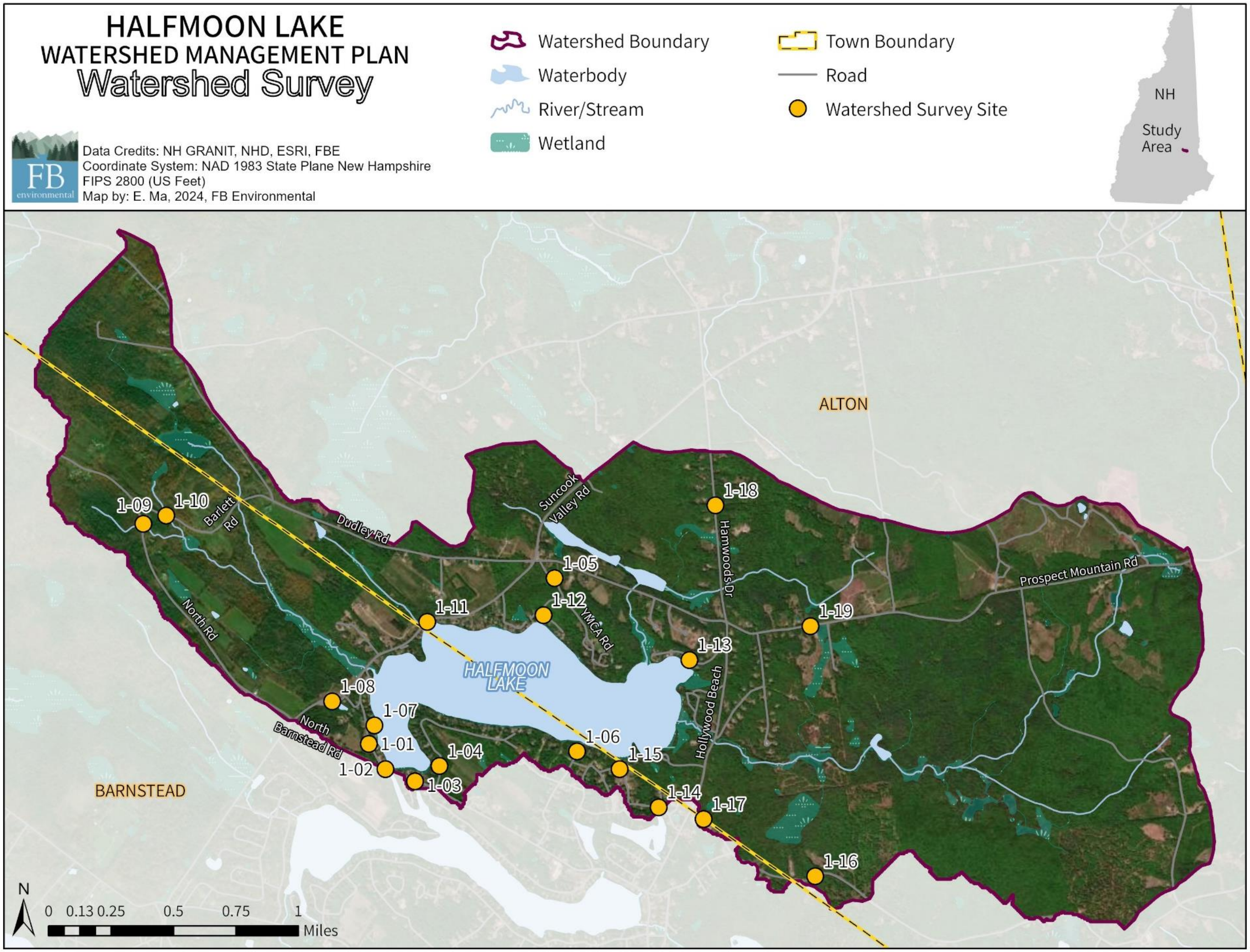


Figure 18. *Location of identified nonpoint source sites in the Halfmoon Lake watershed.*

3.1.2 Shoreline Survey

FBE technical staff, assisted by the HMLA president and the local water quality monitor, conducted a shoreline survey of Halfmoon Lake on June 12, 2024. The shoreline survey uses a simple scoring method to highlight shoreline properties around the lake that exhibit significant erosion. This method of shoreline survey is a rapid technique to assess the overall condition of properties within the shoreland zone and prioritize properties for technical assistance or outreach. One boat was used for surveying parcels with lake frontage. Technical staff and volunteers documented the condition of the shoreline for each parcel using a scoring system that evaluates vegetated buffer, presence of bare soil, extent of shoreline erosion, distance of structures to the lake, and slope. These scores were summed to generate an overall "Shoreline Disturbance Score" and "Shoreline Vulnerability Score" for each parcel, with high scores indicating poor or vulnerable shoreline conditions. Photos were taken at each parcel and were cataloged by tax map-lot number. These photos will provide HMLA with a valuable tool for assessing shoreline conditions over time. It is recommended that a shoreline survey be conducted in mid-summer every five years to evaluate changing conditions.

A total of 146 parcels were evaluated along the shoreline of Halfmoon Lake in Alton and Barnstead. The average Shoreline Disturbance Score (Buffer, Bare Soil, and Shoreline Erosion) for the entire lake was 6.12 (Table 14). About 38% of the shoreline (or 56 parcels) scored 7 or greater. A disturbance score of 7 or above indicates shoreline conditions that may be detrimental to lake water quality. These shoreline properties tended to have inadequate buffers, evidence of bare soil, and shoreline erosion. The average Shoreline Vulnerability Score (Distance and Slope) was 3.95 (Table 14). About 79% (or 116 parcels) scored 4 or greater. A vulnerability score of 4 or greater indicates that the parcel may have a home less than 150 ft. from the shoreline and a moderate or steep slope to the shoreline. Parcels with a vulnerability score of 4 or greater are more prone to erosion issues whether or not adequate buffers and soil coverage are present.

Table 14. *Average scores for each evaluated condition criterion and the average Shoreline Disturbance Score and average Shoreline Vulnerability Score for Halfmoon Lake. Lower values indicate shoreline conditions that are effective at reducing erosion and keeping excess nutrients out of the lake.*

Evaluated Condition	Average Score
Buffer (1-5)	3.05
Bare Soil (1-4)	1.69
Shoreline Erosion (1-3)	1.37
Shoreline Disturbance Score (3-12)	**6.12**
Distance (0-3)	2.41
Slope (1-3)	1.53
Shoreline Vulnerability Score (1-6)	**3.95**

The pollutant loading estimates are based on the Shoreline Disturbance Scores. The 56 parcels with elevated disturbance scores (greater than 7), are contributing an estimated 23.71 kg of phosphorus annually[7]. Remediation efforts on all properties using a 50% Best Management Practices (BMP) efficiency rate could result in an annual reduction of 11.86 kg of phosphorus.

Certain site characteristics, such as slope, can cause shorelines to be naturally more vulnerable to erosion. Other site characteristics such as structure distance to the lake, are often a direct consequence of the historic development on that parcel and cannot be easily changed. Shoreline buffers and amount of exposed soil are more easily changed to strengthen the resiliency of the shoreline to disturbance in the watershed.

[7] Based on Region 5 model bank stabilization estimate for fine sandy loams, using 50 ft or 100 ft or 200 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

In summary, the overall average shoreline condition of Halfmoon Lake is good (average disturbance score below 7). Improvements can be made to combat erosion issues with 56 properties (38%) needing to address erosion issues that are impacting the lake. Halfmoon Lake is also generally more prone to erosion issues because many homes are located close to shore and on moderate to steep slopes (average vulnerability score is 3.9).

Scores should be used to prioritize areas of the shoreline for remediation. Recommendations largely include improving shoreline vegetated buffers. Encouraging landowners to plant and/or maintain vegetated buffers as a BMP along their shoreline, particularly in areas of bare soil, will help mitigate erosion and reduce sediment and nutrient loading to the lake.

3.1.3 Soil & Shoreline Erosion

Erosion can occur when ground is disturbed by digging, construction, plowing, foot or vehicle traffic, or wildlife. Rain and associated runoff are the primary pathways by which eroded soil reaches lakes and streams. Once in surface waters, nutrients are released from the soil particles into the water column, causing excess nutrient loading to surface waters or cultural eutrophication. Since development demand near lakes is high, construction activities in lake watersheds can be a large source of nutrients. Unpaved roads and trails used by motorized vehicles near lakes and streams are especially vulnerable to erosion. Stream bank erosion can also have a rapid and severe effect on lake water quality and can be triggered or worsened by upstream impervious surfaces like buildings, parking lots, and roads which send large amounts of high velocity runoff to surface waters. Maintaining natural vegetative buffers around lakes and streams and employing strict erosion and sedimentation controls for construction can minimize these effects.

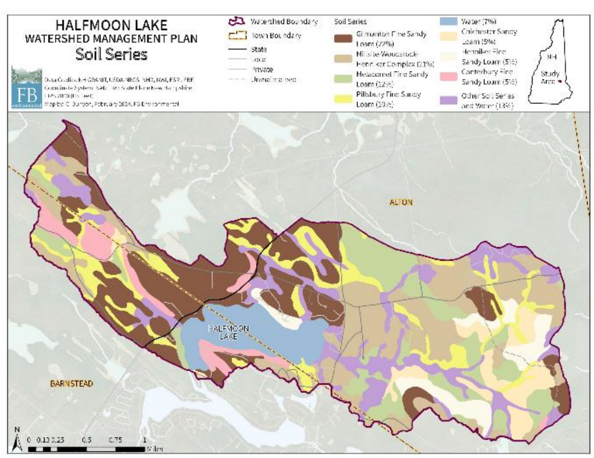
3.1.3.1 Surficial Geology

The composition of soils in the area reflect the dynamic geological processes that have shaped the landscape of New Hampshire over millions of years. Some 300 to 400 million years ago, much of the northeastern United States was covered by a shallow sea; layers of mineral deposition compressed to form sedimentary layers of shale, sandstone, and limestone (Goldthwait, 1951). Over time, the Earth's crust then folded under high heat and pressure to change the sedimentary rocks into metamorphic rocks (quartzite, schist, and gneiss parent material). This metamorphic parent material has since been modified by bursts of molten material intrusions to form igneous rock, including granite for which New Hampshire is famous for (Goldthwait, 1951). Erosion has further modified and shaped this parent material over the last 200 million years.

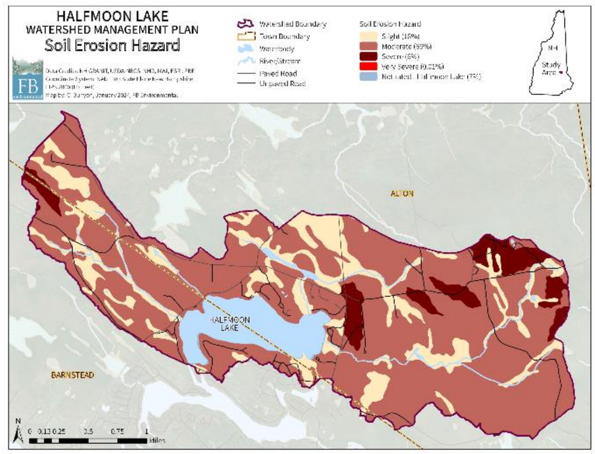
The current landscape formed 12,000 years ago at the end of the Great Ice Age, as the mile-thick glacier over half of North America melted and retreated, scouring bedrock and depositing glacial till to create the deeply scoured basin of the region's lakes. The retreating action also eroded mountains and left behind remnants of drumlins and eskers from ancient stream deposits. The glacier deposited a layer of glacial till more than three feet deep. Glacial till is composed of unsorted material, with particle sizes ranging from loose and sandy to compact and silty to gravely. This material laid the foundation for vegetation and streams as the depression basins throughout the region began to fill with water (Goldthwait, 1951). According to the USGS Statewide Aquifer Transmissivity data layer provided through the NH GRANIT, there are no high-yielding aquifers beneath the surface of the Halfmoon Lake watershed, though many exist within the towns of Alton and Barnstead.

3.1.3.2 Soils and Erosion Hazard

The soils in the Halfmoon Lake watershed (Appendix A, Map A-8) are a direct result of geologic processes. Of the 15 different soil series present within the Halfmoon Lake watershed (excluding soils beneath waterbodies), the most prevalent soil group in the watershed is Gilmanton Fine Sandy Loam (853 acres, 24%), followed by Millsite-Woodstock-Henniker Complex (793 acres, 22.3%), Metacomet Fine Sandy Loam (473 acres, 13.3), and Pillsbury Fine Sandy Loam (380 acres, 10.7%). Millsite-Woodstock-Hennicker and Metacomet are moderaly well-drained soil, with Millsite being well drained and Phillsbury poorly drained. The remaining 29.6% of the watershed (excluding the lake area) is a combination of 47 additional soil series ranging from 5.2% to 0.15% of the watershed.



Soil erosion hazard is dependent on a combination of factors, including land contours, climate conditions, soil texture, soil composition, permeability, and soil structure (O'Geen et al., 2006). Soil erosion hazard should be a primary factor in determining the rate and placement of development within a watershed. Soils with negligible soil erosion hazard are primarily low-lying wetland areas near abutting streams. The soil erosion hazard is determined from the associated slope and soil erosion factor K_w[8] used in the Universal Soil Loss Equation (USLE). The USLE predicts the rate of soil loss by sheet or rill erosion in units of tons per acre per year. A rating of "slight" specifies erosion is unlikely to occur under standard conditions. A rating of "moderate" specifies some erosion is likely and erosion-control measures may be required. A rating of "severe" specifies erosion is very likely and erosion-control measures and revegetation efforts are crucial. A rating of "very severe" specifies significant erosion is likely and control measures may be costly. These ratings are derived as part of the Soil Erosion Hazard Off-Road/Off-Trail for each soil series. Excluding the lake area, "severe" and "very severe" erosion hazard areas account for 6.4% of the Halfmoon Lake watershed and are mostly concentrated on the western portion of the watershed (Appendix A, Map A-9). Moderate erosion hazard areas account for 68.5% of the watershed land area. The remaining watershed area has soils not rated for the soil erosion factor K_w and/or located in low-lying areas with slopes less than 15%. Development should be restricted in areas with severe and very severe erosion hazards due to their inherent tendency to erode at a greater rate than what is considered tolerable soil loss. Since a highly erodible soil can have greater negative impact on water quality, more effort and investment are required to maintain its stability and function within the landscape, particularly from BMPs that protect steep slopes from development and/or prevent stormwater runoff from reaching water resources.



3.1.3.3 Shoreline Erosion

Water level fluctuations in lakes and ponds can occur on long- and short-term timescales due to naturally changing environmental conditions or as a response to human activity. The effect of lake level fluctuation on physical and environmental conditions depends on several factors including the degree of change in water level, the rate of change, seasonality, and the size and depth of the waterbody (Leira & Cantonati, 2008; Zohary & Ostrovsky, 2011). Changes in lake level can impact flora and fauna mainly by altering available habitat, impacting nesting locations, and altering available food sources. In addition to impacts to the biological communities, lakes can experience physical impacts on water quality from changes in lake level. Frequent lake level fluctuations can impact the shoreline, leading to erosion and increased sedimentation in near-shore habitats, inhibiting light penetration and altering water clarity. Exposed shoreline sediment that is inundated at high water levels can release phosphorus, leading to alterations in nutrient accumulation and algae populations. High and low water levels can have detrimental effects on water systems, so finding a balance in managing water level at appropriate times throughout the year is critical to maintaining a healthy waterbody for both recreational enjoyment and aquatic life use. Management strategies become even more challenging when considering the impact of increased wake boating and extreme weather events (droughts and storms) on water level. Residents of the Halfmoon Lake watershed have expressed concern about enhanced watershed erosion throughout the watershed, but particularly along Route 28 which has led to a buildup of sediment at the Route 28 Inlet monitoring site.

3.1.4 Wastewater

3.1.4.1 Septic Systems

Untreated discharges of sewage (domestic wastewater) are prohibited regardless of source. An example of an NPS discharge of untreated wastewater is from insufficient or malfunctioning subsurface sewage treatment and disposal systems, commonly referred to as septic systems, but which also include holding tanks and cesspools. When properly designed, installed, operated, and maintained, septic systems can reduce phosphorus concentrations in sewage within a zone close to the system (depending on the development and maintenance of an effective biomat, the adsorption capacity

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[8] K_w = the whole soil k factor. This factor includes both fine-earth soil fraction and large rock fragments.

of the underlying native soils, and proximity to a restrictive layer or groundwater). Age, overloading, or poor maintenance can result in system failure and the release of nutrients and other pollutants into surface waters (EPA, 2016). Nutrients from insufficient septic systems can enter surface waters through surface overflow or breakout, stormwater runoff, or groundwater. Cesspools are buried concrete structures that allow solid sludge to sink to the bottom and surface scum to rise to the top and eventually leak out into surrounding soils through holes at the top of the structure. Holding tanks are completely enclosed structures that must be pumped regularly to prevent effluent back-up into the home.

HMLA completed a thorough review and inventory of available data on septic systems along the shoreline of Halfmoon Lake in the spring and early summer of 2024. The primary objective of this data survey was to determine the number of septic systems along the shoreline of Halfmoon Lake and the proportion of older septic systems. HMLA queried the NHDES OneStop online database for subsurface permits and reviewed Alton and Barnstead tax parcel records on file in each municipal office. There were 195 shoreline properties identified (within 300 feet of the shoreline), 161 of which had homes built on them (83%). Septic system permits and town records identified 39% of these homes had newer septic systems (≤ 25 years, and 60% had older septic systems (>25 years). If no record of septic installation or replacement was found, the age of the wastewater system was assumed to be the age of the home (63% of homes). FBE also acquired data on the seasonal or year-round use of waterfront homes from local knowledge during the Shoreline Survey, and HMLA collected data on the number of bedrooms per parcel during the septic system inventory. This data was used as data inputs of the LLRM model to adjust the load entering shoreland septic systems. The average home within 300 feet of the shoreline has 2.6 bedrooms, and 24% were known to be seasonal (25% were known to be occupied year-round, 12% did not have structures, and 39% were unknown).

FBE estimated the pollutant loading from shoreline septic systems using default literature values for daily water usage, phosphorus concentration output per person, and system phosphorus attenuation factors. The number of people using shoreline septic systems was calculated by multiplying the number of "old" (>25 years) and "new" (≤ 25 years) shoreline septic systems used seasonally or year-round by the number of bedrooms (as a surrogate for the average number of persons using the septic systems). As detailed in the *Halfmoon Lake Lake Loading Response Model Report* (FBE, 2024a), shoreline septic systems contribute 24.3 kg/yr of total phosphorus loading to Halfmoon Lake, comprising 10% of the total phosphorus load from all sources to the lake. Septic systems, cesspools, or holding tanks are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures, which leach untreated, nutrient-rich wastewater effluent directly to the lake.

3.1.5 Fertilizers

When lawn and garden fertilizers are applied in excessive amounts, in the wrong season, or just before heavy precipitation, they can be transported by rain or snowmelt runoff to lakes and other surface waters where they can promote cultural eutrophication and impair the recreational and aquatic life uses of the waterbody. Many states and local communities are beginning to set restrictions on the use of fertilizers by prohibiting their use altogether or requiring soil tests to demonstrate a need for any phosphate application to lawns.

3.1.6 Pets

In residential areas, fecal matter from pets can be a significant contributor of nutrients to surface waters. Each dog is estimated to produce 200 grams of feces per day, which contain concentrated amounts of phosphorus (CWP, 1999). If pet feces are not properly disposed, these nutrients can be washed off the land and transported to surface waters by stormwater runoff. Pet feces can also enter by direct deposition of fecal matter from pets standing or swimming in surface waters.

3.1.7 Agriculture

Agricultural activities, including dairy/cattle farming, raising livestock and poultry, growing crops, and keeping horses and other animals for pleasure or profit, involve managing nutrients. Agricultural activities are closely linked to water quality due to the potential for nutrient/pollutant runoff and soil erosion from farmland. Nonpoint pollution from agriculture, particularly surface runoff from farms, is a leading cause of water impairment in watersheds across the U.S. (Adler, 2013). Practices such as plowing, fertilizer/manure application, livestock grazing, and poor storage of nutrients can result in significant pollution if not managed carefully. Studies have shown that excessive or poorly timed application of fertilizers, can lead to the runoff of nutrients into nearby water bodies, contributing to problems like algal blooms and eutrophication leading to low dissolved oxygen (EPA, 2004). The key to nutrient application is to apply the right amount of nutrients at the right time. When appropriately applied to soil, synthetic fertilizers or animal manure can fertilize crops and restore nutrients to the land. When improperly managed, pollutants in manure can enter surface waters through several pathways, including surface runoff and erosion, direct discharges to surface water, spills and other dry-weather discharges, and leaching into soil and groundwater. For agricultural land use management strategies and resources, please see Section 4.2.8.

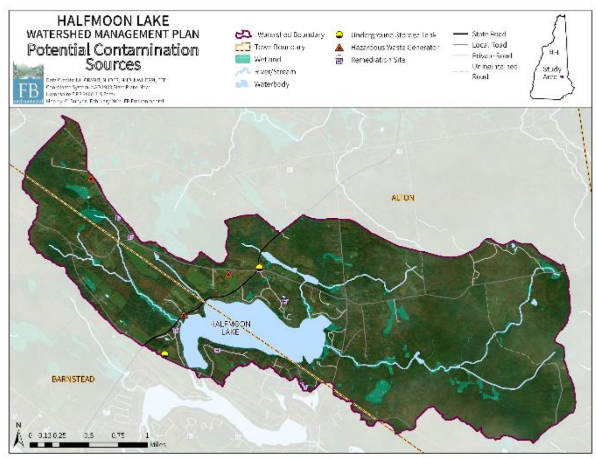
3.1.8 Future Development

Understanding population growth, and ultimately development patterns, provides critical insight to watershed management, particularly as it pertains to lake water quality. According to the US Census Bureau, Alton and Barnstead have experienced steady population growth since the middle part of the last century. Alton's population has increased from 1,647 people in 1970 to 5,895 people in 2020, while Barnstead's population has increased from 1,119 people in 1970 to 4,915 people in 2020. The desirability of Halfmoon Lake and the greater Lakes Reation/Lake Winnipesaukee area as a recreational destination will likely stimulate continued population growth in the future. Growth figures and estimates suggest that towns should continue to consider the effects of current municipal land-use regulations on local water resources. As the region's watersheds are developed, erosion from disturbed areas increases the potential for water quality decline.

3.2 POTENTIAL CONTAMINATION SOURCES

Point source (PS) pollution can be traced back to a specific source such as a discharge pipe from an industrial facility, municipal treatment plant, permitted stormwater outfall, or a regulated animal feeding operation, making this type of pollution relatively easy to identify. Section 402 of the CWA requires all such discharges to be regulated under the National Pollutant Discharge Elimination System (NPDES) program to control the type and quantity of pollutants discharged. NPDES is the national program for regulating point sources through issuance of permit limitations specifying monitoring, reporting, and other requirements under Sections 307, 318, 402, and 405 of the CWA.

NHDES operates and maintains the OneStop database and data mapper, which houses data on Potential Contamination Sources (PCS) within the State of New Hampshire. Identifying the types and locations of PCS within the watershed may help identify sources of pollution and areas to target for restoration efforts.



In February, 2024, FBE downloaded datasets for above ground storage tanks, underground storage tanks, automobile salvage yards, solid waste facilities, hazardous waste sites, local potential contamination sources, NPDES outfalls, and remediation sites in the Halfmoon Lake watershed. Out of the eight possible categories, only three occur in the watershed: remediation sites underground storage tanks, and hazardous waste generators (Appendix A, Map A-11).

3.2.1 Remediation sites

The eight remediation sites present within the Halfmoon lake watershed consist of multiple leaking oil tanks (both above and below ground), an unlined wastewater lagoon, an initial response spill, and multiple on-premises-use facilities containing fuel oil. Four of the remediation sites are in Alton and four are in Barnstead.

3.2.2 Underground storage tanks

The underground storage tank layer identifies the locations of registered underground storage tanks in New Hampshire. One is in Barnstead, which is a reported storage tank that has been permanently closed since 1998, and the one located in Alton was a gas station that has been permanently closed since 2005.

3.2.2 Hazardous Waste Generator

There are three hazardous waste generators located within the watershed, with two (inactive) in Alton and one (active) generator in Barnstead. The active hazardous waste generator has been in operation since 2000 and is regulated by the

Resource Conservation and Recovery Act (RCRA). The site qualifies as a “NH Small Quantity Generator,” producing no more than 220 pounds of non-acute hazardous waste per year.

3.3 WILDLIFE

Fecal matter from wildlife such as geese, gulls, other birds, and beaver may be a significant source of nutrients in some watersheds. This is particularly true when human activities, including the direct and indirect feeding of wildlife and habitat modification, result in the congregation of wildlife (CWP, 1999). Congregations of geese, gulls, and ducks are of concern because they often deposit their fecal matter next to or directly into surface waters. Examples include large mowed fields adjacent to lakes and streams where geese and other waterfowl gather, as well as the underside of bridges with pipes or joists directly over the water that attract large numbers of pigeons or other birds. Studies show that geese inhabiting **riparian** areas increase soil nitrogen availability (Choi et al., 2020) and gulls along shorelines increase phosphorus concentration in beach sand pore water that then enters surface waters through groundwater transport and wave action (Staley et al. 2018). When submerged in water, the droppings from geese and gulls quickly release nitrogen and phosphorus into the water column, contributing to eutrophication in freshwater ecosystems (Mariash et al., 2019). On a global scale, fluxes of nitrogen and phosphorus from seabird populations have been estimated at 591 Gg N per year and 99 Gg P per year, respectively (with the highest values derived from arctic and southern shorelines) (Otero et al., 2018). Additionally, other studies show greater concentrations of nitrogen, ammonia, and dissolved organic carbon downstream of beaver impoundments when compared to similar streams with no beaver activity in New England (Bledzki et al., 2010). Congregations of waterfowl were observed along the southwestern shores of Halfmoon Lake during the first HMLA meeting in of July of 2024, and community members noted geese and ducks can be regularly spotted swimming in the shallows. The LLRM estimated that waterfowl are likely contributing 7.0 kg/yr (3%) of the total phosphorus load to Halfmoon Lake.

3.4 CLIMATE CHANGE

Climate change will have important implications for water quality that should be considered and incorporated to WMPs. In the last century, New England has already experienced significant changes in stream flow and air temperature. Out of 28 rural stream flow stations throughout New England, 25 showed increased flows over the record likely due to the increase in frequency of extreme precipitation and total annual precipitation in the region. In 79 years of recorded flooding in the Oyster River in Durham, NH, three of the four highest floods occurred in the past 10 years (Ballestero et al., 2017). Average annual air temperature in New England has risen by 1°C to 2.3 °C since 1895 with greater increases in winter air temperature (IPCC, 2013). Lake ice-out dates are occurring earlier as warmer winter air temperature melts the snowpack and lake ice; earlier ice-out allows a longer growing season and increases the duration of anoxia in bottom waters. Increasing storm frequencies will flush more nutrients to surface waters for algae to feed on and flourish under warmer air temperatures.

These trends will likely continue to impact both water quality and quantity. Climate change models predict a 10-40% increase in stormwater runoff by 2050, particularly in winter and spring and an increase in both flood and drought periods as seasonal precipitation patterns shift. Adding to this stress is population growth and corresponding development in New Hampshire. The build-out analysis for the watershed showed that about 2,701 acres is still developable and up to 1,178 new buildings could be added to the watershed at full build-out based on current zoning standards. Halfmoon Lake is at serious risk for sustained water quality degradation with the possibility for new development in the watershed unless climate change resiliency and **low impact development** (LID) strategies are incorporated to existing zoning standards.

4 MANAGEMENT STRATEGIES

The following section details management strategies for achieving the water quality goal and objectives using a combination of structural and non-structural restoration techniques, as well as outreach and education and an adaptive management approach. A key component of these strategies is the idea that existing and future development can be remediated or conducted in a manner that sustains environmental values. All stakeholder groups have the capacity to be responsible watershed stewards, including citizens, businesses, the government, and others. Specific action items are provided in the Action Plan (Section 5).

4.1 STRUCTURAL NONPOINT SOURCE (NPS) RESTORATION

Structural NPS restoration techniques are engineered infrastructure designed to intercept stormwater runoff, often allowing it to soak into the ground, be taken up by plants, harvested for reuse, or released slowly over time to minimize flooding and downstream erosion. These BMPs often incorporate some mechanism for pollutant removal, such as sediment settling basins, oil separators, filtration, or microbial breakdown. They can also consist of removing or disconnecting impervious surfaces, which in turn reduces the volume of polluted runoff generated, minimizing adverse impacts to receiving waters.

4.1.1 Watershed & Shoreline BMPs

Nine-teen (19) NPS sites identified during the 2024 watershed survey and 22 high/medium impact rated shoreline properties from the 2024 shoreline survey were documented to have some impact to water quality through the delivery of phosphorus-laden sediment (refer to Section 3.1.1-3.1.2). As such, structural BMPs to reduce the external watershed phosphorus load are a necessary and important component for the protection of water quality in the watershed.

The following series of BMP implementation action items are recommended for achieving Objective 1:

- Address the top five high priority sites (and the remaining 14 medium and low priority sites as opportunities arise) identified during the 2024 watershed survey. The sites were ranked based on phosphorus load reduction and waterbody proximity. The full prioritization matrix with recommended improvements is provided in Appendix B.
- Provide technical assistance and/or implementation cost sharing to two high impact shoreline properties identified during the 2024 shoreline survey. Encourage landowners to implement stormwater and erosion controls on the 20 medium impact shoreline properties identified during the 2024 shoreline survey. Workshops and tours of demonstration sites can help encourage landowners to utilize BMPs on their own property. Conduct regular shoreline surveys to continue prioritizing properties for technical follow-up.

For the proper installation of structural BMPs in the watershed, HMLA and other stakeholders should work with experienced professionals on sites that require a high level of technical knowledge (engineering). Whenever possible, pollutant load reductions should be estimated for each BMP installed. More specific and additional recommendations are included in Section 5. For helpful tips on implementing BMPs, see Additional Resources.

4.2 NON-STRUCTURAL NONPOINT SOURCE (NPS) RESTORATION

Non-structural NPS restoration techniques refer to a broad range of behavioral practices, activities, and operational measures that contribute to pollutant prevention and reduction. The following section highlights important restoration techniques for several key areas, including pollutant reduction best practices, zoning and ordinance updates, land conservation, septic system regulation, sanitary sewer system inspections, fertilizer use prohibition, pet waste management, agricultural practices, nuisance wildlife controls, and in-lake treatment.

4.2.1 Pollutant Reduction Best Practices

Pollutant reduction best practices include recommendations and strategies for improving road management and municipal operations for the protection of water quality. Following standard best practices for road maintenance and drainage management protects both infrastructure and water quality through the reduction of sediment and other pollutant transport. Refer to the *New Hampshire Stormwater Manual* (NHDES, 2008) for standard road design and maintenance best practices.

Even though neither of the watershed towns are required to comply with the six minimum control measures under the New Hampshire Small MS4 General Permit, each town could consider instituting the permit's key measures, such as street sweeping, catch basin cleaning, and road/ditch maintenance, if not already in place. The MS4 permit also covers illicit discharge detection and elimination plans (and ordinance inclusion), source control and pollution/spill prevention protocols, and education/outreach and/or training for residents, municipal staff, and stormwater operators, all of which are aimed at minimizing polluted runoff to surface waters.

4.2.2 Zoning and Ordinance Updates

Regulations through municipal zoning and ordinances such as LID strategies that prevent polluted runoff from new and re-development projects in the watershed are equally important as implementing structural BMPs on existing development. In fact, local land use planning and zoning ordinances can be the most critical components of watershed protection. FBE completed a preliminary ordinance review of natural resource protections for the Towns of Alton and Barnstead (Table 15). Both of these towns have already incorporated several important regulations into their ordinances. A more robust review of these ordinances is encouraged for more specific recommendations for improving ordinances and regulations related to natural resource protection. The town should also consider its staffing capacity to enforce existing and proposed regulations.

Local land use planning and zoning ordinances should consider incorporating climate change resiliency strategies for protecting water quality and improving infrastructure based on temperature, precipitation, water levels, wind loads, storm surges, wave heights, soil moisture, and groundwater levels (Ballestero et al., 2017). There are nine strategies which can aid in minimizing the adverse effects associated with climate change and include the following (McCormick and Dorworth, 2019).

- **Installing Green Infrastructure and Nature-Based Solutions:** Planning for greener infrastructure requires that we think about creating a network of interconnected natural areas and open spaces needed for groundwater recharge, pollution mitigation, reduced runoff and erosion, and improved air quality. Examples of green infrastructure include forest, wetlands, natural areas, riparian (banks of a water course) buffers, and floodplains; all of which already exist to various extents in the watershed and have minimized the damage created by intense storms. As future development occurs, these natural barriers must be maintained or even increased to reduce runoff of pollutants into freshwaters. See also Section 4.2.3: Land Conservation.
- **Using LID Strategies:** Use of LID strategies requires replacing traditional approaches to stormwater management using curbs, pipes, storm drains, gutters, and retention ponds with innovative approaches such as bioretention, vegetated swales, and permeable paving.
- **Minimizing Impervious Surfaces:** Impervious surfaces such as roads, buildings, and parking lots should be minimized by creating new ordinances and building construction design requirements which reduce the imperviousness of new development. Property owners can increase the permeability for their lots by incorporating permeable driveways and walkways.
- **Encouraging Riparian Buffers and Maintaining Floodplains:** Municipal ordinances should forbid construction in floodplains, and in some instances, floodplains should be expanded to increase the land area to accommodate larger rainfall events. Riparian (vegetated) buffers and filter strips along waterways should be preserved and/or created to slow runoff and filter pollutants.
- **Protecting and Re-establishing Wetlands:** Wetlands are increasingly important for preservation because wetlands hold water, recharge groundwater, and mitigate water pollution.
- **Encouraging Tree Planting:** Trees help manage stormwater by reducing runoff and mitigating erosion along surface waters. Trees also provide critical shading and cooling to streams and land surfaces.
- **Promoting Landscaping Using Native Vegetation:** Landowners should promote the use of native vegetation in landscaping, and landscapers should become familiar with techniques which minimize runoff and the discharge of nutrients into waterbodies (Chase-Rowell et al., 2012).
- **Slowing Down the Flow of Stormwater:** To slow and infiltrate stormwater runoff, roadside ditches can be armored or vegetated and equipped with turnouts, settling basins, check dams, or infiltration catch basins. Rain

gardens can retain stormwater, while water bars can divert water into vegetated areas for infiltration. Water running off roofs can be channeled into infiltration fields and drainage trenches.

- **Coordinating Infrastructure, Housing, and Transportation Planning**: Coordinate planning for infrastructure, housing, and transportation to minimize impacts on natural resources. Critical resources including groundwater must be conserved and remain free of pollutants especially as future droughts may deplete groundwater supplies.

4.2.3 Land Conservation

Land conservation is essential to the health of a region, particularly for the protection of water resources, enhancement of recreation opportunities, vitality of local economies, and preservation of wildlife habitat. Land conservation is one of many tools for protecting water quality for future generations. Unfortunately, for Halfmoon Lake, there is no conserved land located within the watershed (though conserved land exists within both towns). As land conservation is essential to the future of this region, local groups should continue to pursue opportunities for land conservation in the Halfmoon Lake watershed based on the highest valued habitat identified by the New Hampshire Fish & Game (NHFG). NHFG ranks habitat based on value to the State, biological region (areas with similar climate, geology, and other factors that influence biology), and supporting landscape. These habitat rankings are published in the State's 2015 Wildlife Action Plan (with updated statistics and data layers released in January 2020), which serves as a blueprint for prioritizing conservation actions to protect Species of Greatest Conservation Need in New Hampshire (NHFG, 2015). The Halfmoon Lake watershed is located between two ecological regions, with a small North-Eastern portion of the watershed falling within the Sebago-Ossipee Hills and Plains region, and the remaining area within the Worcester/Monadnock Platea region (NHFG, 2015). Approximately 314 acres (8%) of the Halfmoon Lake watershed are considered Highest Ranked Habitat in New Hampshire, and 962 acres (25%) is classified as the highest ranked habitat in the biological region (Appendix A, Map A-12).

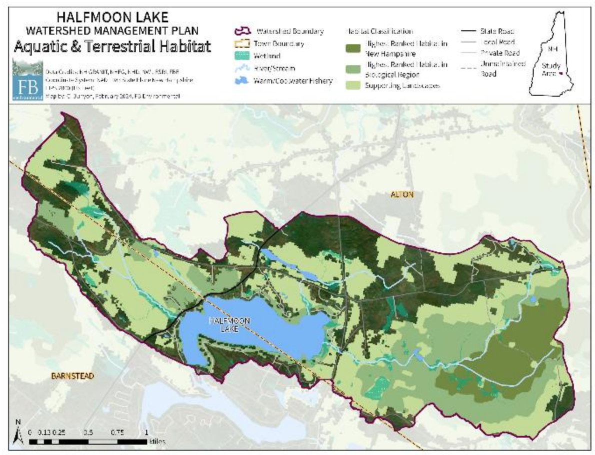


Table 15. *Ordinance review summary of regulatory and non-regulatory tools for natural resource protection in the towns of Alton and Barnstead.*

	STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
REGULATORY TOOLS	Zoning districts addressing environmental protection.	"Shoreland Protection Overlay District," "Aquifer Protection Overlay District," and the "Floodplain Development Overlay District".	"Aquifer Recharge District," "Shoreland Protection District" overlay, and "Barnstead Floodplain Management Ordinance."	Establish a "Halfmoon Lake Watershed Overlay District" where more stringent standards may apply that would not be applicable to Alton Bay. For example, limiting land uses around the shoreline of Halfmoon Lake to prohibit some of the non-residential uses still allowed as part of the Shoreland Protection Act. Some overlay districts may include stricter standards for development or sewage disposal.	Establish a "Halfmoon Lake and Locke Lake Watershed Overlay District" where more stringent standards may apply that would not be applicable to other waterbodies in Barnstead. For example, limiting land uses around the shoreline of Halfmoon Lake to prohibit some of the non-residential uses still allowed as part of the Shoreland Protection Act. Some overlay districts may include stricter standards for development or sewage disposal.
	Shoreland zoning.	"Shoreland Protection Overlay District"(Zoning, section 601 - RSA § 483-B:5-b (2018)). To protect the shoreland zone of any lake, pond, river, perennial stream, or impoundment from unauthorized construction/excavation/fill activities. "Setbacks" for buildings and structures are as follows: 30 feet from the reference line of the aquatic feature, and a 25-foot natural buffer must remain for all wetlands >10,000 square feet (Zoning, section 327). "Frontage" for shorefront lots shall be at least 150 feet for lots created after 3/13/2018 (Zoning, section 412).	The Shoreland Protection Ordinance was updated in 2002 to reflect new state laws (Master Plan, page 10). "Refer to RSA 483-B: 1-20, Comprehensive Shoreland Protection Act and Administrative Rules Env-Wq 1401-1414 as amended" (Zoning, page 25). "There must be fifty (50) feet between the nearest edge of any building and the high water line. There must be at least two hundred (200) feet of shoreline frontage for each dwelling unit" (Zoning page 14).	Increase all building setbacks from any lake, pond, river, perennial stream, or impoundment to at least 50 feet. Increase the setback from wetlands to 50 feet.	Consider expanding the setback to be greater than the state minimum of 50' from waters greater than 10ac or streams of fourth order or greater, to possibly 75 or 100 feet. Consider establishing a vegetated buffer requirement of at least 25 feet along each properties' shoreline.
	Subdivision of waterfront parcels.	Parcels intended for shared common access to those other than the property owners (i.e., a community beach) shall be at least one acre in size, a minimum shoreland frontage of 150 feet, only have public facility/recreational structures, parking greater than 1/4 mile from the common area, and impervious surfaces not exceeding 10%	None identified.	None identified.	Institute provisions for waterfront parcels used for a shared or common purpose that regulates minimum lot size, shoreline frontage, and impervious area restrictions.

STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
	of the parcel's area (Zoning, section 326).			
Cluster development and/or open space provisions for subdivisions.	The 2022 Master Plan Draft document explains an approach to subdivision where "scenic, agricultural, and habitat values of the open space" are retained. "This type of subdivision can also be used to concentrate development away from wetlands, shorelines and floodplains, steep areas, and important wildlife corridors" (Master Plan Draft, page 5-24).	The Open Space Preservation Development (OSPD) encourages "better site planning than would normally occur by the lot-by-lot method under conventional subdivision procedures, including the preservation of open space and natural features unique to the particular parcel of land." One of the primary objectives is "to preserve open space, wetland, agricultural land, tree and other vegetative cover, scenic vistas, and wildlife habitat" (Zoning, page 20). "At least fifteen (15) percent of the tract's developable land shall be set aside as common open space" (Zoning, page 23). An Environmental Impact Assessment is also required (Zoning, page 21).	Implement a Conservation Subdivision ordinance that achieves the goals of the master plan and encourages land conservation and environmentally-sound development. Some ordinances require 50% of the land to be dedicated as open space, and requires this land to be recorded in the Registry of Deeds.	Increase the percentage of land required to be set-aside and require that this land be recorded in the Registry of Deeds.
Protection of wetlands.	A natural, 25-foot buffer must exist between wetlands >10,000 square feet and any building, driveway, or structure (Zoning, section 327) "Protect waterbodies and wetlands from saltation and pollution caused by stormwater runoff." "Natural drainage systems [perennial and intermittent streams, wetlands, and swales] shall not be altered and shall be protected from excessive volume and velocity of flow" (Zoning, section 359).	"There must be fifty (50) feet between the nearest edge of any building and the high water line of any fire pond, pond, river, stream, brook, or other wetland as defined in Article 2" (Zoning, page 14).	Establish a Wetland Protection District that regulates natural buffers, setbacks, and limits on impervious cover within a set distance from wetlands. Some ordinances have increased diligence around prime wetlands.	Establish a Wetland Protection District that regulates natural buffers, setbacks, and limits on impervious cover within a set distance from wetlands. Some ordinances have increased diligence around prime wetlands.

STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
Protection of groundwater.	"Aquifer Protection Overlay District" (Zoning, section 602). "To protect groundwater resources from adverse development or land use practices that might reduce the quality and quantity of water that may be available..."	The "Aquifer Recharge District" protects "groundwater water quality in stratified drift aquifers that are delineated as potential groundwater recharge areas" (Zoning, page 41).	Implement a maximum impervious cover per lot in the Aquifer Protection Overlay District.	Amend the impervious cover restriction from only paving less than 10% of the lot's surface, to include a whole impervious surface percent maximum including buildings.
Protection of steep slopes.	"All lots created after March 2007 must have a minimum buildable area made up of contiguous upland and slopes (not greater than 25% grade), of no less than 75% of the minimum lot requirement for the zone" (Zoning, section 412).	The Steep Slope Protection Area includes all slopes equal to or greater than 15% to "to reduce damage to streams, lakes and groundwater from the consequences of excessive or improper construction, erosion, storm water runoff, or effluent from improperly sited or designed sewage disposal systems" among other purposes (Zoning, page 15).	Establish a Steep Slope Protection Area including all slopes equal to or greater than 15%. Some ordinances only apply to areas with disturbance is greater than a certain area, and require an engineering plan, BMPs, LID techniques, and natural stormwater control measures, and exclude extremely steep (>25%) slopes from buildable area.	None identified.
Septic pump-out ordinance or regulation of septic and sewer systems.	A year-round septic system must accompany any "in kind" replacement of a seasonal use to year-round use structure (Zoning, section 320). Septic systems must be sited to limit the possibility of impairment if located in the Floodplain Development Overlay District (Zoning, section 660).	"To prevent land saturation of septic system effluent," "Wastewater Treatment Systems shall comply with the requirements of Chapter 149-E, New Hampshire Code of Administration rules Env-WS 1000 Revised Statutes, and with such Rules and Regulations that may be promulgated by the New Hampshire Department of Environmental Services" (Zoning, page 12)	Require septic pump outs & inspections within an overlay district, require inspections at point of sale or home expansion, require certain design criteria in sensitive areas.	Require septic pump outs & inspections within an overlay district, require inspections at point of sale or home expansion, require certain design criteria in sensitive areas.
Nutrient loading analysis required for fresh waterbodies.	None identified, though the stormwater management section (Zoning, section 359) identifies its purpose is to "prevent or reduce non-point source pollution resulting from development," to "minimize impact of development on existing hydrology and water quality by controlling runoff, soil erosion and sedimentation resulting from site development," and to "protect water bodies and wetlands from saltation and pollution caused by stormwater runoff."	None identified. Though the Master Plan states the Planning Board is encouraged to support "research and prepare for the voters a Steep Slope ordinance, and a Water Quality/Stormwater Management Ordinance that will prevent erosion and pollution of the Town's lakes and streams" Master Plan, page 12).	Require stormwater management plans or phosphorus control plans to quantify nutrient loading from planned developments and the estimated load reductions from BMPs and LID techniques.	Require stormwater management plans or phosphorus control plans to quantify nutrient loading from planned developments and the estimated load reductions from BMPs and LID techniques.

STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
Low impact development requirements and standards.	The "use of nontraditional and/or nonstructural stormwater management measures, such as Low Impact Development (LID) includes site design to reduce runoff rates, volumes, and pollutant loads, are preferred and shall be implemented to the maximum extent practical. Such techniques include, but are not limited to, minimization and/or disconnection of impervious surfaces; development design reducing rate and volume of runoff; reforestation or enhancement of natural riparian areas, wetlands, and forests and use of practices to intercept, treat, and infiltrate runoff from developed areas disturbed throughout the site with methods described in the Stormwater Manual" (Zoning, section 359).	None identified.	Current standards are only applicable to sites with slope of land 15% or greater before or after development, or where development is within 20 feet of 15% slopes. Make the standards applicable to all sites. Mention nutrient reduction as a priority.	Update Site Plan Review regulations or other ordinance to require low impact development to the maximum extent practicable to reduce stormwater runoff volumes an maintain site hydrology. Require or encourage on-site stormwater treatment through vegetation and BMPs to treat pollutants such as sediment, nitrogen, and phosphorus. Require conducting a drainage analysis and other engineered plans if applicable for a certain site.
Environmental Ordinances (e.g. green building codes, green infrastructure, tree preservation, limits on impervious surface cover)	For waterfront parcels, impervious cover shall not exceed 10% of the parcel.	None identified.	Currently uses the 2018 International Building Code, which allows for certain green infrastructure/stormwater control practices such as green roofs and rain harvesting from roofs. Consider updating to the newest standard and adopting other environmental codes and regulations.	Update from the 2009 International Building Code (IBC) to more recent versions (2021 or more recent). Consider updating to the newest standard and adopting other environmental codes and regulations.
Fertilizer and/or pesticide ordinances.	None identified. Though the harm of fertilizers and pesticides to water quality are mentioned (Master Plan Draft, pages 3-4 and 3-5).	None identified.	Implement a fertilizer ordinance. This may be town-wide or within an overlay district. Stipulations may be made such that natural fertilizers may be allowed, or special types of fertilizers may be sued for agricultural purposes, but not residential.	Implement a fertilizer ordinance. This may be town-wide or within an overlay district. Stipulations may be made such that natural fertilizers may be allowed, or special types of fertilizers may be sued for agricultural purposes, but not residential.

	STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
	Implement and enforce a Stormwater Management Plan.	The purpose and intent of stormwater management is "to protect public health, safety, and general welfare managing stormwater generated by the development of land in Alton. The 'Guide to Erosion Control & Stormwater Management for Homeowners & Contractors' (Guide) is available in the Planning Department to assist in preparing stormwater management plans." (Zoning, section 359).	A Sediment and Erosion Control Plan, prepared by a professional engineer or Certified Professional Erosion Sediment Control, is required for construction to show "specific methods that will be used to control soil erosion and sedimentation, soil loss, and excessive storm water runoff, both during and after construction" (Zoning, page 16).	Implementation and enforcement through building and lot development/management regulations suggested through other strategies presented here.	Implementation and enforcement through building and lot development/management regulations suggested through other strategies presented here.
CONSERVATION FUNDING STRATEGIES	Development transfer overlay district.	None identified.	None identified.	Create a Development Transfer Overlay District encompassing infrastructure-dense areas and growth areas. This overlay district may allow a developer to build at additional density within these areas upon payment of a fee, which is then used to purchase conservation land in areas rich in natural resources or are prioritized for conservation.	Create a Development Transfer Overlay District encompassing infrastructure-dense areas and growth areas. This overlay district may allow a developer to build at additional density within these areas upon payment of a fee, which is then used to purchase conservation land in areas rich in natural resources or are prioritized for conservation.
	Conservation impact fees.	None identified.	Not specific to conservation, but impact fees may be required for development induced off-site improvements which can include wastewater treatment and disposal facilities, water treatment and distribution facilities, sanitary sewers, storm water, drainage and flood control facilities, and more (Zoning, page 40).	Implement conservation impact fee.	Implement conservation impact fee.
	Wetland mitigation funds.	None identified.	None identified. Though Barnstead does have a Hazard Mitigation Plan (2019).	Connect with NHDES about Aquatic Resource Mitigation (ARM) funding. There is $416,908 in ARM funding available for the Winnipesaukee Area in 2024.	Connect with NHDES about Aquatic Resource Mitigation (ARM) funding. There is $4,527,928 in ARM funding available for the Merrimack River Area in 2024.
	Fee in lieu of land dedication.	None identified.	None identified.	Implement a fee in lieu of land dedication.	Implement a fee in lieu of land dedication.

	STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
	Stormwater utility district.	None identified.	None identified.	Implement a stormwater utility fee within a Stormwater Utility District. The fee is often a single rate charged to each homeowner within the district at the same time as their property taxes. Stormwater utility fees can generate funds for stormwater infrastructure maintenance, replacement, green infrastructure, and more to prevent or mitigate localized flooding, combined sewer overflows, or infrastructure failure.	If municipal stormwater management is present in Barnstead, implement a stormwater utility fee within a Stormwater Utility District. The fee is often a single rate charged to each homeowner within the district at the same time as their property taxes. Stormwater utility fees can generate funds for stormwater infrastructure maintenance, replacement, green infrastructure, and more to prevent or mitigate localized flooding, combined sewer overflows, or infrastructure failure.
	Open space or non-lapsing conservation fund.	None identified.	None identified.	Establish an open space of non-lapsing conservation fund.	Establish an open space of non-lapsing conservation fund.
	Has a Land Use Change Tax per RSA 79-A:25.	Yes. As stated in the Master Plan Draft 2022 document, "currently only 50% goes to the Conservation Fund and 50% goes to the General Fund" (Master Plan Draft, page 3-26).	None identified.	Dedicate a larger percentage of the land use change tax to the conservation fund.	Institute land-use change tax pursuant to RSA 79-A:25 and dedicate a significant percentage to conservation.
	Participate or collaborate with a local watershed association.	None identified. However there is the Halfmoon Lake Watershed Association among others within the Town including but not limited to the Merrymeeting Lake Association and the Lake Winnipesaukee Association.	None identified. However, there is the Halfmoon Lake Watershed Association among others within the Town including but not limited to the Friends of the Suncook River, and the Suncook Lake Association.	Collaborate with local lake associations	Collaborate with local lake associations.
	Participate or collaborate with a local land trust.	The Lakes Region Conservation Trust.	None identified, though there is the Lakes Region Conservation Trust.	Collaborate with the Lakes Region Conservation Trust.	Collaborate with Lakes Region Conservation Trust and other conservation/land trusts.
NON-	Open space plan.	None identified.	Not as a stand alone plan. The Open Space Preservation Development regulations can be found within Article 6 of the Town Zoning Ordinance.	Seek funding for and create an Open Space Plan for the town.	Seek funding for and create an Open Space Plan for the town.

STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
Master plan addresses natural resources and environmental protection.	Yes [2022 Draft]. Sub-chapters relevant to environmental protection include (Ch.3) Natural Resources, (Ch.5) Land Use, and (Ch.6) Infrastructure.	Yes (2015). Sub-chapters relevant to environmental protection include section C (Land Use Policies) and section F (Recreation and Conservation).	None identified.	Begin or continue the process of updating the Master Plan.
A town-wide natural resources inventory.	Yes, completed in 2002.	None identified.	Update the Natural Resources Inventory.	Seek funding for and create a town-wide Natural Resources Inventory.
Smart Growth Plan.	None identified.	Smart Growth Audit: Barnstead NH. June 2007.	Create a Smart Growth plan.	Update the Smart Growth Audit.
Stormwater system mapping	None identified.	None identified.	Provide digital mapping of stormwater infrastructure, including catch basins, wastewater and stormwater lines, and outfalls.	Map stormwater infrastructure, including catch basins, wastewater and stormwater lines, and outfalls.
Consistent Public Outreach and Engagement / Public education programs	None identified.	None identified.	Implement public outreach program for green infrastructure, stormwater management, fertilizer use, winter salt application, and septic system maintenance. Program may include mailers, events, workshops, or pamphlets.	Implement public outreach program for green infrastructure, stormwater management, fertilizer use, winter salt application, and septic system maintenance. Program may include mailers, events, workshops, or pamphlets.
Incentive-based programs for voluntary low impact development implementation.	None established, but language proposing the ideas can be found in the 2022 Draft Master Plan. "Incentives might include reduced lot sizes, lot frontage and setbacks on these subdivision roads compared to existing state and town through-roads" (Master Plan Page 5-24).	None identified.	Implement incentive-based programs that achieve the goals of the Master Plan.	Consider incentive based programs that encourage low-impact development.
Incentive-based programs for stormwater reduction efforts.	None identified.	None identified.	Consider incentive-based programs for stormwater reduction efforts, such as retrofits or other BMPs.	Consider incentive-based programs for stormwater reduction efforts, such as retrofits or other BMPs.
Have established conservation commission.	Yes.	Yes.	Continue doing great work with the conservation commission!	Continue doing great work with the conservation commission!

	STRATEGY	Alton	Barnstead	Alton Recommendations	Barnstead Recommendations
	Incentivize and/or encourage property owners to implement low impact development stormwater practices.	None identified.	None identified.	Consider incentivizing and encouraging low impact development through outreach programs, workshops, or financial incentives.	Consider incentivizing and encouraging low impact development through outreach programs, workshops, or financial incentives.
	Encourage property owners to put land into farmland/tree growth programs.	None identified.	None identified. Though conservation of farmland is encouraged (Master Plan, page 9).	Consider encouraging landowners to take advantage of state agricultural and forestry programs.	Consider encouraging landowners to take advantage of state agricultural and forestry programs.

4.2.4 Septic System Regulation

When properly designed, installed, operated, and maintained, septic systems can treat residential wastewater and reduce the impact of excess pollutants in ground and surface waters. It is important to note, however, that traditional septic systems are designed for pathogen removal from wastewater and not specifically for other pollutants such as nutrients. The phosphorus in wastewater is "removed" only by binding with soil particles or recycled in plant growth but is not removed entirely from the watershed system. Nutrient removal can only be achieved through more expensive, alternative septic systems. Proper design, installation, operation, maintenance, and replacement considerations include the following:

- Proper **design** includes adequate evaluation of soil conditions, seasonal high groundwater or impermeable materials, proximity of sensitive resources (e.g., drinking water wells, surface waters, wetlands, etc.);
- Proper siting and **installation** mean that the system is installed in conformance with the approved design and siting requirements (e.g., setbacks from waterways);
- Proper **operation** includes how the property owner uses the system. While most systems excel at treating normal domestic sewage, disposing of some materials, such as toxic chemicals, paints, personal hygiene products, oils and grease in large volumes, and garbage, can adversely affect the function and design life of the system, resulting in treatment failure and potential health threats; proper operation also includes how the property owner protects the system; allowing vegetation with extensive roots to grow above the system will clog the system; driving large vehicles over the system may crush or compact piping or leaching structures;
- Proper **maintenance** means having the septic tank pumped at regular intervals to eliminate accumulations of solids and grease in the tank; it may also mean regular cleaning of effluent filters, if installed. The frequency of septic pumping is dependent on the use and total volume entering the system. A typical 3-bedroom, 1,000 gallon tank should be pumped every 3-4 years;
- Proper **replacement** of failed systems, which may include programs or regulations to encourage upgrades of conventional systems (or cesspools and holding tanks) to more innovative alternative technologies.

Management strategies for reducing water quality impacts from septic systems (as well as cesspools and holding tanks) start with education and outreach to property owners so that they are better informed to properly operate and maintain their systems. Other management strategies include setting local regulations for enforcing proper maintenance and inspection of septic systems and establishing funding mechanisms to support replacement of failing systems (with priority for cesspools and holding tanks).

4.2.5 Fertilizer Use Prohibition

Management strategies for reducing water quality impacts from residential, commercial, and municipal fertilizer application start with education and outreach to property owners. New Hampshire law prohibits the use of fertilizers within 25 feet of a surface water. Outside of 25 feet, property owners can get their soil tested before considering the application of fertilizers to their lawns and gardens to determine whether nutrients are needed and if so in what quantity or ratio. A soil test kit can be obtained through the UNH Cooperative Extension. Many New England communities are starting to adopt local regulations prohibiting the use of both fertilizers and pesticides, especially near critical waterbodies. Alton and Barnstead should consider a similar prohibition, at the very least for a watershed zoning overlay of major lakes and ponds as nearly all shoreline properties are privately owned.

4.2.6 Pet Waste Management

Pet waste collection as a pollutant source control involves a combination of educational outreach and enforcement to encourage residents to clean up after their pets. Public education programs for pet waste management are often incorporated into a larger message of reducing pollutants to improve water quality. Signs, posters, brochures, and newsletters describing the proper techniques to dispose of pet waste can be used to educate the public and create a cause-and-effect link between pet waste and water quality (USEPA, 2005). Adopting simple habits, such as carrying a plastic bag on walks and properly disposing of pet waste in dumpsters or other refuse containers, can make a difference. It is recommended that pet owners do not put dog and cat feces in a compost pile because it may contain parasites, bacteria, pathogens, and viruses that are harmful to humans and may or may not be destroyed by composting. "Pooper-scooper" ordinances are often used to regulate pet waste disposal. These ordinances generally require the removal of pet waste from public areas, other people's properties, and occasionally from personal property, before leaving the area. Fines are typically the enforcement method used to encourage compliance with these ordinances.

4.2.7 Agricultural Practices

Manure and fertilizer management and planning are the primary tools for controlling nutrient runoff from agricultural areas. Direct outreach and education should be conducted for small hobby farms and any larger-scale operations in the watershed.

Best management practices (BMPs) aim to reduce nutrient, sediment, and bacteria load into water bodies while ensuring agricultural productivity; however, the selection of practices should consider local conditions – such as climate, soil type, hydrology, land use, funding, and other factors – to maximize effectiveness (EPA, 2004). In the Halfmoon watershed, agricultural activities such as hay farming, livestock grazing, and cropland comprise a relatively large percentage of the watershed (244 acres, 7% not including the lake area), when compared to other watersheds in the region, and may pose a threat to water quality through increased nutrient and sediment loads.

The NRCS is a key resource for farmers and landowners in implementing BMPs to improve water quality. Through various programs, the NRCS provides both financial and technical assistance for projects aimed at reducing runoff and improving soil health (Levey, 2023). In New Hampshire, the most implemented practices (by acre application) between 2005 and 2023 were cover cropping (31.8%) and conservation crop rotation (29%), which continue to be the most two popular practices to date (USDA, 2023a). Larger-scale agricultural operations can work with the NRCS to complete a Comprehensive Nutrient Management Plan (CNMP). These plans address soil erosion and water quality concerns of agricultural operations through setting proper nutrient budgets, identifying the types and amount of nutrients necessary for crop production (by conducting soil tests and determining proper calibration of nutrient application equipment), and ensuring the appropriate storage and handling of manure. Manure should be stored or applied to fields properly to limit runoff of solids containing high concentrations of nutrients. Manure and fertilizer management involve managing the source, rate, form, timing, and placement of nutrients. Writing a plan is an ongoing process because it is a working document that changes over time. The Environmental Quality Incentives Programs (EQIP) through NRCS is one of their flagship programs with the highest rates of BMP implementation in 2023 (64%). Other notable programs include the Conservation Program and Conservation Technical Assistance (USDA, 2023b).

These programs offered by the NRCS, can serve as an essential resource for farmers, particularly in addressing environmental concerns in agricultural watersheds (USDA NRCS, 2024). Through continued collaboration with the NRCS and other stakeholders, farmers in the Halfmoon watershed can play a pivotal role in in enhancing water quality while maintaining agricultural productivity – supporting two essential natural resources for community wellbeing in the region.

Many of the programs offered by the NRCS are implemented confidentially on private lands, and no public information was available regarding practices within the Halfmoon watershed. Because of this confidentiality, there may be established agricultural BMPs and/or current projects underway within the region. Nutrient load reductions from agricultural BMPs were not calculated as part of the Watershed Survey and therefore not factored into the loads needed to reach the Water Quality Goal. Any load reductions made on agricultural lands will therefore be a bonus to help the community reach their Water Quality Goal.

NRCS Resources

To access the technical and financial support offered through these programs, it is recommended that farmers and landowners contact their local NRCS office.

In the state of NH, there are seven (7) NRCS field offices, each serving a different area (see coverage areas here). Halfmoon Lake is served by the Concord Field Office which covers both Merrimack and Belknap Counties; Farmers in the watershed can contact the office at the following address and phone number:

10 Ferry Street, Suite 211
Concord, NH 03301
(603) 223-6023

Information on agricultural BMPs have been published in section 1 of the NRCS Field Office Technical Guide (FOTG) for NH, under the NH Ag BMPS" section. In this document, agricultural BMPs are sorted into three main sections: manure, agricultural compost, and chemical fertilizer (Figure 19). These classifications support the initial identification of appropriate BMPs for each farm, field, or site, depending on local needs. Once the relevant BMPs are identified, producers can better understand which NRCS practices will support BMP implementation. A full list of NRCS practices are available in Section 4 of the FOTG, with practices relevant to water quality highlighted in Table 16.

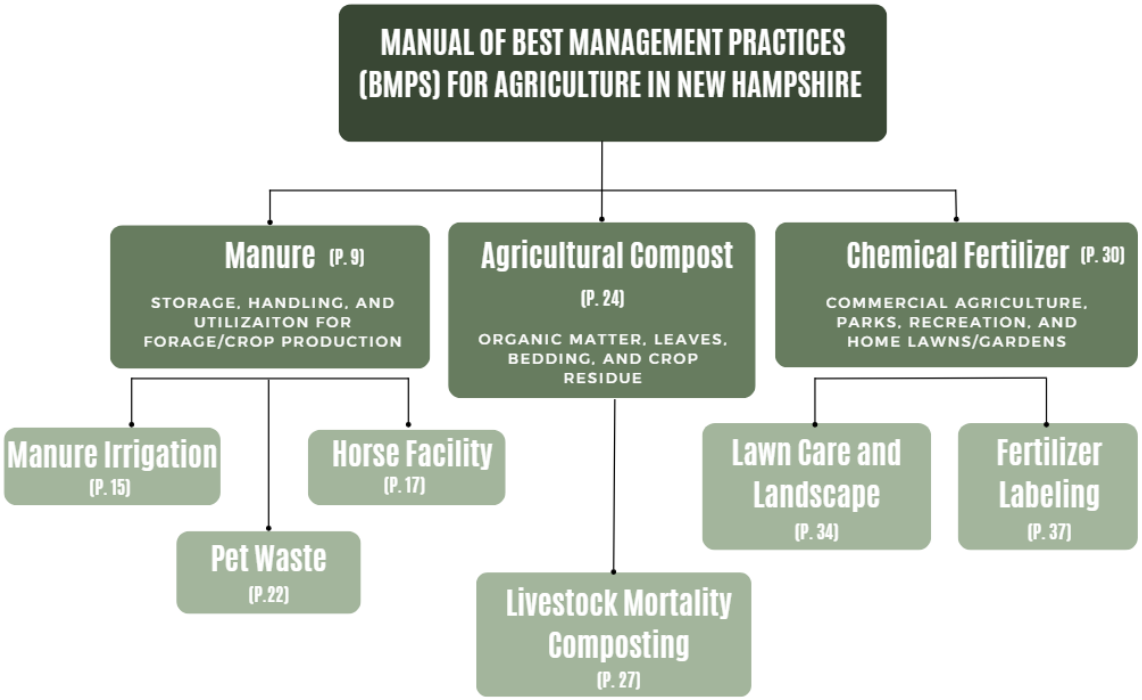


Figure 19. *Overview of the major topics covered in the "Manual of Best Management Practices (BMPs) for Agriculture in New Hampshire," to orient producers to relevant sections.*

Table 16. Adapted from the "USDA Conservation Choices; Water Quality Practices" table adjusted to meet current NH NRCS practices (USDA NRCS, n.d).

Conservation Practice	Descriptions	N	P	Sediment	NRCS Practice #
Cover Crop	Crops, including grasses, legumes, and forbs for seasonal cover, conservation, and soil health.	X	X	X	340, 328,
Drainage Water Management	Water control structure to keep water in the root zone to support excess nutrient uptake before draining.	X	X	X	587
Filter Strip	Strip of vegetation near water to remove pollutants from runoff and wastewater.	X	X	X	393, 327, 386, 390,
Manure Management	Manure storage until conditions are appropriate for field application.	X	X		318, 313
No-Till/Strip-Till	Reducing soil tillage to support soil health.	X	X	X	329, 345, 346
Nutrient Management	Managing the amount, source, placement, and timing of plant nutrients and soil amendments.	X	X		590
Prescribed Grazing	Managing the harvest of vegetation by rotating grazing animals.	X	X	X	528
Riparian Forest Buffer	Vegetation planted along stream or river to reduce nutrients/pollutants in surface runoff.	X	X	X	342, 391, 612,
Wetlands	Marshy area with saturated soils to filter out nutrients/pollutants, sediments.	X	X	X	659, 657

4.2.8 Nuisance Wildlife Controls

Human development has altered the natural habitat of many wildlife species, restricting wildlife access to surface waters in some areas and promoting access in others. Minimizing the impact of wildlife on water quality generally requires either reducing the concentration of wildlife in an area or reducing their proximity to a waterbody. In areas where wildlife is observed to be a large source of nutrient contamination, such as large and regular congregations of waterfowl, a program of repelling wildlife from surface waters (also called harassment programs) may be implemented. These programs often involve the use of scarecrows, kites, a daily human presence, or modification of habitat to reduce attractiveness of an at-risk area. Providing closed trash cans near waterbodies, as well as discouraging wildlife from entering surface waters by installing fences, pruning trees, or making other changes to landscaping, can reduce impacts to water quality. Public education and outreach on prohibiting waterfowl or other wildlife feeding is an important step to reducing the impact of nuisance wildlife on the lake.

4.3 OUTREACH & EDUCATION

Awareness through education and outreach is a critical tool to protecting and restoring water quality. Most people want to be responsible watershed stewards and not cause harm to water quality, but many are unaware of best practices to reduce or eliminate contaminants from entering surface waters. HMLA is the primary entity for education and outreach campaigns in the watershed and for development and implementation of the plan. HMLA should continue all aspects of their education and outreach strategies and consider developing new ones or improving existing ones to reach more watershed residents. Refer to Section 5: Action Plan. Examples include providing educational materials to existing and new property owners, as well as renters, by distributing them at various locations and through a variety of means, such as websites, newsletters, social media, community events, or community gathering locations. Additionally, HMLA should continue to engage with local stakeholders such as conservation commissions, land trusts, municipalities, businesses, and landowners. Educational campaigns should include raising awareness of water quality, septic system maintenance, fertilizer and pesticide use, pet waste disposal, waterfowl feeding, invasive aquatic species, boat pollution, shoreline buffer improvements, gravel road maintenance, and stormwater runoff controls.

4.4 ADAPTIVE MANAGEMENT APPROACH

An adaptive management approach, to be employed by the Watershed Management Plan Committee, is highly recommended for protecting Halfmoon Lake. Adaptive management enables stakeholders to conduct restoration actions in an iterative manner. Through this management process, restoration actions are taken based on the best available information. Assessment of the outcomes following restoration action, through continued watershed and water quality monitoring, allows stakeholders to evaluate the effectiveness of one set of restoration actions and either adopt or modify them before implementing effective measures in the next round of restoration actions. This process enables efficient utilization of available resources through the combination of BMP performance testing and watershed monitoring activities. Adaptive management features establishing an ongoing program that provides adequate funding, stakeholder guidance, and an efficient coordination of restoration actions. Implementation of this approach ensures that restoration actions are implemented and that surface waters are monitored to document restoration over an extended time. The adaptive management components for implementation efforts should include:

- **Maintaining an Organizational Structure for Implementation.** Communication and a centralized organizational structure are imperative to successfully implementing the actions outlined in this plan. A diverse group of stakeholders through HMLA should be assembled to coordinate watershed management actions. This group can include representatives from state and federal agencies or organizations, municipalities, local businesses, and other interested groups or private landowners. Refer to Section 6.1: Plan Oversight.
- **Establishing a Funding Mechanism.** A long-term funding mechanism should be established to provide financial resources for management actions. In addition to initial implementation costs, consideration should also be given to the type and extent of technical assistance needed to inspect and maintain structural BMPs. Funding is a key element of sustaining the management process, and, once it is established, the plan can be fully vetted and restoration actions can move forward. A combination of grant funding, private donations, and municipal funding should be used to ensure implementation of the plan. Refer to Section 6.3 for a list of potential funding sources.

- **Determining Management Actions.** This plan provides a unified watershed management strategy with prioritized recommendations for restoration using a variety of methods. The proposed actions in this plan should be used as a starting point for grant proposals. Once a funding mechanism is established, designs for priority restoration actions on a project-area basis can be completed and their implementation scheduled. Refer to Section 5: Action Plan.
- **Continuing and Expanding the Community Participation Process.** Plan development has included active involvement of a diversity of watershed stakeholders. Plan implementation will require continued and ongoing participation of stakeholders, as well as additional outreach efforts to expand the circle of participation. Long-term community support and engagement is vital to successfully implement this plan. Continued public awareness and outreach campaigns will aid in securing this engagement. Refer to Section 4.3: Outreach & Education.
- **Continuing the Long-Term Monitoring Program.** A water quality monitoring program is necessary to track the health of surface waters in the watershed. Information from the monitoring program will provide feedback on the effectiveness of management practices. Refer to Section 6.4: Monitoring Plan.
- **Establishing Measurable Milestones.** A restoration schedule that includes milestones for measuring restoration actions and monitoring activities in the watershed is critical to the success of the plan. In addition to monitoring, several environmental, social, and programmatic indicators have been identified to measure plan progress. Refer to Section 6.5: Indicators to Measure Progress for interim milestones.

5 ACTION PLAN

5.1 ACTION PLAN

The Action Plan (Table 17) outlines responsible parties, approximate costs[9], an implementation schedule, and potential funding sources for each recommendation within the following major categories: (1) Watershed & Shoreline BMPs; (2) Road and Driveway Management; (3) Municipal Operations; (4) Municipal Land Use Planning & Zoning; (5) Land Conservation; (6) Septic System Management; (7) Agricultural Practices; and (8) Education and Outreach. The plan is designed to be implemented from 2025-2034 and is flexible to allow for new priorities throughout the 10-year implementation period as additional data are acquired.

Table 17. *Action plan for the Halfmoon Lake watershed. Item numbers coorelate with the graphical represntation of the Implementation Schedule (Figure 20)*

#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
	Watershed and Shoreline BMPs			
1	Complete design and construction of mitigation measures at the top 6 high and medium priority sites identified in the watershed survey. **Achieves 43% (19.5 kg/yr P of 45 kg/yr P) of Objective 1** for Halfmoon Lake.	HMLA, Municipalities, private landowners and associations	$478K-$912K* 2025-26 *Site 1-19 significantly increases the cost	CWSRF, Grants (319, Moose Plate, NFWF 5-Star, ILFP), Municipalities, private landowners
2	Complete design and construction of mitigation measures at the next 7 prioritized sites (high, medium, and low) identified in the watershed survey as opportunities arise. **Achieves 6.2% (2.8 kg/yr P of 45 kg/yr P) of Objective 1.**	HMLA, Municipalities, private landowners and associations	$83K-$120K 2027-29	CWSRF, Grants (319, Moose Plate, NFWF 5-Star, ILFP), Municipalities, private landowners
3	Complete design and construction of mitigation measures at the remaining 6 lower priority sites identified in the watershed survey as opportunities arise (refer to Appendix B for complete list). **Achieves 2.1% (0.97 kg/yr P of 45 kg/yr P) of Objective 1.**	HMLA, Municipalities, private landowners and associations	$69K-$109K 2030-34	CWSRF, Grants (319, Moose Plate, NFWF 5-Star, ILFP), Municipalities, private landowners

[9] Cost estimates for each recommendation will need to be adjusted based on further research and site design considerations.

#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
4	Promote the LakeSmart program evaluations and certifications through NH Lakes to educate property owners about lake-friendly practices such as revegetating shoreline buffers with native plants, avoiding large grassy areas, and increasing mower blade heights to 4 inches. Coordinate with NHDES Soak Up the Rain NH program for workshops and trainings. Cost assumes coordination of and materials for up to 10 workshops.	HMLA, BCCD, NH Lakes, NHDES Soak Up the Rain NH, Municipalities	$5,000 2025-34	NH Lakes, NHDES Soak Up the Rain NH, Grants (319, Moose plate), CWSRF, Municipalities
5	Provide technical assistance and/or implementation cost sharing to watershed/shoreline property owners to install stormwater and/or erosion controls such as rain gardens and buffer plantings. Prioritize high impact properties identified during the shoreline survey. Cost assumes technical assistance and implementation cost sharing provided to the two high impact shoreline properties. **Achieves 2.6% (1.16 kg/yr P of 45 kg/yr P) of Objective 1.**	HMLA, BCCD, Municipalities	$3K 2025-26	Grants (319, Moose plate), CWSRF
6	Implement stormwater and erosion controls on watershed/shoreline properties. Prioritize medium impact properties identified during the shoreline survey. Cost assumes landowner implementation costs (budget: $3K each) for the 20 medium impact shoreline properties. **Achieves 12.8% (5.78 kg/yr P of 45 kg/yr P) of Objective 1.**	Landowners, HMLA	$TBD based on cost sharing abilities. 2027-34	Landowners
7	Repeat the shoreline surveys in 5-10 years when updating the WMP. Use the results to target education and technical assistance for high impact sites. Cost assumes hired consultant for survey and summation of shoreline survey results.	HMLA, Municipalities	$7K 2029, 2034	Municipalities, Grants (Moose plate), CWSRF
8	Further investigate sources of nutrient loading in the Subwatershed of the Route 28 Inlet stream in the form of road management, septic loads, and residential/agricultural BMPs. Recommend and implement mitigation measures. Cost assumes stormwater retrofit inventory and expanded septic inventory.	HMLA, Municipalities	$10-15k 2025-26	Municipalities, Grants (319)
	Road and Driveway Management			
9	Review practices for road and drainage maintenance currently used by public and private entities/groups and determine areas for improvement.	Municipalities, HMLA, BCCD	$3K 2025	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star)
10	Continue providing education and training to contractors and municipal staff on protocols for road maintenance best practices. Assumes one workshop. Consider holding joint workshop with other municipalities or lake associations (or other wider service area) for cost sharing savings.	Municipalities, HMLA, BCCD	$15K 2025	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star)

#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
11	Develop and/or update a written protocol for road maintenance best practices.	Municipalities, HMLA, BCCD	$20K 2025	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star)
12	Incorporate water quality considerations and strategies into roadway evaluations and action plans (e.g., Sanbornton Roadway Evaluation).	Municipalities, HMLA, BCCD	N/A 2026-28	Municipalities
13	Establish inspection and maintenance agreements for private unpaved roads. Cost does not include the implementation of proper road maintenance by private landowners and assumes that municipalities can accommodate this additional effort in current budgets.	Municipalities, private landowners	N/A 2029-34	Municipalities, private landowners
14	Hold informational workshops on proper road/driveway management and winter maintenance and provide educational materials for homeowners about winter maintenance and sand/salt application for driveways and walkways. Cost assumes up to five workshops.	HMLA, BCCD, Municipalities, private landowners	$5-10K 2025, 2029	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star), private landowners
15	Participate in Green SnowPro training. Become Green SnowPro Certified once program rules for municipalities have been adopted by the Joint Legislative Committee on Administrative Rules.	Municipalities (Public Works/Highway)	Est. $150-$250/person 2025-26	Municipalities
16	Contact the NH State DOT regarding decreasing their road salt usage on state roads within the watershed due to current trends in water quality and discuss reduced salt areas and low-salt approaches.	Municipalities, NH DOT	2025-28	Municipalities
17	Establish a street sweeping program to sweep municipal paved roads. Consider purchasing a street sweeping machine with neighboring municipalities to sweep up road salt and sand in dry weather periods between winter storms as our winters see more rain between snow events. Encourage homeowners to sweep their impervious surfaces after each snowmelt.	Municipalities, private landowners	TBD 2028-30	Municipalities
	Municipal Operations			
18	Review and optimize MS4 compliance for towns (regardless of MS4 designation), including infrastructure mapping, erosion and sediment controls, illicit discharge programs, and good housekeeping practices such as regular catch basin cleaning.	Municipalities (Public Works/Highway)	TBD 2025-26	Municipalities

#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
19	Review and update winter operations procedures to be consistent with Green SnowPro best management practices for winter road, parking lot, and sidewalk maintenance. Continue practicing low salt application practices in the watershed.	Municipalities (Public Works/Highway)	N/A 2025	Municipalities
20	For Barnstead, work with BCEP Solid Waste District and for Alton, work with the Alton Solid Waste Center to adopt a program to accept residential yard waste at respective transfer stations for composting.	Municipalities (Public Works/Highway)	TBD 2026-34	Municipalities
21	Develop best practice design standards for stormwater control measures, including deep sump catch basins.	Municipalities (Public Works/Highway)	N/A 2026-29	Municipalities
	Municipal Land Use Planning & Zoning			
22	Present WMP recommendations to Select Boards/City Council and Planning Boards in Barnstead and Alton and discuss the connection between municipal land use planning and water quality.	HMLA, Conservation Commissions	$1K 2025	Grants (319), CWSRF
23	Meet with municipal staff to review recommendations to improve or develop ordinances addressing setbacks, buffers, lot coverage, low impact development, and open space. Encourage municipalities to set standards more stringent than the state baseline.	HMLA, Municipalities	$3K 2025-28	Municipalities, Grants (319), CWSRF
24	Incorporate WMP recommendations into municipal master plans and encourage regular review of the WMP action plan.	Municipalities	N/A 2025-29	Municipalities
25	Adopt/strengthen zoning ordinance provisions and enforcement mechanisms:	Municipalities	N/A 2028-31	Municipalities
	1) to promote low impact development practices and reduce impervious areas;			
	2) to require stormwater regulations that align with MS4 Permit requirements;			
	3) to promote or require vegetative buffers around lake shore and tributary streams;			
	4) to require shorefront "tear down and replace" home construction to be no more non-conforming than existing structures;			
	5) to require shorefront seasonal to year-round conversions of homes to demonstrate no additional negative impacts to lake water quality;			

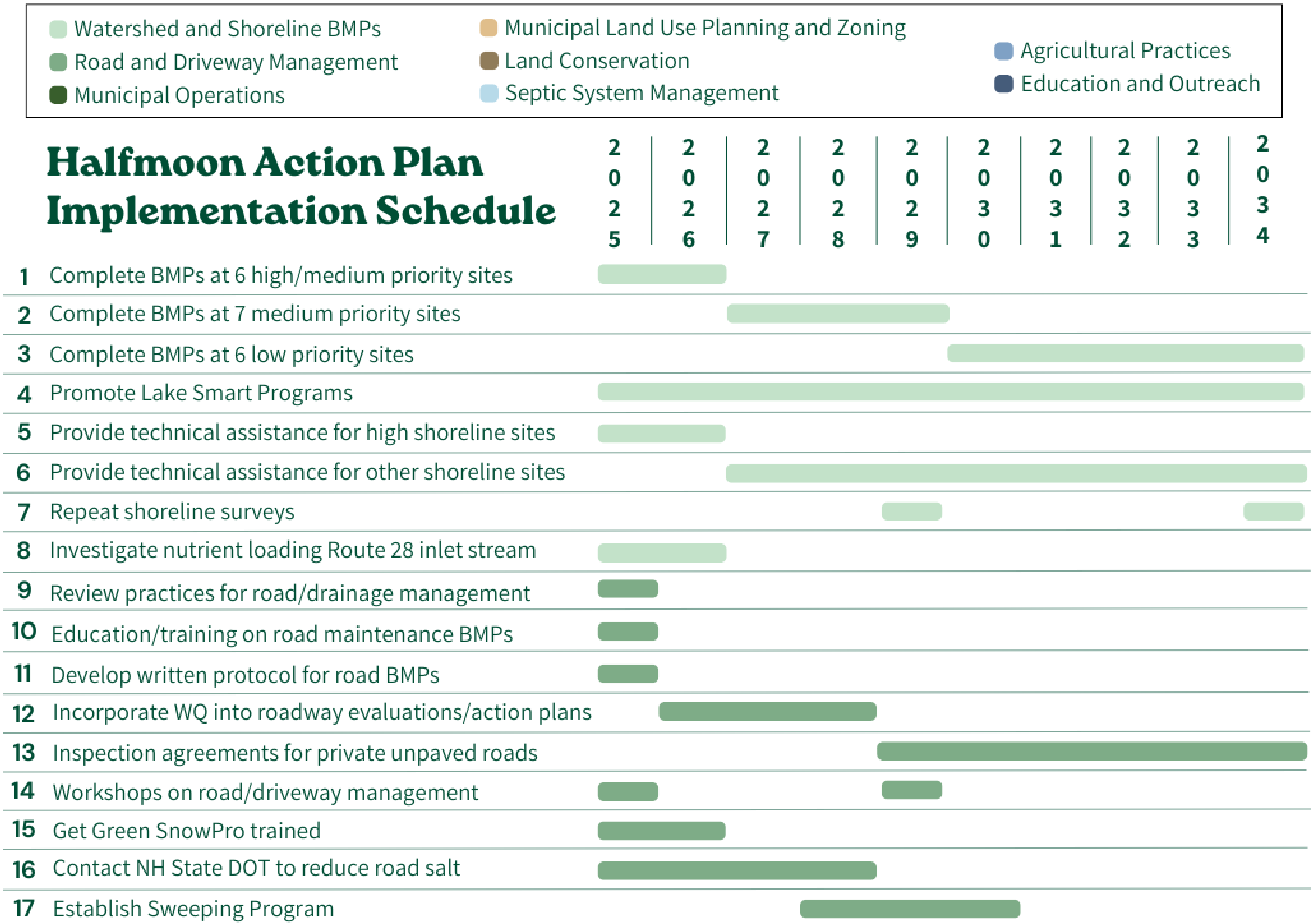
#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
	6) to establish a lake protection overlay zoning ordinance that prohibits erosion from sites in sensitive areas (e.g., lake shorefront, along lake tributaries, steep slopes); and			
	7) to enhance performance standards for unpaved roads to prevent erosion and protect lake water quality.			
26	Increase municipal staff capacity through code enforcers/ building inspectors for inspections and enforcement of stormwater regulations on public and private lands.	Municipalities	TBD 2026-34	Municipalities
	Land Conservation			
27	Complete a NRI for the Town of Barnstead. Town of Alton recently completed an NRI in 2022.	Municipalities, Conservation Commissions	$25K per municipality 2025-29	Municipalities, Grants (NFWF NEFRG), CWSRF
28	Create a priority list of watershed areas that need protection based on NRIs. Refer to Section 4.2.3 to understand current conservation lands and valuable habitats and wildlife in the watershed that can be used to help identify potential areas to target for conservation.	HMLA, Municipalities, Conservation Commissions, Lakes Region Land Trust or other local land trusts	$4-8K 2025-29	Grants (NFWF NEFRG, NAWCA), CWSRF, Municipalities
29	Identify potential conservation buyers and property owners interested in easements within the watershed. Use available funding mechanisms, such as the Regional Conservation Partnership Program (RCPP) and the Land and Community Heritage Investment Program (LCHIP), to provide conservation assistance to landowners.	HMLA, Municipalities, Conservation Commissions, Lakes Region Land Trust or other local land trusts	N/A 2029-33	Grants (Moose Plate, LCHIP, RCCP, NAWCA, LWCF, ACEP, CSP, EQIP)
30	Maximize conservation of intact forest and other ecologically important properties though education, zoning, and public or private conservation.	HMLA, Municipalities, Conservation Commissions, Lakes Region Land Trust or other local land trusts, private landowners	TBD 2029-33	Grants (Moose Plate, LCHIP, RCCP, NAWCA, LWCF, ACEP, CSP, EQIP, NFWF NEFRG), Municipalities, private landowners
31	Enhance community education regarding private land conservation easements. Host workshops educating landowners on the benefits.	HMLA, Conservation Commissions	2025-29	Grants (Moose Plate, LCHIP, RCCP, NAWCA, LWCF, ACEP, CSP, EQIP, NFWF NEFRG), Municipalities, private landowners

#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
32	Inspect wetlands for Prime Wetland Designations within the watershed. Provide greater support to the Barnstead and Alton Conservation Commissions in this endeavor if needed.	Municipalities, Lakes Region Land Trust, Conservation Commissions	2027-29	Municipalities
33	The Town of Barnstead's Master Plan Update identifies expanding conserved land for recreation, wildlife habitat, and natural beauty as a goal within the 50-year Conservation and Recreation Plan. A survey through the Town of Alton's Master Plan development identified most people agree or strongly agree that money should be annually appropriated for important land conservation purchases. Consider advocating for land protection within the Halfmoon Lake watershed for its many ecosystem benefits.	Municipalities, Conservation Commissions	2025-34	Grants (Moose Plate, LCHIP, RCCP, NAWCA, LWCF, ACEP, CSP, EQIP, NFWF NEFRG), Municipalities, private landowners
	Septic System Management			
34	Distribute educational materials to property owners about septic system function and maintenance.	Municipalities, HMLA	$3K 2025, 2029, 2034	Municipalities, Grant (319), CWSRF
35	Look into whether any septic pumping companies would give a quantity discount or a discount to members to incentivize septic system pumping.	HMLA	N/A 2025-26	CWSRF
36	Evaluate locations of older and/or noncompliant septic systems (including cesspools or holding tanks) to identify clusters where conversion to community septic systems might be desirable.	HMLA, Municipalities	TBD 2026-28	CWSRF, Municipalities
37	Institute a minimum pump-out/inspection interval for shorefront septic systems (e.g., once every 3-5 years). Pump-outs (~$250 per system) are the responsibility of the owner.	Municipalities	N/A 2029-30	Municipalities
38	Create ordinances that require the inspection of septic systems for all home conversions (from seasonal to permanent residences) and property sales to ensure systems are sized and designed properly. Require upgrades if needed. Consider modeling an ordinance on Barnstead and Alton's septic system regulations pertaining to the Halfmoon Lake watershed area.	Municipalities	N/A 2025-27	Municipalities
39	Develop and maintain a towns-wide septic inventory database base to facilitate code enforcement of any septic system ordinances.	Municipalities	5k 2025-34	Municipalities, CWSRF

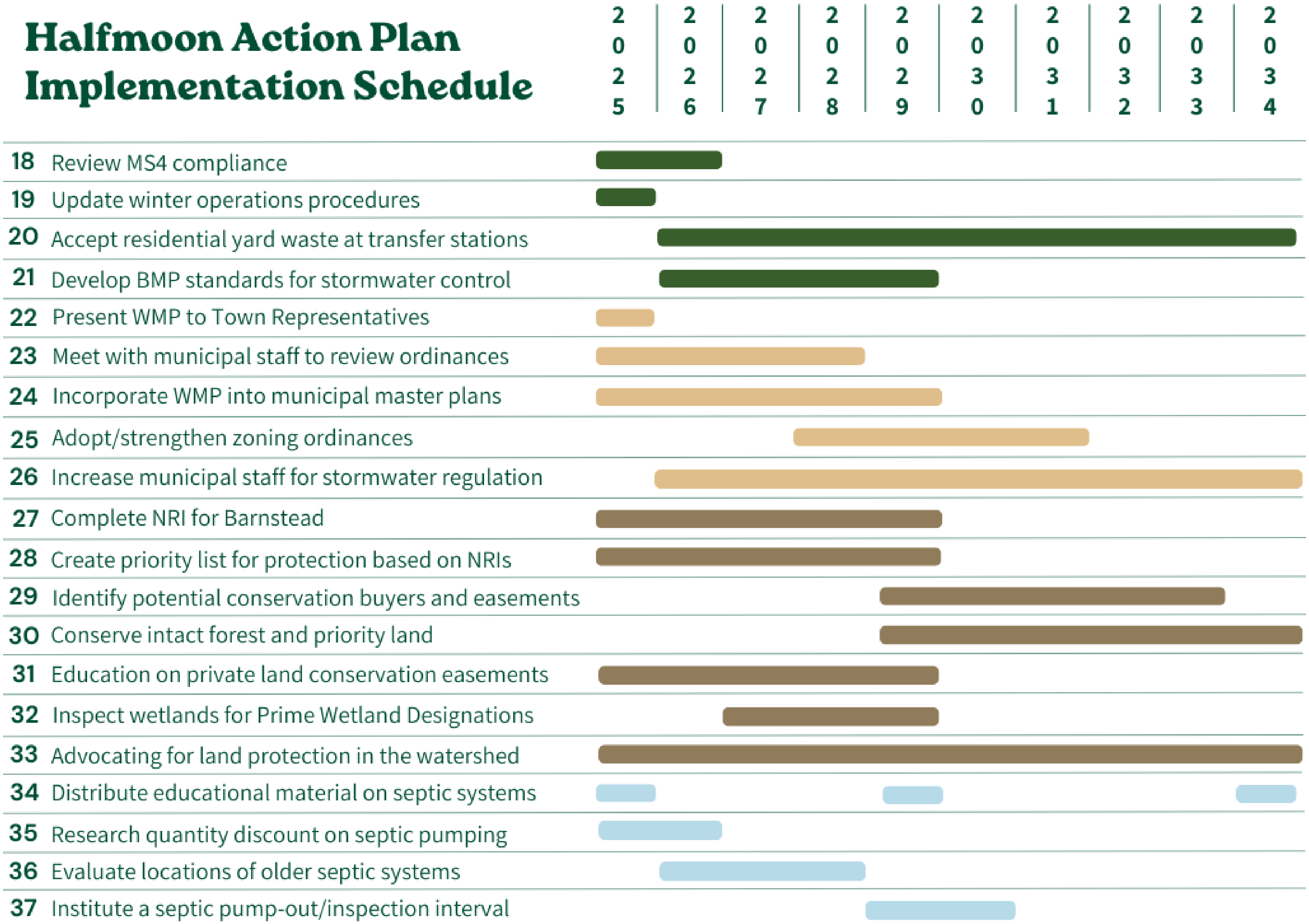
#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
40	Conduct a septic system risk assessment to identify areas in town which may be more susceptible to septic system malfunction due to high groundwaters, soil filtering capacity, risk of flooding, age of infrastructure.	Municipalities	15k-20k 2029-31	Municipalities
	Agricultural Practices			
41	Work with NRCS to implement soil conservation practices such as cover crops, no-till methods, timing of manure applications, and others agricultural BMPs which reduce erosion and nutrient pollution to surface waters from agricultural fields.	NRCS, farm owners	TBD 2025-34	Grants, NRCS
	Education and Outreach			
42	Share additional/dynamic information on the HMLA website, such as water quality data, loon updates, weather conditions, and webcam, to generate more traffic to the website.	HMLA	TBD 2025-34	Grants
43	Combine education opportunities by the HMLA and Conservation Commissions regarding eagles, osprey, loons, water quality, and how humans can help the ecosystem through initiating LakeSmart, soak up the rain, municipal regulations, and proper septic practices, to generate larger audiences. Consider repeating workshop topics every few years as new members and new homeowners enter the watershed.	HMLA, Conservation Commissions	2025-34	Municipalities
44	Educate managers of private boat launches about invasive species management, consider beginning a Lake Host program.	HMLA	$10K 2025-34	Grants (NHDES AIPC)
45	Continue searching for variable milfoil and other invasive aquatic species throughout the lake, but particularly in the cove closest to the public boat ramp.	HMLA, Landowners	TBD 2025-34	
46	Offer workshops for landowners with 10 acres or more for NRCS assistance with land conservation. Cost assumes up to two workshops.	HMLA	$5K 2027-29	Grants (RCCP, ACEP, CSP, EQIP)
47	Encourage private property and road owners to hire Green SnowPro certified commercial salt applicators.	HMLA, Municipalities	N/A 2025-34	Grants, Municipalities
48	Educate private property owners on questions to ask hired landscaping companies to ensure they are complying with shoreland fertilizer rules.	HMLA	N/A 2025-34	

#	Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
49	Educate contractors and municipal staff about erosion and sediment control practices required on plans. Work with municipalities to ensure that there are sufficient resources to enforce permitting conditions.	Municipalities, HMLA, BCCD	$6K 2025-34	Municipalities, Grants (319), CWSRF
50	Create flyers/brochures or other educational materials through printed or online mediums, regarding topics such as stormwater controls, road maintenance, buffer improvements, fertilizer and pesticide use, pet waste disposal, boat pollution, invasive aquatic species, waterfowl feeding, and septic system maintenance. Consider creating a "watershed homeowner" packet that covers these topics and is distributed (mailed separately or in tax bills or posted at community gathering locations or events) to existing and new property owners, as well as renters. Hold 1-2 informational workshops per year to update the public on restoration progress and ways that individuals can help. Cost is highly variable.	Municipalities, HMLA, BCCD	$20K-$60K 2025-34	Municipalities, Grants (319), CWSRF
51	Collaborate with NH Lakes on legislative or advocacy issues such as boat speed limits.	HMLA, NH Lakes	N/A 2025-34	Grants

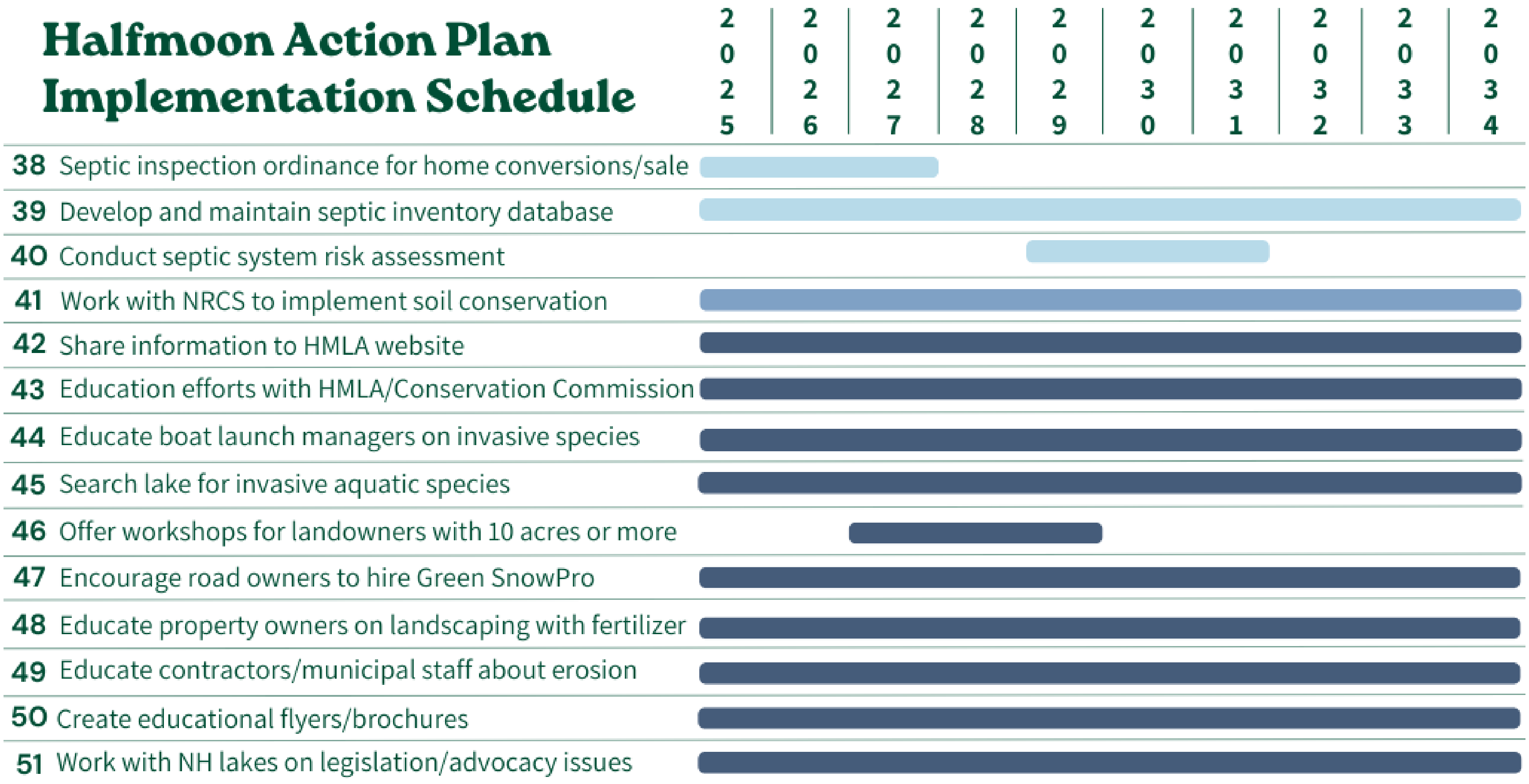
Figure 20. A graphical timeline of the Halfmoon Lake Action Plan implementation.



Halfmoon Action Plan Implementation Schedule



Halfmoon Action Plan Implementation Schedule



5.2 POLLUTANT LOAD REDUCTIONS

To meet the water quality goal, Objective 1 set a target phosphorus load reduction of 45 kg/yr to achieve an in-lake total phosphorus concentration of 8.1 ppb, which meets state water quality standards for mesotrophic waterbodies and is anticipated to substantially reduce the likelihood of cyanobacteria blooms in Halfmoon Lake. The following opportunities for phosphorus load reductions to achieve Objective 1 were identified in the watershed based on field and desktop analyses:

- Remediating the 19 watershed survey sites could prevent up to **23.4 kg/yr** of phosphorus load from entering Halfmoon Lake.
- Treating shoreline sites could reduce the phosphorus load to Halfmoon Lake by **1.16 kg/yr** for the two high impact site (disturbance score 11+), **5.78 kg/yr** for the 20 medium impact sites (disturbance score between 9-10), and **4.92 kg/yr** for the 34 low impact sites (disturbance score between 7-8) identified from the shoreline survey.
- Upgrading the 97 shorefront septic systems older than 25 years is estimated to reduce the phosphorus load to Halfmoon Lake by **9.7 kg/yr**.

Addressing these field-identified phosphorus load reduction opportunities coming from the external watershed load (i.e., watershed and shoreline sites and shorefront septic systems) could reduce the phosphorus load to Halfmoon Lake by 45.5 kg/yr, which meets 100% of the needed reductions to achieve Objective 1 for Halfmoon Lake (Table 18).

Objective 2 (preventing or offsetting additional phosphorus loading from anticipated new development) can be met through ordinance revisions that implement LID strategies and encourage cluster development with open space protection and/or through conservation of key parcels of forested and/or open land.

It is important to note that, while the focus of the objectives for this plan is on phosphorus, the treatment of stormwater and sediment erosion will result in the reduction of many other kinds of pollutants that may impact water quality. These pollutants would likely include other nutrients (e.g., nitrogen), petroleum products, bacteria, road salt/sand, and heavy metals (cadmium, nickel, zinc, etc.). Without a monitoring program in place to measure these other pollutants, it will be difficult to track the success of efforts that reduce these other pollutants. However, there are various spreadsheet models available that can estimate reductions in these pollutants depending on the types of BMPs installed. These reductions can be tracked to help assess long-term response.

Table 18. *Breakdown of phosphorus load sources and modeled water quality for current and target conditions that meet the water quality goal (Objective 1) and that reflect all field identified reduction opportunities in the watershed. Reduction percentages are based out of the current condition value for each parameter.*

Parameter	Unit	Current Condition	WQ Goal & Estimated Reduction Needed *(includes all field-identified reduction opportunities)*	
			Target Condition	**Reduction (Unit, % change)**
Halfmoon Lake				
Total P Load (All Sources)[3]	kg/yr	248.6	203.6	-45, (18%)
(A) Background P Load[1]	kg/yr	78.3	78.3	-
(B) Disturbed (Human) P Load[2]	kg/yr	170.3	125.3	-45, (26%)
(C) Developed Land Use P Load	kg/yr	136	101	-35, (26%)
(D) Septic System P Load	kg/yr	24	14.6	-9.7, (40%)
(E) Internal P Load	kg/yr	22	22	0, (0%)
In-Lake TP*	ppb	11.9	9.7	-2.18, (18%)
In-Lake Chl-a*	ppb	3.9	3	-0.9, (23%)
In-Lake SDT*	meters	3.5	4.4	0.9, (26%)
In-Lake Bloom Probability*	days	18	5	-18, (72%)

[1] Sum of forested/water/natural land use load, waterfowl load, and atmospheric load

[2] Sum of developed land use load, shorefront septic system load, and internal load (B = C+D+E)

[3] Total P Load (All Sources) = A + B

** Water quality parameters were sourced from the model.*

6 PLAN IMPLEMENTATION & EVALUATION

The following section details the oversight and estimated costs (with funding strategy) needed to implement the action items recommended in the Action Plan (Section 5), as well as the monitoring plan and indicators to measure progress of plan implementation over time.

6.1 PLAN OVERSIGHT

The recommendations of this plan will be carried out largely by HMLA with assistance from a diverse stakeholder group, including representatives from the municipalities (e.g., select boards, planning boards), conservation commissions, state and federal agencies or organizations, nonprofits, land trusts, schools and community groups, local business leaders, and landowners. HMLA will need to meet regularly and work hard to coordinate resources across stakeholder groups to fund and implement the management actions. The Action Plan (Section 5) will need to be updated periodically (typically every 2, 5, and 10 years) to ensure progress and to incorporate any changes in watershed activities. Measurable milestones (e.g., number of BMP sites, volunteers, funding received, etc.) should be tracked by HMLA.

The Action Plan (Section 5) identifies the stakeholder groups responsible for each action item. Generally, the following responsibilities are noted for each key stakeholder:

- **HMLA** will be responsible for plan oversight and implementation. HMLA will conduct water quality monitoring, facilitate outreach activities and watershed stewardship, and raise funds for stewardship work.
- **Municipalities** will work to address NPS problems identified in the watershed, including conducting regular best practices maintenance on roads, adopting ordinances for water quality protection, and addressing other recommended actions specified in the Action Plan. HMLA and other local groups can work with each municipality to provide support in reviewing and tailoring the recommendations to fit the specific needs of each community.
- **Conservation Commissions** will work with municipal staff and boards to facilitate the implementation of the recommended actions specified in the Action Plan.
- **The BCCD** can provide administrative capacity and can help acquire grant funding for BMP implementation projects and education/outreach to watershed residents and municipalities.
- **NHDES** can provide technical assistance, permit approval, and the opportunity for financial assistance through the 319 Watershed Assistance Grant Program and other funding programs.
- **Private Landowners** will seek opportunities for increased awareness of water quality protection issues and initiatives and conduct activities in a manner that minimizes pollutant impact to surface waters.

The success of this plan is dependent on the continued effort of volunteers and a strong and diverse committee that meets regularly to coordinate resources for implementation, review progress, and make any necessary adjustments to the plan to maintain relevant action items and interim milestones. A reduction in nutrient loading is no easy task, and because there are many diffuse sources of phosphorus reaching the rivers, lakes, and ponds from existing development, roads, septic systems, and other land uses in the watershed, it will require an integrated and adaptive approach across many different parts of the watershed community to be successful.

6.2 ESTIMATED COSTS

The strategy for reducing pollutant loading to Halfmoon Lake to meet the water quality goal and objectives set in Section 2.6 will be dependent on available funding and labor resources but will include approaches that address sources of phosphorus loading, as well as water quality monitoring and education and outreach. Additional significant but difficult to quantify strategies for reducing phosphorus loading to the lake are revising local ordinances such as setting LID requirements on new construction, identifying and replacing malfunctioning septic systems, performing proper road maintenance, and improving agricultural practices (refer to Section 5: Action Plan for more details). With a dedicated stakeholder group in place and with the help of grant or local funding, it is possible to achieve the target phosphorus reductions and meet the established water quality goal for Halfmoon Lake in the next 10 years. **The cost of successfully implementing the plan is estimated to be at least $0.6-$1.2 million over the next 10 or more** years (Table 19). However, many costs are still unknown or were roughly estimated and should be updated as information becomes available. In addition, costs to private landowners (e.g., septic system upgrades, private road maintenance, etc.) are not reflected in the estimate.

Table 19. *Estimated pollutant reduction (TP) in kg/year and estimated total and annual 10-year costs for implementation of the Action Plan to meet the water quality goal and objectives for Halfmoon Lake. The light gray shaded planning actions are necessary to achieve the water quality goal. Other planning actions are important but difficult to quantify for TP reduction and costs, the latter of which were roughly estimated here as general placeholders.*

Planning Action	TP Reduction (kg/yr)	Estimated Total Cost	Estimated Annual Cost
Watershed & Shoreline BMPs	**35.26**	$503,152 - $1,052,200	$50,315 - $105,220
Road Management	TBD	$43,600 - $49,000	$4,360 - $4,900
Municipal Operations	TBD	TBD	TBD
Municipal Land Use Planning & Zoning	**(57)***	$4,000	$400
Land Conservation	Included in land use planning & zoning	$29,000 - $33,000	$2,900 - $3,300
Septic System Management	**9.7**	$23,000 - $28,000	$2,300 - $2,800
Agricultural Practices	TBD	TBD	TBD
Education & Outreach	TBD	$41,000 - $81,000	$4,100-$8,100
Total	**45**	**$643,752 - $1,247,200**	**$64,375-$124,720**

** Estimated increase in phosphorus load from new development in the next 10 years.*

6.3 FUNDING STRATEGY

It is important that HMLA develop a strategy to collect the funds necessary to implement the recommendations listed in the Action Plan (Section 5). Funding to cover ordinance revisions and third-party review could be supported by municipalities through tax collection (as approved by majority vote by town residents). Monitoring and assessment funding could come from a variety of sources, including state and federal grants, municipalities, or donations. Funding to improve septic systems, roads, and shoreland zone buffers would likely come from property owners. As the plan evolves into the future, the establishment of a funding subcommittee will be a key part in how funds are raised, tracked, and spent to implement and support the plan. Listed below are state and federal funding sources that could assist HMLA with future water quality and watershed work on Halfmoon Lake.

Funding Options:

- **EPA/NHDES 319 Grants (Watershed Assistance Grants)** – This NPS grant is designed to support local initiatives to restore impaired waters (priorities identified in the NPS Management Program Plan, updated 2014) and protect high quality waters. 319 grants are available for the implementation of watershed-based plans and typically fund $50,000 to $150,000 projects over the course of two years. https://www.des.nh.gov/business-and-community/loans-and-grants/watershed-assistance
- **NH State Conservation Committee (SCC) Grant Program (Moose Plate Grants)** – County Conservation Districts, municipalities (including commissions engaged in conservation programs), and qualified nonprofit organizations are eligible to apply for the SCC grant program. Projects must qualify in one of the following categories: Water Quality and Quantity; Wildlife Habitat; Soil Conservation and Flooding; Best Management Practices; Conservation Planning; and Land Conservation. The total SCC grant request per application cannot exceed $24,000. https://www.mooseplate.com/grants/
- **Land and Community Heritage Investment Program (LCHIP)** – This grant provides matching funds to help municipalities and nonprofits protect the state's natural, historical, and cultural resources. https://www.lchip.org/index.php/for-applicants/general-overview-schedule-eligibility-and-application-process
- **Aquatic Resource Mitigation Fund (ARM)** – This grant provides funds for projects that protect, restore, or enhance wetlands and streams to compensate for impacted aquatic resources. The fund is managed by the NHDES Wetlands Bureau that oversees the state In-Lieu Fee (ILF) compensatory mitigation program. A permittee can make a payment to NHDES to mitigate or offset losses to natural resources because of a project's impact to the environment. https://www.des.nh.gov/climate-and-sustainability/conservation-mitigation-and-restoration/wetlands-mitigation

- **New England Forest and River Grant (NFWF NEFRG)**– This grant awards $50,000 to $200,000 to projects that restore and sustain healthy forests and rivers through habitat restoration, fish barrier removal, and stream connectivity such as culvert upgrades. https://www.nfwf.org/newengland/Pages/home.aspx
- **Aquatic Invasive Plant Control, Prevention and Research Grants (NHDES AIPC)** – Funds are available each year for projects that prevent new infestations of exotic plants, including outreach, education, Lake Host Programs, and other activities. https://www.des.nh.gov/business-and-community/loans-and-grants/rivers-and-lakes
- **Clean Water State Revolving Fund (NHDES CWSRF)** – This fund provides low-interest loans to communities, nonprofits, and other local government entities to improve and replace wastewater collection systems with the goal of protecting public health and improving water quality. A portion of the CWSRF program is used to fund NPS pollution prevention, watershed protection and restoration, and estuary management projects that help improve and protect water quality in NH. https://www.des.nh.gov/business-and-community/loans-and-grants/clean-water-state-revolving-fund
- **Regional Conservation Partnership Program (RCCP) -** This NRCS grant provides conservation assistance to producers and landowners for projects carried out on agricultural land or non-industrial private forest land to achieve conservation benefits and address natural resource challenges. Eligible activities include land management restoration practices, entity-held easements, and public works/watershed conservation activities. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/rcpp/
- **Agricultural Conservation Easement Program (ACEP) -** This NRCS grant protects the agricultural viability and related conservation values of eligible land by limiting nonagricultural uses which negatively affect agricultural uses and conservation values, protect grazing uses and related conservation values by restoring or conserving eligible grazing land, and protecting, restoring, and enhancing wetlands on eligible land. Eligible applicants include private landowners of agricultural land, cropland, rangeland, grassland, pastureland, and non-industrial private forestland. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep/
- **Conservation Stewardship Program (CSP) -** This NRCS grant helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resource concerns. Eligible lands include private agricultural lands, non-industrial private forestland, farmstead, and associated agricultural lands, and public land that is under control of the applicant. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/
- **Environmental Quality Incentives Program (EQIP) -** This NRCS grant provides financial and technical assistance to agricultural producers and non-industrial forest managers to address natural resource concerns and deliver environmental benefits. Eligible applicants include agricultural producers, owners of non-industrial private forestland, water management entities, etc. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/
- **National Fish and Wildlife Federation (NFWF) Five Star and Urban Waters Restoration Grants (NFWF 5-Star) -** Grants seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. Eligible projects include wetland, riparian, in-stream and/or coastal habitat restoration; design and construction of green infrastructure BMPs; water quality monitoring/assessment; outreach and education. https://www.nfwf.org/programs/five-star-and-urban-waters-restoration-grant-program
- **North American Wetlands Conservation Act (NAWCA) Grants -** The U.S. Standard Grants Program is a competitive, matching grants program that supports public-private partnerships carrying out projects in the United States that further the goals of the North American Wetlands Conservation Act (NAWCA). These projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated uplands habitats for the benefit of all wetlands-associated migratory birds. https://www.fws.gov/service/north-american-wetlands-conservation-act-nawca-grants-us-standard
- **National Park Service - Land and Water Conservation Fund Grant Program (LWCF) -** Eligible projects include acquisition of parkland or conservation land; creation of new parks; renovations to existing parks; and development of trails. Municipalities must have an up-to-date Open Space and Recreation Plan. Trails constructed using grant funds must be ADA-compliant. https://www.nhstateparks.org/about-us/community-recreation/land-water-conservation-fund-grant

6.4 MONITORING PLAN

A long-term water quality monitoring plan is critical to evaluate the effectiveness of implementation efforts over time. Given the available historic data summarized in this report, the following monitoring efforts are recommended to be conducted by HMLA as feasible.

- Continue collecting temperature and dissolved oxygen profiles and Secchi disk transparency at the deep spot of Halfmoon Lake a minimum of once per month from May 15th through September 30th (preferably twice a month) between 10am and 2pm. Profiles should measure dissolved oxygen and temperature at each meter in the lake profile and be submitted to the Volunteer Lake Monitoring Program.
- Continue routine sampling for turbidity, pH, specific conductivity, and chloride at all long-term monitoring locations at a minimum.
- Continue conducting visual assessments for cyanobacteria from May through November.

NHDES requires **dissolved oxygen** samples to meet stringent requirements in order to be included in State assessment. These requirements are intended to ensure that dissolved oxygen data is consistent and represents the highest stress periods of the year and time of day (June 1 to September 30 and between 10am and 2pm). Samples also must be collected from the epilimnion (defined as the surface to the first 1 or more ˚C change in temperature). To meet Class B standards, no more than two or 10% of samples (whichever is greater) that meet these requirements can have a dissolved oxygen concentration less than 5 mg/L.

If additional funding is available, we also recommend the following to better characterize the contribution of phosphorus from internal loading:

- Repeat the September 2024 investigatory sampling of total phosphorus grab samples at the deep spot of Halfmoon Lake every 2 meters from the surface (1 meter) to the bottom (8.5 meters) at the deep spot of Halfmoon Lake, for a total of 2-3 times in August through September.
- Consider collecting conductivity, chloride, and turbidity during wet weather at the stream inlets multiple times throughout the year, including in the winter and during spring snowmelt.
- Consider collecting sediment samples (top 4 inches) collected from the deep spot of Halfmoon Lake to analyze elemental ratios of phosphorus, aluminum, and iron and characterize biologically labile fractions of phosphorus should anoxia continue to occur from July until fall turnover.
- Consider coordinating with NH VLAP to conduct another phytoplankton study to assess these population dynamics and investigate if the shift from golden-browns and diatoms to cyanobacteria persists.
- Recruit additional water quality monitors to aid in sample collection and increase public awareness.

6.5 INDICATORS TO MEASURE PROGRESS

The following environmental, programmatic, and social indicators and associated numeric targets (milestones) will help to quantitatively measure the progress of this plan in meeting the established goal and objectives for the Halfmoon Lake watershed (Table 20). These benchmarks represent short-term (2026), mid-term (2029), and long-term (2034) targets derived directly from actions identified in the Action Plan (Section 5). Setting milestones allows for periodic updates to the plan, maintains and sustains the action items, and makes the plan relevant to ongoing activities. HMLA should review the milestones for each indicator on an ongoing basis to determine if progress is being made, and then determine if the plan needs to be revised because the targets are not being met.

Environmental Indicators are a direct measure of environmental conditions. They are measurable quantities used to evaluate the relationship between pollutant sources and environmental conditions. They assume that recommendations outlined in the Action Plan (Section 5) will be implemented accordingly and will result in the improvement of water quality. Programmatic indicators are indirect measures of watershed protection and restoration activities. Rather than indicating that water quality reductions are being met, these programmatic measurements list actions intended to meet the water quality goal. Social Indicators measure changes in social or cultural practices and behavior that lead to implementation of management measures and water quality improvement.

Table 20. *Environmental, programmatic, and social indicators for the Halfmoon Lake Watershed-Based Management Plan.*

Indicators	Milestones*		
	2026	**2029**	**2034**
ENVIRONMENTAL INDICATORS			
Achieve an average summer deep spot epilimnion total phosphorus concentration of 8.1 ppb at the deep spot station in Halfmoon Lake	<9.2 ppb	<8.7 ppb	<8.1 ppb
Achieve an average summer deep spot epilimnion chlorophyll-a concentration of less than 3.0 ppb at the deep spot station in Halfmoon Lake	<3.6 ppb	<3.3 ppb	<3.0 ppb
Eliminate the occurrence of cyanobacteria or algal blooms in Halfmoon Lake (milestones based on model results)	18 days/yr	9 days/yr	0 days/yr
Achieve an average summer water clarity of 6 m or deeper at the deep spot station in Halfmoon Lake	5 m+	5.5 m+	6 m+
Prevent and/or control the introduction and/or proliferation of invasive aquatic species all waterbodies	Absence of invasives	Absence of invasives	Absence of invasives
PROGRAMMATIC INDICATORS			
Amount of funding secured from municipal/private work, fundraisers, donations, and grants	$200,000	$625,000	$1,250,000
Number of NPS sites remediated (19 identified)	6	13	19
Linear feet of buffers improved in the shoreland zone	500	2,000	5,000
Percentage of shorefront properties with LakeSmart certification	25%	50%	75%
Number of watershed/shoreline properties receiving technical assistance for implementation cost sharing	2	10	25
Number of workshops and trainings for stormwater improvements to residential properties (e.g., NHDES Soak Up the Rain NH program)	1	2	5
Number of updated or new ordinances that target water quality protection	1	2	3
Number of new municipal staff for inspections and enforcement of regulations	1	1	2
Number of voluntary or required septic system inspections (seasonal conversion and property transfer)	2	10	25
Number of septic system upgrades	2	10	25
Number of informational workshops and/or trainings for landowners, municipal staff, and/or developers/landscapers on local ordinances, watershed goals, and/or best practices for road management and winter maintenance	1	5	10
Number of parcels with new conservation easements or number of parcels put into permanent conservation	1	2	5
Number of copies of watershed-based educational materials distributed or articles published	200	500	1,000
Number of new best practices for road management and winter maintenance implemented on public and private roads by the municipalities	2	5	10
Number of municipalities fully implementing key aspects of the MS4 program	1	1	2
Number of meetings and/or presentations to municipal staff and/or boards related to the WMP	2	5	10
Number of CNMPs completed or NRCS technical assistance provided for farms in the watershed	1	2	3
SOCIAL INDICATORS			
Number of new association members	5	10	25
Number of volunteers participating in educational campaigns	3	10	15
Number of people participating in informational meetings, workshops, trainings, BMP demonstrations, or group septic system pumping	50	75	100
Number of watershed residents installing conservation practices on their property and/or participating in LakeSmart	5	25	50

Indicators	Milestones*		
	2026	**2029**	**2034**
Number of municipal DPW staff receiving Green SnowPro training	1	3	5
Number of groups or individuals contributing funds for plan implementation	25	50	100
Number of newly trained water quality and invasive species monitors	2	4	6
Percentage of residents making voluntary upgrades or maintenance to their septic systems (with or without free technical assistance), particularly those identified as needing upgrades or maintenance	10%	25%	50%
Number of farmers working with NRCS or BCCD	1	2	3
Number of daily visitors to the HMLA website	10	25	50

**Milestones are cumulative starting at year 1, 2025.*

ADDITIONAL RESOURCES

Buffers for wetlands and surface waters: a guidebook for New Hampshire municipalities. Chase, et al. 1997. NH Audubon Society.

Conserving your land: options for NH landowners. Lind, B. 2005. Center for Land Conservation Assistance / Society for the Protection of N.H. Forests.

Gravel road maintenance manual: a guide for landowners on camp and other gravel roads. Maine Department of Environmental Protection, Bureau of Land and Water Quality. April 2010.

Gravel roads: maintenance and design manual. U.S. Department of Transportation, Federal Highway Program. November 2000. South Dakota Local Transportation Assistance Program (SD LTAP).

Innovative land use techniques handbook. New Hampshire Department of Environmental Services. 2008.

Landscaping at the water's edge: an ecological approach. University of New Hampshire, Cooperative Extension. 2007.

New Hampshire Homeowner's Guide to Stormwater Management: Do-It-Yourself Stormwater Solutions for Your Home. New Hampshire Department of Environmental Services, Soak Up the Rain NH. Revised November 2019.

NRCS *Field Office Technical Guide (FOTG)* for NH to provide information regarding agricultural BMPs

Protecting water resources and managing stormwater. University of New Hampshire, Cooperative Extension & Stormwater Center. March 2010.

Stormwater Manual, Volumes 1-3. New Hampshire Department of Environmental Services. 2008.

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Cyanobacteria in New Hampshire Waters. WD-WMB-10, 2023.

Erosion Control for Construction within the Protected Shoreland. SP-1, 2020.

Lake Eutrophication. WD-BB-3, 2019.

Lawn Care within the Protected Shoreland. SP-2, 2020.

New Hampshire Fish Consumption Guidelines. ARD-EHP-25, 2021.

New Hampshire Volunteer Lake Assessment Program (VLAP). WB-BB-26, 2019.

Phosphorus: Too much of a good thing. WD-BB-20, 2019.

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Why Watersheds Are Important to Protect. WMB-19, 2020.

You and Your Septic System, a Homeowner's Guide to Septic System Maintenance. SSB-13 2020.

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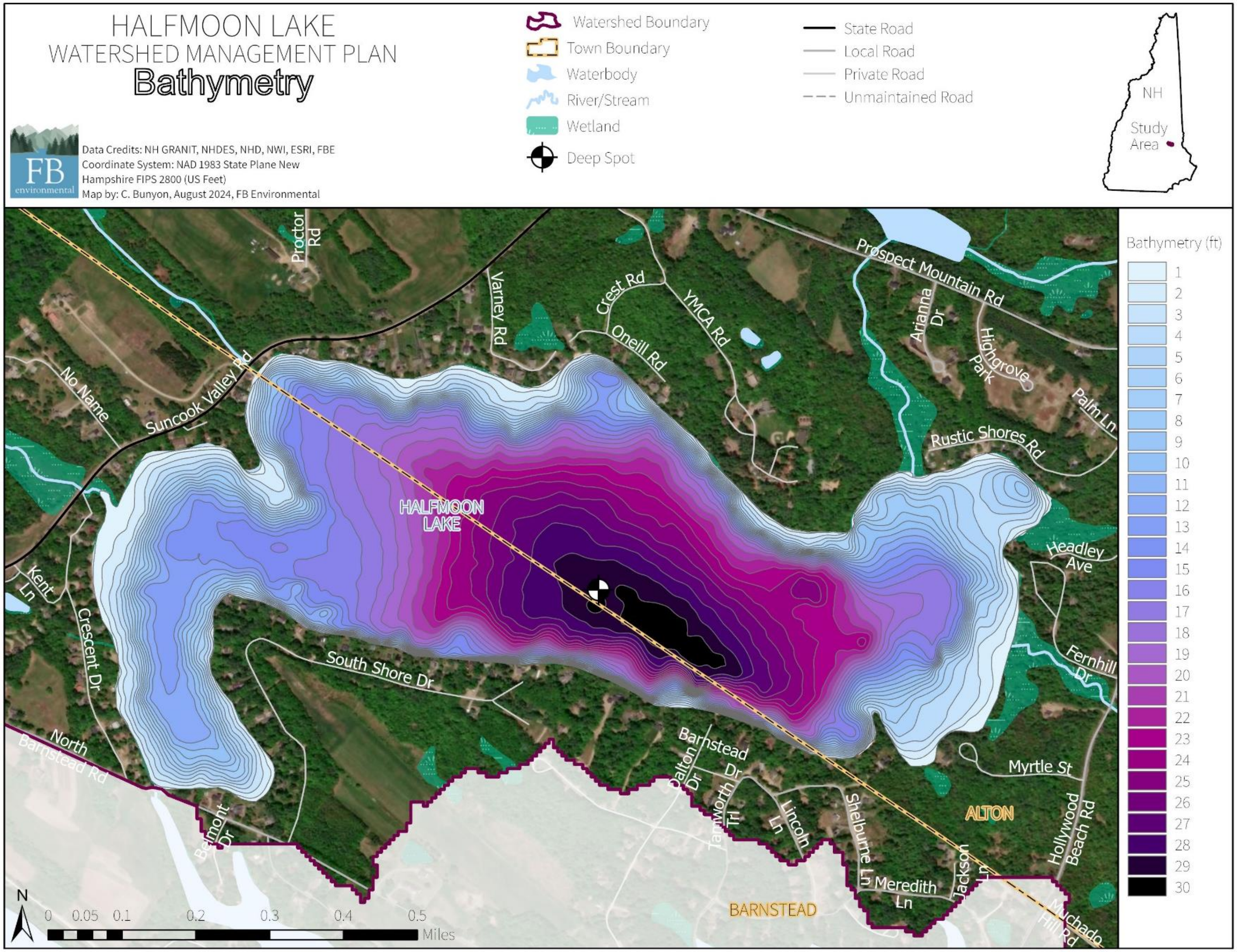
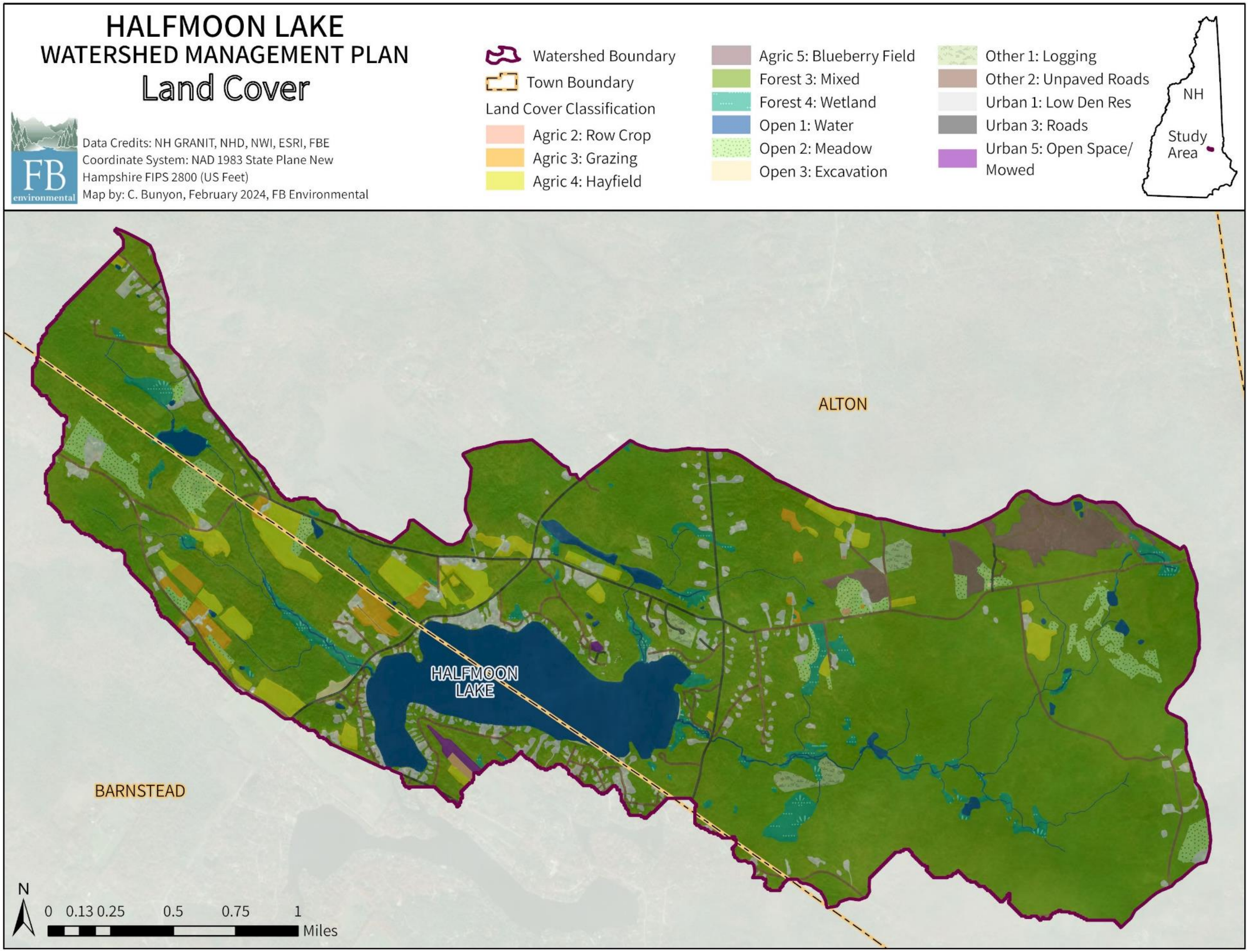
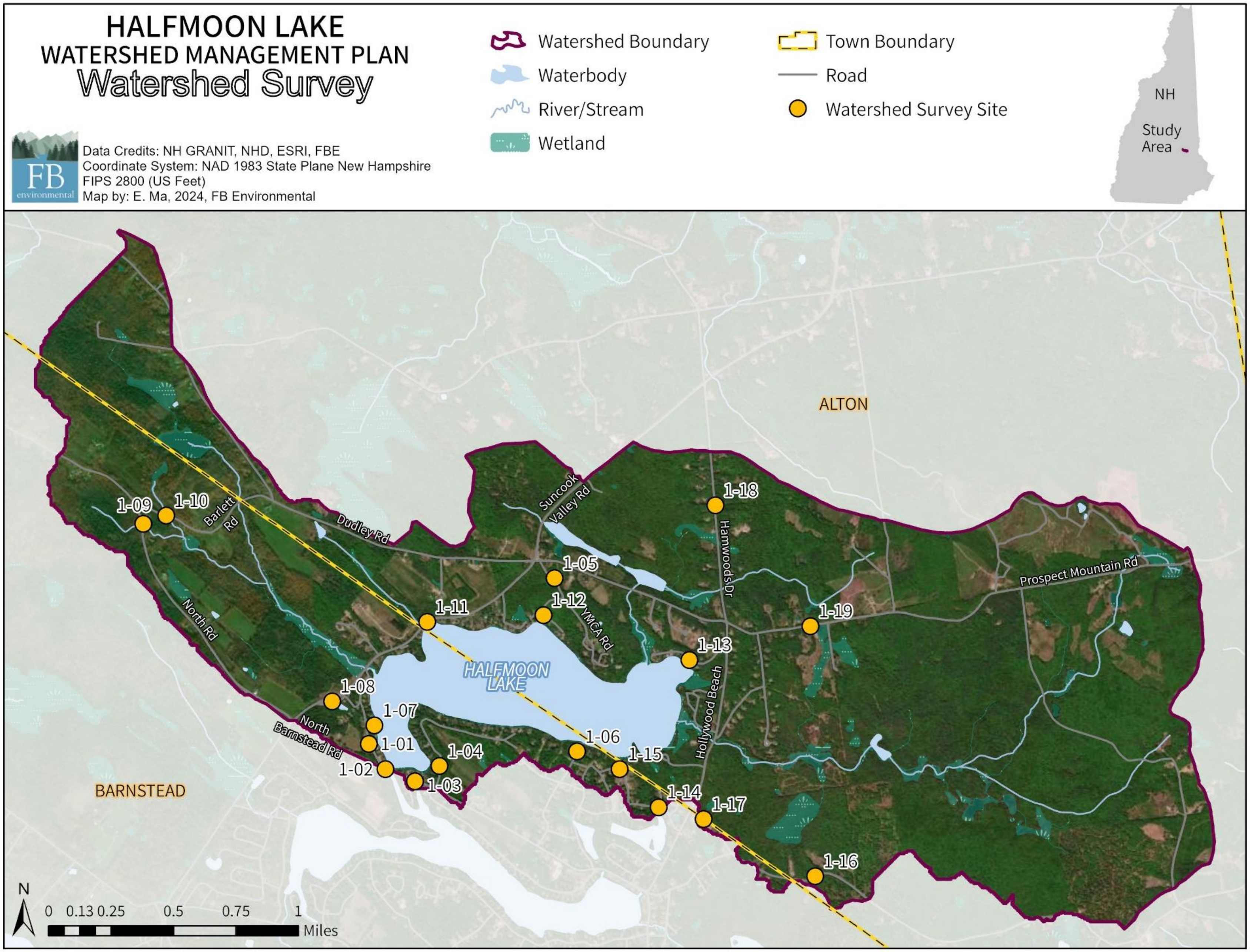
APPENDIX A: SUPPORTING MAPS



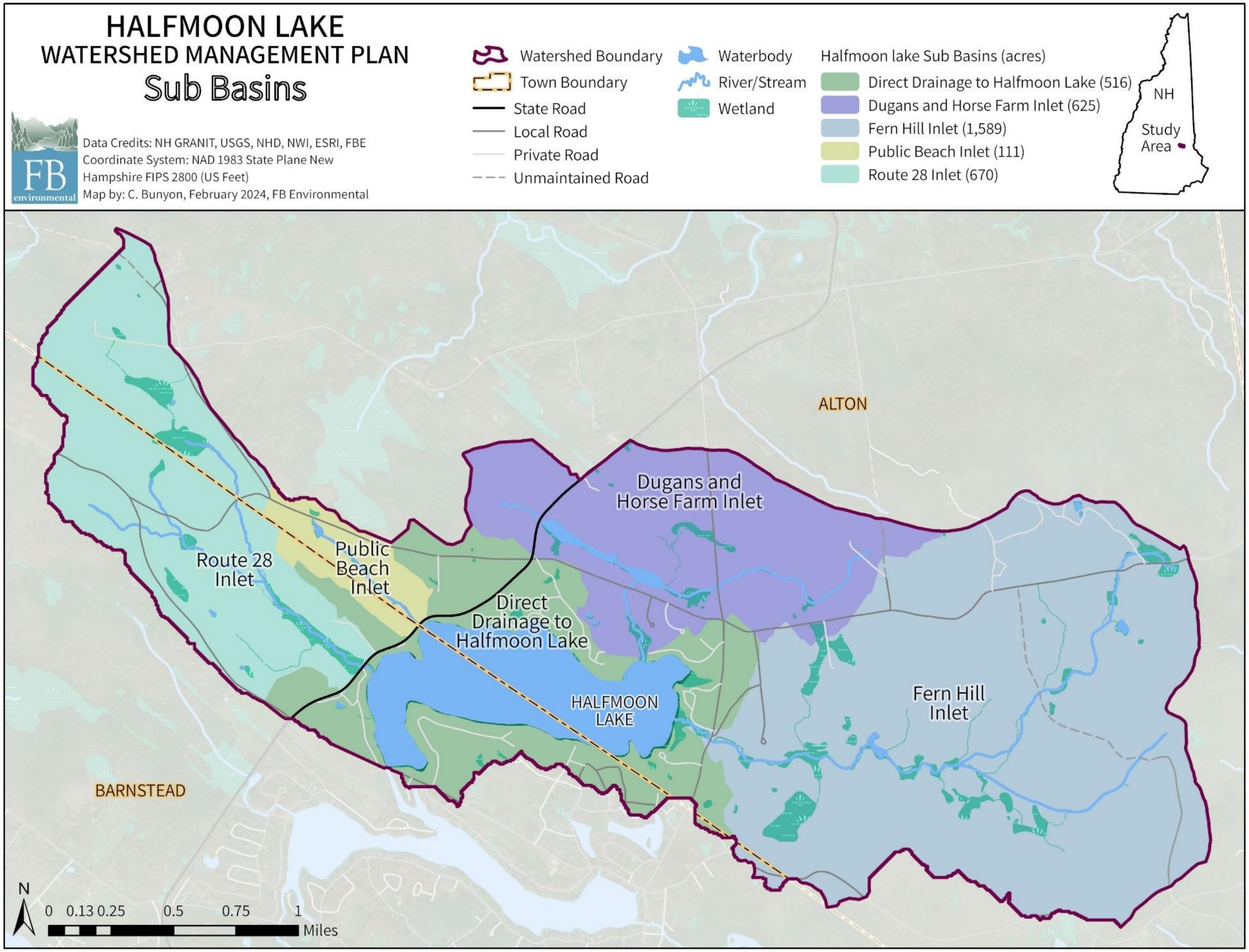
Map A-1. Bathymetry as 1-foot depth contours for Halfmoon Lake. Surveyed by NHDES in 2023.



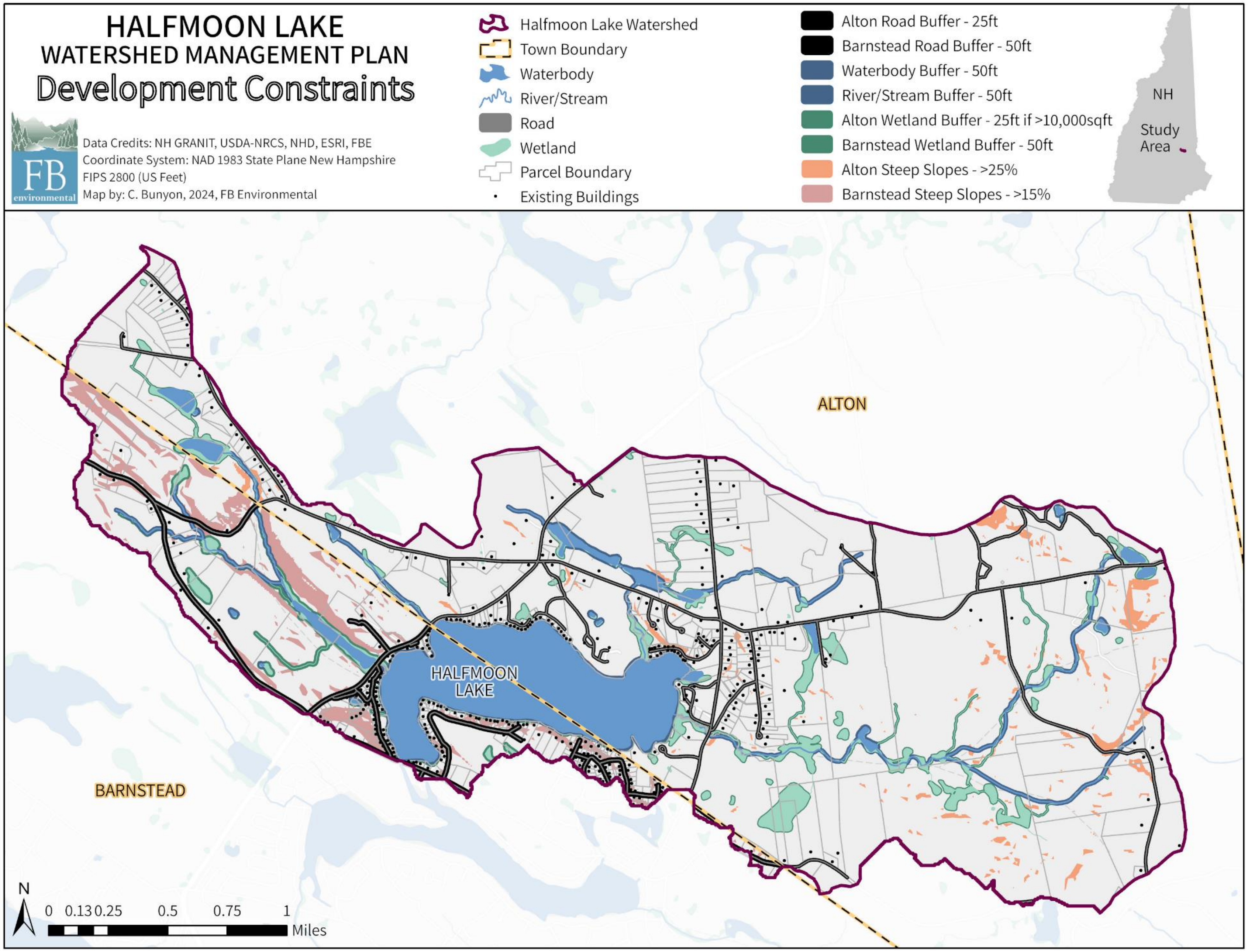
Map A-2. Land cover for the Halfmoon Lake watershed.



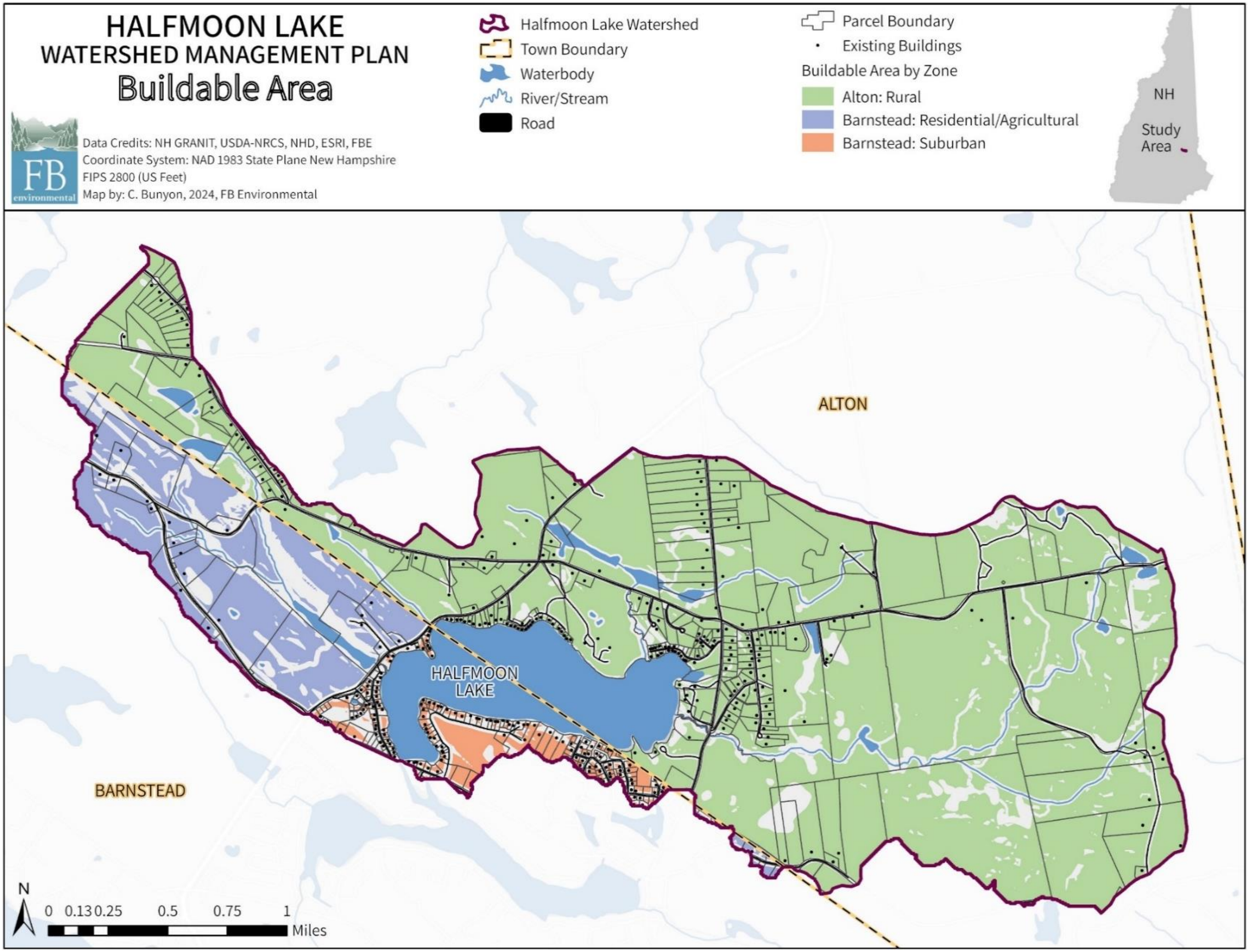
Map A-3. Location of identified NPS sites during the Watershed Survey of the Halfmoon Lake watershed.



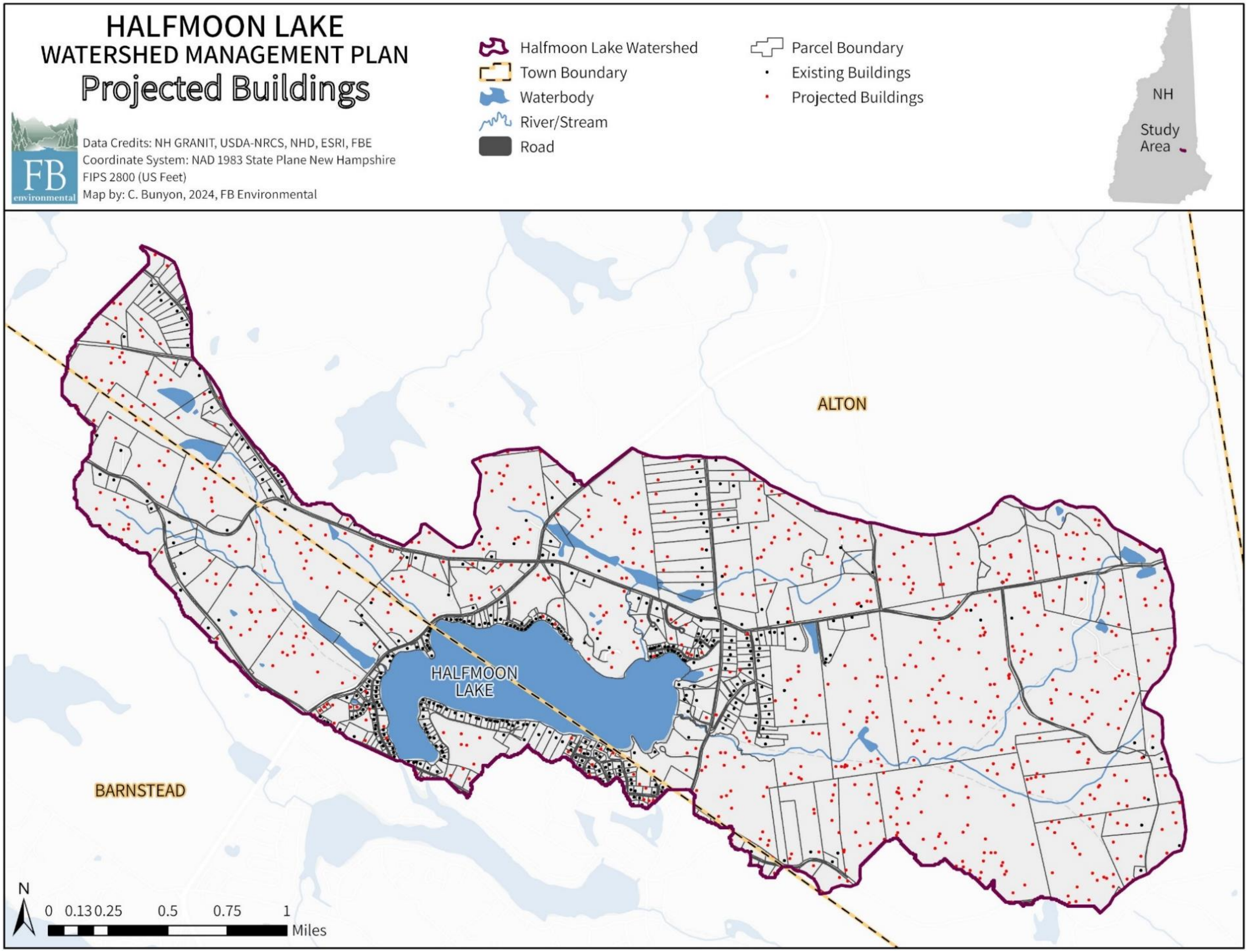
Map A-4. Subbasins within the Halfmoon Lake watershed.



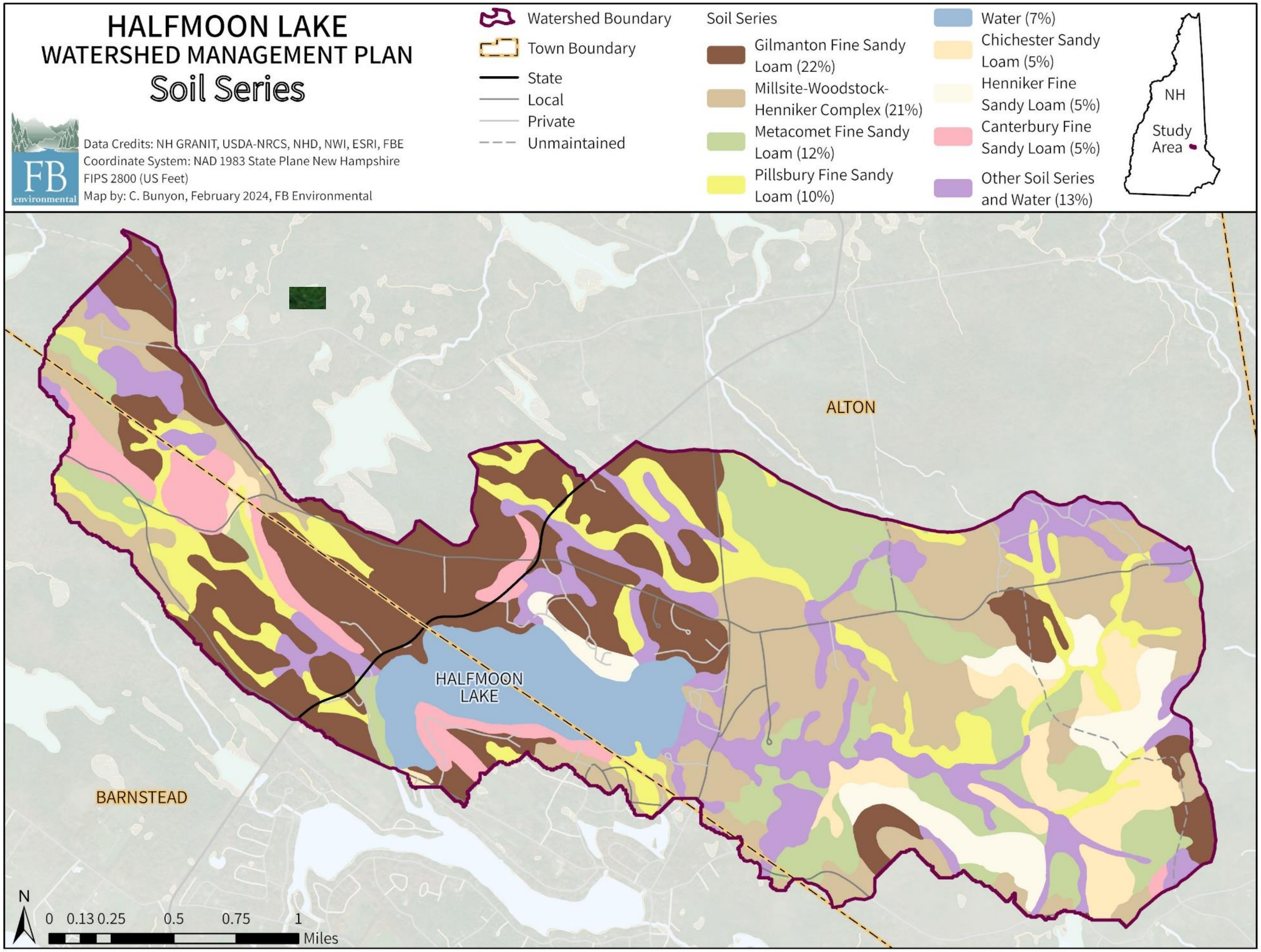
Map A-5. Development constraints in the Halfmoon Lake watershed in Alton and Barnstead, NH



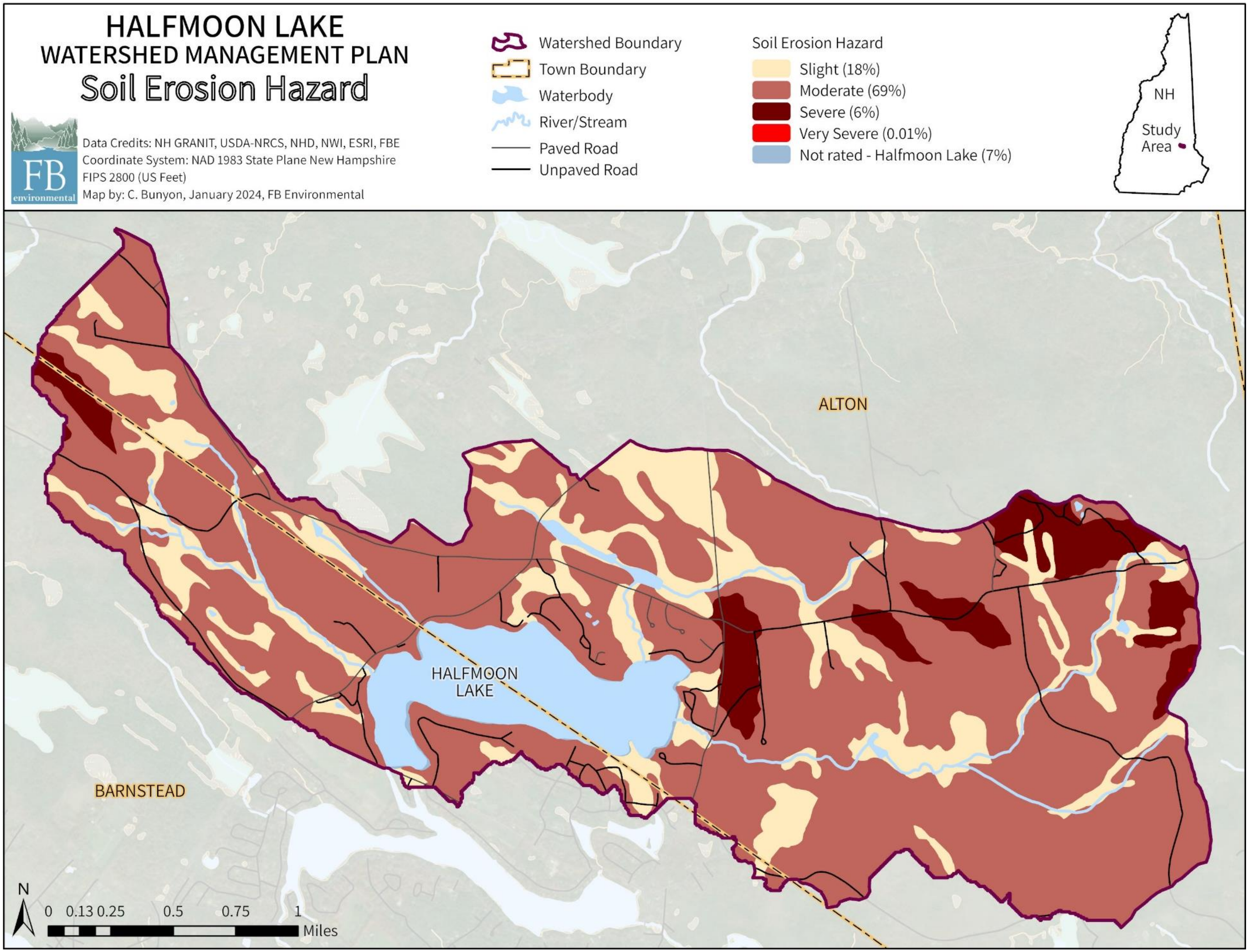
Map A-6. Buildable area by municipal zone in the Halfmoon Lake watershed in Alton and Barnstead, New Hampshire.



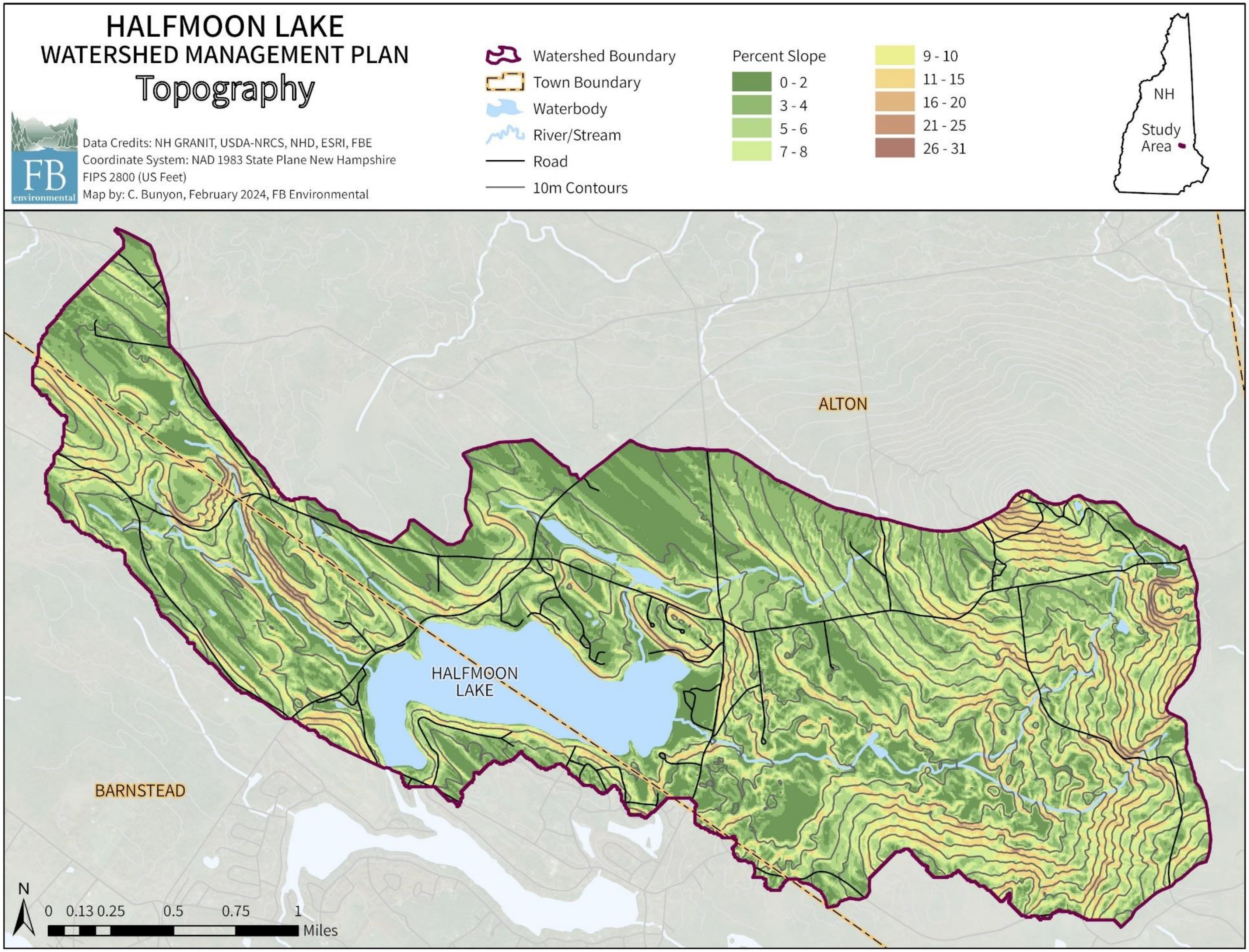
Map A-7. Projected buildings in the Halfmoon Lake watershed in Alton and Barnstead, New Hampshire.



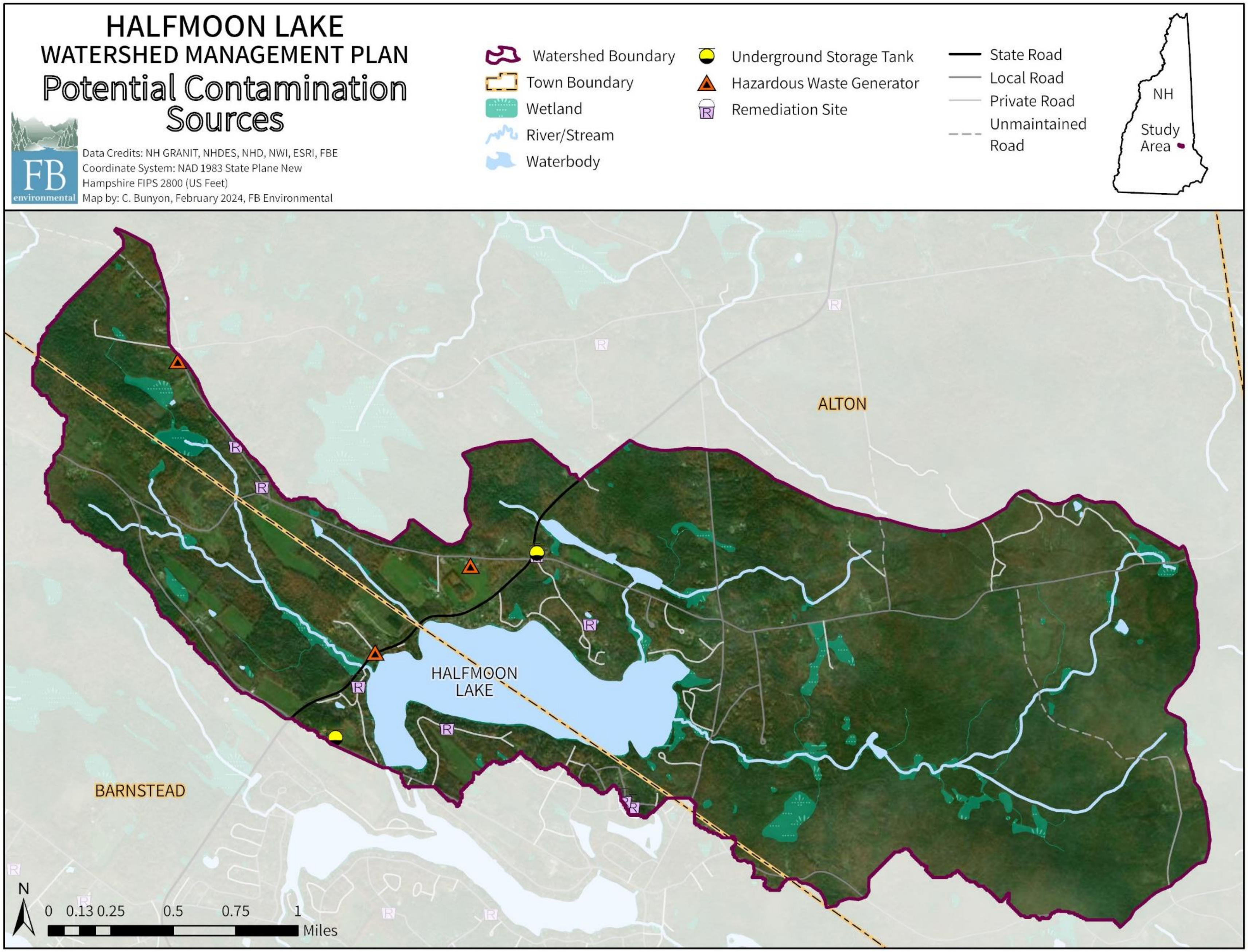
Map A-8. Soil series in the Halfmoon Lake watershed.



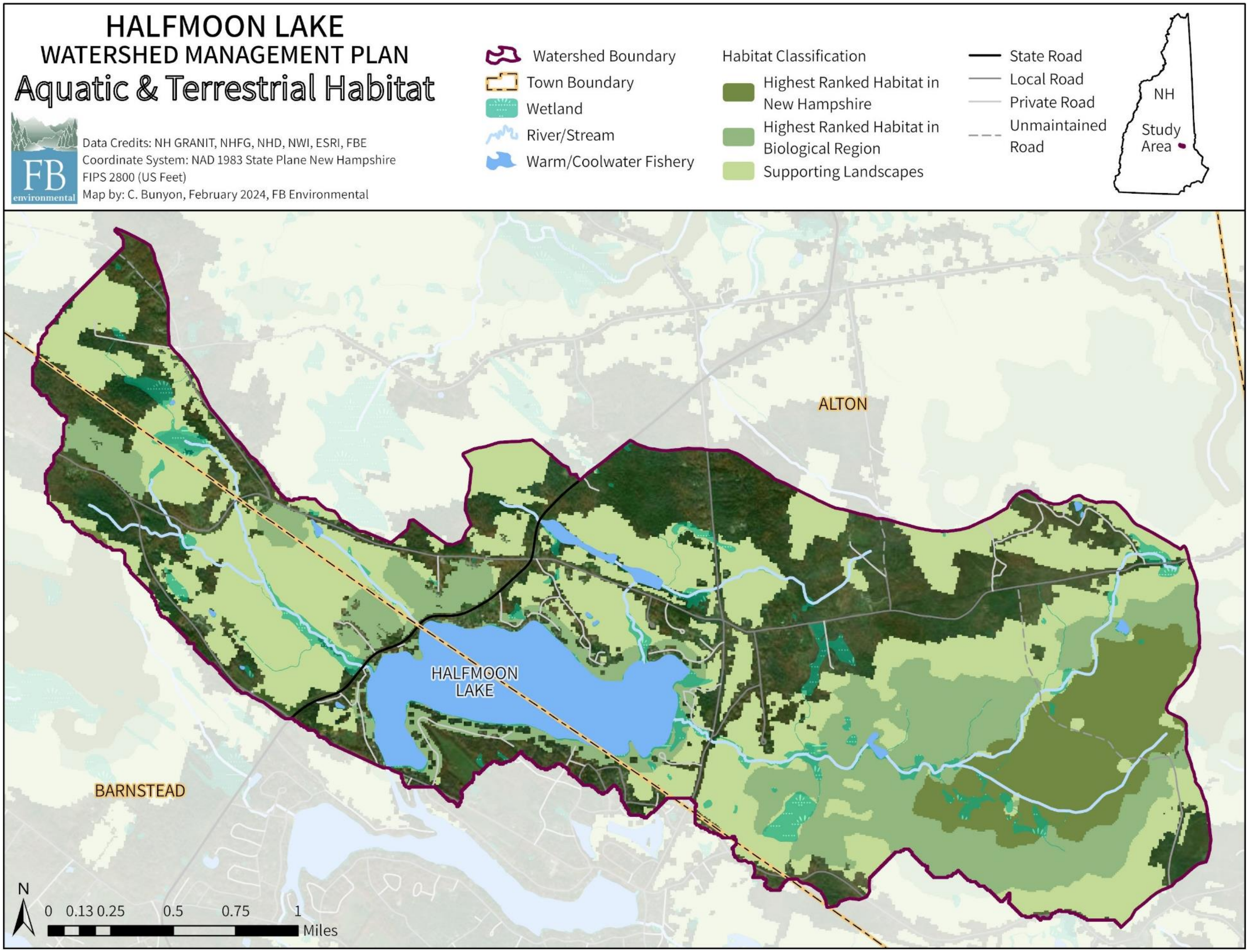
Map A-9. Soil Erosion Hazard in the Halfmoon Lake watershed.



Map A-10: Landscape topography of the Halfmoon Lake watershed derived from a digital elevation model.



Map A-11. Potential sources of contamination in the Halfmoon Lake watershed.



Map A-12. High value habitat in the Halfmoon Lake watershed according to the 2015 New Hampshire Wildlife Action Plan.

APPENDIX B: BMP MATRIX

Table B-1. Site ID, location description, problem description, BMP recommendation, water quality impact, estimated load reduction and implementation costs, and ranking for the 19 nonpoint source sites identified in the Halfmoon Lake watershed. Pollutant load reduction and cost estimates are preliminary and are for planning purposes only. Cost estimates are based on pre-COVID19 ranges (adjusted for 2024 inflation), and thus actual construction costs could be highly variable at this time. The top three priority sites for remediation are highlighted in gray. Rank was determined by a weighting the low-high impacts with cost per TP load reduction, then adjusted based on feedback from the Steering Committee and members of the community.

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION			ESTIMATED COST		RANK
					TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	Est. Low Cost	Est. High Cost	
1-02	Boat Ramp and Road Shoulder	The surface of the privately owned and steeply sloping boat ramp on North Barnstead Road contains a large amount of loose sediment which has been eroding directly into Halfmoon Lake. Looking uphill, the road shoulder of Crescent Road is eroding on both sides of the road, which directs stormwater runoff to the boat ramp. According to watershed residents, gullies form in the road shoulders on each side of North Barnstead Road during every large storm event. Watershed residents mentioned that these gullies are frequently repaired though the southern road shoulder gully continues to overtop the road and contributes stormwater flow to the boat ramp. The southern road shoulder is designed so that runoff from the road and nearby agricultural field flows down the road shoulder and into the stream that connects Halfmoon Lake to Locke Lake. However, an undersized culvert prevents water from moving downhill to the stream, so stormwater flows across the road and down the boat ramp into Halfmoon Lake. According to watershed residents, this site has been washing out for over 30 years.	Regular road maintenance to maintain proper crowning to the southern road shoulder will also help decrease the amount of stormwater volume reaching the boat ramp. The road shoulder ditches should be armored with rip rap and check dams to slow stormwater movement and promote infiltration. Engage with local farmers about agricultural BMPs such as a larger vegetated buffer between the fields and the road to prevent agricultural runoff from reaching the road and the nearby lakes. The culvert on the south side of the road should be enlarged and inspected for blockages frequently to accommodate peak stormflow. In time, re-engage with the boat ramp owner about repairing the boat ramp. The repairs may include installing permeable pavers and subsurface stabilizers to prevent further erosion from the loose surface material while continuing to allow access to the lake.	High	5.8	1.5	3.9	$35,000	$50,000	1
1-11	Public Beach Boat Launch	A gap in the shoreline buffer along Route 28 was observed at a site used as a boat launch. The sandy substrate showed evidence of erosion into Halfmoon Lake from the boat launch to mile marker 59. According to the Town of Alton tax forms, the property is town-owned and is used by Marine Patrol for boat access. Watershed residents specify that Marine Patrol does not often use this access point, and typically use the other boat ramp	Armor nearby road ditches with check dams and rip rap to reduce the amount and velocity of stormwater reaching the boat ramp area. Repair gullies in the launch area and consider adding subsurface interlocking stabilizers to create a well-defined boat ramp. Assess the use of the lot and enhance the shoreline buffer in sections where access is not necessary. Additionally, disconnecting or removing impervious (or compacted sand) surfaces where not needed can add space for additional stormwater	High	0.9	0.7	0.5	$10,000	$15,000	2

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANK
		on Rt 28 in Barnstead. However, this site is frequently used by local fishermen.	controls and prevent erosion of the launch area. Consider defining an access point with a dock or wooden launch for canoes/kayaks to prevent erosion and vegetation trampling at the water's edge.							
1-06	Dalton Drive Beach Ramp	Stormwater runoff begins on the very steep and unpaved/residential Dalton Road before leading down a steeply sloped paved parking lot and down to the beach area on Halfmoon Lake. On the east side of the road, there is a large gully leading through a slightly crushed culvert, under a driveway, and continuing down the road shoulder. Large gullies serve as a signal that erosion is occurring at the site as sediment has moved downslope along with stormwater. Under low flow, stormwater travels through this gully and continues through a culvert with a possibly buried outlet. Under high flow conditions, the stormwater flows within the ditch and across the road surface before continuing across the beach surface. On the beach, there are many signs of shoreline erosion, including small gullies and rills.	First, sweep the paved area for any loose debris. Then, install water bars and rubber razors approximately every 20 feet along the unpaved section of the road. Rubber razors direct stormwater away from the road surface and into ditches or forested areas, preventing stormwater from accumulating on the road. Install ditches on the road shoulder that are armored with rip rap or grass and check dams or coir logs. Check dams or coir logs may be used to slow stormwater movement and trap sediment while promoting retention for infiltration. Water bars may be installed on the beach in upslope areas to prevent runoff from the road from forming gullies on the beach. These will also direct stormwater into more vegetated areas. Leverage existing funding through the Locke Lake Association to implement stormwater controls at Dalton Drive Beach and ensure that improvements to lake access and recreation are completed in a lake-friendly manner that considers stormwater, vegetated buffers, and other best management practices.	High	0.6	0.5	2.4	$10,000	$15,000	3
1-05	YMCA Road	There are large amounts of road shoulder erosion and bare soil on both sides of YMCA road before the intersection of Crest Road. Stormwater follows road shoulder erosion channel into the forested area where it enters a wetland. The wetland flows under the road through a crushed, undersized, and clogging culvert to form a stream that ultimately outlets to Halfmoon Lake toward the end of Varney Road. Depending on the rainfall in the area, the blocked/undersized culvert can significantly impact the hydrology of the site, according to watershed residents. The road is currently maintained by local residents who have access to the proper machinery and equipment to keep the road drivable.	Convert the erosion channel into a vegetated swale, complete with grass/vegetation and check dams. Consider amending soils with biochar (while avoiding nutrient amendments) to promote and stabilize vegetation growth if necessary. Create a small rain garden or a bioretention area or constructed wetland (depending on soil conditions) at the end of the channel before the stormwater enters the wetland with wetland plants that can tolerate high sun exposure. According to the USDA-NRCS soil survey, the soil in the area is sandy and very poorly drained (high water table). Constructed wetlands may be more suitable than bioretention in poorly drained areas. Assess which green stormwater infrastructure practice is suitable based on on-site soil conditions, which may require an engineer. Ensure the culvert is not filling with sediment and clean out the culvert as needed.	Medium	4.7	1.2	3.2	$15,000	$20,000	4
1-12	Oneill Road	Stormwater flows down Crest Road, turns the corner, and follows the steeply sloping O'Neill	Remove plow berms and stabilize the ditch with rip rap and install check dams to slow stormwater movement	Medium	0.2	0.6	3.8	$8,000	$12,000	5

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANK
		Road to erode a bare ditch leading to a road culvert that crosses the road and discharges to a wooded (possible wetland) area on private shoreline property. The backslope of the ditch was seeping shallow groundwater into the ditch at the time of the survey. Bare soil areas at the corner were eroding into the ditch.	and capture sediment. Alternatively, plant grass in bare soil areas to stabilize the soil. Consider amending soils with biochar (while avoiding nutrient amendments) to promote and stabilize vegetation growth if necessary. Consider if a rain garden is applicable on the corner of Crest and O'Neill Roads to capture stormwater from uphill on Crest Road. A rain garden would limit the amount of stormwater and sediment that travels downhill to Oneill Road. Consider installing a plunge pool at the culvert outlet at the discretion of the homeowner.							
1-19	Prospect Mountain Road	Prospect Mountain Road is an unpaved road with significant amounts of road surface, shoulder, and ditch erosion. Homeowners in this upper area of the watershed showed FBE staff evidence of this erosion in a stream (Grand Brook) and wetland complex on their property. Grand Brook is a headwater tributary to Fern Hill Inlet. Large amounts of unpaved road surface material was observed in Grand Brook as a result of recurring erosion from Prospect Mountain Road. Homeowners cite frequent road washouts on Prospect Mountain Road as the source of contaminants to the stream, which sometimes experiences macroalgae blooms. The road surface is regularly maintained by the Town of Alton, and road ditches are regularly dug-out, though there is no armoring in the road ditches. Residents cite that the ditches often fill in after plowing in the winter. Some stormwater management is present along the road, such as turnouts and sediment plunge pools in various locations. The road is steeply sloping, which exacerbates the erosion problems associated with unpaved roads. Erosion from Prospect Mountain Road impacts various streams and wetlands mostly in the headwaters of the Fern Hill Inlet and Horse Farm Inlet subwatersheds.	Coordination and collaboration with the Town of Alton is the primary recommendation for addressing erosion issues on Prospect Mountain Road as the Town regularly maintains the road surface and road shoulder ditches/turnouts. Depending on the amount of available funding, various opportunities are available to remediate erosion on Prospect Mountain Road. Short-term or lower-cost fixes may center around coordinating with the Town of Alton Department of Public Works to reshape and armor road ditches with rip rap. Sediment fabric may be placed underneath the rip rap for easy clean-out and maintenance. Sediment plunge pools and turnouts may also be armored with rip rap in order to stabilize the bare soil around them and prevent additional erosion. Long-term solutions include paving the road, complete with a full drainage system or engineered BMPs that capture stormwater and promote infiltration. Paving the road surface would also decrease the amount of sediment pushed into the road shoulders during winter plowing events. This effort may also entail upgrading or upsizing culverts to accommodate peak stormflows to prevent road washouts. Efforts to remediate erosion on Prospect Mountain Road should be accompanied by property level stormwater management, especially on nearby farms, to reduce the volume of runoff that reaches the road.	High	19.6	15.0	9.7	$400,000	$800,000	6
1-08	Route 28	Road shoulder erosion begins at the top of a small hill on Route 28 and leads toward a wetted area and stream near Halfmoon Lake. The road is pitched so that all stormwater moves to the northwest side of the road. There is a small gully at	Create a ditch with a rounded U-shaped bed on the northwest side of Route 28. Armor the ditch with either rip rap or vegetation with check dams. Large open areas between the gully and the wetland may be candidate areas for a vegetated swale or bioretention	Medium	2.4	0.6	1.6	$10,000	$15,000	7

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANK
		the bottom of the ditch, and the gully bed consists of scoured sand and cobble-sized rocks, suggesting a high energy, eroding environment that has already washed away finer soil particles such as silt. The gully deepens and widens as it approaches the wetted area, then forms a delta and smaller gully that leads to the wetland.	area. The simplest recommendation for the wetted area would be to let the existing grass and any emerging shrubs grow in the wetted area rather than mowing the vegetation. The area may be planted with wetland plants or shrubs for better infiltration and nutrient uptake.							
1-15	Shelburne Lane	Stormwater begins at the top of Shelburne Lane and leads downhill to New Castle Drive. Road shoulder erosion was present on both sides of Shelburne Lane, with the west side having more severe erosion. On the east side, small gullies were present, and stormwater is turned out onto a private property where a vegetated swale exists which is excellent. At the western corner of Shelburne Lane and New Castle Drive, stormwater accumulates in a ditch. Stormwater on the eastern corner of the two roads has carved a deep gully leading downstream toward Halfmoon Lake.	For the entire west side of Shelburne Lane, consider installing stormwater ditches to prevent gully formation. These ditches would likely need to carry stormwater underneath driveways, which would require installing culverts. The right of way appears wide on Shelburne Lane and there may be enough existing space in the road shoulder to create these ditches. The ditches may be stabilized with grass or other vegetation and may even be converted into swales (such as those observed on adjacent properties) with check dams. Alternatively, due to the slope of the site, rip rap and check dams may be needed to prevent ditch erosion. In downstream areas on New Castle Road, coir logs and check dams may be used to slow stormwater movement and settle out any sediment that may have made its way past the uphill stormwater improvements. Encourage homeowners to practice property level stormwater management to decrease the amount of runoff contributing to the road shoulder stormwater following the excellent examples present in the area.	High	2.5	0.7	1.9	$25,000	$35,000	8
1-16	Muchado Hill Road #1	Road shoulder erosion was observed on Muchado Hill Road beginning from the edge of the watershed (top of hill) on the north side of Muchado Hill Road (Alton) and ends at a stream crossing.	Reshape the road ditches to have a U-shaped bed wide/deep enough to accommodate peak stormflows. Armor the ditches with rip rap and check dams/coir logs. Install turnouts where possible to direct stormwater into forested areas. Plunge pools may also be installed to collect and settle sediment. Encourage residents to construct residential BMPs to mitigate stormwater runoff from adjacent impervious surfaces from reaching the road shoulders.	Medium	1.7	0.4	1.2	$10,000	$15,000	9
1-17	Muchado Hill Road #2	Road shoulder erosion was observed on Muchado Hill Road (Barnstead) leading downhill to a stream crossing.	Reshape the road ditches to have a U-shaped bed wide/deep enough to accommodate peak stormflows. Armor the ditches with rip rap and check dams/coir logs. Install turnouts where possible to direct stormwater into forested areas. Plunge pools may also	Low	1.6	0.4	1.1	$8,000	$12,000	10

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANK
			be installed to collect and settle sediment if turnouts are not possible due to the slope of the forested area to the road.							
1-01	Crescent Drive	Stormwater on the unpaved Crescent Drive follows the southern road shoulder, causing road shoulder/surface erosion and ponding that is nearly constant in the road shoulder. During high storm-flow conditions, the stormwater crosses the road through a gully across the road surface and leads directly into Halfmoon Lake according to residents. The observed water at the site originates from the steeply sloped residential area between Crescent Drive and North Barnstead Road before leading down to the road surface.	Encourage property owners to implement property-level stormwater management by distributing resources such as the New Hampshire Homeowners' Guide to Stormwater Management through the NHDES Soak Up the Rain program. Encourage bioretention areas on individual properties and near the road shoulder. Convert the ditch to a vegetated swale by reshaping and stabilizing it by planting it with wetland plants. Check dams may also be installed in the ditch to slow stormwater movement and allow for infiltration. Repair the gully across the road surface and consider installing a cross-culvert to prevent the gully from reforming if the property-level BMPs are not sufficient. A riprap plunge pool at the culvert outfall would capture and settle out sediment before the water continues toward the lake during heavy storms.	Low	0.9	0.2	0.6	$5,000	$8,000	11
1-10	Bartlett Road Western Stream Crossing	Road shoulder ditch erosion on both sides of Bartlett Road leads directly to a stream crossing. The existing ditch was flowing at the time of the survey. The ditch flows into the forest, toward a wet area, and snakes back into the stream, which then crosses beneath Bartlett Road. Note: Further down the road at another stream crossing, the road appears to have been recently reconstructed and the ditches armored with check dams.	Reshape and armor the road shoulder ditches using rip rap and check dams. Install a plunge pool where the ditch flows into the forested area to capture and settle sediment before stormwater reaches the stream. Line the plunge pool with landscape or infiltration fabric to allow for easier cleanout of sediment. Armor the plunge pool with rip rap. Install turnouts to direct stormwater into forested areas every 50 feet or wherever possible. Plunge pools may be utilized together with the turnouts. Continue efforts further up the road to rebuild the road and upgrade stormwater management practices. Continue evaluating culvert size at both culverts on the road, with special consideration of the increased flows associated with climate change.	Medium	1.4	0.4	0.9	$15,000	$20,000	12
1-04	22 South Shore Road	According to watershed residents, a large sediment delta has formed in Halfmoon Lake at the outlet of a stream that flows between two properties on South Shore Drive. The stream originates from the road ditches on South Shore Drive, which receive runoff from the unpaved road surface, the steeply sloped forest areas, and the airfield to the east of the site. Small perennial streams contribute water to the ditches. The ditches flow to a culvert which	Reshape ditches to be deeper and have a U-shaped bed, where needed. Armor the ditches with riprap, particularly the inlet area to the culvert. Consider installing a plunge pool at the culvert outlet to capture and trap sediment and promote infiltration before water continues into the lake. Consider amending soils with biochar (while avoiding nutrient amendments) to promote and stabilize vegetation growth if necessary. Consider reshaping the area upstream of the culvert	High	0.4	0.1	0.5	$10,000	$15,000	13

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANK
		crosses beneath the road between the two properties. Existing efforts to control sedimentation at this site include coir logs and reducing winter sand use. Reducing sediment loading to Halfmoon Lake helps to reduce the phosphorus load because phosphorus is bound in soil particles (especially finer particles like silt) and can become released in the water. This section of the lake has the most milfoil, an invasive plant species, according to watershed residents. Milfoil has been in Halfmoon Lake for over 20 years and its abundance varies periodically. Watershed residents conjecture that phosphorus loading at the site due to sedimentation may fuel the milfoil.	into a wide basin to promote infiltration. Continue using coir logs to slow stormwater movement and trap sediment. Continue using low sand practices during winter months. Preserve the natural hydrology of the streams as much as possible.							
1-09	North Road Stream Crossing	Road shoulder and ditch erosion was identified on both sides of North Road leading directly to the Route 28 tributary of Halfmoon Lake. The culvert is perched on the downstream side of the crossing. Most of the erosion is on the northern side of the road, though the unpaved road surface contributes to the sediment load at this site. There is slight erosion on the sides of the culvert outlet. An existing plunge pool is present at the downstream side of the culvert which under low to normal flow likely captures and settles sediment, preventing it from reaching the lake.	Reshape road ditches to have a rounded U-shaped bed large enough to accommodate peak storm flows. Armor the ditches with rip rap and check dams or coir logs. Install a guard rail and stabilize the culvert outlet and decrease foot/car traffic close to the edge. Continue using and maintaining plunge pools to capture sediment. Inspect the plunge pool before and after each storm to clean out any accumulated sediment.	Medium	1.9	0.5	1.3	$25,000	$35,000	14
1-18	Hamwoods Drive	The gravel road shoulder on Hamwoods Drive is eroding into the road ditch, which is also eroding as it leads downgradient toward the nearest culvert.	Shave the edge of the road shoulder to the ditch to remove the angular edge. Currently, the edges of the ditch are very steep. Reshape the ditch to have a U-shaped bed large enough to accommodate peak stormflows. Some locations along the ditch are already armored with rip rap. Use additional rip rap to armor the sides of the ditch in the locations without existing rip rap. Sediment plunge pools, check dams, and coir logs may all be used to slow stormwater movement to capture and settle out sediment.	Low	1.3	0.3	0.9	$20,000	$30,000	15
1-03	North Barnstead Road & Belmont Drive	A culvert that connects a small drainage area to Locke Lake is often clogged, and the backflow regularly saturates the area, crosses the road, and enters Halfmoon Lake. According to residents, the grassy area can pool up to one foot deep during storms and discharges to Halfmoon Lake through a small ditch in the forested area.	Investigate the culvert and assess whether or not it is clogged. Direct stormwater into the grassy road shoulder. Create a depressed bioretention area or rain garden in the road shoulder to promote retention and infiltration of stormwater. Soils in the area are well drained and coarse-loamy in texture according to the USDA-NRCS soil survey. Assess the on-site soil	Medium	0.0	0.05	0.1	$5,000	$12,000	16

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANK
			conditions to determine if bioretention is a suitable option. Stabilize the culvert inlet with rip rap or crushed stone lined with permeable landscape fabric for easy cleaning.							
1-07	Crescent Drive Beach	There are small gullies on Crescent Drive Beach from the parking lot to the shoreline as well as areas with poor to no buffer with evidence of shoreline erosion.	Divert stormwater from the parking lot away from the beach using a swale or water bars to a designated and depressed area for infiltration with water-loving plants. Diverting water into a designated infiltration area allows for infiltration of the stormwater before it can erode downhill areas and reach the waterbody. Sandy soils such as those around the Halfmoon Lake shoreline typically have lower phosphorus retention capabilities than more finely textured soils. However, these soils may have reasonable capacity to retain phosphorus if high in iron and aluminum oxides. In cases where coarse, sandy soils are present or the water table is shallow (saturated soils), there is unlikely to be robust phosphorus retention in the soil. We recommend a thorough evaluation of the soils in the area to determine if they have high phosphorus retention capacity and the water table depth. Consider amending the soils with a filtering material with a high phosphorus retention capacity to reduce the amount of phosphorus reaching the lake. Filtering materials such as fly ash or blast furnace slag have high phosphorus retention capabilities and have shown the potential to improve phosphorus treatment in bioretention systems (Li et al., 2018). Proper maintenance of the vegetation in bioretention areas is integral as it prevents nitrogen and phosphorus from fluxing into the lake. Maintenance can include harvesting overgrown or dying plants, revegetating, weeding, or trimming. At the site, we also recommend revegetating the shoreline on the western side by the tree with deep rooting shrubs. Revegetate the shoreline on the eastern side to expand the shrub line across the grassed area.	Medium	0.1	0.02	0.0	$3,000	$5,000	17
1-14	Meredith Lane	Road shoulder erosion spans from the corner of Meredith Lane and Jackson Lane down to a small stream crossing on Meredith Lane. A large sediment pile was observed at the stream crossing, as well as gullies and plow berms on each side of the road.	Remove the plow berms and install a ditch armored with rip rap and check dams. Install a sediment plunge pool near the outlet of the ditch to capture and settle out sediment. Utilize turnouts approximately every 50 feet along the ditch to divert stormwater into the forested areas.	Low	0.2	0.05	0.1	$6,000	$12,000	18

SITE	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION			ESTIMATED COST		RANK
					TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	Est. Low Cost	Est. High Cost	
1-13	Rustic Shores	Erosion was observed on the north side of Rustic Shores Road in the extremely steep residential area leading directly to a culvert that outfalls onto private property and ultimately leads to Halfmoon Lake. At the end of Rustic Shores Road is the outlet of a major tributary (Dugan's/Horse Farm Inlet) to Halfmoon Lake. Watershed residents report that stormwater may enter the stream from the road's surface and shoulders. Observations also note that there is minimal room for stormwater management along Rustic Shores Road due to the very steeply sloped terrain and density of buildings.	Regrade and crown the road to prevent gullies from forming in the road surface. Reshape the ditch to have a U-shaped bed and armor it with rip rap and check dams/coir logs. Regular maintenance of the rip rapped ditch should be expected. Deepen and armor the existing plunge pool and line it with a sediment filtration fabric for easy clean out. Assess the open area at the dead end in coordination with the homeowners and determine if it is suitable for a rain garden or vegetated swale. Rain gardens and vegetated swales capture stormwater and settle out sediment while the plants can take up water and nutrients, allowing stormwater runoff to infiltrate into the soil where nutrients can be retained in the soil and plants rather than enter the stream.	Low	0.1	0.02	0.1	$10,000	$15,000	19
				TOTAL	**46.2**	**23.4**	**33.8**	**$630,000**	**$1,141,000**	