MERRYMEETING RIVER & LAKE
WATERSHED MANAGEMENT PLAN

FOR THE CYANOBACTERIA MITIGATION
STEERING COMMITTEE OF NEW DURHAM/ALTON

[FINAL September 2019]

FB ENVIRONMENTAL ASSOCIATES
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BASEMAP

Merrymeeting River & Lake Watershed

New Durham, Strafford County, NH
Alton, Belknap County, NH

Watershed
Merrymeeting River
Ponds
Streams
Wetlands
Lake Bathymetry (ft)
0 - 25, 26 - 50, 51 - 75, 76 - 95, 96 - 125
State Road
Local Road
Private Road
Towns
Conserved Land
Logged Parcel

ESRI World Imagery captured on 6/27/2016.

The Merrymeeting River & Lake Watershed area covers 23,669 acres, largely in New Durham and Alton, NH. The Jones Dam Pond and Downing Pond suffer from toxic cyanobacteria blooms, which are likely fueled by excess phosphorus measured in the Jones, Marsh, and Downing Ponds. One identified point source of phosphorus is the Powder Mill State Fish Hatchery, which is estimated to contribute 800 lbs. P/yr to the river. This source is being addressed by engineers, the EPA, NH Fish & Game, and the Hatchery BMP Working Group.

While the Merrymeeting River suffers from excess phosphorus loading, Merrymeeting Lake is one of the clearest lakes in New Hampshire and supports a thriving population of coldwater fish, including land-locked salmon and brown and rainbow trout that are stocked by the hatchery. Cyanobacteria microcystin levels are very low and no invasive aquatic plants have been found. The community has taken great strides in protecting their lake by limiting future development and educating residents on the importance of reducing P-based fertilizer use.

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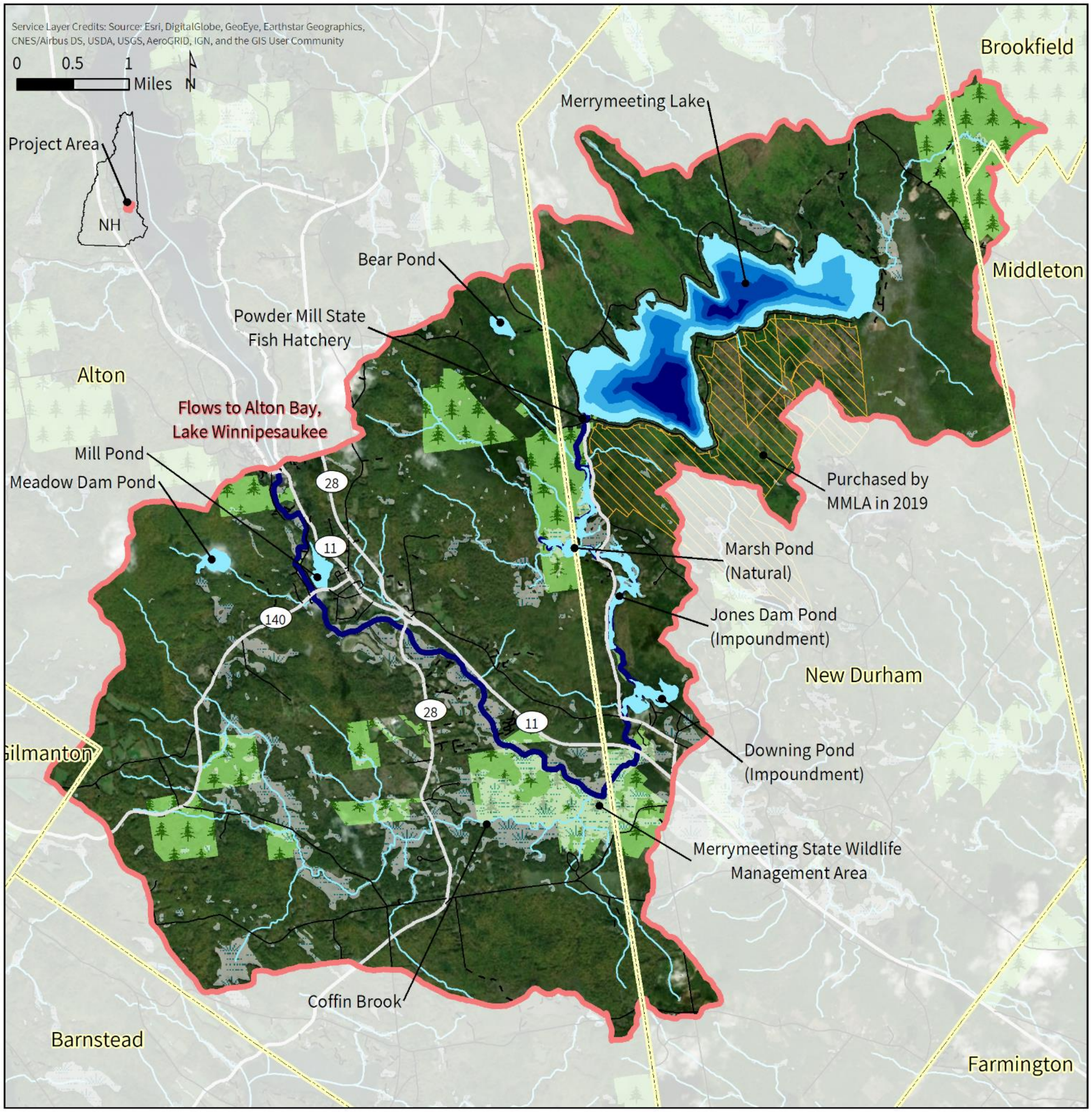
Prepared by L. Diemer, FBE 01-22-2019
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI



MERRYMEETING RIVER & LAKE WATERSHED MANAGEMENT PLAN

Prepared by **FB ENVIRONMENTAL ASSOCIATES**
in cooperation with the Cyanobacteria Mitigation Steering Committee of New Durham/Alton, DK Water Resource Consulting, and Horsley Witten Group

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Funding for this project was provided by the towns of New Durham and Alton, New Hampshire.

EXECUTIVE SUMMARY

According to the 303(d) New Hampshire List of Impaired Waters, Marsh, Jones, and Downing Ponds are impaired for primary contact recreation due to elevated levels of cyanobacteria hepatotoxic microcystins. Toxic cyanobacteria blooms are often indicative of enhanced nutrient loading, particularly phosphorus, from point source (PS) and nonpoint source (NPS) pollution such as stormwater runoff from developed and agricultural land uses. In this case, point source discharges from the Powder Mill State Fish Hatchery are estimated to contribute 342 kg P/yr (67% of the total load) to the river as it flows into Marsh Pond. Local groups and town officials are working with state and federal agencies to set an appropriate phosphorus load discharge limit for the Powder Mill State Fish Hatchery; this permitted limit will dictate the achievable in-pond concentrations for Marsh, Jones, and Downing Ponds, and thus, the water quality goals described herein should be considered preliminary. Below Downing Pond and in Alton, the Merrymeeting River flows through the Merrymeeting Marsh Wildlife Management Area where Coffin Brook, which serves as prime habitat for bridle shiners and wild brook trout, joins the Merrymeeting River. Coffin Brook has been identified as a major source of phosphorus load to the Merrymeeting River. Mill Pond in Alton was also listed as impaired for aquatic life use due to elevated levels of cyanobacteria based on assessments completed during the plan development process.

Even with a substantial reduction in the phosphorus load discharged from the Powder Mill State Fish Hatchery, legacy phosphorus in anoxic sediment will continue to generate an internal phosphorus load to the ponds and unmitigated sources of pollution (i.e., phosphorus) will likely increase as development or other human activities in the watershed increase (e.g., conversion of small, seasonal properties to large, year-round homes). The build-out analysis for the watershed showed that about 11,653 acres are still developable and up to 3,762 new buildings could be added to the watershed at full build-out based on current zoning standards. As a result of anticipated new development, an increase in in-pond phosphorus concentration, as well as associated cyanobacteria and algae growth, will contribute to dissolved oxygen depletion as algal cells and other organic matter sink, die, and decompose in the ponds, stimulating further internal phosphorus loading. It is therefore important to take proactive steps to manage and treat pollutants entering surface waters from existing and future pollution sources in the Merrymeeting River and Lake watershed. These actions will ensure continued ecosystem health and recreational enjoyment by current and future generations.

While the Merrymeeting River (and its ponds) suffer from excess phosphorus loading, Merrymeeting Lake is one of the clearest lakes in New Hampshire and supports a thriving population of coldwater fish, including land-locked salmon and rainbow trout that are stocked by the Powder Mill State Fish Hatchery. Cyanobacteria microcystin levels are very low and no invasive aquatic plants have been found. The lake, however, is threatened by existing and future development (including the two roads circling the lake within 100 feet of the shoreline), highspeed boating that aggravates shoreline erosion, defective culverts, and timber harvesting (a large operation was undertaken on the southern side of the lake). As a large headwater source to the Merrymeeting River, preserving the excellent water quality of Merrymeeting Lake will be crucial to sustaining downstream water quality improvements, including the economically vital Lake Winnipesaukee to which the Merrymeeting River flows.

> The Merrymeeting River and Lake Watershed Management Plan provides a roadmap for improving the water quality of surface waters within the Merrymeeting River and Lake watershed and a mechanism for procuring funding (e.g., Section 319 grants) to secure actions needed to achieve the water quality goal. USEPA requires that a nine-element watershed plan (or an acceptable alternative plan) be created so that communities become eligible for watershed assistance grants.

As part of the development of this plan, a build-out analysis, water quality and assimilative capacity analysis, and shoreline/watershed surveys were conducted (Section 3). Results of these efforts were used to run a land-use model, or Lake Loading Response Model (LLRM), that estimated the pre-development, current, and projected future amount of total phosphorus being delivered to the lake, ponds, and river from the watershed (Section 3.3). An Action Plan (Section 5.2) with associated timeframes, responsible parties, and estimated costs was developed based on feedback from community members that attended the public forum in August 2018. A watershed survey of the entire watershed and a shoreline survey of Merrymeeting Lake only were completed in 2018; seventy-eight (78) pollutant sites and 285 high to medium impact rated shoreline properties were identified and prioritized for remediation (refer to Section 3.5 and 5.2). Completing the action items set forth in the Action Plan (5.2) will help achieve the water quality goal and objectives determined by the watershed community. Management strategies for achieving the water quality goal and objectives involve using a combination of structural and non-structural BMPs (such as ordinance revisions that better protect water quality), as well as an adaptive management approach that allows for regular updates to the plan (refer to Section 4).

The success of this plan is dependent on the continued effort of volunteers, and a strong and diverse steering committee (like the one established for plan development) 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 benchmarks. Measurable milestones (number of BMP sites, volunteers, funding received, etc.) should be tracked by a steering committee and reported to NHDES on a regular basis.

A reduction in nutrient loading is no easy task, and because there are many diffuse sources of phosphorus reaching the river, lake, and ponds from existing residential 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.

ACKNOWLEDGMENTS

CYANOBACTERIA MITIGATION STEERING COMMITTEE (CMSC)

Fred Quimby (chair), Gene Young (vice chair), David Swenson, Ray Howard, Mark Sullivan, Bill Meyer, Bill Mannion, Bob Craycraft, Reuben Wentworth, Glen Normandeau (alt. Jason Smith), and David Neils.

WATER QUALITY VOLUNTEERS ASSISTING CMSC

Mike Gelinas, Doug Gilman, Nancy Haseltine, George Haseltine, Gene Young, David Gould, Don Cundy , Tom Foster, Fred Quimby, Bill Meyer, Ron Keslar, Sally Ferbert, Bill Malay, Tom Rogenski, Emma Murzic, Alex Amann, Kaylee Verrington, Lucy Spence , Ayla Pitts, Abigail Foley, Taylor Hickox, Olivia Anderson, Jeff Allard, John Bruckner, Roger Hickey, Bill McGrew, Greg Poston, Stephanie Schmid, Mark Sullivan, John Seusing, Greg Barsanti, John and Nancy Downing, and Paul Richardson.

COMMUNITY FORUM ATTENDEES

Kaylie Verrington, Emma Murzic, Sabina Perkins, Mike Gelinas, Nancy Bryant, Phil Wiltmann, Bill Meyer, Cynthia Quimby, Jason Smith, Ken Drinan, Al Pace, Brad Ligols, Art & Susan Hoover, Tom Rogenski, Pat Tarpey, Jerry Katz, David Bickford, Joan Anderson-Watts, Nancy & Walter Ahlin, Cecil Williams, Jeff Allaid, Bonnie Bilcastro, Nancy Malone, Linda Callaway, David Michaels, Scott Kinmond, Laurie Smith, Stephanie Schmid, John Chapin, Jim Giwca, Matt Murphy, Terry Jaruis, Dot Veisel, Robert Craycraft, and Gene Young.

SUPPORTING ROLES – THANK YOU

Craig Day, Tom Irwin, Kelly McAdam, Lisa Morin, Andrew Chapman, Ted Diers, Wes Wilder, Amanda McQuaid, David Niels, Todd Guerdat, William Muir, Ann Blodget, Alan Hanscom, Jeffrey Marcoux, Cheryl Bondi, Kevin Nyhan, Walter Henderson, Pat Tarpey, Marty Cornelissen, Sabina Perkins, Ron Gehl, Brian Hart, Matt Murphy, Russ Weldon, Edward Malone, Hilary Snook, Don Vachon, Scott Kinmond, Elizabeth Dionne, and Tom Varney.

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LIST OF ABBREVIATIONS

ACRONYM	DEFINITION
ALU	Aquatic Life Use
ARM	Aquatic Resource Mitigation fund
BMP	Best Management Practices
CALM	Consolidated Assessment & Listing Methodology
CHL-A	Chlorophyll-a
CWA	Clean Water Act
CWSRLF	Clean Water State Revolving Loan Fund
DASH	Diver Assisted Suction Harvesting
DO	Dissolved Oxygen
EMD	Environmental Monitoring Database
FBE	FB Environmental Associates
HWG	Horsley Witten Group
LCHIP	Land and Community Heritage Investment Program
LID	Low Impact Development
LLMP	Lakes Lay Monitoring Program
LLRM	Lake Loading Response Model
LWA	Lake Winnipesaukee Association
MMLA	Merrymeeting Lake Association
NCEI	National Centers for Environmental Information
NH GRANIT	New Hampshire Geographically Referenced Analysis and Information Transfer System
NHD	National Hydrography Dataset
NHDES	New Hampshire Department of Environmental Services
NHDOT	New Hampshire Department of Transportation
NHFGD	New Hampshire Fish and Game Department
NPS	Nonpoint Source Pollution
NWI	National Wetlands Inventory
PCR	Primary Contact Recreation
PMSFH	Powder Mill State Fish Hatchery
ppb, ppm	parts per billion, parts per million
PS	Point Source Pollution
SCC	State Conservation Committee
SDT	Secchi Disk Transparency
TP	Total Phosphorus
UNH	University of New Hampshire
USEPA	United States Environmental Protection Agency
VLAP	Volunteer Lake Assessment Program

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.

Areal water load is a term used to describe the amount of water entering a lake on an annual basis divided by the lake's surface area.

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, nitrogen-fixing bacteria that can grow prolifically as blooms when enough nutrients are available. Some cyanobacteria can 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 less 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 corridor 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.

1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Located in the Towns of Alton and New Durham, New Hampshire and draining to the economically vital Lake Winnipesaukee[1], the Merrymeeting River and Lake is an important water resource that supports an abundance of plants and animals and has attracted people to its waters for over 100 years. Residents, transient boaters, and summer tourists alike enjoy the river and lake's scenic beauty and quiet, rural character. However, the water quality of the Merrymeeting River and several ponds (Marsh Pond, Jones Pond, and Downing Pond) are listed by the New Hampshire Department of Environmental Services (NHDES) as impaired for aquatic life due to the presence of toxic **cyanobacteria** microcystins, among other degraded water quality parameters (NHDES, 2018a). In addition, while Merrymeeting Lake currently has excellent water quality (arguably among the best in New Hampshire), Merrymeeting Lake is threatened by anticipated increases in pollutants from future development. As a large headwater source to the Merrymeeting River, preserving the excellent water quality of Merrymeeting Lake will be crucial to sustaining downstream water quality improvements. It is therefore important to take proactive steps to manage and treat pollutants entering surface waters from existing and future **point and nonpoint source (NPS) pollution** in the Merrymeeting River and Lake watershed. These actions will ensure continued ecosystem health and recreational enjoyment by current and future generations.

The Merrymeeting River and Lake Watershed Management Plan is the culmination of a major effort by many individuals who care about the long-term protection of water quality in the watershed. The plan provides a roadmap using the United States Environmental Protection Agency's (USEPA's) nine key planning elements for preserving and/or improving water quality and a mechanism for acquiring funding for implementation of management actions (e.g., Section 319 grants). USEPA requires that a watershed plan, or an acceptable alternative plan, be created so that communities become eligible for watershed assistance implementation grants. In addition, this plan sets the stage for ongoing dialogue among key stakeholders in the community and promotes coordinated action to address future development in the watershed. Plan success is dependent on the continued effort of volunteers, as well as a strong and diverse steering committee that meets regularly to review progress and make any necessary adjustments to the plan.

As part of the development of this plan, a **build-out analysis**, water quality and **assimilative capacity** analysis, and shoreline/watershed surveys were conducted (Section 3). Results of these efforts were used to run a land-use model, or Lake Loading Response Model (LLRM), that estimated the pre-development, current, and projected future amount of **total phosphorus** delivered to the river and lake from the watershed (Section 3.3). An Action Plan (Section 5.2) with associated

[1] A USEPA survey completed in 1974 showed that the Merrymeeting River was the second largest phosphorus and water load among 27 major tributaries to Lake Winnipesauke (USEPA, 1974).

timeframes, responsible parties, and estimated costs was developed based on feedback from community members that attended the public forum. The forum was designed to provide stakeholders with information on the watershed and water quality of Merrymeeting River and Lake, to solicit stakeholder input on action items, and to discuss the timing and elements of the plan.

1.2 STATEMENT OF GOAL

The goal of the Merrymeeting River and Lake Watershed Management Plan is to maintain and/or improve water quality in the Merrymeeting River and Lake so that toxic cyanobacteria blooms are eliminated. The goals will be achieved by accomplishing three objectives. More detailed action items to achieve these objectives are provided in the Action Plan (Section 5.2).

Objective 1: Maintain the excellent water quality of Merrymeeting Lake at 3.5 ppb for in-lake total phosphorus. In the next 10 years, offset an anticipated additional load of 16 kg P/yr from new development.

Objective 2: Improve the water quality of Marsh, Jones, and Downing Ponds to meet an annual and monthly average of 10 ppb for in-pond total phosphorus by reducing 293 kg P/yr (78%) from the Powder Mill State Fish Hatchery and offsetting an anticipated additional load of 14 kg P/yr from new development in the next 10 years. The former will be dependent on state and federal regulatory permit limits that are currently pending. The latter can be achieved by implementing low-impact development regulations on new development and/or implementing stormwater or septic system improvements to reduce pollution from existing development.

Objective 3: Improve the water quality of the Merrymeeting River as it enters Alton Bay to meet an annual and monthly average of 10 ppb for total phosphorus by reducing 88 kg P/yr from existing development and offsetting an anticipated additional load of 110 kg P/yr from new development in the next 10 years. This can be achieved by implementing low-impact development regulations on new development and/or implementing stormwater or septic system improvements to reduce pollution from existing development.

1.3 INCORPORATING EPA'S NINE ELEMENTS

USEPA guidance lists nine components that are required within a watershed plan to restore waters impaired or likely to be impaired by NPS pollution. These guidelines highlight important steps in restoring and protecting water quality for any waterbody affected by human activities. The following locates and describes the nine required elements found within this plan:

A. **IDENTIFY CAUSES AND SOURCES: Section 3.5** highlights known sources of NPS pollution to Merrymeeting River and Lake and describes the results of the watershed and shoreline surveys conducted in 2018. These sources of pollution 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:** described under (C) below: **Sections 3.5 and 4.1.1** describe the calculation of pollutant load to Merrymeeting River and Lake and the amount of reduction needed to meet the water quality goal. **Section 4** describes how estimated phosphorus load reductions to Merrymeeting River and Lake can be met using specific management measures, including **structural Best Management Practices (BMPs)** for existing development, **non-structural BMPs** for future development, and an **adaptive management approach**.

C. **DESCRIPTION OF MANAGEMENT MEASURES: Sections 4 and 5.2** identify ways to achieve the estimated phosphorus load reduction and reach water quality targets. The Action Plan focuses on six major topic areas that address NPS pollution, including: water quality monitoring, watershed and shorefront BMPs, roads, municipal planning and conservation, and septic systems. 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 5.1, 5.2, and 5.4** include 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 (towns of Alton and New Durham, NHDES, and USEPA), local groups (MMLA), private donations, and landowner contributions for BMP implementation on private property. The towns of Alton and New Durham, and other core stakeholders, led by the CMSC, should oversee the planning effort by meeting regularly and efficiently coordinating resources to achieve the objectives set forth in this plan.

E. **INFORMATION & EDUCATION & OUTREACH: Sections 1.5 and 5.5** describe how the Education and Outreach component of the plan is already being or will be implemented to enhance public understanding of the project, because of leadership from the CMSC and the towns of Alton and New Durham.

F. **SCHEDULE FOR ADDRESSING PHOSPHORUS REDUCTIONS: Section 5.2** provides a list of action items and recommendations to reduce stormwater and phosphorus runoff to Merrymeeting River and 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 a steering committee on an annual basis (see Section 4.3 on Adaptive Management).

G. **DESCRIPTION OF INTERIM MEASURABLE MILESTONES: Section 5.3** outlines indicators of implementation success that should be tracked annually. Using indicators to measure progress makes the plan relevant and helps sustain the action items. The indicators are divided into three different categories: Environmental, Programmatic, and Social Indicators. Environmental indicators are a direct measure of environmental conditions, such as improvement in water clarity or reduced median in-lake phosphorus concentration. Programmatic indicators are indirect measures of restoration activities in the watershed, such as how much funding has been secured or how many BMPs have been installed. Social indicators measure change in social behavior over time, such as the number of new monitoring volunteers.

H. **SET OF CRITERIA: Sections 3.4 and 5.3** 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 5.2.1** of the Action Plan describes the long-term water quality monitoring strategy for Merrymeeting River and 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 goal of this plan is to improve water quality by lowering the median phosphorus concentration to eliminate the presence of toxic cyanobacteria microcystins. The success of this plan cannot be evaluated without ongoing monitoring and assessment and careful tracking of load reductions following successful BMP implementation projects.

1.4 PLAN DEVELOPMENT AND COMMUNITY PARTICIPATION PROCESS

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

Five **meetings** and one **river paddle** were held. The following list does not include several regular meetings of the CMSC.

- **May 31, 2018:** FBE with the CMSC held a kick-off meeting and presentation to give a broad overview of the project and watershed plan development process, as well as discuss the project timeline. Twenty-seven watershed stakeholders were in attendance.
- **August 17, 2018:** FBE met with Fred Quimby, Mike Gelinas, and Bob Craycraft at the University of New Hampshire (UNH) to discuss the current status of available data for use in the plan and the need for additional sampling in late summer and fall.
- **September 22, 2018:** FBE, DK, and Mike Gelinas completed a boat and river paddle of the ponds and lower portion of Merrymeeting River.
- **December 12, 2018:** FBE and HWG introduced the top 10 erosion areas identified in the watershed during the watershed survey. The CMSC helped to prioritize the identified erosion sites in the draft BMP Matrix for update and inclusion in the plan and for determination of the four sites for conceptual BMP designs.
- **March 29, 2019:** FBE met with Fred Quimby, Mike Gelinas, and Bob Craycraft at the UNH to discuss the upcoming water quality sampling season.
- **May 30, 2019:** FBE and DK presented the modeling and build-out analysis results, along with the draft water quality goals and objectives. The CMSC discussed and provided final feedback on the goals and objectives.

Three **public presentations** were given to the Merrymeeting River and Lake community. These events were advertised in the local *Baysider*.

- **August 23, 2018.** A community forum and public presentation was held at the New Durham Elementary School. The forum and presentation were designed to provide local stakeholders with information on the watershed and water quality of Merrymeeting River and Lake, to solicit stakeholder concerns, identify threats to water quality, and prioritize actions to mitigate identified threats. About 47 people attended the community forum and provided valuable input to the plan. Attendees were broken out into four focus groups based on areas of concern (septic systems, planning and conservation, roads and shorefront watershed BMPs, and water quality monitoring). From group discussions and additional actions items provided by FBE, numerous recommendations for achieving action items were identified and prioritized. Recommendations from the forum were incorporated to the Action Plan (Section 5.2).
- **October 25, 2018.** A panel discussion was held regarding the status of the Powder Mill State Fish Hatchery.
- **June 19, 2019.** A final public presentation was held at the New Durham Elementary School. FBE, DK, and HWG presented on the results of the project to date, including the water quality analysis, assimilative capacity, build-out analysis, modeling, and conceptual BMP designs. Questions and insights gained from public meeting attendees were thoughtfully incorporated to the draft and final plan.

FBE presented to the Merrymeeting River and Lake community in August 2018.

1.5 WATERSHED PROTECTION GROUPS

The New Durham/Alton Cyanobacteria Mitigation Steering Committee (CMSC) was formed to address the Powder Mill State Fish Hatchery point source discharge to the Merrymeeting River after it was identified as the major cause of the cyanobacteria impairment in downstream ponds. The group of 20 individuals representing both communities meets 5 times a year and alternates sites for the meeting between Alton and New Durham. Meetings are open to the public and announced on both town websites and in the *Baysider* newspaper. The CMSC raised the funds necessary to complete plan development for the watershed so that the towns could be eligible for federal and state grants. Working groups of the CMSC include the Powder Mill State Fish Hatchery BMPs, Merrymeeting River Water Quality, Watershed Management Plan, and Financing & Public Relations.

The Merrymeeting Lake Association (MMLA) protects the natural resources and ecological conditions of Merrymeeting Lake by supporting the Lake Host and Weed Watcher programs, along with water quality testing through the Lakes Lay Monitoring Program (LLMP). The LLMP by the UNH Extension is a group of scientists, students, researchers, and volunteers who are dedicated to the preservation and management of lakes through citizen-based monitoring and research. The program is jointly administered by the UNH Cooperative Extension Natural Resources Program Team and the Center for Freshwater Biology at the UNH. The Lake Host program is a courtesy boat inspection program implemented by NH LAKES in cooperation with volunteers. Lake Host volunteers monitor boats coming in and out of the lake to identify and prevent the introduction of invasive aquatic plants, such as variable milfoil. The Weed Watcher program uses trained volunteers assigned to areas of the lake to monitor monthly (May-September) for changes in weed growth and presence of invasive species. VLAP is a cooperative program between NHDES and lake associations that trains volunteers to collect lake and tributary water quality data. The Merrymeeting River and ponds in New Durham are surveyed annually for invasive aquatic plant species through the New Durham Milfoil Committee. The New Durham Water Quality Committee meets in New Durham Town Hall every third Wednesday of the month. All meetings are open to the public.

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 management plans. This work is achieved by providing financial and technical assistance to local watershed management organizations; investigating actual and potential nonpoint source water contamination problems; among other activities.

2. WATERSHED CHARACTERIZATION

This section provides information on the local climate, demographic history, underlying soil and geographical characteristics, and present land cover in the Merrymeeting River and Lake watershed.

2.1 POPULATION, GROWTH TRENDS, AND LAND COVER

2.1.1 DESCRIPTION, LOCATION, AND CLIMATE

The Merrymeeting River and Lake watershed is located in the towns of Alton (60.5%), New Durham (37.6%), Brookfield (1.0%), Middleton (0.6%), and Gilmanton (0.3%), New Hampshire. This 37-square-mile (23,669-acre) watershed area encompasses Merrymeeting Lake (1,242 acres), Marsh Pond (45 acres), Jones Pond (57 acres), and Downing Pond (54 acres), among other small ponds. From the southwestern outlet of Merrymeeting Lake, water flows south via the Merrymeeting River through Marsh Pond, Jones Pond, Downing Pond, the Merrymeeting State Wildlife Management Area, and Wentworth Pond (and over the Alton Power Dam) before reaching its outlet at Alton Bay on Lake Winnipesaukee.

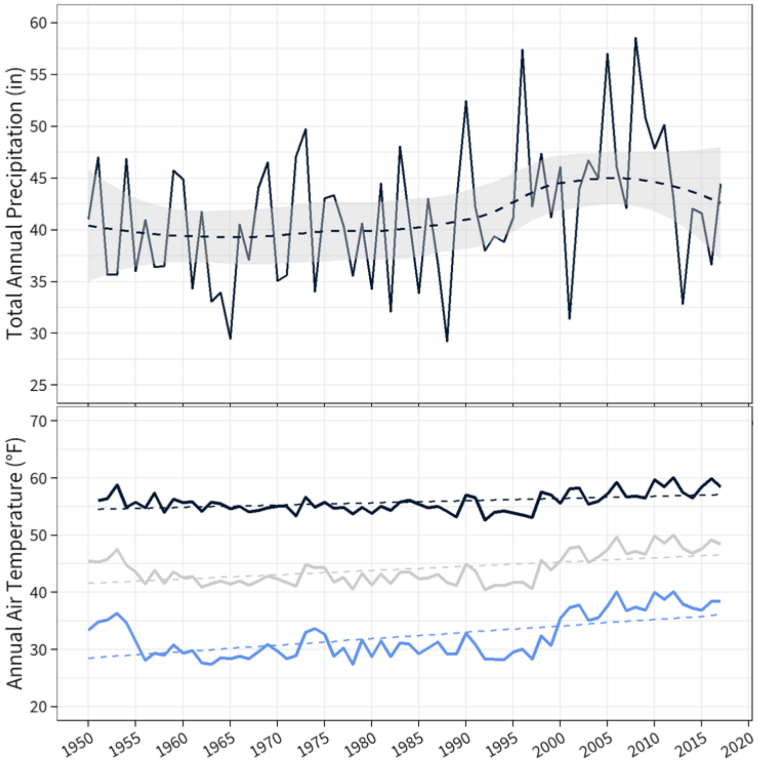


Figure 2-1. Total annual precipitation and annual max, average, and min of monthly air temperature from 1950 - 2017 for the Merrymeeting River and Lake watershed area. Data collected from NOAA NCEI.

The Merrymeeting River and 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 severe thunder and lightning storms, hurricanes, and heavy snowfalls. The area experiences moderate to high rainfall and snowfall, averaging 41.5 inches of precipitation annually (data collected and from 1950-2018 from the New Durham 4 weather station (USC00275783), with gaps covered by the following weather stations:

Brookfield 0.9 (US1NHCR0003), Rochester Skyhaven Airport (USW00054791), Alexandria 3 (USC00270040), Plymouth (USC00276944), Grafton (USC00273530), and Hanover (USC00273850) (Figure 2-1). Annual air temperature (from average monthly data) generally ranges from 26 °F to 60 °F with an average of 42 °F (NOAA NCEI, 2018).

2.1.2 POPULATION AND GROWTH TRENDS

The Merrymeeting Lake and River watershed area has long been treasured as a recreational haven for both summer vacationers and year-round residents. The area is among the oldest summer vacation spots in New Hampshire and offers fishing, hiking, boating, sailing, canoeing, kayaking, and swimming in the summer, and ice fishing, cross-country skiing, snowshoeing, and snowmobiling in the winter. According to the most recent U.S. Census (2010), most New Durham and Alton residents are working class families and enjoy the natural beauty of the towns year-round, but a significant number (29% in New Durham, 45% in Alton) also enjoy the area seasonally (Table 2-1). Seasonal visitors use amenities around the lake and river, including public boat launches, public beaches, family camps, and conservation lands.

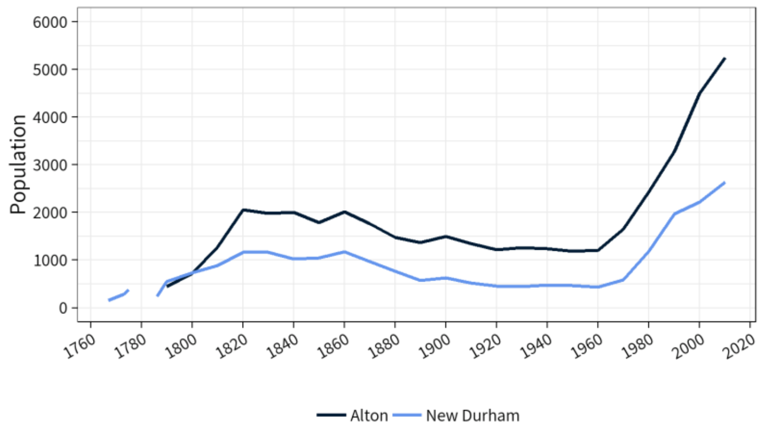


Figure 2-2. Historical demographic data for the towns of New Durham and Alton in the Merrymeeting River and Lake watershed. The population of this community has grown dramatically over the last 50 years.

Understanding population growth and demographics, and ultimately development patterns, provide critical insight to watershed management, particularly as it pertains to lake water quality. After a declining population trend from 1820 to 1960, the population of both New Durham and Alton grew exponentially from 1960 to 2010 when the population of New Durham and Alton peaked at 2,638 and 5,250 respectively, growing 19% and 17% in population from 2000 to 2010, respectively (NHOEP, 2011; Table 2-2, Figure 2-2). The desirability of the Merrymeeting River and Lake and the greater Lake Winnipesaukee area as a recreational destination will likely stimulate continued population growth in the future. Growth figures and estimates suggest that New Durham and Alton should 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 (refer to Section 3.3.3 for Build-Out Analysis results).

Table 2-1. 2010 population demographics for the Merrymeeting River and Lake watershed.

COUNTY/TOWN	TOTAL POP	AGED 0-19	AGED 20-64	AGED 65+	TOTAL HOUSING UNITS	TOTAL OCC. HOUSES	OWNER OCC. HOUSES	SEASONAL HOUSES[1]	RENTER OCC. HOUSES
Strafford County	123,143	31,677	76,821	14,645	51,697	47,100	31,242	1,670	15,858
New Durham	2,638	672	1,648	318	1,523	1,014	923	446	91
Belknap County	60,088	13,773	36,258	10,057	37,386	24,766	18,523	10,467	6,243
Alton	5,250	1,227	3,136	887	4,281	2,145	1,786	1,928	359

[1] *Seasonal houses are considered "vacant" by the US Census Bureau.*

Note: The Merrymeeting River and Lake watershed also extends into the towns of Brookfield (1.0% of the watershed), Middleton (0.6% of the watershed), and Gilmanton (0.3% of the watershed), but no significant development exists in these portions of the watershed.

Table 2-2. Population growth rates for the watershed community of the Merrymeeting River and Lake watershed.

CITY/TOWN	1960	1970	1980	1990	2000	2010	50-YR GROWH RATE (1960-2010)	20-YR GROWTH RATE (1990-2010)	10-YR GROWTH RATE (2000-2010)
Strafford County	59,799	70,431	85,408	104,233	112,233	123,143	21%	9%	10%
New Durham	474	583	1,183	1,974	2,220	2,638	91%	17%	19%
Belknap County	28,912	32,367	42,884	49,216	56,325	60,088	22%	11%	7%
Alton	1,241	1,647	2,440	3,286	4,502	5,250	65%	30%	17%

Note: The Merrymeeting River and Lake watershed also extends into the towns of Brookfield (1.0% of the watershed), Middleton (0.6% of the watershed), and Gilmanton (0.3% of the watershed), but no significant development exists in these portions of the watershed.

WATER SPORTS ON MERRYMEETING LAKE

Merrymeeting Lake provides a clean water recreational resource for people of New Hampshire, the nation, and worldwide. The lake is accessible to all that want to use it via a state sponsored public boat launch with free parking. In addition, there are over 500 homes with direct lake access. The lake supports a commercial marina that stores boats, repairs boats, and provides rental boat slips and gasoline, as well as four waterski programs. Waterskiing has been a recreational activity on Merrymeeting lake since the 1950's-60's or in the days of wooden boats, wooden skis, and clotheslines tied to broken broom handles for tow ropes. As waterskiing grew in popularity during the 1970's-90's, there were major advances in fiberglass technology for boats and equipment, making it more accessible. During that time, there have been at least two officially recognized ski clubs on the lake where a permitted slalom course was available for members to prepare and practice for regional competitions. Recently the sport has expanded to more recreational use from knee boarding into wakeboarding, as well as Air Chair hydrofoils. The past few years have seen the extended use of wake surfing, making the sport even more accessible for less athletic individuals where speeds are slower and falls easier. There is one youth summer camp on the lake, Water Monkey Camp, focused on wakeboarding, waterskiing, and wake surfing. Campers from all over the U.S. and abroad spend time on the water learning from coaches. When not on the boats, campers and staff are exploring the shores on standup (SUP) boards or having a meal at the waterfront clubhouse. In addition, the camp contributes to cooleffect.org and Southeast Land Trust (SELT) to offset nearly 50 metric tons of CO_2 (25 tons created by the boats and 25 extra tons to help offset camper travel). Campers learn the importance of the watershed environment and recycling. This includes diverting all food waste to the local Bickford Farm for their pigs. Over 400 pounds of food waste was produced and provided to the farm in summer 2019. – Russ Weldon & Matt Murphy

2.1.3 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 via stormwater runoff and baseflow (see Section 3.3 on Watershed Modeling).

Current land cover in the Merrymeeting River and Lake watershed was determined using a combination of land cover data from NH GRANIT's New Hampshire Land Cover Assessment 2001 [NHLC01], National Wetland Inventory (NWI) wetlands, National Hydrography Dataset (NHD) waterbodies, ESRI World Imagery from June 27, 2016, and Google Earth satellite images from September 11, 2017. For more details on methodology, see the Merrymeeting River and Lake - Lake Loading Response Model Report (FBE, 2019a).

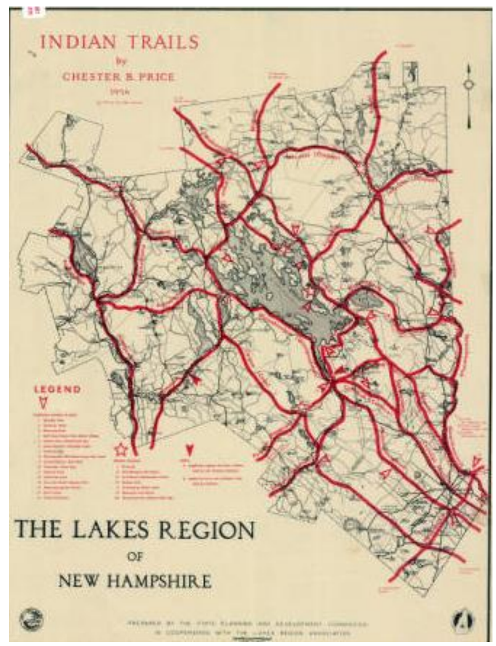
The Merrymeeting River and Lake watershed is 37 square miles (23,669 acres) and is surrounded by woodlands. As of 2016-2017 aerial imagery, development accounts for 8% (1,749 acres) of the watershed, while forested areas dominate at 79% (17,758 acres). Wetlands and open water represent 11% (2,388 acres) of the watershed, not including Merrymeeting Lake and ponds. Agriculture represents 2% (379 acres) and includes row crops, hayfields, and grazing pastures (refer to Appendix A, Map 2). The Merrymeeting River watershed in New Durham is characterized largely by residential development along the shorelines of the lake, ponds, and river with a few commercial businesses (gravel pit, marina, and water skiing school) and farms that support livestock (cows, pigs, chickens, turkeys, horses, and ducks) and crops (blueberries and Christmas trees). The Merrymeeting River watershed in Alton is characterized by dense residential and commercial development along the river leading to Alton Bay, as well as significant agricultural lands in the Coffin Brook watershed. Commercial businesses in Alton include supermarkets, automotive shops, retail shops, gas stations, restaurants, floral shops, medical clinics and offices, hardware stores, general offices, salons, banks, gyms, funeral homes, septic haulers, landscapers, post office, car washes, and greenhouses. Farms in Alton support livestock (sheep, cows, bison, camels, chickens) and crops (vegetables, Christmas trees, blueberries).

Developed areas within the Merrymeeting River and Lake watershed are characterized by **impervious surfaces**, including areas with asphalt, concrete, and rooftops that force rain and snow that would otherwise soak into the ground to runoff as stormwater. Stormwater runoff carries pollutants to waterbodies that may be harmful to aquatic life, including sediments, nutrients, pathogens, pesticides, hydrocarbons, and metals. The build-out analysis conducted for the watershed, coupled with projected population growth trends, indicates that the percentage of developed area will continue to increase. Therefore, it is imperative that watershed communities incorporate **low impact development** (LID) techniques into new development projects. More information on LID strategies and BMP implementation can be found in the Action Plan in Section 5.2.

FEATURE: History of Development in the Merrymeeting Lake and River Watershed

Adapted from research documents gathered by former Town Historian Eloise Bickford, current Town Historian Catherine Orlowicz, and author of "The History of New Durham" Ellen Jennings.

Before European settlement, the area was inhabited by Native Americans who travelled along well-established trails for hunting, fishing, and crop growing. According to Chester B. Price of New Durham and author of the book titled "Historic Indian Trails of New Hampshire 1756 to 2003," the trails traversed New Durham in several places. For example, the Ko-KchiKook (Cocheco) Trail (now Old Bay Road and Main Street) in New Durham traveled to Alton Bay at Lake Winnipesaukee, and the Abenaki Trail (now Kings Highway) traveled to Wolfeboro. New Durham had one known Native American campsite located at Coldrain Pond. Another was located at Quannippi, now called Alton Bay.



Native American trails in the Lakes Region of New Hampshire.

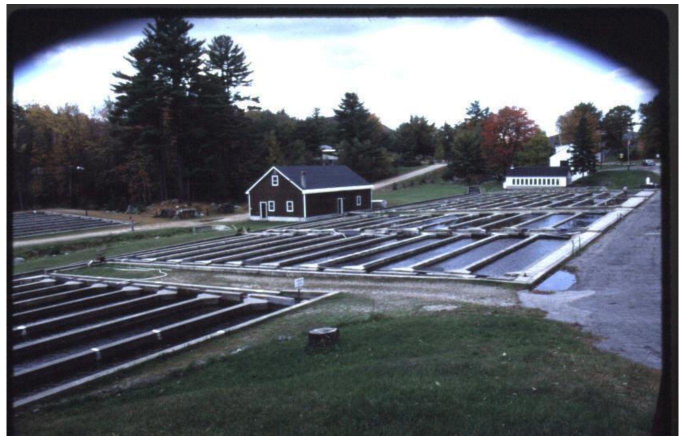
By 1721, the New Hampshire Colonial Assembly voted to cut a road from Dover (Cocheco) to Lake Winnipesaukee to construct a fort at the lake. The road followed the trails used by the Native Americans traveling to Alton Bay and became known as Bay Road. As the trails became roads and a peace treaty between Europeans and Native Americans was signed by 1760, colonial settlement and wood harvesting in the area took root. People settled around the many waterbodies in New Durham, including Merrymeeting Lake, Coldrain Pond, Merrymeeting River, March and Chalk Ponds, as well as the Mad, Isinglass, Ela, and Cocheco Rivers. The water was used for power, moving goods, and food.

Many sawmills were soon erected in the area, most notably the one that created Downing Pond through a dam constructed in the late 1700's during which time the towns of New Durham and Alton were granted their town charters. Several streams feeding into the pond were also impounded for the operation of private sawmills. Throughout the 1800's, harvested logs were floated downstream to Downing Pond at the sawmill where they were manufactured into various products, such as fly-brush killers, sink and small brushes, wire brushes, and handles. In the early 1900's, the sawmill operation changed ownership to Dean Allen and then merged with the Rogers Company to become the Allen-Rogers Manufacturing Company, expanding operations to meet a larger market. A catastrophic fire in 1931 closed the Downing Pond sawmill operation permanently.

Allen Handle Company, New Durham, NH 1919 to 1931.

A sawmill and dam were also constructed at the outlet to Merrymeeting Lake and were owned by Captain James Jewett from 1815-1822, then Nicholas Noyes until 1835 at which time a new dam, sawmill, clapboard-shingle machine, and grist mill were added. The sawmill operation at the Merrymeeting Lake outlet changed owners three more times until 1852 when the sawmill was converted to a gun powder manufacturing operation and greatly increased the number of buildings. From 1856 to 1861, the gun powder mills were called Eureka Powder Works Co. Manufacturing. By 1859, the property was sold to Lewis P. Childs of Providence, RI and renamed the Union Powder Works Company. It was during his ownership that black powder was produced and shipped to support the Union efforts during the Civil War. In 1861, there was a great explosion that required the mills to be rebuilt, and the demands of the Civil War took the whole supply. The history of the mill is vague but includes a time in 1874 when local men took over the factory.

By 1922, George Jones purchased the water rights around Merrymeeting Lake to control the flow of water downstream to Downing Pond. He built an electric power plant, which was purchased by Twin State Power Company and then Public Service Electric Company. A new dam was also built at Jones Pond and Merrymeeting Lake in 1924. To generate the required electrical power, Merrymeeting Lake had to be drawn down about 8 to 10 feet in the summer, which was unpopular for the summer residents. The NHFGD gained ownership of the power plant and dams around 1944. The power plant was converted to the state's largest fish hatchery, which has remained in operation to the present day and is fed by the cold, clean waters of Merrymeeting Lake. The Merrymeeting Lake dam was rebuilt in 1984 to its current state.



Powder Mill State Fish Hatchery, 1947.

The Town of New Durham disposed of town trash in Marsh Pond in the 1960s. The disposal site was closed by placing 21 truckloads of sand over the accumulated pile and compacting it with bulldozers. A boat landing was built at Marsh Pond and a new dump was opened on Brackett Road.

2.1.4 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. In the Merrymeeting Lake and River watershed, there is the Marks Wildlife Management Area (WMA), Merrymeeting State WMA, New Durham Ballfield, Levey Park, Merrymeeting Marsh Dam-Alton, and the Alton Bay State Forest. Eleven percent, (2,594 acres) of the Merrymeeting River and Lake watershed has been classified as conservation land (refer to Appendix A, Map 1). The largest parcel of conserved land is the Merrymeeting State WMA (552 acres) in the southeastern part of the watershed, followed by Ellis R. Hatch Jr. WMA (551 acres) in the most northern part of the watershed. The Ellis R. Hatch Jr. WMA expands outside of the watershed area to cover a total of 1,492 acres in the towns of Brookfield and Middleton. In March 2019, the MMLA, the Southeast Lake Trust (SELT) of NH, and Moose Mountains Regional Greenways (MMRG) met their fundraising goal of $2.9 million to acquire, conserve, and steward the more than 2,000-acre Birch Ridge Community Forest. Another 1,800 acres north of Merrymeeting Lake (not entirely within the watershed) was purchased by former Beaver Brook Forest Lands, who are currently working with the Society for the Protection of NH Forests to place a conservation easement on the area. In addition, the town of New Durham has identified floodplains and wetlands surrounding the shores of Merrymeeting Lake and River as local conservation priorities. Two drinking water protection areas were also marked in the Merrymeeting River watershed.

2.2 PHYSICAL FEATURES

2.2.1 TOPOGRAPHY

The highest elevation in the watershed (about 2,077 feet above sea level) is located on the summit of Prospect Mountain at the southernmost extent of the watershed. Merrymeeting Lake and the direct shoreline drainage area are at approximately 647 feet above sea level. The seven mountains surrounding Merrymeeting Lake are carved from the Merrymeeting ring-dike complex of the White Mountain magma series, which is characteristic of previous ancient volcanic activity. These elevation measurements were derived from Google Earth.

2.2.2 SOILS AND GEOLOGY

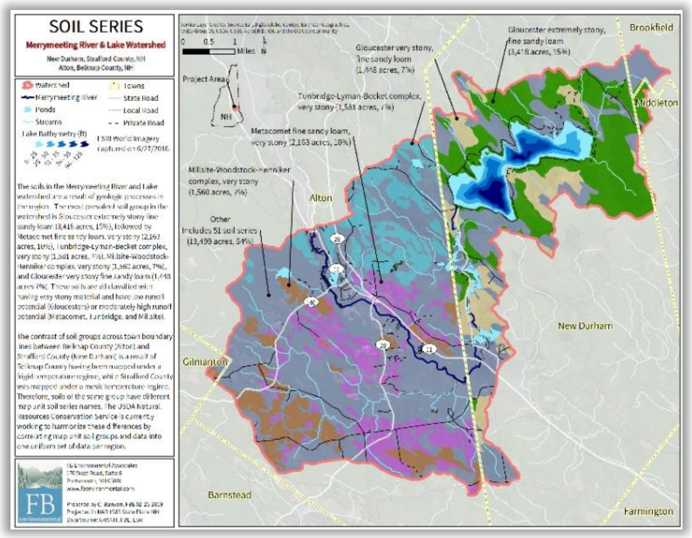
Surficial Geology

The composition of soils surrounding Merrymeeting River and Lake reflects 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 invading vegetation and meandering streams as the depression basins throughout the region began to fill with water (Goldthwait, 1951). The seven mountains surrounding Merrymeeting Lake are part of the ring-dike complex of the White Mountain magma series from ancient volcanic activity.

Soils

The soils in the Merrymeeting River and Lake watershed (Appendix A, Map 3) are a direct result of geologic processes. The most prevalent soil group in the watershed is Gloucester extremely stony find sandy loam (3,418 acres, 15%), followed by Metacomet fine sandy loam, very stony (2,163 acres, 10%), Tunbridge-Lyman-Becket complex, very stony (1,581 acres, 7%), Millsite-Woodstock-Henniker complex, very stony (1, 560 acres, 7%), and Gloucester very stony fine sandy loam (1,448 acres, 7%). These soils are all classified with having very stony material and have low runoff potential (Gloucesters) or moderately high runoff potential (Metacomet, Tunbridge, and Millsite). The remaining 54% of the watershed (excluding the lake area) is a combination of 51 additional soil series ranging from 6% to 0.01% of the watershed.



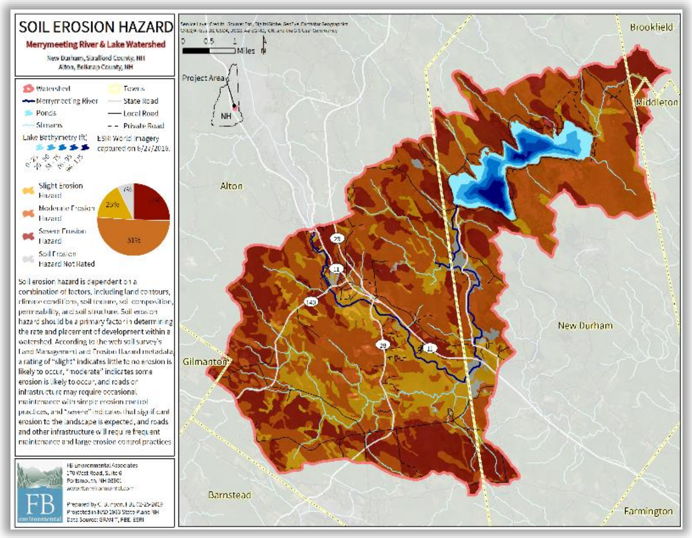
Five soil classes cover 46% of the watershed. Refer to Appendix A, Map 3.

The contrast of soil groups across town boundary lines between Belknap County (Alton) and Strafford County (New Durham) is a result of Belknap County having been mapped under a frigid temperature regime, while Strafford County was mapped under a mesic temperature regime. Therefore, soils of the same group have different map unit soil series names. The USDA Natural Resources Conservation Service (NRCS) is currently working to harmonize these differences by correlating map unit soil groups and data into one uniform set of data per region.

Soil Erosion Hazard

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. According to the web soil survey's Land Management and Erosion Hazard metadata, a rating of "slight" indicates little to no erosion is likely to occur, "moderate" indicates some erosion is likely to occur, and roads or infrastructure may require occasional maintenance with simple erosion control practices, and "severe" indicates that significant erosion to the landscape is expected, and roads and other infrastructure will require frequent maintenance and large erosion control practices.

Most of the watershed was classified as having "moderate" erosion hazard (51%), followed by "slight" (25%), "severe" (17%), and not rated (7%). The largest tracts of soil with severe erosion hazard were on steep slopes along the watershed boundary. Slight erosion hazard areas were found in low-lying wetland areas throughout the watershed.



Moderate to severe soil erosion hazard areas cover 68% of the watershed. Refer to Appendix A, Map 4.

Development should be restricted in areas with highly erodible soils 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 soil stability and function within the landscape, particularly from practices that protect steep slopes from development and/or prevent stormwater runoff from reaching water resources.

As for the hydrogeology of the region, the Merrymeeting River is underlaid by an aquifer that extends from Alton Bay to the watershed boundary between the Merrymeeting and Ela Rivers (Ayotte, 1997). From Alton Bay to the Merrymeeting River Wildlife Management Area, the aquifer's saturated thickness measured between 20 to 40 ft; near the Alton-New Durham town line, the aquifer's saturated thickness measured up to 100 ft. The aquifer's transmissivity was recorded between 1,000 to 8,000 ft^2/day. The west side of the Merrymeeting River in Alton showed a buried esker surrounded by glaciolacustrine deltaic sediment (Figure 2-3).

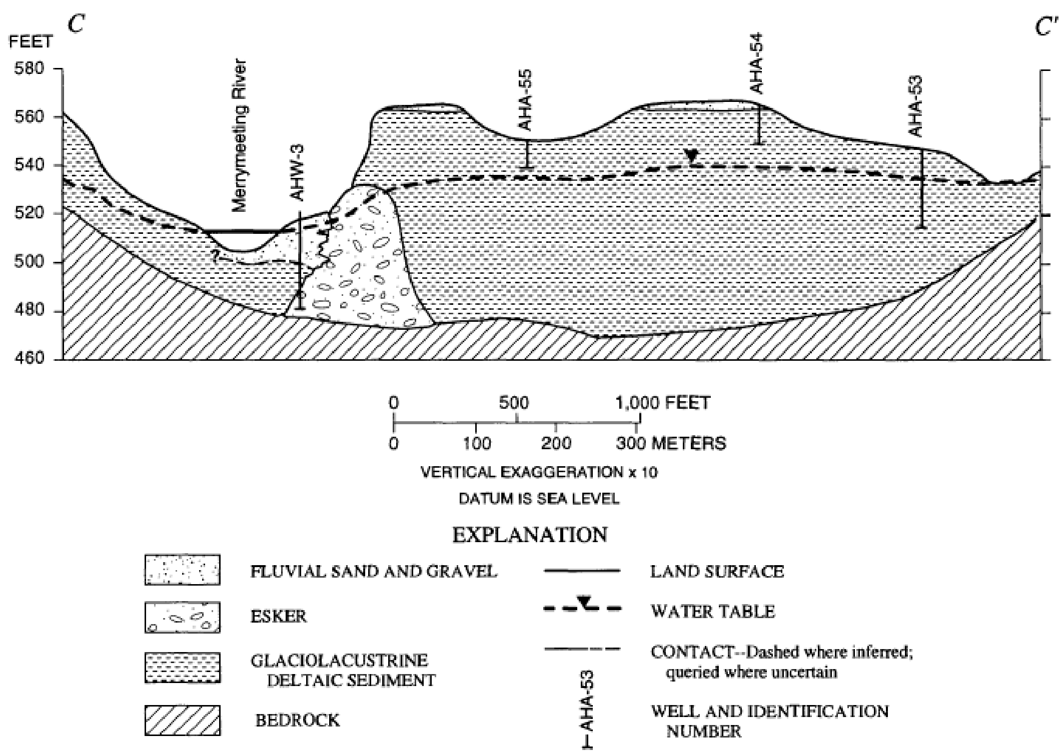
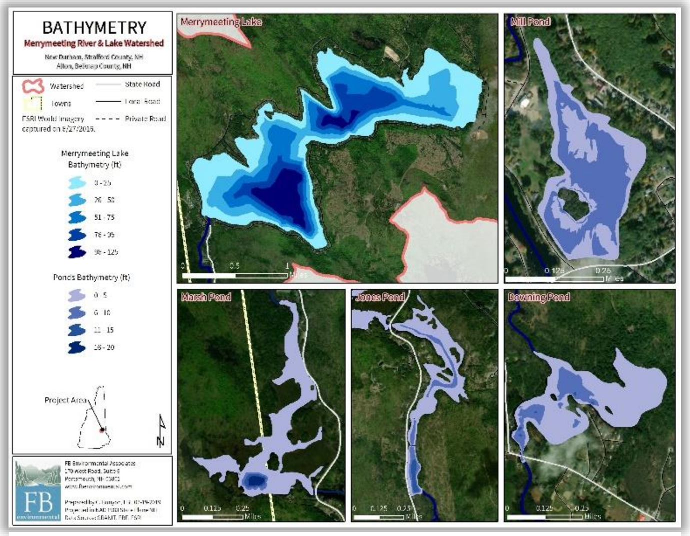


Figure 2-3. Geohydrologic section through the Merrymeeting River aquifer, Alton, New Hampshire. Taken directly from Ayotte (1997).

2.2.3 LAKE MORPHOLOGY AND MORPHOMETRY

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 Merrymeeting Lake is 1.94 square miles (1,242 acres) with a mean depth of 43 feet (13.1 m) and a maximum depth of 135 feet (41.2 m) (NHFGD bathymetry file; NHDES, 2005). There are 11.2 miles of shoreline, and the volume of Merrymeeting Lake is 65,348,008 m^3. The **areal water load** is 13.3 ft/yr (4.0 m/yr), and the flushing rate is 0.3 times per year. The low flushing rate of 0.3 means that the entire volume of Merrymeeting Lake is replaced every 3 years, which increases time for pollutants to settle in lake bottom sediments or be taken up by biota. Merrymeeting Lake is a natural lake controlled by a dam, downstream of which begins Merrymeeting River.



Bathymetry of Merrymeeting Lake, Mill Pond, Marsh Pond, Jones Pond, and Downing Pond (NH GRANIT, NHDES). Refer to Appendix A, Map 5.

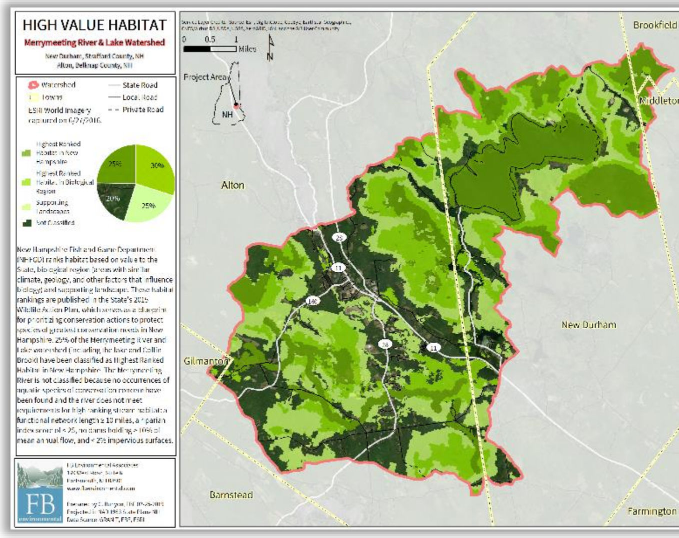
The surface area of Marsh Pond is 45 acres with a mean depth of 9 feet (2.7 m) and a maximum depth of 18 feet (5.5 m) (NHDES bathymetry file; NHDES, 1986). There are 1.2 miles of shoreline, and the volume of Marsh Pond is 522,795 m^3. The areal water load is 509 ft/yr (155 m/yr), and the flushing rate is 54 times per year. The high flushing rate of 54 means that the entire volume of the pond is replaced 54 times each year, acting more like a riverine than a lacustrine system. Marsh Pond is a natural pond partially impacted by the Jones Pond dam impoundment. David Neils and Scott Ashley from NHDES completed bathymetric mapping of Mill Pond and Marsh Pond on May 6, 2019 to support plan development and future studies of these waterbodies.

The surface area of Jones Pond is 57 acres with a mean depth of 4.3 feet (1.3 m) and a maximum depth of 15 feet (4.6 m) (NHDES bathymetry file; NHDES, 1986). There are 2.2 miles of shoreline, and the volume of Jones Pond is 269,970 m3. The areal water load is 427 ft/yr (130 m/yr), and the flushing rate is 112 times per year. The high flushing rate of 112 means that the entire volume of the pond is replaced 112 times each year, acting more like a riverine than a lacustrine system. Jones Pond is an artificial pond impounded by a dam.

The surface area of Downing Pond is 54 acres with a mean depth of 3 feet (0.9 m) and a maximum depth of 11.5 feet (3.5 m) (NHDES bathymetry file; NHDES, 2003). There are 2.2 miles of shoreline, and the volume of Downing Pond is 227,545 m3. The areal water load is 482 ft/yr (147 m/yr), and the flushing rate is 141 times per year. The high flushing rate of 141 means that the entire volume of the pond is replaced 141 times each year, acting more like a riverine than a lacustrine system. Downing Pond is an artificial pond impounded by a dam.

2.2.4 HABITATS AND WILDLIFE

NHFGD ranks habitat based on value to the State, biological region (areas with similar climate, geology, and other factors that influence biology), and supporting landscape. The Biological Region classification within the 2015 NH Wildlife Action Plan is a subdivision of New Hampshire based on ecoregional subsections. The Merrymeeting River and Lake watershed is part of the Sebago-Ossipee Hills and Plains ecoregional subsection (NH Wildlife Action Plan, Chapter 3). These habitat rankings are published in the State's 2015 Wildlife Action Plan, which serves as a blueprint for prioritizing conservation actions to protect Species of Greatest Conservation Need in New Hampshire. Over 4,849 acres (25%) of the Merrymeeting River and Lake watershed are considered Highest Ranked Habitat in New Hampshire. This habitat includes Merrymeeting Lake and a 200-meter buffer surrounding the lake. There are two rare or exemplary natural communities of red oak-pine rocky ridge and dry red oak-white pine forest, and two rare or exemplary natural communities of red oak-black birch wooded talus. There is also a rare or exemplary natural community in a medium-level fen system. However, conservation land within the Merrymeeting River and Lake watershed does not always overlap with areas of land classified as highest ranked habitat in New Hampshire. A map of priority habitats for conservation based on the NH Wildlife Action Plan can be found in Appendix A, Map 6.



High value habitat in the Merrymeeting River and Lake watershed. Refer to Appendix A, Map 6.

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, and birds (herons, loons, gulls, geese, multiple species of ducks[2], wild turkeys, ruffed grouse, cormorants, bald eagles, and song birds). Fish are an important natural resource for sustainable ecosystem food webs and provide recreational opportunities. Merrymeeting Lake has been classified by the NHFGD as a cold/warm water fishery which supports a diversity of both warmwater and coldwater fish species. These species include rainbow trout, landlock salmon, lake trout, smallmouth bass, chain pickerel, brown bullhead, and burbot. In the summer of 2018, there were two breeding pairs of loons (*Gavia immer*) on Merrymeeting Lake. NHFGD identified largemouth bass, brown bullhead, and chain pickerel in both Marsh Pond and Downing Pond. Coffin Brook is recognized by the State of New Hampshire as prime habitat for bridle shiners and wild brook trout. NHFGD stocks Merrymeeting Lake annually with rainbow trout and land-locked salmon from the Powder Mill State Fish Hatchery.

The New Durham segment of the Merrymeeting River watershed is home for a variety of threatened and endangered species including reproducing populations of both bald eagles and common loons, as well as the Ebony Boghaunter, Blanding's turtle, spotted turtle, wood turtle, and the plants Flatstem Pondweed and Hollow Joe-Pye Weed.

2.3 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.

Representatives from Merrymeeting Lake participate in the NH Lake Association Lake Host Program to inspect boats both entering and exiting Merrymeeting Lake for invasive aquatic plants to try and mitigate the spread of invasive aquatic plant species. Because of the superb efforts from the Lake Hosts inspecting boats, variable milfoil (2007, 2010, 2012, 2013, 2014) and water chestnut (2012) have been caught before entering or leaving the lake. According to the *Merrymeeting Lake News and Guide* of 2007, provided by the MMLA, Merrymeeting Lake does not host any invasive plants or animals.

A Long-Term Variable Milfoil Management Plan was developed by NHDES in March 2014 for Jones and Downing Ponds. Variable milfoil was first documented in Jones Pond around 2000-2002; no variable milfoil was found during a survey of upstream waterbodies (Marsh Pond, Merrymeeting Lake) in 2009. Variable milfoil was first reported in Downing Pond in 2010 but likely established before then. The Town of New Durham, through the formation of the New Durham Milfoil Committee, has been actively involved in funding control activities, including hand-removal by weed control certified divers and herbicide treatments as needed. The contract diver uses Diver Assisted Suction Harvesting (DASH) and noted in 2017 that the rich layer of sediment on the bottom of the ponds makes harvesting variable milfoil nearly impossible. The Committee collaborates with contractors, state agency personnel, and representatives from other groups dealing with similar milfoil issues.

The last quarter mile of Merrymeeting River before entering Alton Bay has also been treated annually for variable milfoil.

[2] American black duck, black scoter, canvasback, common goldeneye, hooded merganser, long tailed duck, wood duck, red breasted merganser, northern pintail, and mallard.

3. ASSESSMENT OF WATER QUALITY

This section provides an overview of the water quality standards that apply to Merrymeeting Lake, Marsh Pond, Jones Pond, and Downing Pond; the methodology used to assess water quality; the past, current, and future state of water quality based on the modeling assessment; the established water quality goals and objectives; and the potential pollutant sources in the watershed.

3.1 APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

The State of New Hampshire is required to follow federal regulations under the **Clean Water Act (CWA)** with some flexibility as to how those regulations are enacted. The main components of water quality regulations include designated uses, water quality criteria, and antidegradation provisions. The Federal CWA, the NH *RSA 485-A Water Pollution and Waste Control*, and the NH Surface Water Quality Regulations (Env-Wq 1700) are the regulatory bases for governing water quality protection in New Hampshire. These regulations form the basis for New Hampshire's regulatory and permitting programs related to surface waters. States are required to submit biennial water quality status reports to Congress via the USEPA. The reports provide an inventory of all waters assessed by the state and indicate which waterbodies exceed the state's water quality standards. These reports are commonly referred to as the "Section 303(d) list" and the "Section 305(b) report."

3.1.1 DESIGNATED USES & WATER QUALITY CLASSIFICATION

The 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 aquatic life, fish consumption, shellfish consumption, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating and fishing), and wildlife (Table 3-1). Surface waters can have multiple designated uses.

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). A brief description of these classes is provided in Table 3-2 (NHDES, 2016a). Water quality criteria are then developed to protect these designated uses. 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. Water quality criteria for lakes are discussed in Section 3.1.2; no water quality criteria for total phosphorus currently exist for rivers in New Hampshire. **Merrymeeting River and Lake, Marsh Pond, Jones Pond, and Downing Pond are considered Class B waterbodies.**

Table 3-1. Designated uses for New Hampshire surface waters (adapted from NHDES, 2016a).

Designated Use	NHDES Definition	Applicable Surface Waters
Aquatic Life	Waters that provide suitable chemical and physical conditions for supporting a balanced, integrated, and adaptive community of aquatic organisms.	All surface waters
Fish Consumption	Waters that support fish free from contamination at levels that pose a human health risk to consumers.	All surface waters
Shellfish Consumption	Waters that support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers.	All tidal surface waters
Drinking Water Supply After Adequate Treatment	Waters that with adequate treatment will be suitable for human intake and meet state/federal drinking water regulations.	All surface waters
Primary Contact Recreation	Waters suitable for recreational uses that require or are likely to result in full body contact and/or incidental ingestion of water.	All surface waters
Secondary Contact Recreation	Waters that support recreational uses that involve minor contact with the water.	All surface waters
Wildlife	Waters that provide suitable physical and chemical conditions in the water and the **riparian corridor** to support wildlife as well as aquatic life.	All surface waters

Table 3-2. New Hampshire surface water classifications.

Classification	Description (RSA 485-A:8)
Class A	Class A waters shall be of the highest quality. There shall be no discharge of any sewage or wastes into waters of this classification. The waters of this classification shall be considered as being potentially acceptable for water supply uses after adequate treatment.
Class B	Class B waters shall be of the second highest quality. The waters of this classification shall be considered as being acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies.

3.1.2 LAKE WATER QUALITY CRITERIA

New Hampshire's water quality standards provide a baseline measure of water quality that surface waters must meet to support designated uses. Water quality standards are the "yardstick" for identifying water quality exceedances and for determining the effectiveness of state regulatory pollution control and prevention programs. Water quality criteria are designed to protect those designated uses. To determine if a waterbody is meeting its designated uses, water quality thresholds for various water quality 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. Aquatic Life Use (ALU) and Primary Contact Recreation (PCR) are the two major uses for Merrymeeting Lake, Marsh Pond, Jones Pond, and Downing Pond, with ALU being the focus of the plan.

Aquatic Life Use (ALU)

Criteria for ALU ensure that waters provide suitable habitat for the survival and reproduction of desirable fish, shellfish, and other aquatic organisms. For ALU assessment, the state has narrative nutrient criteria with a numeric translator or threshold, consisting of a "nutrient indicator" or total phosphorus and a "response indicator" or chlorophyll-a (see also: Env-Wq 1703.03, Env-Wq 1703.04, Env-Wq 1703.14, and Env-Wq 1703.19). The nutrient and response indicators are intricately linked since increased phosphorus loading frequently results in greater algal concentrations, which can be estimated by measuring chlorophyll-a levels in the lake. More algae may lead to decreased oxygen at the bottom of the lake, decreased water clarity, and possibly changes in aquatic species composition.

As shown in Table 3-3, ALU criteria vary by lake trophic state, since each trophic state has a certain algal biomass (chlorophyll-a) that represents a balanced, integrated, and adaptive community. Exceedances of the chlorophyll-a criterion suggests that the algal community is out of balance. Since phosphorus is the primary limiting nutrient for growth of freshwater algae (chlorophyll-a), phosphorus is included in this assessment process. For ALU assessment, phosphorus and chlorophyll-a are combined per the decision matrix presented in Table 3-4. The chlorophyll-a concentration will dictate the assessment if both chlorophyll-a and phosphorus data are available and the assessments differ.

Dissolved oxygen is also used as an indicator for ALU assessment and is critical to the balanced, integrative, and adaptive community of organisms (see Env-Wq 1703.19). For Class B waters, non-support use determinations are based on a daily average measurement of 75% dissolved oxygen saturation or less and an instantaneous dissolved oxygen measurement of 5 ppm or less, which apply to any depth in a vertical profile (except within 1 meter of lake bottom) collected from June 1 to September 30 (see Env-Wq 1703.07).

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 Merrymeeting Lake, the trophic state was determined to be oligotrophic during both surveys (1977, 2005). This means that in-lake water quality was consistent with the standards for oligotrophic lakes. The 2005 survey reported that Merrymeeting Lake was a deep lake with visibility over 28 feet, had low nutrients, and excellent dissolved oxygen levels in the bottom waters. For Marsh, Jones, and Downing Ponds, the trophic state was determined to be eutrophic (1986), mesotrophic (1986), and eutrophic (2003), respectively. The surveys reported that the ponds were experiencing reduced clarity, elevated nutrients, abundant plant and algae growth, and low dissolved oxygen levels in bottom waters and noted that the upstream Powder Mill State Fish Hatchery was likely contributing to elevated total phosphorus concentrations in the ponds.

Table 3-3. Aquatic life use (ALU) 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 3-4. Decision matrix for aquatic life use (ALU) 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

3.1.3 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.

3.2 WATER QUALITY SUMMARY

3.2.1 STUDY DESIGN AND DATA ACQUISITION

Water quality data were obtained from the NHDES Environmental Monitoring Database (EMD) and Robert Craycraft, Lakes Lay Monitoring Program (LLMP) Coordinator at the UNH Cooperative Extension. Water quality data were combined into a common spreadsheet, and then sorted by date, station, and depth zone for Quality Assurance/Quality Control (QA/QC). QC duplicates were averaged, any data not marked as "valid" were excluded, and any data below detection limit were replaced with half the detection limit. All data used in the analysis were collected by trained volunteer monitors through the UNH LLMP following procedures in the NH Center for Freshwater Biology and Lakes Lay Monitoring Program QAPP, RFA#16059, dated March 9, 2016.

Water quality data were summarized by parameter (total phosphorus, chlorophyll-a, **Secchi Disk Transparency**, and dissolved oxygen-temperature profile data) according to methods described in Appendix B of the NHDES Guidance for Developing Watershed Management Plans in New Hampshire for Section 319 Nonpoint Source Grant Program Project (revised April 14, 2010) and the State of New Hampshire 2016 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology (CALM) (dated August 8, 2019) (NHDES, 2018b). Median total phosphorus and chlorophyll-a for recent (2009-2018), seasonal (May 24 – September 15) epilimnetic samples represents the 'Existing Median Water Quality' applied to the NHDES Assimilative Capacity Analysis for determining if a waterbody is Impaired, Tier 1, or Tier 2 (see section on Assimilative Capacity Analysis). Similar methodology was used to calculate summary statistics for Secchi disk transparency. Dissolved oxygen and temperature data were compared to Class B water quality standards and to hypolimnetic total phosphorus concentrations to assess **internal phosphorus loading**. Recent tributary or mainstem river data (largely from 2016-2018) were summarized by day, then month, then year to obtain median annual water quality summaries for total phosphorus.

3.2.2 TOTAL PHOSPHORUS, CHLOROPHYLL-A, AND SECCHI DISK TRANSPARENCY

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. 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, see Figure 3-1) or the amount of dissolved or particulate materials in a lake. Such changes are likely the result of human disturbance or other impacts to a watershed.

Total phosphorus in the **epilimnion** of Merrymeeting Lake has ranged from 2.3 to 9.0 ppb, with an all monthly data median of 3.5 ppb (i.e., the Existing Median Water Quality applied to the assimilative capacity analysis; Table 3-5). Merrymeeting Lake has low (excellent) phosphorus compared to average levels in New Hampshire lakes. The ponds exhibited significantly worse water quality; total phosphorus in the epilimnion of Marsh, Jones, and Downing Ponds has ranged from 31-65 ppb, 22-36 ppb, and 19-34 ppb, with an all monthly data median of 43 ppb, 27 ppb, and 25 ppb, respectively (Table 3-5).

Chlorophyll-a in Merrymeeting Lake has ranged from 0.1 to 1.6 ppb, with an all monthly data median of 0.8 ppb (i.e., the Existing Median Water Quality applied to the assimilative capacity analysis; Table 3-5). Merrymeeting Lake has low (excellent) chlorophyll-a compared to average levels in New Hampshire lakes. The ponds exhibited significantly worse water quality; chlorophyll-a in Marsh, Jones, and Downing Ponds has ranged from 4-31 ppb, 6-17 ppb, and 4-9 ppb, with an all monthly data median of 8 ppb, 8 ppb, and 6 ppb, respectively (Table 3-5).

Secchi disk transparency with a viewscope in Merrymeeting Lake has ranged from 7.5 to 13.5 m, with an all monthly data median of 10.1 m (Table 3-5). Merrymeeting Lake has deep water clarity compared to average water clarity in New Hampshire lakes. Moderate interannual variability in Secchi disk transparency likely reflects year-to-year weather influences. Wetter years may increase the amount of sediment delivered to the lake and cause lower transparency readings. The ponds exhibited significantly reduced water clarity, partly due to their shallow nature; SDT in Marsh, Jones, and Downing Ponds has ranged from 2.5-3.3 m, 2.5-3.6 m, and 1.8-3.3 m, with an all monthly data median of 3.0 m, 2.8 m, and 3.1 m, respectively (Table 3-5).

Table 3-5. Summary statistics for total phosphorus (TP) in the epilimnion (discrete grab sample at mid-layer depth), chlorophyll-a (Chl-a) in the metalimnion (composite sample of multiple depths), and Secchi disk transparency (SDT) with a viewscope for Merrymeeting Lake, Marsh Pond, Jones Pond, Downing Pond based on seasonal (May 24 – Sept 15) samples. n = total number of sampling events (used in summary statistics).

SITE	Median	Mean	Min	Max	n
TP-EPILIMNION (PPB)					
MERRYMEETING LAKE-2 OWLS HEAD	3.3	3.8	2.3	7.3	30
MERRYMEETING LAKE-3 EAST END	3.5	3.9	2.6	9.0	30
MERRYMEETING LAKE-DEEP SPOT	3.8	4.0	2.6	6.8	30
MARSH POND - 2 DEEP	43.1	44.2	30.7	65.1	7
JONES POND SITE 3 - DEEP	26.7	28.6	22.3	35.8	5
DOWNING POND SITE 8 - DEEP	25.2	25.8	19.4	34.3	8
CHLA-METALIMNION (PPB)					

SITE	Median	Mean	Min	Max	n
MERRYMEETING LAKE-2 OWLS HEAD	0.8	0.8	0.1	1.6	33
MERRYMEETING LAKE-3 EAST END	0.9	0.8	0.1	1.2	33
MERRYMEETING LAKE-DEEP SPOT	0.7	0.8	0.1	1.5	33
MARSH POND - 2 DEEP	7.9	11.3	4.0	30.5	8
JONES POND SITE 3 - DEEP	7.9	9.4	6.1	17.2	6
DOWNING POND SITE 8 - DEEP	6.4	6.1	3.8	8.9	9
SDT-VIEWSCOPE (M)					
MERRYMEETING LAKE-2 OWLS HEAD	10.1	10.3	7.7	13.1	33
MERRYMEETING LAKE-3 EAST END	9.6	9.7	7.5	12.3	33
MERRYMEETING LAKE-DEEP SPOT	10.8	10.9	8.4	13.5	33
MARSH POND - 2 DEEP	3.0	3.0	2.5	3.3	8
JONES POND SITE 3 - DEEP	2.8	3.0	2.5	3.6	7
DOWNING POND SITE 8 - DEEP	3.1	2.9	1.8	3.3	5
DOWNING POND-DEEP SPOT	3.0	2.9	1.8	3.3	9

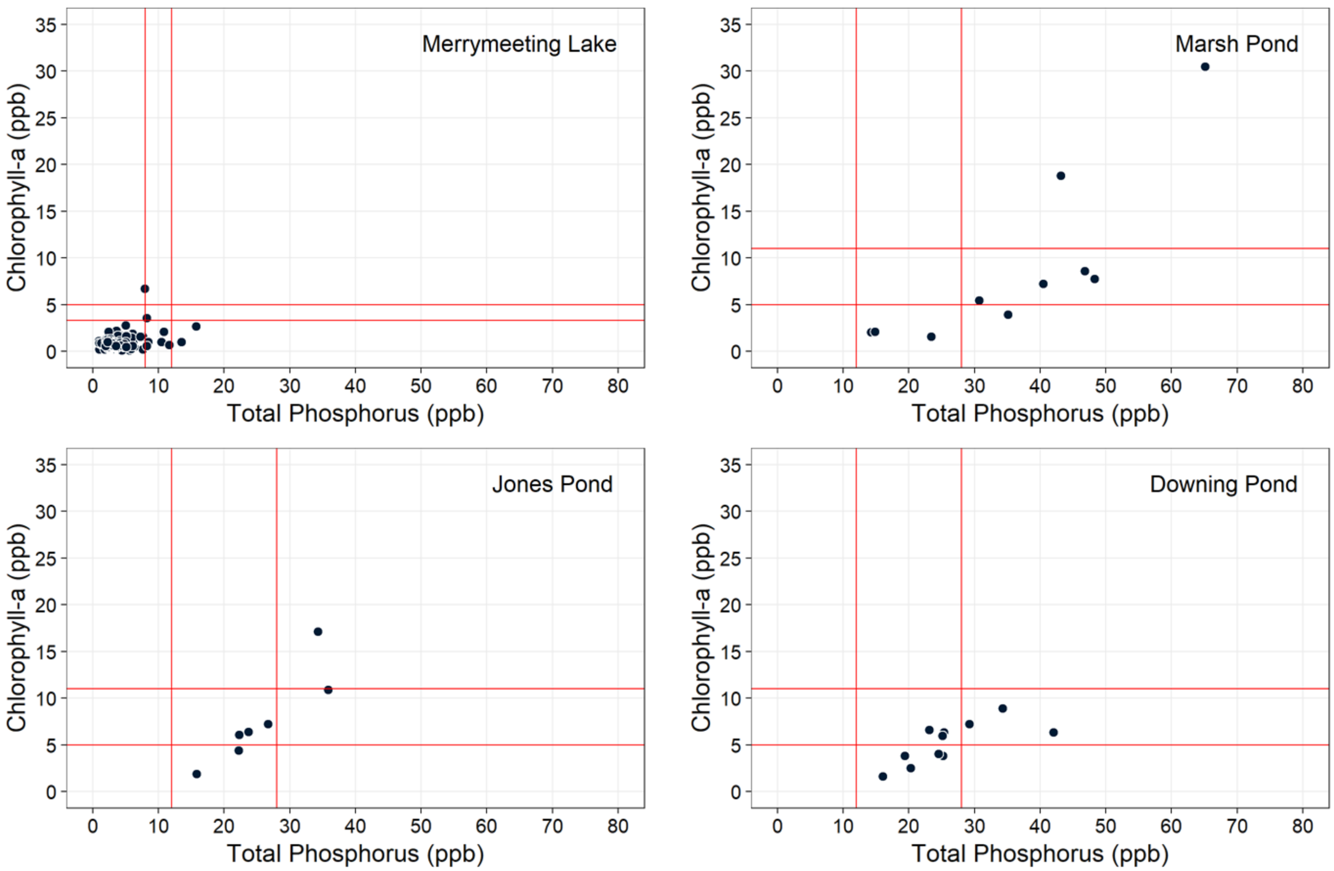


Figure 3-1. The relationship between chlorophyll-a and total phosphorus in Merrymeeting Lake (top left), Marsh Pond (top right), Jones Pond (bottom left), and Downing Pond (bottom right) shows that chlorophyll-a (measure of algae) generally increases in response to greater total phosphorus concentrations. Thresholds (red lines) for chlorophyll-a and total phosphorus for oligotrophic (3.3 ppb Chl-a, 8 ppb TP), mesotrophic (5 ppb Chl-a, 12 ppb TP), and/or eutrophic (11 ppb Chl-a, 28 ppb TP) waterbodies per NHDES.

3.2.3 TEMPERATURE AND DISSOLVED OXYGEN

A common phenomenon for New England lakes is the depletion of dissolved oxygen in bottom waters throughout the summer months. This occurs when **thermal stratification** prevents warmer, oxygenated surface waters from mixing with cooler, oxygen-depleted bottom waters in a lake. Dissolved oxygen concentrations can change dramatically with lake depth as oxygen is produced in the top portion of a lake (where sunlight drives photosynthesis) and oxygen is consumed near the bottom of a lake (where organic matter accumulates and decomposes). Dissolved oxygen levels below 5-6 ppm (and water temperatures above 24 °C) can stress and reduce habitat for cold-water fish and other sensitive aquatic organisms. The minimum water quality criterion is 5 ppm dissolved oxygen for Class B waters. 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 becomes a readily available food source for algae. While thermal stratification and depletion of oxygen in bottom waters are natural phenomena, it is important to keep tracking these parameters to make sure the extent and duration of low oxygen are not exacerbated by human activities and do not inhibit aquatic life use.

Dissolved oxygen and temperature profiles from the deep spots of Merrymeeting Lake, Marsh Pond, and Jones Pond show midsummer thermal stratification, with high dissolved oxygen and warm water temperatures near the surface followed by a marked decrease in temperature and dissolved oxygen below the metalimnion (i.e., **thermocline**), except for Merrymeeting Lake which shows a metalimnion maxima (i.e., supersaturation) and high oxygen levels throughout the water column (Figure 3-2). Downing Pond exhibited no thermal stratification and had relatively uniform dissolved oxygen and temperature readings throughout its shallow water column.

Low levels of oxygen (<5 ppm) in the **hypolimnion** (e.g., bottom waters) were common in the ponds (Figure 3-2). Extremely low dissolved oxygen (anoxia, <1 ppm) in the hypolimnion of Marsh and Jones Ponds was likely triggering a release of phosphorus from sediments, also known as internal loading (see Internal Phosphorus Loading). When thermal stratification of Marsh and Jones Ponds breaks down in the fall, these phosphorus-rich waters are mixed and re-distributed throughout the rest of the water column (a.k.a., **fall turnover**), which can stimulate algae and/or cyanobacteria growth for the next season.

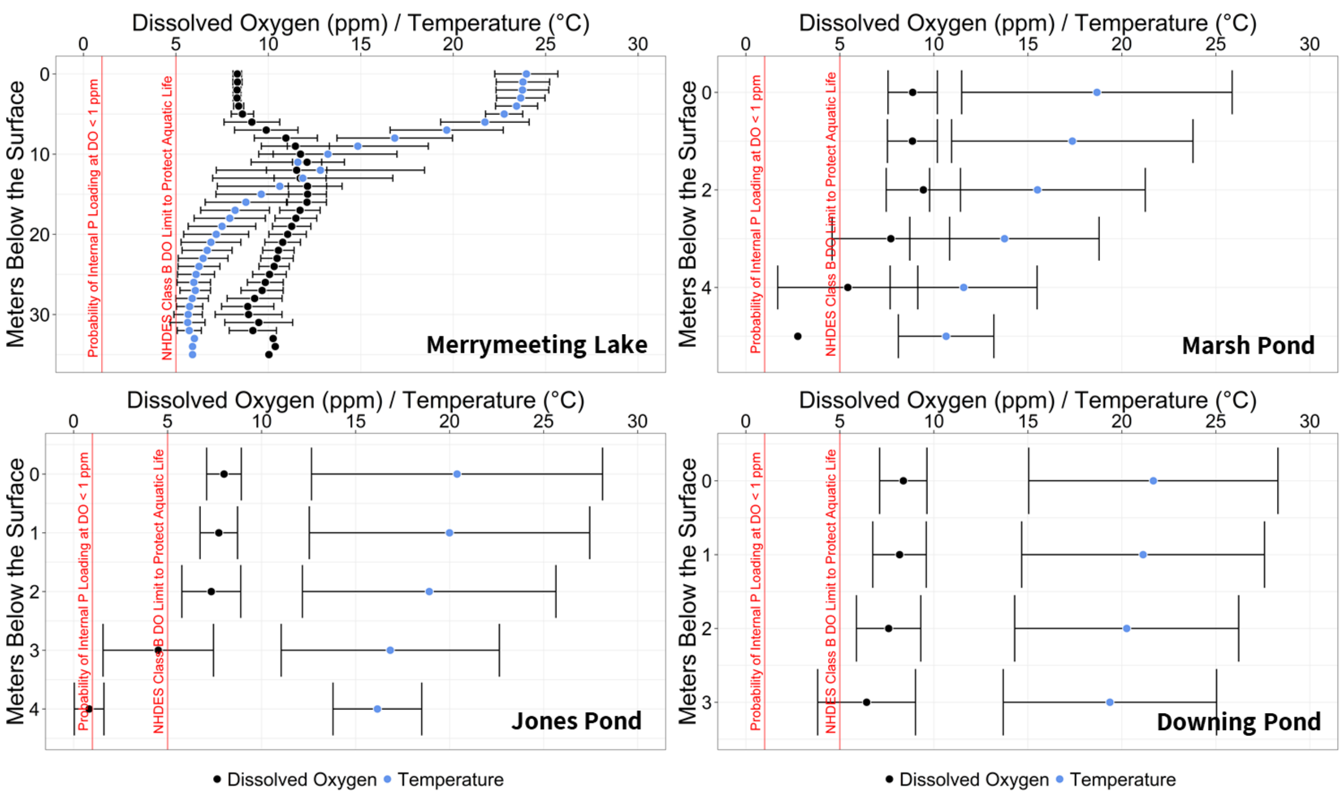


Figure 3-2. Average dissolved oxygen and temperature profiles of the deep spot of Merrymeeting Lake, Marsh Pond, Jones Pond, and Downing Pond. Error bars represent standard deviation or spread of the data at each depth interval. Vertical red lines denote dissolved oxygen thresholds for Class B Aquatic Life Use at 5 ppm and probability of internal phosphorus loading at 1 ppm.

3.2.4 INTERNAL PHOSPHORUS LOADING

Internal loading estimates were derived from dissolved oxygen and temperature profiles (to determine average annual duration and depth of anoxia defined as <1 ppm dissolved oxygen) and epilimnion/hypolimnion total phosphorus data (to determine average difference between surface and bottom phosphorus concentrations) collected at the deep spots of Merrymeeting Lake from 1977-2018 and Marsh, Jones, and Downing Ponds from 2017-2018. These estimates, along with anoxic volume and surface area, helped determine rate of release and mass of internal phosphorus loading per year.

There was no evidence of significant internal loading or an extended anoxic period in both Merrymeeting Lake and Downing Pond (Figure 3-3). Both Merrymeeting Lake and Downing Pond showed bottom phosphorus concentrations to be nearly the same as near-surface phosphorus concentrations and showed no anoxia in bottom waters. Minimum dissolved oxygen concentration in the deepest layer of Merrymeeting Lake ranged from 6-7 ppm at the three deep spots. Downing Pond is shallow (3 m at its deep spot) and flushed regularly (141 times per year) by large upstream flows from Merrymeeting Lake, Marsh Pond, and Jones Pond, preventing a stable thermal layer from forming in summer and causing consistent replenishment of oxygen-rich waters throughout the water column.

Marsh and Jones Pond had evidence of significant internal loading (Figure 3-3). Because of thermal stratification and lack of vertical profile mixing in summer, increases in bottom phosphorus from internal loading at Marsh and Jones Ponds were cumulative until system flushing in October when Merrymeeting Lake was drawn down to its winter level. Bottom phosphorus concentration in Jones Pond decreased in September (earlier than observed at Marsh Pond and before system flushing) likely due to a partial breakdown of thermal stratification and mixing of upper layers following a large rain event. A similar, though less pronounced, pattern was observed for Downing Pond, which is one meter shallower than Jones Pond and two meters shallower than Marsh Pond.

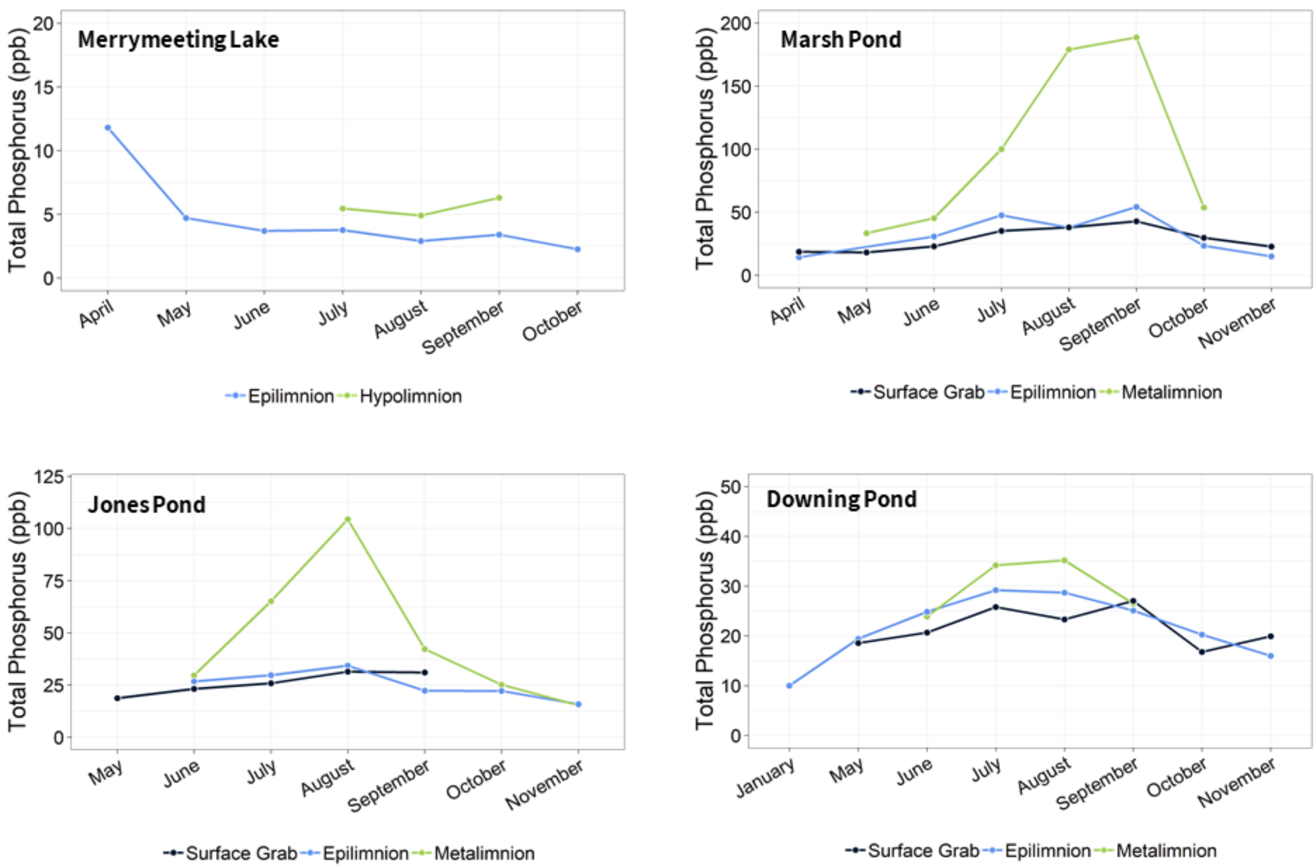


Figure 3-3. Median total phosphorus concentrations by month and by depth zone (surface, epilimnion, and metalimnion/hypolimnion) for Merrymeeting Lake, Marsh Pond, Jones Pond, and Downing Pond. Note differences in y-axis scales for total phosphorus for each waterbody. Significant internal loading was evident at Marsh and Jones Ponds.

3.2.5 CYANOBACTERIA

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. Cyanobacteria can regulate their buoyancy with internal gas bubbles, allowing the cells to rise and descend in the water column to optimize sunlight and nutrient capture for growth. There are several different species of cyanobacteria, such as:

- **Anabaena/Dolichospermum**: typically observed as filaments, associated with microcystins, anatoxins, saxitoxins, and cylindrospermopsin
- **Microcystis**: typically observed as variations of small-celled colonies, associated with microcystins and anatoxins
- **Planktothrix/Oscillatoria**: typically observed as filaments, associated with microcystins and cylindrospermopsin, can maintain high growth rate at relatively low light intensities as seen when it forms metalimnetic blooms in Marsh and Jones Ponds

Cyanobacteria blooms and their associated toxins have been recorded in the Merrymeeting River, including Marsh, Jones, and Downing Ponds, and more recently Mill Pond (Table 3-6). These blooms feed on the nutrient-rich waters of the Merrymeeting River and ponds downstream of the Powder Mill State Fish Hatchery and Coffin Brook.

It is unlikely that cyanobacteria will be fully eradicated in the Merrymeeting River and 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). However, we can substantially minimize conditions favorable for blooms, such as reducing nutrient-rich runoff from the landscape during warm, sunny spells and substantially reducing the point source discharge of phosphorus from the Powder Mill State Fish Hatchery. Water level and flow also helps to either flush out blooms or limit upstream nutrient sources to stymie growth. The dam at Downing Pond was lower by 8 inches in 2017 and 14 inches in 2018, which coupled with wet years increased the flushing rate through Downing Pond and no cyanobacteria blooms

Cyanobacteria in the Merrymeeting River. Photo Credit: Mike Gelinas.

Sabina Perkins, a Master's student at UNH, monitored a dense nearly monospecific layer of cyanobacteria in Marsh Pond monthly April through October in 2018, tracking the formation and persistence of the deep-water cyanobacteria layer and the physical/chemical/light environments where it was found. Cyanobacteria blooms take different forms: surface scums, subsurface epilimnetic blooms, benthic mats, and in some lakes, metalimnetic layers. There is limited field research on the seasonal behavior of metalimnetic layers and the contribution of layer-produced cyanotoxins to the overall toxin profile of New Hampshire lakes. Cyanobacteria abundance and dominance were quantified through cell counts using an Imaging Flow Cytobot (IFCB) and with phycocyanin fluorescence estimates. Persistent, nearly monospecific populations of *Planktothrix isothrix* were detected in the metalimnion of Marsh Pond multiple years in a row. The layers appeared to migrate up from the sediments, finding a depth with high nutrients, thermal stability, and low light levels that still allowed for photosynthesis. Very low levels of microcystin toxin ranging from below the detectable limit to 7 ng/L (more than 40 times lower than the most conservative drinking water allowance set by the EPA at 300 ng/L) were measured in both the surface and cyanobacteria layer at Marsh Pond. This raises the possibility that the dominant strain found in the metalimnetic layers may not produce microcystin or did not experience conditions in the 2018 growing season that favored the production of microcystin. While these dense *Planktothrix isothrix* layers did not appear to be producing microcystin at levels considered harmful to human health, we did not test for other toxins, like anatoxin, that *Planktothrix sp.* are known to produce and therefore cannot say definitively that these layers do not represent a human health risk.

were recorded. Thus, controlling water flow may be one management strategy for minimizing cyanobacteria blooms in the future, along with phosphorus load reduction actions.

Table 3-6. Cyanobacteria blooms occurring in the Merrymeeting River watershed since 2015. MMWMA=Merrymeeting Marsh Wildlife Management Area.

Organism	Year	Location	Illness Reported	Count/mL
Anabaena spp.	2015	Downing Pond	No	4,100,000
Anabaena spp.	2016	Downing Pond	1 cat died	170,000
Anabaena spp.	2016	MMWMA	1 human illness	Unknown
Planktothrix spp.	2016	Jones Pond	No	2,300,000
Planktothris spp.	2017	Jones Pond	1 human rashes	1,700,000
Planktothrix spp.	2018	Jones Pond	No	948,000
Planktothrix spp.	2019	Jones Pond	No	282,000
Planktothrix spp.	2018	Marsh Pond	No	3,000,000
Planktithrix spp.	2019	Marsh Pond	No	150,000
Microcystis spp.	2018	Mill Pond	No	30,000

Anabaena spp. was not speciated. *Planktothrix* spp. was speciated as *Planktothrix agardhii variety isothrix*. *Microcystic* spp. had the microscopic appearance of *Microcystis aeruginosa*.

3.2.6 TRIBUTARY & MAINSTEM WATER QUALITY ANALYSIS

Several tributaries feed into Merrymeeting Lake, Marsh Pond, Jones Pond, and Downing Pond before the Merrymeeting River continues to flow south then northwest and joins with Coffin Brook in Alton before emptying into Alton Bay of Lake Winnipesaukee. Trained volunteers spent considerable time collecting numerous samples throughout the Merrymeeting River and Lake watershed from 2016-2018, contributing to a growing database that helps to track areas with elevated phosphorus concentrations in the watershed. The data for these tributary and mainstem sites were used as general guidelines for setting attenuation factors and confirming overall model calibration (Table 3-7, see Watershed Modeling). Aside from the Powder Mill Fish Hatchery point source discharge, the watershed load (representing the contributing land cover) to Coffin Brook was determined to be a significant source of phosphorus to the Merrymeeting River in Alton.

Tributaries to the south side of Merrymeeting Lake that were impacted by the large-scale logging in 2017-19 were tested for total phosphorus, conductivity, and/or turbidity by CMSC from 2017-19. Two tributaries draining the 2017 logging area showed moderately elevated total phosphorus but returned to pre-logging conditions the next year. Two of seven tributaries draining the 2018-19 logging area showed elevated total phosphorus as well, but one of the tributaries was extremely elevated in total phosphorus, prompting a visit from the State Forester and subsequent installation of erosion prevention measures.

While there are no state criteria for nutrients in rivers and streams, we can compare the statistics presented in Table 3-7 to the distribution of total phosphorus in New Hampshire rivers based on data collected from 1990-2018 (Figure 3-4). The statewide median total phosphorus concentration in rivers is 14 ppb, with 5 ppb, 9 ppb, 22 ppb, and 50 ppb representing the 5th, 25th, 75th, and 95th percentiles, respectively. Most of the sampled tributary and maintain sites of the Merrymeeting River fall in the 50th percentile or greater compared to other rivers in the state.

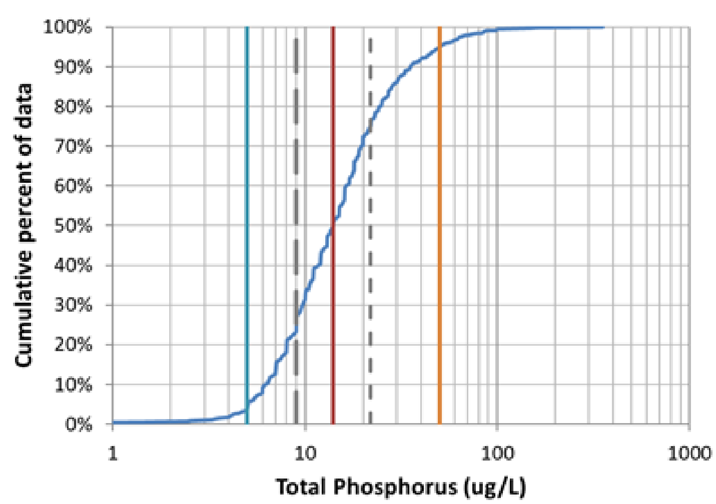


Figure 3-4. Cumulative frequency distribution plot of total phosphorus data collected in New Hampshire rivers from 1990-2018 (shown as blue line). Data represent 32,422 samples from 710 assessment units that had 10 more samples. Plot obtained from NHDES. The statewide median total phosphorus concentration in rivers is 14 ppb (red line), with 5 ppb (teal line), 9 ppb (long dashed grey line), 22 ppb (short dashed grey line), and 50 ppb (orange line) representing the 5th, 25th, 75th, and 95th percentiles, respectively.

Table 3-7. Summary statistics for total phosphorus (TP) in ppb for tributary and mainstem river sites (data includes all samples year-round through 2018). n = total number of sampling events (used in summary statistics).

SITE	Waterbody	Sub-basin	Median	Mean	Min	Max	n
Adder Hole Cove	Merrymeeting Lake	Adder Hole Brook	10.6	17.0	9.7	30.8	3
130 SSR	Merrymeeting Lake	Broad Cove Brook	8.9	19.8	5.7	40.7	7
250 NSR	Merrymeeting Lake	Direct Shoreline MML	18.0	18.0	16.9	19.0	2
45 SSR	Merrymeeting Lake	Direct Shoreline MML	12.3	22.5	12.3	43.0	3
386 SSR	Merrymeeting Lake	East Durgin Brook	3.6	3.6	3.6	3.6	1
1 PPR	Merrymeeting Lake	East Pine Point Brook	14.1	13.3	11.0	14.7	3
368 MMR (Mt. Bet Bk)	Merrymeeting Lake	Mount Bet Brook	4.3	4.1	3.8	4.3	3
MM LAKE OUTFLOW (MERRYMEETING ROAD)	Merrymeeting Lake	Outflow	4.1	5.2	2.9	21.3	18
Camp Pride Road East	Merrymeeting Lake	Peter Brook	14.0	14.7	11.3	18.9	3
195 NSR	Merrymeeting Lake	Pleasant Cove Brook	11.2	10.9	8.2	13.3	3
284 SSR	Merrymeeting Lake	Unnamed Trib to MML	7.7	8.1	4.5	12.4	5
Camp Pride Road West	Merrymeeting Lake	Upper Goodwin Brook	9.5	9.5	7.0	11.9	3
423 MMR	Merrymeeting Lake	West Durgin Brook	6.8	6.7	5.1	8.1	3
BEAR POND TRIBUTARY	Marsh Pond	Bear Pond Brook	6.8	7.8	5.8	11.7	4
UNNAMED STREAM	Marsh Pond	Bear Pond Brook	5.5	5.7	4.0	7.7	3
Logging Harvest Pole 314-55	Marsh Pond	Brackett Rd Culvert Drainage	425.1	425.1	425.1	425.1	1
MARSH POND SITE 1 - BOAT ACCESS	Marsh Pond	Direct Drainage to Marsh Pond	37.3	37.0	12.7	62.9	22
Outfall #2	Marsh Pond	PMFH	52.5	56.7	23.0	120.0	10
Hatchery	Marsh Pond	PMFH	36.0	81.1	2.5	576.6	11
Outfall #1	Marsh Pond	PMFH	38.9	38.9	38.9	38.9	1
West Str. 1B	Marsh Pond	North Trib to Marsh Pond	12.0	12.0	12.0	12.0	1
BRIDGE ON MERRYMEETING LAKE ROAD	Marsh Pond	Outflow	30.1	28.7	13.1	57.6	20
Rattlesnake Mt. Brook	Marsh Pond	Rattlesnake Mountain Brook	3.4	3.4	2.4	4.3	2
MARSH SW SITE	Marsh Pond	West Trib to Marsh Pond	9.2	11.3	7.9	18.7	4
West Str. 1A	Marsh Pond	West Trib to Marsh Pond	8.9	8.9	8.9	8.9	1
Brackett Road Ephemeral Culvert	Jones Pond	Culvert Drainage to Jones Pond	7.9	12.7	1.7	37.1	6
Hoover Bridge	Jones Pond	Jones Pond	23.6	23.5	12.8	45.0	18
JONES POND SITE 3S - DEEP	Jones Pond	Jones Pond - near outflow	31.4	31.4	31.4	31.4	1
Jones Pond 70 MMR	Jones Pond	Trib to Jones Pond	18.2	18.2	7.3	29.0	2
DOWNING POND SITE 5 - NORTH BACKWATER	Downing Pond	Direct Drainage to Downing Pond	31.0	31.0	31.0	31.0	1
DOWNING POND SITE 9 - MM LAKE RD AT CUL	Downing Pond	Direct Drainage to Downing Pond	30.5	30.5	30.5	30.5	1
SITE 7N	Downing Pond	Direct Drainage to Downing Pond	59.3	59.3	59.3	59.3	1
SITE 7S	Downing Pond	Direct Drainage to Downing Pond	29.9	29.9	29.9	29.9	1
Small inlet near Site 4	Downing Pond	Direct Drainage to Downing Pond	12.4	12.4	12.4	12.4	1
Downing Pond Deep near inlet	Downing Pond	Downing Pond - DEEP	17.7	17.7	17.7	17.7	1
DOWNING POND SITE 10 - MAIN ST BRIDGE	Downing Pond	Downing Pond - outflow	22.1	21.7	12.1	34.7	19
Downing Pond Foxy Johnny	Downing Pond	Foxy Johnny Trib to Downing Pond	13.4	17.3	10.1	28.4	3
SITE 4 DOWN	Downing Pond	MMR - Jones to Downing Pond	43.4	43.4	43.4	43.4	1
SITE 4 UP	Downing Pond	MMR - Jones to Downing Pond	31.3	29.6	18.1	39.5	3
Bickford Woodlot BW #1	Downing Pond	North Trib to Downing Pond	6.0	6.0	6.0	6.0	1
Bickford Woodlot BW #2	Downing Pond	South Trib to Downing Pond	17.7	31.7	13.6	63.8	3
DOWNING POND SITE 6	Downing Pond	South Trib to Downing Pond	21.2	21.2	21.2	21.2	1
Coffin Brook	MMR-Alton	Coffin Brook-1 (Outflow in marsh)	21.8	21.8	20.4	23.1	2
MMR - COFFIN BROOK @ RT. 28	MMR-Alton	Coffin Brook-3 (Rt. 28)	20.5	21.3	10.0	42.9	17
Coffin Brook @ Coffin Brook Rd	MMR-Alton	Coffin Brook-4 (CBR)	25.6	25.0	10.9	39.9	16
Coffin Bk 302-366 Rt.140	MMR-Alton	Coffin Brook-6	21.5	21.5	21.5	21.5	1
Rt 140 Youngstown Rd	MMR-Alton	Coffin Brook-6	18.5	18.5	18.5	18.5	1
Rt 140 Rocky Mt (332 Gilman Hy)	MMR-Alton	Coffin Brook-7 (Rt. 140)	22.6	22.6	4.9	40.2	2
Meadow Dam	MMR-Alton	Meadow Pond (Outflow @ Rt. 140)	6.3	6.3	6.3	6.3	1
Tanya Silver	MMR-Alton	Meadow Pond (Outflow @ Rt. 140)	6.3	6.3	6.3	6.3	1
Mill Pond @ Culvert	MMR-Alton	Mill Pond	33.2	33.2	33.2	33.2	1
Mill Pond near Fire Station	MMR-Alton	Mill Pond	33.0	33.0	33.0	33.0	1
School Street Culvert (Alton)	MMR-Alton	Mill Pond	19.1	19.1	19.1	19.1	1
Rt. 11 State Boat Access	MMR-Alton	MMR-2 (Site 11)	20.0	22.5	13.3	42.9	19
127 NDR (Alton)	MMR-Alton	MMR-3 (Rt. 28)	15.2	15.2	15.2	15.2	1
244 NDR (Alton)	MMR-Alton	MMR-3 (Rt. 28)	89.6	89.6	89.6	89.6	1
99 NDR (Alton)	MMR-Alton	MMR-3 (Rt. 28)	11.5	11.5	11.5	11.5	1
Merrymeeting River @ Route 28 (Alton)	MMR-Alton	MMR-3 (Rt. 28)	15.0	16.3	10.8	27.3	18
MM River Before Coffin Brook	MMR-Alton	MMR-3 (Rt. 28)	19.7	19.7	18.1	21.3	2

SITE	Waterbody	Sub-basin	Median	Mean	Min	Max	n
MM River Both MM & Coffin Brook	MMR-Alton	MMR-3 (Rt. 28)	19.6	19.6	17.7	21.5	2
Route 140 (Alton)	MMR-Alton	MMR-4 (Rt. 140)	15.3	15.6	10.8	22.2	18
Alton Power Dam	MMR-Alton	MMR-5 (Rt. 11)	18.4	18.4	18.4	18.4	1
ROUTE 11 BRIDGE @ ALTON BAY	**MMR-Alton**	**MMR-5 (Rt. 11)**	**16.7**	**16.3**	**11.0**	**20.9**	**18**
Liberty Tree Park	MMR-Alton	NA	73.2	73.2	73.2	73.2	1
Rt. 140 at Ingalls Rd	MMR-Alton	NA	4.4	4.4	3.8	4.9	2
Wentworth Pond @ Culvert	MMR-Alton	NA	26.9	26.9	26.9	26.9	1
826 SBCR	MMR-Alton	Trib 1E to Coffin Brook	5.6	5.6	5.3	5.9	2
Coffin Bk 829 SBCR	MMR-Alton	Trib 1W to Coffin Brook	5.9	5.9	4.0	7.8	2
510 SBCR	MMR-Alton	Trib 2S to Coffin Brook	2.5	4.5	2.5	8.4	3
Rt 28 sand pit	MMR-Alton	Trib 3 to Coffin Brook	37.3	37.3	16.9	57.6	2
Stockbridge Corner Rd (SBCR) 188	MMR-Alton	Trib 4S to Coffin Brook	14.4	17.4	11.8	25.9	3
CBR N 1	MMR-Alton	Trib 5 to Coffin Brook	21.3	20.9	8.4	33.9	5
Coffin Bk on Horne Rd	MMR-Alton	Trib 5N to Coffin Brook	16.6	18.5	15.3	23.6	3
CBR N 2 (0.3 miles from CBRN1-127 CBR)	MMR-Alton	Trib 5S to CB / Trib 5N to CB	24.6	22.6	13.7	27.5	4
CBR N 3 (100 feet from CBRN2, 99 CBR)	MMR-Alton	Trib 5S to CB / Trib 5N to CB	7.0	6.7	4.8	7.8	4
Rt 140 (630 Gilman Highway)	MMR-Alton	Trib 5S-W to Coffin Brook	8.7	8.5	8.1	8.7	3
Coffin Bk Rt.140 before Halls Hill	MMR-Alton	Trib 6 to Coffin Brook	40.0	40.0	40.0	40.0	1
Coffin Bk Rt.140 before Horne	MMR-Alton	Trib 6 to Coffin Brook	28.5	26.5	15.3	35.6	3
Hall's Hill Rd (430 HHRd.)	MMR-Alton	Trib 6W to Coffin Brook	16.9	17.4	16.9	18.5	3
Moore Farm @ Russell Way & NDR	MMR-Alton	Trib to MMR-3 (Moore Farm)	57.2	57.2	57.2	57.2	1
RT 28 Circle True Harvest Store	MMR-Alton	Trib to MMR-4	22.5	22.5	22.5	22.5	1

3.3 WATERSHED MODELING

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 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. USEPA guidelines for watershed plans require that both the assimilative capacity of the waterbody and pollutant loads from the watershed be estimated.

3.3.1 ASSIMILATIVE CAPACITY

A lake receives natural and human-derived inputs of nutrients, such as phosphorus, in runoff or groundwater inputs from its watershed. This phosphorus can be taken up by aquatic life within the lake, settle in the bottom sediments, or flow out of the lake to downstream waterbodies. In this sense, there is a natural balance between the amount of phosphorus flowing in and out of a lake system, also known as the ability of a lake to "assimilate" phosphorus. The assimilative capacity is based on factors such as lake volume, watershed area, precipitation, and runoff/baseflow export coefficients. If a lake is receiving more phosphorus from the watershed than it can assimilate, then its water quality will decline over time as algae or cyanobacteria blooms become more frequent. Decomposition of accumulated organic matter from dead algae or cyanobacteria and plants can result in anoxia in bottom waters, which can release phosphorus back into the water column (i.e., internal loading) as food for cyanobacteria, algae, and plants and can also be lethal to fish and other aquatic organisms.

The assimilative capacity analysis, including calculations for total assimilative capacity, reserve assimilative capacity, and remaining assimilative capacity, were conducted in accordance with the Standard Operating Procedure for Assimilative Capacity Analysis for New Hampshire Waters (Appendix B in the NHDES Guidance for Developing Watershed Management Plans in New Hampshire for Section 319 Nonpoint Source Grant Program Project, revised April 14, 2010).

For New Hampshire waters, water quality thresholds used in assimilative capacity analyses are based on a waterbody's trophic class. For Merrymeeting Lake, the trophic state was determined to be oligotrophic in 1977, 1989, and 2005. This means that in-lake water quality should be consistent with the standards for oligotrophic lakes. Marsh Pond was assessed as eutrophic in 1986; Jones Pond was assessed as mesotrophic in 1986; and Downing Pond was assessed as eutrophic in 2003. Since TMDLs for individual lakes and ponds have not been completed yet in New Hampshire, NHDES bases their attainment assessments on water quality criteria associated with these trophic classifications (even though they may represent an impacted condition; in this case, the ponds have been impacted by the point source discharges from the hatchery since it became operational in 1947). The NHDES CALM states that the water quality goal should be based upon the most likely best achievable trophic classification, which is ultimately set by the community with the support of modeling efforts (to ensure that the goal is reasonably achievable given natural phosphorus load sources, the lake or pond's morphometry, etc.) (NHDES, 2018b). Only one biological survey was completed prior to hatchery construction – on Jones Pond in 1938, which showed good oxygenation throughout the water column. At a minimum, these ponds should exhibit mesotrophic conditions or better without the influence of the hatchery. It was agreed on by the Water Quality Goals Committee, which included NHDES representation, that Marsh, Jones, and Downing Ponds should be considered mesotrophic.

As an example of applying the assimilative capacity criteria, for oligotrophic waterbodies, the nutrient indicator (phosphorus) threshold is 8.0 ppb and the response indicator (chlorophyll-a) threshold is 3.3 ppb. NHDES recommends 10% of the water quality threshold be kept in reserve; therefore, the Existing Median Water Quality should remain below 7.2 ppb for total phosphorus and below 3.0 ppb for chlorophyll-a to be in the Tier 2 High Quality Water category for an oligotrophic waterbody. Refer to Section 3.1.2 for Lake Water Quality Criteria.

Results of the assimilative capacity analysis for Merrymeeting Lake showed that Merrymeeting Lake is Tier 2 for high quality waters (for both total phosphorus and chlorophyll-a assessments; Table 3-8). Tier 2 waters have one or more water quality parameters that are better than the water quality standard and that also exhibit a reserve capacity of at least 10% of the waterbody's total assimilative capacity. Both total phosphorus and chlorophyll-a in Merrymeeting Lake are well within the NHDES ALU criteria for oligotrophic lakes and reflect excellent water quality.

Results of the assimilative capacity analysis for Marsh, Jones, and Downing Ponds showed that the ponds are impaired for both total phosphorus and chlorophyll-a assessments and have greatly exceeded their capacity to assimilate additional nutrients, and thus reflect degraded water quality (Table 3-8).

Table 3-8. Assimilative capacity (AC) analysis results for Merrymeeting Lake, Marsh Pond, Jones Pond, and Downing Pond.

Waterbody	Parameter	AC Threshold (ppb)	Existing Median WQ (ppb)	Remaining AC (ppb)	Analysis Results
Merrymeeting Lake	Total Phosphorus	7.2	3.5	+3.7	Tier 2 (High Quality)
Merrymeeting Lake	Chlorophyll-a	3	0.8	+2.2	Tier 2 (High Quality)
Marsh Pond	Total Phosphorus	10.8	43.1	-32.3	Impaired
Marsh Pond	Chlorophyll-a	4.5	7.9	-3.4	Impaired
Jones Pond	Total Phosphorus	10.8	26.7	-15.9	Impaired
Jones Pond	Chlorophyll-a	4.5	7.9	-3.4	Impaired
Downing Pond	Total Phosphorus	10.8	25.2	-14.4	Impaired
Downing Pond	Chlorophyll-a	4.5	6.4	-1.9	Impaired

3.3.2 LAKE LOADING RESPONSE MODEL (LLRM) RESULTS

A second analysis was used to link watershed loading conditions with total phosphorus and chlorophyll-a concentrations to predict past, current, and future water quality in Merrymeeting Lake, Marsh Pond, Jones Pond, Downing Pond, and the Merrymeeting River in Alton. An Excel-based model, known as the Lake Loading Response Model (LLRM), was used to develop a water and phosphorus loading budget for the lake and its tributaries by using environmental data. Water and phosphorus loads (in the form of mass and concentration) are traced from various sources in the watershed, through tributary and lake/pond sub-basins, to the confluence of the Merrymeeting River and Lake Winnipesaukee at Alton Bay. The model incorporates data about watershed and sub-basin boundaries, land cover, point sources (e.g., Powder Mill State Fish Hatchery), 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. The model generates annual average predictions[3] of total phosphorus, chlorophyll-a, Secchi disk transparency, and algae bloom probability. The model can be used to identify current and future pollution sources, estimate pollution limits and water quality goals, and guide watershed improvement projects. Refer to FBE (2019a) for a full description of the model inputs, limitations, and assumptions. Refer to Appendix A, Map 7 for phosphorus load by land area in the watershed.

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

We split the watershed into five models: Merrymeeting Lake (Model 1), Marsh Pond (Model 2), Jones Pond (Model 3), Downing Pond (Model 4), and Coffin Brook-MMR in Alton (Model 5) (Figure 3-5). Models 2-5 used the previous model's output as an upstream point source input. This approach allowed for better model parameterization and estimation of pollution source loads by land use type and source for each of the targeted waterbodies.

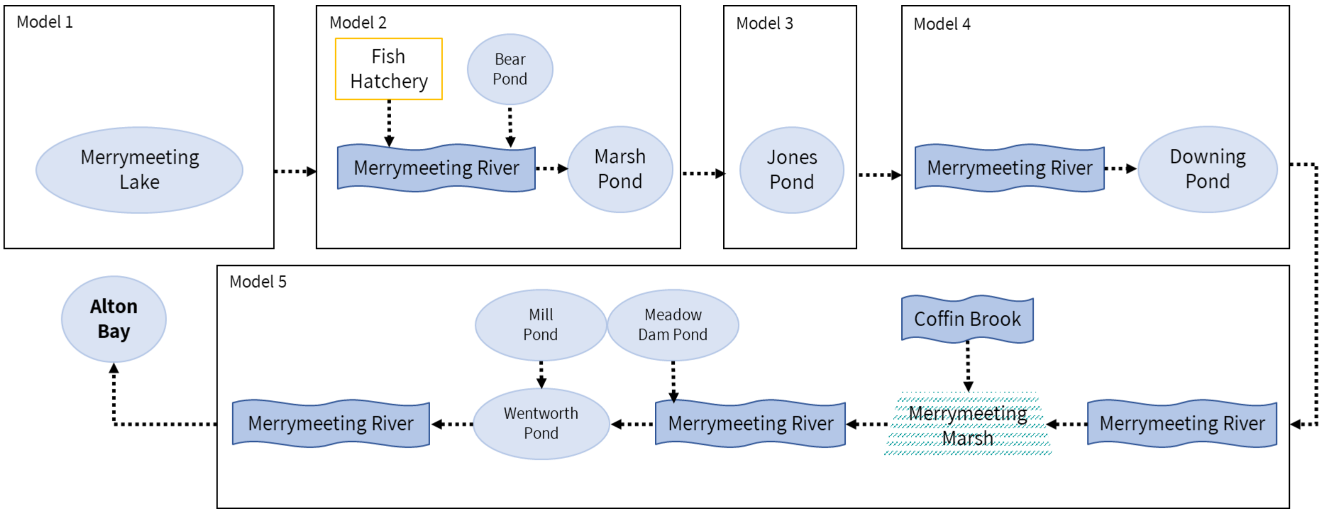


Figure 3-5. Conceptual diagram that illustrates the major flow paths through the Merrymeeting River and Lake watershed. Because of the hydrologic complexity of the watershed, the watershed was split into five separate but sequential models.

Overall, model predictions were in good agreement with observed data and were within 0-6% (relative percent difference) of observed median annual total phosphorus (Table 3-9). Differences in predicted and observed values for chlorophyll-a and Secchi disk transparency were more variable. 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 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.

Table 3-9. Predictions for Models 1-5. TP = total phosphorus. Chl-a = chlorophyll-a. SDT = Secchi disk transparency. Annual TP represents year-round (not seasonal) observed data. See footnotes for additional details.

Model	Waterbody	Annual TP (ppb)*	Predicted Annual TP (ppb)	Observed Mean Chl-a (ppb)	Predicted Mean Chl-a (ppb)	Observed Mean SDT (m)	Predicted Mean SDT (m)
1	Merrymeeting Lake	3.5 (4.2)	4.2	0.8	0.7	10.3	7.6
2	Marsh Pond	17.7	16.9	4.7	6.3	4.0	2.6
3	Jones Pond	15.7	16.0	4.8	5.9	3.2	2.8
4	Downing Pond	15.3	15.6	3.4	5.7	3.1	2.8
5	Coffin Brook-MMR	14.3	15.2	--	--	--	--

**Observed annual TP of 3.5 ppb and 4.2 ppb for Merrymeeting Lake represents median in-lake epilimnion TP and 20% adjusted increase from median in-lake epilimnion TP, respectively. Most lake data are collected in summer when TP concentrations are typically lower than annual average concentrations for which the model predicts. Observed annual TP for Models 2-5 are flow-weighted based on both observed and estimated data (see OTHER MAJOR MODEL INPUTS in FBE 2019a).*

Watershed runoff and baseflow (56-100%) were the largest loading contribution across all sources for Models 1-5, followed by atmospheric deposition (<1-19%), septic systems (1-18%), waterfowl (1-7%), and internal loading (0-1%) (Table 3-10; Figure 3-6). Waterbodies downstream of Merrymeeting Lake were dominated (28-67%) by the upstream point source load from the Powder Mill State Fish Hatchery that discharges to the river below the outlet to Merrymeeting Lake. The percent contribution of the direct watershed load greatly increased for Model 5 (Coffin Brook-MMR) at Alton Bay because of the large watershed input from Coffin Brook and along the Merrymeeting River mainstem through Alton (while the upstream load was diluted and attenuated through the river system before discharging to Alton Bay).

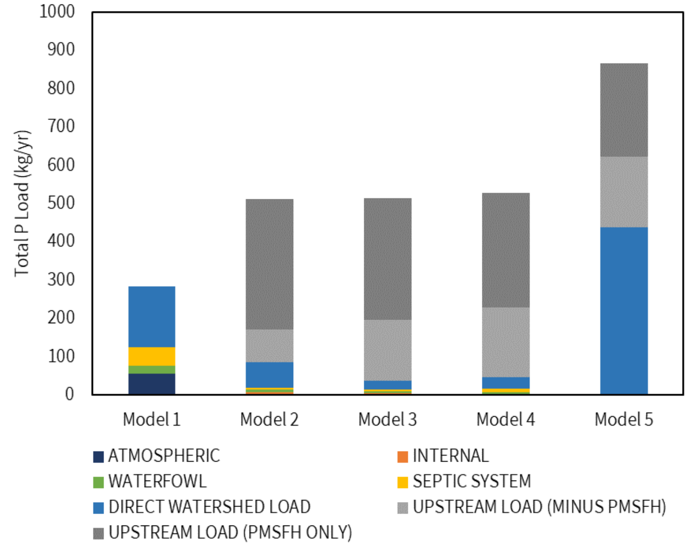


Figure 3-6. Total phosphorus (TP) load (kg/yr) by source (atmospheric, internal loading, waterfowl, septic systems, watershed load) for Model 1 (Merrymeeting Lake), Model 2 (Marsh Pond), Model 3 (Jones Pond), Model 4 (Downing Pond), and Model 5 (Coffin Brook/Merrymeeting River in Alton).

Although small relative to the point source load from the Powder Mill State Fish Hatchery, pollutant load contribution from development in the watershed, including septic systems, is an important and manageable source of phosphorus to surface waters in the watershed. Development in the watershed is largely concentrated around or near shorelines 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, which leach untreated, nutrient-rich wastewater effluent to surface waters.

Internal loading is also a concern given that low dissolved oxygen in bottom waters of Marsh and Jones Ponds is causing a significant release of phosphorus from bottom sediments (as evidenced by the large difference between bottom and surface phosphorus concentrations). Low flushing rate in late summer may further exacerbate internal loading as both the duration of anoxia and the residence time for nutrients are prolonged. The percent contribution of internal phosphorus load to Marsh and Jones Ponds (relative to other sources) will be more significant when the point source load from the Powder Mill State Fish Hatchery is remediated; future internal load from legacy point source loading will also continue to be a significant source despite remediation and may need to be addressed separately.

Table 3-10. Total phosphorus (TP) and water loading summary by source for Models 1-5.

MODEL & SOURCE LOAD	**CURRENT**		
	P (kg/yr)	%	Water (cu.m/yr)
Model 1 - Merrymeeting Lake			
ATMOSPHERIC	55	19%	3,722,937
INTERNAL	0	0%	0
WATERFOWL	20	7%	0
SEPTIC SYSTEM	50	18%	43,181
WATERSHED LOAD	158	56%	16,544,959
TOTAL LOAD TO LAKE	**284**	**100%**	**20,311,078**
Model 2 - Marsh Pond			
ATMOSPHERIC	2	0%	135,221
INTERNAL	6	1%	0
WATERFOWL	6	1%	0
SEPTIC SYSTEM	5	1%	3,623
DIRECT WATERSHED LOAD	66	13%	7,858,621
UPSTREAM LOAD (FROM MML)	85	17%	11,848,464
UPSTREAM LOAD (FROM PMSFH)	342	67%	8,462,614

MODEL & SOURCE LOAD	CURRENT		
	P (kg/yr)	%	Water (cu.m/yr)
TOTAL LOAD TO LAKE	**513**	**100%**	**28,308,544**
Model 3 - Jones Pond			
ATMOSPHERIC	3	0%	172,000
INTERNAL	3	0%	0
WATERFOWL	3	1%	0
SEPTIC SYSTEM	6	1%	4,288
DIRECT WATERSHED LOAD	22	4%	1,692,302
UPSTREAM LOAD (FROM MARSH)	159	31%	19,845,929
UPSTREAM LOAD (FROM PMSFH)	320	62%	8,462,614
TOTAL LOAD TO LAKE	**515**	**100%**	**30,177,132**
Model 4 - Downing Pond			
ATMOSPHERIC	2	0%	161,176
INTERNAL	0	0%	0
WATERFOWL	6	1%	0
SEPTIC SYSTEM	9	2%	6,606
DIRECT WATERSHED LOAD	29	5%	1,732,592
UPSTREAM LOAD (FROM JONES)	183	35%	21,714,518
UPSTREAM LOAD (FROM PMSFH)	299	57%	8,462,614
TOTAL LOAD TO LAKE	**528**	**100%**	**32,077,507**
Model 5 - Coffin Brook/MMR			
DIRECT WATERSHED LOAD	438	50%	27,839,805
UPSTREAM LOAD (FROM JONES)	186	21%	21,554,828
UPSTREAM LOAD (FROM PMSFH)	243	28%	7,724,371
TOTAL LOAD TO RIVER	**867**	**100%**	**57,119,004**

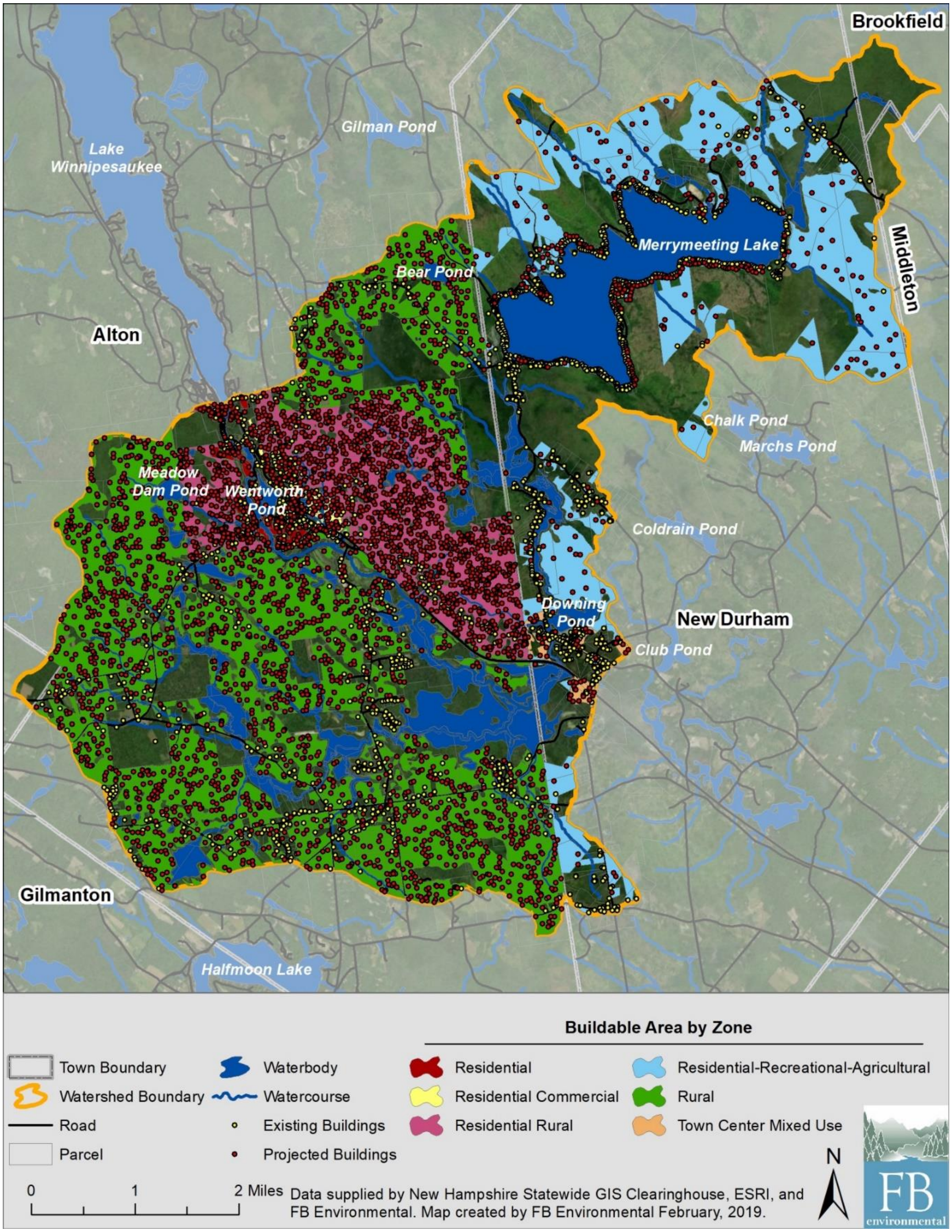
3.3.3 HISTORICAL & FUTURE PHOSPHORUS LOADING: BUILD-OUT ANALYSIS

Once the models are calibrated for current total phosphorus concentrations, we can then manipulate land cover and other factor loadings to estimate pre-development and future phosphorus loading (e.g., what total phosphorus concentrations were prior to human development and what total phosphorus concentrations will be following full buildout of the watershed under current zoning).

To predict the pre-development phosphorus load, FBE manipulated the models so that all development was converted back to natural vegetation, septic system inputs were set to zero, and internal loading estimates were smaller (assuming anoxic conditions observed today are the result of excess organic matter and nutrient loading from human activities in the watershed). The phosphorus load for pre-development conditions for Merrymeeting Lake was estimated at 125 kg/yr (56% less than current conditions), with an in-lake phosphorus concentration of 1.9 ppb. The phosphorus load for pre-development conditions for the Marsh, Jones, and Downing Ponds were estimated at 80 kg/yr, 86 kg/yr, and 96 kg/yr (82-84% less than current conditions), with in-pond phosphorus concentrations of 2.6 ppb, 2.7 ppb, and 2.8 ppb, respectively. The phosphorus load for pre-development conditions for Coffin Brook-Merrymeeting River in Alton was estimated at 196 kg/yr (77% less than current conditions), with an in-stream phosphorus concentration of 3.4 ppb.

To predict the future phosphorus load from increased development, FBE first performed a build-out analysis for the Merrymeeting River and Lake watershed in the towns of New Durham and Alton (FBE, 2019b). The build-out analysis identified an estimated 11,653 acres (55%) of the watershed as developable. Up to 3,762 new buildings (a 101% increase from 2018) could be added at **full build-out** by the year 2090, using the 30-year compound annual growth rate of 1.68% (Appendix A, Map 8). This predicted increase in development was then input to the model for the Merrymeeting River and Lake watershed.

The additional future phosphorus load to Merrymeeting Lake was estimated at 117 kg/yr, with an in-lake phosphorus concentration of 6.0 ppb. The additional future phosphorus load to Marsh, Jones, and Downing Ponds were estimated at 194 kg/yr, 194 kg/yr, and 214 kg/yr, with in-pond phosphorus concentrations of 12-23 ppb, 12-22 ppb, and 13-22 ppb, respectively (the range of in-pond phosphorus concentrations reflects model results with and without the hatchery point source) (Figure 3-7). The additional future phosphorus load to Coffin Brook-Merrymeeting River in Alton was estimated at 1,006 kg/yr, with an in-stream phosphorus concentration of 29-33 ppb (the range of in-stream phosphorus concentration reflects model results with and without the hatchery point source). We presented the alternate extreme future scenarios in this way because the actual change in load from the Powder Mill State Fish Hatchery is unknown until the permit limit is set by USEPA. **In either**



Map of buildable area by zone for the Towns of New Durham and Alton, as well as existing and projected buildings in the Merrymeeting River and Lake watershed based on a full build-out analysis. The build-out analysis identified an estimated 11,653 acres (55%) of the watershed as developable. Up to 3,762 new buildings (a 101% increase from 2018) could be added at full build-out by the year 2090, using the 30-year compound annual growth rate of 1.68% (Appendix A, Map 8). "Full build-out" refers to the time and circumstances whereby no more building construction may occur, or the point at which lots have been subdivided to the minimum size allowed based on current zoning standards and there is no more "developable" land. Performing a build-out analysis shows a locality what land is available for development, how much development can occur, and at what densities. Municipalities can use the analysis as a tool for planning development patterns in the future and understanding development impacts to water quality.

future scenario, the Merrymeeting River and its ponds are at serious risk for sustained water quality degradation as a result of new development in the watershed.

Results of the build-out analysis and future load modeling reinforce the concept of comprehensive planning at the watershed level to address future development and its effect on water quality. Future development will increase the amount of polluted runoff that drains to Merrymeeting River and Lake. Any new increases in phosphorus can disrupt the ecological balance in favor of increased algae growth, resulting in degraded water clarity. **Therefore, it is recommended that town officials revisit zoning ordinances to ensure that existing laws encourage LID techniques (see Section 5.2).** The impact from new buildings and septic systems can be greatly reduced by implementing LID techniques and ensuring that all new septic systems are well separated from surface waters both horizontally and vertically (above seasonal high groundwater in suitable soil).

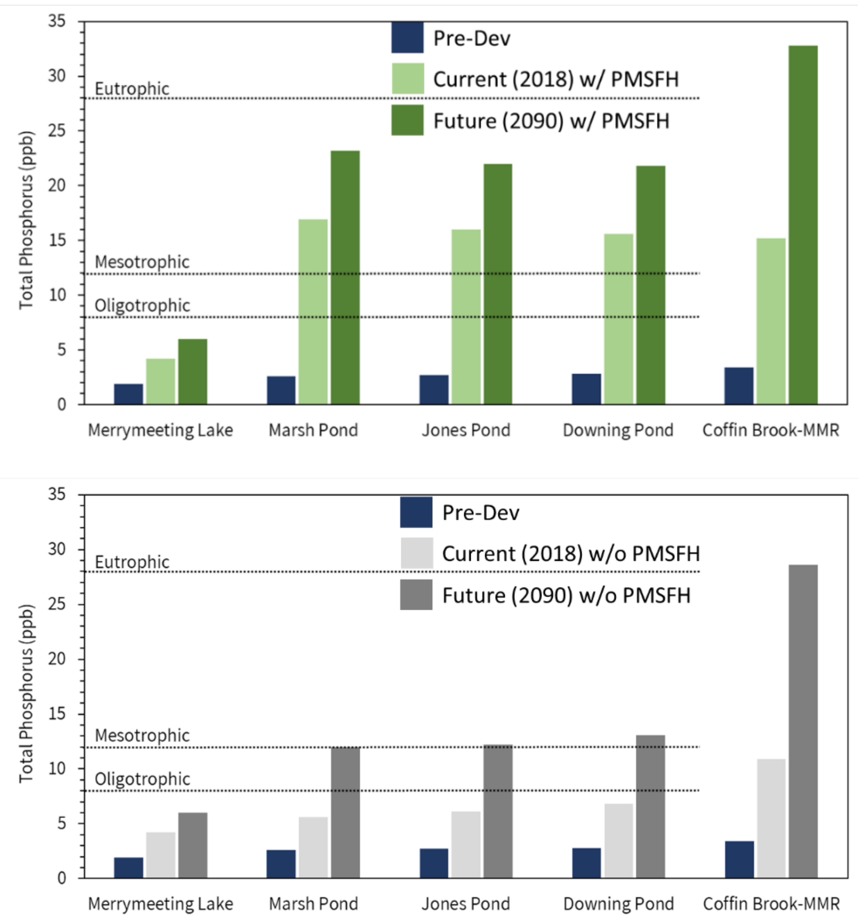


Figure 3-7. **[TOP]** Modeled total phosphorus concentrations for pre-development, current, and future conditions with the average annual load (2014-2018) from the Powder Mill State Fish Hatchery unchanged. **[BOTTOM]** Modeled total phosphorus concentrations for pre-development, current, and future conditions with the average annual load from the Powder Mill State Fish Hatchery removed. Dotted lines represent phosphorus concentration thresholds for each trophic class, which apply to lakes and ponds and not to rivers.

3.4 ESTABLISHMENT OF WATER QUALITY GOAL

The goal of the Merrymeeting River and Lake Watershed Management Plan is **to improve water quality in Merrymeeting Lake, Marsh Pond, Jones Pond, Downing Pond, and the Merrymeeting River at Alton Bay to eliminate the presence of toxic cyanobacteria blooms that impair these waterbodies for aquatic life use and primary contact recreation**. This goal will be achieved by accomplishing three objectives. More detailed action items to achieve these objectives are provided in Section 5.2.

Objective 1: Reduce pollutant loading to Merrymeeting Lake by 16 kg/yr to maintain an in-lake median total phosphorus concentration of 3.5 ppb in the next 10 years.

Objective 2: Reduce pollutant loading to Marsh, Jones, and Downing Ponds by 307 kg/yr to achieve in-pond median annual and monthly total phosphorus concentrations of 10 ppb.

- Reducing the Powder Mill State Fish Hatchery phosphorus loading by 78% (293 kg/yr) and preventing future phosphorus loading anticipated from new development in the next 10 years (14 kg/yr) can be achieved through hatchery system design upgrades and by implementing LID regulations on new development and/or implementing stormwater or septic system improvements to reduce pollution from existing development; refer to Section 3.5. Note that these reduction targets account for Objective 1 reduction targets.

Objective 3: Reduce pollutant loading to the Merrymeeting River at Alton Bay by 198 kg/yr to achieve an in-stream median annual and monthly total phosphorus concentration of 10 ppb.

- Reducing current phosphorus loading by 88 kg/yr and preventing future phosphorus loading anticipated from new development in the next 10 years (110 kg/yr) can be achieved by implementing LID regulations on new development and/or implementing stormwater or septic system improvements to reduce pollution from existing development; refer to Section 3.5. Note that these reduction targets account for Objective 1 and 2 reduction targets.

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 3-11). Understanding where water quality will be following watershed improvements compared to where water quality should have been following no action will help guide adaptive changes to interim goals (e.g., goals are on track or goals are 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, the committee should meet to update the water quality data and model and assess why goals are or are not being met. The group will then decide on how to adjust the next interim goals to better reflect water quality conditions and practical limitations to implementation.

Table 3-11. Interim benchmarks for the water quality objectives. Refer to Action Plan (Section 5.2) for specific recommendations related to each objective. TP = total phosphorus.

Water Quality Objective	Interim Goals/Benchmarks		
	2020	2023	2028
1. Reduce pollutant loading to Merrymeeting Lake by 16 kg/yr to maintain an in-lake median total phosphorus concentration of 3.5 ppb in the next 10 years.			
	Prevent or offset 5 kg/yr in TP loading from new or existing development	Prevent or offset 10 kg/yr in TP loading from new ro existing development; re-evaluate water quality and track progress	Prevent or offset 16 kg/yr in TP loading from new or existing development; re-evaluate water quality and track progress
2. Reduce pollutant loading to Marsh, Jones, and Downing Ponds by 307 kg/yr to achieve in-pond median annual and monthly total phosphorus concentrations of 10 ppb.			
	Prevent or offset 5 kg/yr in TP loading from new or existing development	Achieve 293 kg/yr reduction in TP loading with hatchery upgrade; prevent or offset 10 kg/yr in TP loading from new or existing development; re-evaluate water quality and track progress	Achieve 293 kg/yr reduction in TP loading with hatchery upgrade; prevent or offset 14 kg/yr in TP loading from new or existing development; re-evaluate water quality and track progress
3. Reduce pollutant loading to the Merrymeeting River at Alton Bay by 198 kg/yr to achieve an in-stream median annual and monthly total phosphorus concentration of 10 ppb.			
	Achieve 20 kg/yr reduction in TP loading from existing development; prevent or offset 25 kg/yr in TP loading from new or existing development	Achieve 40 kg/yr reduction in TP loading from existing development; prevent or offset 50 kg/yr in TP loading from new or existing development	Achieve 88 kg/yr reduction in TP loading from existing development; prevent or offset 110 kg/yr in TP loading from new or existing development

3.5 POLLUTANT SOURCE IDENTIFICATION

3.5.1 POWDER MILL STATE FISH HATCHERY

The Powder Mill State Fish Hatchery was built by the NHFGD in 1947 and has remained the largest fish hatchery in the State of New Hampshire, stocking brook trout, rainbow trout, brown trout, and land-locked salmon in rivers and lakes throughout the state. On average, the hatchery stocks 2,300 rainbow trout and landlocked salmon in Merrymeeting Lake each year. The hatchery itself covers 25 acres of the 102 acres that are part of the NHFGD-owned Marks Wildlife Management Area.

The NHFGD withdraws water from an intake approximately 50 feet deep in Merrymeeting Lake to supply cold, well-oxygenated water year-round for its fish rearing operations, located just below the Merrymeeting Lake outlet dam. These water withdrawals account for 42% of the average annual water volume outflow from Merrymeeting Lake (data summarized using 2014-2018 monthly average flow reported to EPA). Water from the facility is discharged via Outfall #1 (2,666,933 cubic m/yr) about 0.25 river miles from the lake outlet and Outfall #2 (5,762,681 cubic m/yr) located about 0.53 river miles from the lake outlet (Figure 3-8). The hatchery discharges a near-constant water load containing phosphorus levels approximately 12 times higher than the outflow concentration from Merrymeeting Lake (though monthly average phosphorus levels are variable depending on the time of year and facility activities). The discharge from the hatchery in summer during low baseflow conditions is the only headwater source for the river and increases the concentration of phosphorus in the river and downstream waterbodies (leading to algae and cyanobacteria blooms and excessive plant growth), while the discharge from the hatchery in other times of year during high-flow conditions is diluted by other sources of water with lower phosphorus concentrations (e.g., water release from the lake via the dam's spillway).

The NHFGD operates the hatchery under a USEPA-approved permit that regulates the amount of water and pollutants that can be extracted from the lake and then discharged from the facility. Under the current permit, the NHFGD is required to conduct one 24-hour composite sample at each outfall on a quarterly basis and report the average monthly and maximum daily values. The NHFGD uses an automated composite sampler that samples once every 15 minutes (for a total of 96 samples per day). In most cases, the two reported values of average monthly and maximum daily values will be equal because only one 24-hour composite sample is collected.

The NHFGD is currently under pending litigation from the Conservation Law Foundation to upgrade the hatchery to substantially reduce phosphorus loads discharged from the outfalls. The NHFGD is awaiting the final phosphorus permit limit from the USEPA before proceeding with construction plans for the hatchery upgrade. In the meantime, the NHFGD has been working with the local community to alter current practices at the hatchery that reduce phosphorus loads to the river.

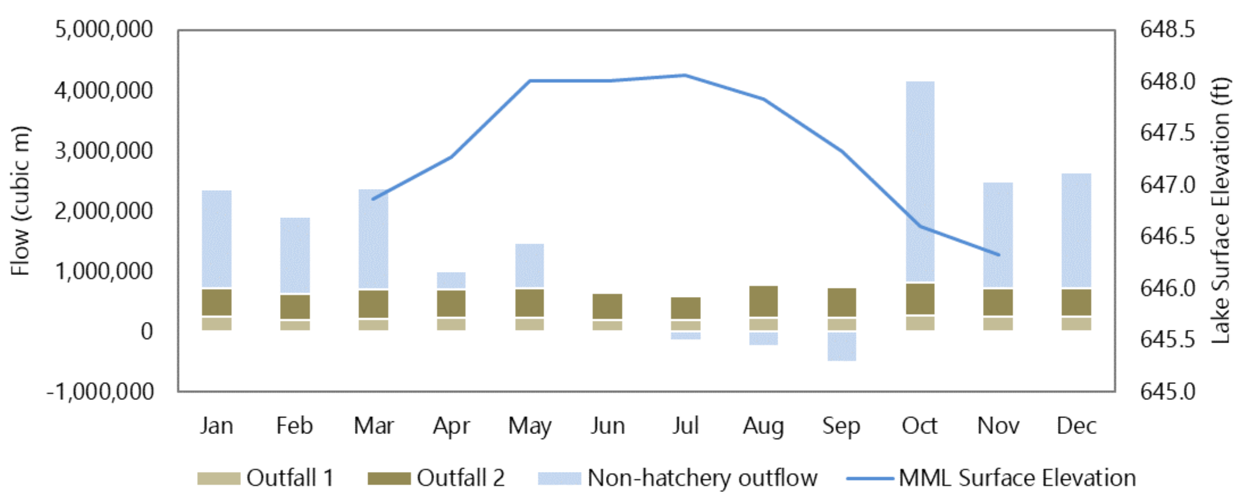


Figure 3-8. Average monthly flow volume discharged by the Powder Mill State Fish Hatchery (Outfalls #1 and #2), estimated monthly flow volume discharged directly from Merrymeeting Lake (non-hatchery outflow), and average monthly Merrymeeting Lake surface elevation (data obtained from Merrymeeting Lake Association). Negative non-hatchery outflow estimates from July-September suggest that both the hatchery and evaporation extract more water than what is replenished by precipitation.

3.5.2 MILL POND

During the process of developing the watershed management plan, Mill Pond was identified as a significant pollution source to the Merrymeeting River. NHDES and CMSC have completed preliminary assessments of Mill Pond showing serious water quality degradation as a result of elevated phosphorus concentrations and subsequent algae and cyanobacteria blooms. NHDES has placed Mill Pond on the 303(d) list of impaired surface waters as impaired for aquatic life use due to elevated levels of cyanobacteria microcystins.

Drainage area to Mill Pond which is connected to Wentworth Pond along the Merrymeeting River via two small culverts under Letter S Road.

Mill Pond was created in the late 1800's when Mill Road (currently known as Letter S Road) was extended south to connect the Wentworth Mills, which included a grist mill, saw mill, and box shop at the dam to Wentworth Pond, to the present Route 140 (Griffin, 1965). The Wentworth Mills district expanded to include a blacksmith shop and slaughterhouse before an arsonist set fire to the entire complex in 1906.

Despite the tragic fires, the area continued to be productive and popular for residents. However, even before the 1900s, people knew that water from Mill Pond was unfit for human consumption. Homes built in the hill district of Main Street (also known as the Belvedere section because of its upscale homes owned by Alton businessmen) therefore drew their water from an aqueduct system that supplied the village. The aqueduct was developed in 1829 by William Emerson and James Jewett and started at a spring near the Charles Coffin Mooney house on Wolfeboro Hill across Route 28 opposite the junction with Old Wolfeboro Road.

The water quality of Mill Pond has since suffered from both legacy and current sources of pollution. A landfill along the banks of Mill Pond was in operation from the early 1900's to about 1950. Following 2018 rain events, CMSC observed seepage from the banks of Mill Pond at the capped landfill, indicating a possible break in the lining. Further investigation is required. A commercial laundromat along Route 11 experienced a complete septic system failure that resulted in raw sewage discharge to Mill Pond for nearly a year in 1979 before it was identified and shut down. About 50 years ago, a large sawdust pile remnant from the sawmill at the former Wentworth Mills was bulldozed into Mill Pond. About 25 years ago, the stormwater system for Route 11 was reconfigured to direct untreated stormwater runoff to Mill Pond. Mill Pond should be prioritized for future monitoring of phosphorus and cyanobacteria, as well as pollutant source investigations of potential NPS pollution issues (see Action Plan in Section 5.2).

3.5.3 WATERSHED SURVEY

A watershed survey is a first-phase, screening-level assessment designed to locate potential sources of NPS pollution within areas that drain to a waterbody. The watershed is assessed by foot or car from public access points (e.g., public roads, common areas) unless information is provided by private landowners. Results of the survey are essential to the watershed planning process because they identify individual NPS sites and prioritize BMP implementation projects throughout the watershed. Full-scale designs and cost estimates will need to be completed for each of the identified watershed survey sites. These follow-up actions are detailed in the Action Plan (Section 5.2).

FBE was contracted to complete a watershed survey that identified and documented evidence of sediment erosion or "hotspots" of nutrient loading to surface waters in the Merrymeeting River and Lake watershed. On multiple dates from May-August, Fred Quimby documented 41 erosion "hotspot" sites that may be detrimental to the lake or river's water quality. On 8/23/2018, FBE technical staff (Forrest Bell and Christine Bunyon) surveyed a portion of the watershed, following up on several sites already identified by Fred Quimby and documenting 3 new erosion "hotspot" sites. On 9/27/2018, FBE technical staff

(Laura Diemer) surveyed the entire watershed, following up on several sites already identified and documenting 35 new erosion "hotspot" sites (78 sites total; **refer to Appendix A, Map 9**). Documentation included describing the problem, making recommendations for fixing the problem, rating the site's impact to water quality, logging the site's geoposition, and taking photographs.

General recommendations included stabilizing pull-offs and driveways, infiltrating concentrated flowpaths via turnouts, settling basins, or trenches, defining and meandering pathways, using coarse gravel or riprap (avoiding small pebbles that can be carried away easily), and installing and armoring ditches and culverts. Many properties were already using catch basins to capture runoff and sediment, which may be the only practical means to capture runoff given the steep grades and lack of suitable area to infiltrate surface water. North and South Shore Roads along Merrymeeting Lake were especially characterized by steep grades and minimal road shoulders and ditches, which generate significant stormwater runoff and erosion issues. Because of these landscape challenges, construction sites are especially vulnerable to improper functioning of stormwater controls. If not already in place, the Town of New Durham should consider incorporating strict regulations and enforcement of stormwater controls during construction on properties around the lake.

Using the NHDES Simple Method Pollutant Loading Spreadsheet Model and EPA Region 5 model, we estimated the pollutant loading (total suspended solids, total phosphorus, and total nitrogen) likely generated from each erosion "hotspot" site (see model spreadsheet for metadata, references, and assumptions). A general cost estimate was also assigned to each site based on the scale of recommended fixes. Based on each site's impact rating, estimated cost, and potential pollutant load reduction, the 78 erosion "hotspot" sites were ranked 1-78 from highest to lowest priority for implementation. The top 10 erosion "hotspot" areas (15 sites) are described in more detail below. A KMZ file was also created for interactive spatial mapping of the 78 identified sites, including descriptions and photographs. Implementing recommendations at all 78 erosion "hotspot" sites would potentially reduce the phosphorus load Merrymeeting River and Lake by 25 kg/yr (10 kg/yr for the top 10 areas) and cost an estimated $1.16-$2.19 million ($326,000-$570,000 for the top 10 areas), including annual maintenance costs for 10 years.

HWG developed preliminary designs and cost estimates for the top 3 erosion "hotspot" areas. We strongly recommend that a full engineered design and cost estimate be completed for each site prior to implementation.

Examples of drainage challenges on the roads around Merrymeeting Lake that are characterized by steep grades to the shoreline (left), minimal road shoulders and ditches or suitable area to infiltrate surface water (middle), and unstable or eroding culvert inlets and outlets (right).

Before (left) and after (right). One site (2-02), identified at the Merrymeeting River boat access ramp off Merrymeeting Rd downstream of the Powder Mill State Fish Hatchery, has since been remediated by local groups.

There were several good examples throughout the watershed of stabilization techniques for stormwater control, using riprap or crushed stone, vegetated swales, and mulch.

TOP 10 EROSION "HOTSPOT" AREAS

Area #1 (New Durham): Merrymeeting Rd downstream of lake outlet (Sites 3, 4, 5, 6)

Observations: Road shoulder and ditch erosion evident on both sides of South Shore Rd leading to Merrymeeting Rd where a portion of the flow is diverted to a cross culvert that is clogged with sediment that deposits in the river. Stormwater also runs off from the state boat landing parking lot and Powder Mill Rd to the river. Gully formations and concentrated stormwater flowpaths observed.

Recommendations: Armor ditches with vegetation/checks dams and/or riprap, enlarge and lengthen culvert with riprap plunge pool, recrown road to divert runoff, install settling basins and turnouts, and stabilize the state boat landing parking lot.

Significant sediment erosion of road ditches and parking area on both hillslopes leading to Merrymeeting River.

Area #2 (Alton): Pine St (Site 3-15)

Observations: Dirt trail access with paved stormwater channel routing to river from private property at the end of Pine St.

Recommendations: Remove paved stormwater channel and install turnouts to vegetated/riprap infiltration areas. Consider installing a catch basin with infiltration field.

Paved stormwater channel diverting road runoff directly to Merrymeeting River.

Area #3 (Alton): Horne Rd (Sites 3-06, 3-07)

Observations: Gully formation along the road shoulder and ditch of Horne Rd was sending a sediment plume to a tributary of Coffin Brook. Flow was observed in one ditch leading to the stream. One road side had a steep bank with washed out road shoulder material.

Recommendations: Install and armor road shoulder and ditches with vegetation/check dams and/or riprap and install turnouts to settling basins.

Significant road surface and ditch erosion evident on Horne Rd leading to a tributary of Coffin Brook.

Area #4 (New Durham): Merrymeeting Rd at Marsh Pond outlet (Sites 31, 35)

Observations: Road shoulder and ditch erosion evident on both sides of Merrymeeting Rd leading to the Merrymeeting River at the Marsh Pond outlet. Multiple raceways direct stormwater to the river from the bridge.

Recommendations: Stabilize and armor road shoulder and water access, including pull-off area, and install turnout or settling basin.

Road runoff forming rills and gullies at Merrymeeting Rd bridge at outlet to Marsh Pond.

Area #5 (Alton): 201 Stockbridge Corner Rd (Sites 3-21, 3-22)

Observations: Deep gullies were forming along the road shoulders and ditches of Stockbridge Corner Rd. Site 3-21 had continuous flow that joined with a flowing pipe from a private residence. Both sites flow to a tributary of Coffin Brook.

Recommendations: Install and armor road shoulder and ditches with vegetation/check dams and/or riprap and install turnouts to settling basins.

Deep gully formations in road shoulders and ditches along Stockbridge Corner Rd, leading to a tributary of Coffin Brook.

Area #6 (Alton): Coffin Brook Rd (Site 39)

Observations: Stormwater runoff from Coffin Brook Rd and a private driveway with concentrated flowpaths (including paved channels) to Coffin Brook stream crossing was observed.

Recommendations: Install and armor road shoulder and ditches with vegetation/check dams and/or riprap and install turnouts to settling basins.

Coffin Brook Rd stormwater runoff leading to Coffin Brook.

Area #7 (Alton): Halls Hill Rd (Sites 3-09, 3-10)

Observations: Road shoulder and ditch erosion evident along Halls Hill Rd, leading to a tributary of Coffin Brook.

Recommendations: Install and armor road shoulder and ditches with vegetation/check dams and/or riprap and install turnouts to settling basins.

Halls Hill Rd ditch erosion leading to a tributary of Coffin Brook.

Area #8 (Alton): 915 Stockbridge Corner Rd (Site 3-26)

Observations: Steep slope new construction drainage leading to tributary to Coffin Brook with ponded area on road surface on Stockbridge Corner Rd.

Recommendations: Stabilize steep slopes and loose gravel with vegetation/riprap. Install and armor road shoulder and ditches with turnouts to settling basins.

Loose soil and gravel and ponding evident near new construction on Stockbridge Corner Rd.

Area #9 (Alton): Letter S Rd at Rt 140 – Mill Pond (Site 40)

Observations: A narrow section of land with Letter S Rd separates Mill Pond from the Merrymeeting River. Road shoulder and bank erosion with minimal buffer was evident. An underwater stone culvert connects Mill Pond with the Merrymeeting River near where Letter S Rd meets Rt 140. Mill Pond was impacted by a failing laundromat septic system in the late 1970's and now experiences significant algae and cyanobacteria blooms.

Recommendations: Armor road shoulder with stone or grass, stabilize banks, add to buffer, and investigate options to improve the underwater culvert connection.

Underwater stone culvert connects Mill Pond with the Merrymeeting River. Surface erosion evident.

Area #10 (Alton): Russell Way at Moore Farm (Site 3-29)

Observations: Driveway erosion from Russell Way at Moore Farm leading from New Durham Rd to a tributary to the Merrymeeting River.

Recommendations: Install driveway turnouts to settling basins or rain gardens.

Surface erosion of Russell Way driveway leading to a tributary to the Merrymeeting River crossing at New Durham Rd.

3.5.4 SHORELINE SURVEY

Using a simple scoring method, the shoreline survey served as an excellent tool for highlighting shoreline properties around Merrymeeting Lake that exhibited 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. Technical assistance visits and BMP recommendations will be needed for individual shoreline properties. These follow-up actions are detailed in the Action Plan (Section 5.2).

A shoreline survey was conducted in September 2018 by local volunteers Fred Quimby and Doug Gilman to document the condition of each shoreline 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" for each parcel, with high scores indicating poor shoreline conditions. Photos were taken at each parcel and were cataloged by tax map-lot number. These photos will provide project stakeholders 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 386 parcels were evaluated along the shoreline of Merrymeeting Lake. The average Shoreline Disturbance Score for the entire lake was 10.4. About 74% of the shoreline (or 285 parcels) scored 10 or greater. A disturbance score of **10 or above** indicates shoreline conditions that may be detrimental to lake water quality. These shoreline properties tend to have inadequate buffers, evidence of bare soil, and structures within 75 ft. of the shoreline. Shoreline properties marked high for shoreline erosion had evidence of undercut or retreating banks, extensive exposed beach sand, or steep collapsing banks.

The information obtained from this survey was used to plan next steps for improving the shoreline of Merrymeeting Lake and inform the watershed management plan. The shoreline survey database highlight areas that are possibly contributing to polluted runoff, and the shoreline disturbance scores should be used to prioritize areas of the shoreline for remediation. Each shoreline property should be visited by a technical consultant for BMP recommendations. 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. It should be noted that natural steep slopes are responsible for some high scores in the watershed. These slopes are poor habitat for vegetation growth and other remediation efforts should be pursued on these properties.

3.5.5 SEPTIC SYSTEM SURVEY

Septic systems, outhouses, and even portable toilets help manage our wastewater and prevent harm to human health, aquatic life, and water resources. However, aging, poorly maintained, and/or improperly sited systems pose a threat to the health of surface waters. Within a septic system, approximately 20% of the phosphorus is removed in the septic tank (due to settling of solid material) and a further 23-99% is removed in the leachfield and surrounding soils (Lombardo, 2006; Lusk et al., 2011). The degree of phosphorus removal efficiency of a septic system depends on site-specific soil and groundwater characteristics, including pH and mineral composition. Depending on the circumstances, older systems may still retain up to 85% of the input phosphorus in the top 30 cm of the soil (Zanini et al., 1998), though a slow, long-term transport of phosphate over long distances in the groundwater table can also occur in older systems (Harman et al., 1996). Phosphorus generally migrates through the soil slower than other dissolved pollutants in groundwater, but studies have shown that this degree of phosphorus reduction and movement is correlated with unsaturated infiltration distance (Weiskel and Howes, 1992), suggesting it is important to have septic systems well above the seasonal high groundwater table.

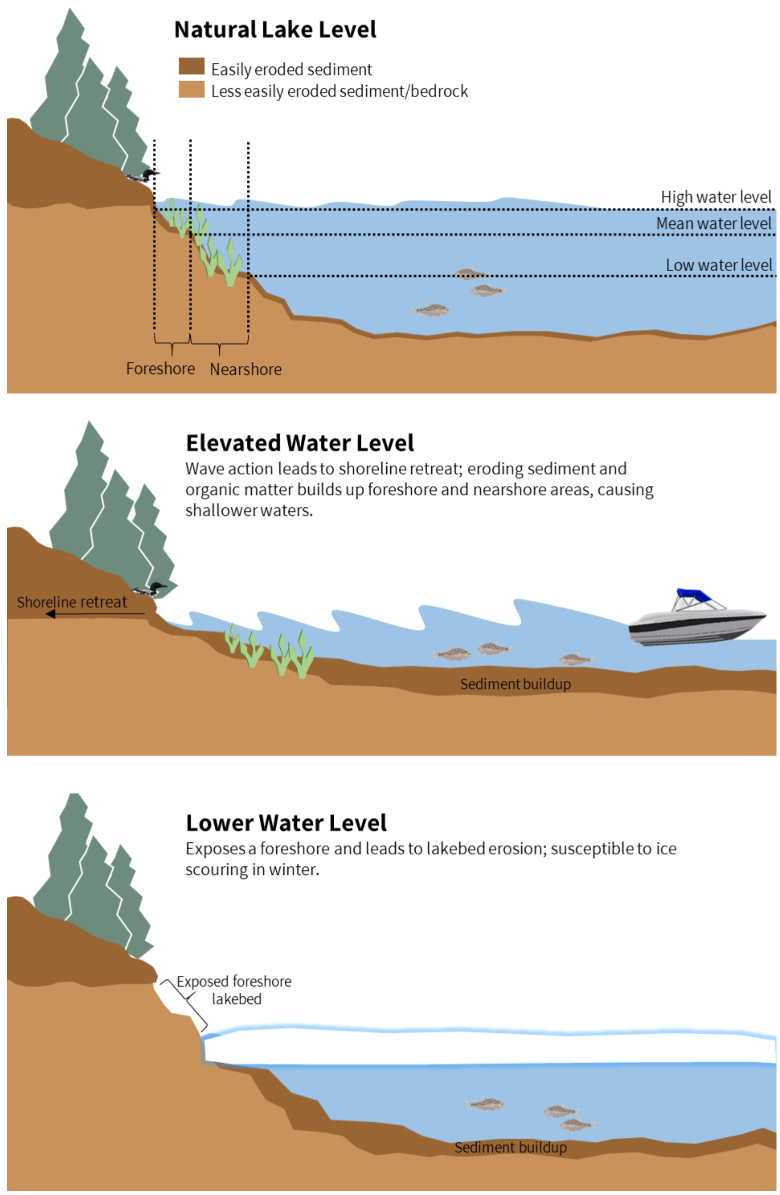
Data for septic systems within 250 feet of a surface water (including wetlands) were obtained from state and local records compiled by the Town of Alton (251 parcels) and CMSC (568 parcels). Data included information on the age, distance to surface water, and use (seasonal or year-round and occupancy) of septic systems, if present. Seasonal and year-round systems in Alton were determined using the occupied seasonal housing rate for the State of New Hampshire (10.4%) from the 2010 US Census.

Wastewater systems were estimated to be the third largest source of phosphorus to surface waters in the Merrymeeting River and Lake watershed, contributing 18% (50 kg/yr) of the total phosphorus load to Merrymeeting Lake, 1% (5 kg/yr) to Marsh Pond, 1% (6 kg/yr) to Jones Pond, and 2% (9 kg/yr) to Downing Pond. Recommendations for addressing input from wastewater are provided in the Action Plan (Section 5.2).

3.5.6 WATER LEVEL

Water level fluctuation in lakes and rivers can cause or worsen shoreline erosion in times of elevated water level, as well as cause or worsen lake or riverbed erosion in times of low water level. In shallow, gently sloping waterbodies, raising the water level redistributes wave energy from the nearshore (i.e., the shallow area between the mean and low water level) to the foreshore (i.e., the shallow area between the high and mean water level where beaches are located), thus causing potential shoreline retreat (Lorang et al., 1993). During times of water level drawdown, wave energy is focused on the exposed section of lake or riverbed that dries out and becomes prone to erosion and ice scouring during winter (Carmignani and Roy, 2017). 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.

One widely-applied theory of shoreline erosion in response to water level rise is the Bruun Rule (Bruun, 1962), which states that the shape of the shore profile will gradually adjust to a rise in water level until it reaches an equilibrium slope, at least down to a depth where waves no longer influence sediments. On Lake Erie, a sustained rapid rise in water level initiated a multi-year sequence of



Conceptual diagram showing the impact of high and low water level on lake shorelines. ©FBE

erosion and shoreline retreat even after water levels began lowering, suggesting that manipulating water level can have long-lasting consequences that are hard to predict or reverse (Lavalle and Lakhan, 2000). Lorang et al. (1993) and Carmignani and Roy (2017) recommend gradually lowering water level in dammed waterways before fall storms as a management practice so that wave energy can be more readily dissipated along the shallow slope of the nearshore shelf, potentially preventing larger erosive events.

CMSC observed shoreline erosion and retreat due to elevated water levels. During a 2.5-3 ft drawdown of Downing Pond for dam repairs, CMSC was able to document the severe bank undercutting and exposed tree roots along the shoreline. The repaired Downing Pond dam will be set 8 inches lower to help slow the rate of bank erosion.

Undercut banks observed at Downing Pond during a drawdown. Photo credit Fred Quimby.

3.5.7 FERTILIZER USE

Fertilizer use can be a significant source of phosphorus and other nutrients to surface waters. CMSC contacted municipal or large-scale agricultural or commercial operators to determine what types of fertilizers are used. It is currently unknown the extent that phosphorus-based fertilizers are used on private lawns throughout the watershed.

The Town of New Durham does not use any phosphorus-based fertilizer. The ballfields on Smitty Way, for example, are treated with either Dimension Fertilizer which contains 18% nitrogen derived from urea and 2% chlorine, or Allectus Turf Fertilizer, which contains 17% nitrogen, 6% soluble potash, 2% iron, and 4.5% chlorine. New Durham does not use a commercial applicator of fertilizer in the spring or the fall. Alton does not fertilize the Jones Fields due to the proximity to the river. The Diamond B farm in New Durham uses a combination of fertilizer methods, including hatchery manure, cattle manure, and chemical fertilizer depending on what the soil tests show.

3.5.8 ABANDONED LANDFILLS

Local officials and residents reported four landfills in the Merrymeeting River and Lake watershed. Abandoned landfills were identified in Alton near Coffin Brook off Coffin Brook Road near a sand pit and behind the Alton highway department on Letter S Rd and in New Durham off Merrymeeting Road at the Town Boat Access. If not properly lined and capped, these historic landfills may be leaching pollutants to surface and groundwater.

3.5.9 CLIMATE CHANGE

Climate change will have important implications for water quality that should be considered and incorporated to watershed management plans. 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 on 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 into the future to impact both water quality and quantity. Climate change models predict an 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. From 1990-2010, the Great Bay area experienced a 19% increase in population but a 120% increase in impervious cover (Ballestero et al., 2017). From 2000 to 2010, the populations of New Durham and Alton grew by 19% and 17%, respectively (NHOEP, 2011). The build-out analysis for the watershed showed that about 11,653 acres is still developable and up to 3,762 new buildings could be added to the watershed at full build-out based on current zoning standards. The

Merrymeeting River and its ponds are at serious risk for sustained water quality degradation as a result of new development in the watershed unless climate change resiliency and LID strategies are incorporated to existing zoning standards.

We must design resiliency into our public stormwater infrastructure based on temperature changes, precipitation, water levels, wind loads, storm surges, wave heights, soil moisture, and ground water 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).

1. **Installing Green Infrastructure:** 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 for the communities being developed. Examples of green infrastructure include forest, wetlands, natural areas, riparian (banks of a water course) buffers, agricultural land, and flood plains; all of which already exist in the watershed and have minimized the damage created by intense storms in the past. As future development occurs, we must be able to maintain or even increase these natural barriers to reduce runoff of pollutants into freshwaters.
2. **Using LID Strategies:** Use of LID strategies requires that we replace the 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.
3. **Minimizing Impervious Surfaces:** Today two-thirds of our impervious surfaces come from roads, highways, and parking lots; we must minimize impervious surfaces by creating new ordinances and building construction design requirements which reduce imperviousness of new development. Parking lot design requirements should promote infiltration of runoff and roads should consider space for pedestrians, bicyclists, and mass transit. Increasing our transportation choices reduces the need for more pavement. Private property owners can also increase the permeability for their lots by incorporating permeable driveways and walkways.
4. **Encouraging Riparian Buffers and Maintaining Flood Plains:** Town ordinances should forbid construction in flood plains, and in some instances flood plains should be expanded to increase the land area which will accommodate larger rainfall events. We also need to preserve and create riparian (vegetated) buffers and filter strips along waterways to slow runoff and filter pollutants.
5. **Protecting and Re-establishing Wetlands:** Wetlands are increasingly important in high runoff areas because wetlands hold water, recharge groundwater, and mitigate water pollution. The watershed contains many large natural wetlands that must be preserved.
6. **Encouraging Tree Planting:** Trees help manage stormwater by reducing runoff and mitigating erosion along surface waters. In addition, trees cool heat islands in more developed areas and provide shade for pedestrians.
7. **Promoting Landscaping Using Native Vegetation:** Communities 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).
8. **Slowing Down the Flow of Stormwater:** To slow and infiltrate stormwater runoff, a variety of techniques can be employed. 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 waterbars can divert water running down roads and walkways into vegetated areas for infiltration. Water running off roofs can be channeled into infiltration fields and drainage trenches (UNH Cooperative Extension, 2007).
9. **Coordinating Infrastructure, Housing, and Transportation Planning**: We should 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.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4. MANAGEMENT STRATEGIES

The goal of the Merrymeeting River and Lake Watershed Management Plan is to improve water quality in Merrymeeting Lake, Marsh Pond, Jones Pond, Downing Pond, and the Merrymeeting River at Alton Bay to eliminate the presence of toxic cyanobacteria blooms that impair these waterbodies for aquatic life use and primary contact recreation. This goal will be achieved by treating current PS and NPS pollution from existing development and preventing future NPS pollution from anticipated new development. See Section 3.4 for specific objectives and reduction targets. A key component of this effort 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, government, and others. The following section details management strategies for achieving the water quality goal and objectives using a combination of structural and non-structural BMPs, as well as an adaptive management approach. Specific action items are provided in the Action Plan (Section 5.2).

4.1 STRUCTURAL NONPOINT SOURCE (NPS) RESTORATION

Seventy-eight (78) watershed NPS sites and 285 high to medium priority shoreline properties around Merrymeeting Lake were identified and documented to have some impact on water quality through the delivery of phosphorus-laden sediment (refer to Section 3.5). As such, structural BMPs are a necessary and important component for the protection of water quality in the watershed. The best approach to treating these NPS sites is to:

- Address high priority watershed and shoreline survey sites with an emphasis on cost-efficient fixes that have a high impact to low cost per kg of phosphorus treated. The BMP matrix (Appendix B) sorts watershed NPS sites by impact-weighted cost to phosphorus reduction ratio. The shoreline survey results are sorted from highest to lowest Shoreline Disturbance Scores.
- Work with landowners to get commitments for treating and maintaining sites. Workshops and tours of demonstration sites can help encourage landowners to utilize BMPs on their own property.
- Work with experienced professionals on sites that require a high level of technical knowledge (engineering) to install and ensure proper functioning of the BMP.
- Estimate pollutant load reduction for each BMP installed.

This approach will help guide the proper installation of structural BMPs in the watershed. More specific and additional recommendations (including public outreach) are included in the Action Plan in Section 5.2. For helpful tips on implementing residential BMPs, see the NHDES Homeowner's Guide to Stormwater Management (see Additional Resources).

4.1.1 ESTIMATION OF POLLUTANT LOAD REDUCTIONS NEEDED

Remediation of the 78 NPS sites identified in the watershed survey could reduce the phosphorus load to Merrymeeting River and Lake by an estimated 25 kg/yr of phosphorus[4] and cost an estimated $1.27-$2.24 million to implement (Table 4-1; refer to Section 3.5 and Appendix B). Full-scale designs and cost estimates will need to be completed for each of the identified watershed survey sites. High priority shoreline properties (13 parcels) should also be resurveyed in person for specific BMP recommendations and more accurate estimated phosphorus reductions and implementation costs by site. However, given some broad assumptions, the 13 high priority properties (with scores of 14 or greater) would cost about $39,000 ($3,000 each) to revegetate and mulch with volunteer labor, which could reduce the phosphorus load by 12.4 kg/yr[5]. Remediation of the 272 medium priority properties (with scores of 10-13) would each cost about $1,500 to revegetate and mulch with volunteer labor and could result in the reduction of an additional 39.2 kg/yr of phosphorus[6]. Note that the total phosphorus load calculated by the Region 5 model method differs from the LLRM output for direct shoreline drainage. This is due to the large assumptions made in the models and the fact that Urban 1 Low Density Residential phosphorus export coefficients are generalized and do not consider specific shoreline condition and proximity to the lake.

If all identified trouble areas were addressed, total phosphorus load could be reduced by 77 kg/yr. The water quality goal and objectives state that the total phosphorus load be reduced or offset by a total of 228 kg/yr by 2028. Success will be achieved by remediating a combination of both watershed and shoreline survey sites, as well as improving land use ordinances to better protect water resources (see Section 4.2). The strategy for reducing pollutant loading to surface waters in the Merrymeeting River and Lake watershed will be dependent on available funding and labor resources but will likely include a combination of approaches (larger watershed BMP sites and smaller residential shoreline BMP sites). Refer to Section 5.2 for specific recommendations.

Table 4-1. Summary of total phosphorus (TP) reductions for BMP implementations in the Merrymeeting River and Lake watershed. Note that the Marsh, Jones, Downing Pond TP Reduction Target does not include the reductions needed from the Powder Mill State Fish Hatchery.

BMP Site Categories	TP Reduction (kg/yr)	TP Reduction Target (kg/yr)
Merrymeeting Lake Watershed Survey Sites (28)	5.3	
Merrymeeting Lake Shoreline Survey – High Impact Sites (13)	12.4	16
Merrymeeting Lake Shoreline Survey – Medium Impact Sites (272)	39.2	
Marsh, Jones, Downing Pond Watershed Survey Sites (12)	5.4	14
Merrymeeting River at Alton Bay Watershed Survey Sites (38)	14.8	198
Total	**77.1**	**228**

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:

1) Nutrients (e.g., nitrogen)
2) Petroleum products
3) Bacteria
4) Road salt/sand
5) Heavy metals (cadmium, nickel, zinc, etc.)

[4] Based on the NHDES Simple Method Pollutant Loading Spreadsheet Model and the USEPA Region 5 model.

[5] Based on Region 5 model bank stabilization estimate for silt loams, using 100 ft (length) by 5 ft (height) and moderate lateral recession rate of 0.2 ft/yr and assuming a 50% BMP efficiency.

[6] Based on Region 5 model bank stabilization estimate for silt loams, using 50 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr and assuming a 50% BMP efficiency.

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.

4.2 NON-STRUCTURAL NONPOINT SOURCE (NPS) RESTORATION

Current zoning in the Merrymeeting River and Lake watershed presents considerable opportunity for continued development, as an estimated 55% of the Merrymeeting River and Lake watershed is still developable (see the build-out analysis in Section 3.3.3). The area's popularity as a permanent residence is growing with seasonal homes being upgraded to year-round single-family dwellings. This may result in a 38-41% increase in phosphorus loading to Merrymeeting River, Marsh Pond, Jones Pond, and Downing Pond and a 116% increase to Merrymeeting River at Alton Bay by 2090 (see Section 3.3.3). Given this future development potential, it is critical for municipalities to develop and enforce stormwater management measures that prevent an increase in pollutant loadings from new and re-development projects, particularly as future development may offset reduced loads from other plan implementation actions. The impact of future development can be mitigated with the implementation of non-structural BMPs, such as land use planning, zoning ordinances, and LID requirements. Though non-structural BMPs often receive little emphasis in watershed planning, it can be argued that local land use planning and zoning ordinances are the most critical components of watershed protection. Refer to Section 5.2 for specific planning recommendations.

4.3 ADAPTIVE MANAGEMENT APPROACH

An adaptive management approach, to be employed by a steering committee, is highly recommended for protecting the Merrymeeting River and Lake watershed. 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 (an expansion of the current steering committee overseeing plan development) should be assembled to coordinate watershed management actions. This group should include representatives from state and federal agencies or organizations, the Town of Alton, the Town of New Durham, conservation commissions, local businesses, and other interested groups or private landowners. Refer to Section 5.1: Plan Oversight.
- **Establishing a Funding Mechanism.** A long-term funding mechanism to be guided by a steering committee should be established to provide financial resources for management actions. A sub-committee of the steering committee can be dedicated to prioritizing and seeking out funding opportunities. 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 management 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 5.4 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, including structural and non-structural restoration actions. The proposed actions in this plan should be used as a starting point for grant proposals. Once a funding mechanism is established, detailed designs for priority restoration actions on a project-area basis can be completed and their implementation scheduled. Refer to Section 5.2: Action Plan.

- **Continuing and Expanding the Community Participation Process.** Plan development has included active involvement of a diversity of watershed stakeholders. Several watershed stakeholders participated in the community forum to develop the Action Plan (refer to Section 1.4). 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 5.2: Action Plan and Section 5.5: Educational Component.
- **Continuing the Long-Term Monitoring Program.** An annual 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 and help optimize management actions through the adaptive management approach. Refer to Section 5.2.1: Water Quality Monitoring.
- **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 5.3: Indicators to Measure Progress and Section 3.4: Establishment of Water Quality Goal for interim benchmarks.

5. PLAN IMPLEMENTATION

5.1 PLAN OVERSIGHT

The recommendations of this plan should be carried out by a steering committee like the one assembled for development of this plan. A steering committee should include the leadership of CMSC, representatives from the towns (e.g., board of select, planning board), members of the conservation commissions, state and federal agencies or organizations, lake associations, nonprofits, land trusts, schools and community groups, local business leaders, and landowners. The committee will need to meet regularly and work hard to coordinate resources across stakeholder groups to implement management actions. The watershed management plan (especially the Action Plan) will need to be updated periodically (typically every five 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 a steering committee and reported to NHDES on a regular basis.

5.2 ACTION PLAN

The Action Plan was developed through the collective efforts of the current steering committee, as well as the public by way of feedback provided during the community forum held in August 2018. The Action Plan outlines responsible parties, approximate costs[7], and an implementation schedule for each recommendation within five major categories: (1) Water Quality Monitoring; (2) Watershed and Shorefront BMPs; (3) Road Maintenance and Training, (4) Municipal Planning and Conservation; and (5) Septic Systems. Accompanying narrative sections also provide “short-term recommendations” or actions to be included in the first, immediate phase of plan implementation.

5.2.1 WATER QUALITY MONITORING

An annual monitoring program is critical to evaluating the effectiveness of watershed restoration activities and determining if the water quality goal and objectives are being achieved over time (per interim benchmarks set in Section 3.4). The Action Plan includes recommendations for enhancing current water quality monitoring efforts in the watershed. The recommendations build on CMSC’s current monitoring program and collaboration with UNH LLMP. Refer to Table 5.1.

NHDES already completed detailed bathymetry mapping of both Mill Pond and Marsh Pond in spring of 2019. NHDES also deployed several continuous loggers in Marsh and Jones Ponds to measure sub-hourly changes in temperature, dissolved oxygen, conductivity, and pH for two weeks in July 2019. NHDES will also be completing a fish and macroinvertebrate study in Coffin Brook and several tributaries to Merrymeeting Lake.

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

SHORT-TERM RECOMMENDATIONS

- **#1-4:** Continue to enhance awareness of water quality issues in the watershed by creating outreach materials and publishing articles.
- **#8:** Investigate various funding sources to continue and expand a regular monitoring program in the watershed.
- **#9-10:** Establish a regular lake/pond and tributary monitoring program that (at a minimum) samples the deep spot of Merrymeeting Lake, Marsh Pond, Jones Pond, Downing Pond, and Mill Pond three times per year in summer for dissolved oxygen and temperature profile readings, Secchi disk transparency readings, hypolimnion and metalimnion grab samples for total phosphorus (if applicable), and epilimnion core samples for total phosphorus, cyanobacteria, and chlorophyll-a. Collect surface grab samples for total phosphorus at major tributary and mainstem river sites.
- **#11-14**: Further investigate pollutant sources to Mill Pond by inspecting the condition of the landfill, modeling Mill Pond separately (to quantify internal loading), sampling bottom sediment for at least phosphorus to aluminum and iron ratios (for internal loading estimates), and mapping the stormwater drainage network to the pond.
- **#15-17:** Continue to work with NHDES to investigate internal loading in the ponds, some of which was already completed in summer 2019.

5.2.2 WATERSHED AND SHOREFRONT BMPS

Aside from the Powder Mill State Fish Hatchery point source discharges, stormwater is a major contributor of pollution to surface waters in the watershed. Most larger sources of runoff from commercial development or roads are regulated, but single lot residential properties go unregulated (which cumulatively can potentially be a significant stormwater runoff contributor). Roofs can contribute heavy metals and animal waste (birds); driveways can contribute sediment, oil, and warmed water; and lawns can contribute fertilizer, pesticides, sediment, and pet waste – all of which can flow off a property untreated to a surface water in the watershed. Direct shoreline areas are typically among the highest for pollutant loading given their proximity to surface waters and desirability for development. The 2018 shoreline survey of Merrymeeting Lake found that 74% of shoreline parcels showed characteristics potentially detrimental to lake water quality. There are many resources available to help private property owners capture and infiltrate runoff, such as the New Hampshire Homeowner's Guide to Stormwater Management. Examples of stormwater controls include rain gardens, dripline trenches, driveway infiltration trenches, infiltration steps, porous pavers, and dry wells. Coordination with landowners will be crucial for successful implementation of the BMPs identified in the Action Plan because many mitigation measures will need to be implemented on private land. A well-executed demonstration BMP in a populated area may inspire friends and neighbors to implement similar practices.

Pollutant load reductions will best be achieved through a combination of the smaller-scale shoreline and larger-scale watershed BMPs, and both will depend on available financial resources and feasibility. A steering committee should develop a long-term strategy to fund these and other action items from the plan. Refer to Table 5.1.

SHORT-TERM RECOMMENDATIONS

- **#21:** Work with state and federal agencies to set a new permit limit on the point source discharge from the Powder Mill State Fish Hatchery and design/implement a new facility that meets the target limit. Estimated TP reduction is 293 kg/yr to achieve a monthly average maximum discharge total phosphorus concentration of 10 ppb.
- **#22-24:** Work with shorefront and watershed landowners to encourage and implement at least one conservation practice on their land, such as stormwater controls. Complete a shoreline survey of all ponds and the river and coordinate with NHDES SOAK Up the Rain NH for demonstration BMPs to help prioritize properties for cost-share opportunities and encourage landowners to implement stormwater controls on their own.
- **#25, 27, 29:** Address priority sites identified in surveys by implementing BMPs at high impact sites identified in the shoreline survey and at the four watershed survey sites for which conceptual designs were developed. Develop a method of tracking and monitoring BMP implementation progress (e.g. NPS Site Tracker).
- **#31-33:** Create a subcommittee that develops a fundraising strategy for completing the action items. Fundraising ideas include establishing a capital reserve fund for towns to spend on BMP installation and maintenance or

developing a "Friends of the Watershed" program for local businesses or landowners to donate to in support of water quality protection efforts.

5.2.3 ROAD MAINTENANCE & TRAINING

Steep road grades are vulnerable to gully and rill formation along roadsides, which act as conduits for sediment erosion and runoff. Many of the NPS sites identified in the watershed survey addressed runoff from private, town, and state roads. The steering committee should team up with landowners, local road agents, and the NHDOT to ensure that landowners and state and local authorities are working to best maintain roads and associated runoff within the watershed. Refer to Table 5.1.

SHORT-TERM RECOMMENDATIONS

- **#34-35**: Work with NHDOT and towns to communicate known problems with culvert function along roads so that they can be remediated. Assess and prioritize culverts in the watershed for replacement/upgrade. A town-wide culvert inventory and assessment of New Durham was completed in 2014 by the Strafford Regional Planning Commission. The culvert assessments were based on the Vermont Stream Geomorphic Assessment, with some modifications by several New Hampshire organizations or agencies. Each year, the Town of New Durham highway department reviews the culvert assessments and selects several culverts for repair or replacement. The Town of Alton does not currently have a culvert inventory and assessment database and no formal plans for repair and replacements, but road agents do examine culverts during storms each year and designate failing culverts for replacement.

One of several stormwater drainage outfalls from Route 11 to Mill Pond that tested high for total phosphorus. Detailed assessment of the stormwater drainage network in this area will help identify appropriate management actions.

- **#36, 39:** Hold workshops on proper road management and winter maintenance and provide educational material for town road agents and homeowners about winter maintenance and sand/salt application for roads, driveways, and walkways. Beginning in 2016, the Town of New Durham began a new winter road maintenance program which shifted from a de-icing treatment of primary sand/salt usage to a treated salt usage. The primary treated salt solution has led to a 45-50% reduction in salt used and a 75% reduction in sand used. One issue than was identified during the plan development process was the use of snowplow pile areas near surface waters. These snowplow piles contain significant amounts of sand, gravel, and possibly salt or other chemicals picked up from the roads with the snow. These piles are at risk for eroding into surface waters.

Plow pile after snowmelt at the end of Pine Street, Alton. These piles are at risk for eroding into surface waters. Private and municipal snowplowers should consider different plow pile locations.

- **#37:** Review BMP road installation and maintenance practices currently used for each town and determine areas for improvement. Develop and/or update a written protocol for BMP road installation and maintenance practices. Examples of good road BMP examples include using vegetation with check dams in ditches, avoiding riprap unless there is a steep grade causing high runoff velocity, in which case a hard settling basin structure may be better for maintenance, avoiding digging out ditches that would expose bare soil, and using catch basins with infiltration fields if there is inadequate space for a ditch system. The Town of Alton currently installs a series of catch basins and sump pumps to divert water into a larger area for treatment and clean-out; these BMPs are acceptable if the town can handle regularly cleaning-out the catch basins of accumulated sediment and other debris.

5.2.4 MUNICIPAL PLANNING AND CONSERVATION

Municipal land-use regulations are a guiding force for where and what type of development can occur in a watershed, and therefore, how water quality is affected because of this development. The build-out analysis indicated that there is room for improvement in protecting water quality through non-structural BMPs such as municipal ordinance adoption or revisions, especially as they relate to new development (e.g., impervious acreage, septic system design, and steep slopes). Efforts to balance development and water quality protection are important to watershed management goals and future water quality. Refer to Table 5.1.

SHORT-TERM RECOMMENDATIONS

- **#40-42:** Identify opportunities for land protection and conservation within the watershed by collaborating with local conservation partners on land conservation initiatives within the watershed. Assign a liaison to communicate with conservation groups. Fund tools, such as natural resource inventories, to help identify and target critical land for protection.
- **#43-45:** Enhance watershed resident education and communication of local land ordinances and BMPs by holding informational workshops for new landowners, towns, and developers on relevant town ordinances, conservation easements, and watershed goals.
- **#46-47:** Present the watershed management plan to the Town of Alton and New Durham and incorporate recommendations for the watershed plan into the town master plans.
- **#49-55, 57:** Complete a full-scale ordinance review that includes working with the planning board to recommend changes, such as site plan review regulations, road and right of way standards, minimum lot sizes, minimum shore frontage per lot, and others. Consider improving municipal ordinance language to better protect water resources by implementing smarter development standards. Meet with town staff to review recommendations to improve or develop ordinances addressing setbacks, buffers, lot coverage, LID, steep slopes, stormwater regulations, and open space. New Durham has already taken steps to update ordinances for better water quality protection. New Durham approved the establishment of the Merrymeeting Lake Overlay District to reduce the amount of future residential home construction in the watershed.
- **#56:** Investigate additional municipal ordinances relating to lake activities, such as assessing if more stringent wake restrictions may have a positive impact on the lake shoreline. Currently, the lake is governed by state law (RSA 270-D:2 - boats shall maintain headway (no wake) speed within 150 ft of the shoreline, docks, and mooring fields. See Water Quality Monitoring (http://www.gencourt.state.nh.us/rsa/html/XXII/270-D/270-D-2.htm). Residents were concerned about shoreline erosion from wakes generated by high-speed and wake boats. Merrymeeting Lake supports several water skiing schools where wake boarding is practiced.
- **#59:** Enhance enforcement of proper land management practices by creating better enforcement of forestry rules and regulations. Consider creating stricter timber harvesting regulations to prevent large-scale logging in the watershed.

5.2.5 SEPTIC SYSTEMS

Watershed modeling indicated that septic systems are notable source of phosphorus load to Merrymeeting River and Lake. To make significant reductions in phosphorus load from wastewater, landowners will need to take responsibility to check their systems and make necessary upgrades, especially to old systems and cesspools. Code enforcement could assist by tracking occupancy loads and having septic system inventories in the town master plan. A comprehensive septic system inventory (or database) could be used to track maintenance and replacement history of systems within the watershed; this would be managed by the town, especially if a wastewater inspection and maintenance program was put into effect and enforced by the town. The 2018 septic system inventory completed by CMSC for properties within 250 feet of major surface waters in the watershed is a good first step in gathering site-specific septic system data (see Section 3.5.5).

"Septic socials" are a great outreach tool to spread awareness of proper septic maintenance. Socials are an opportunity for neighbors to come together to socialize, while also learning about keeping healthy septic systems. Socials could be held for willing groups of landowners, such as road or campground associations. Landowner groups can also benefit by coordinating septic system pumping discounts. Refer to Table 5.1.

SHORT-TERM RECOMMENDATIONS

- **#61-63:** Enforce occupancy loads, have septic system inventories in the town master plan, and inspect all home conversions from seasonal to permanent residences, sold property, or property transfers for proper septic system size and design (replace all cesspools). The cost is the responsibility of the property owner. Consider the septic system ordinances that require regular pump-outs and inspections to ensure the systems are functioning properly. Require a septic system to be fixed before the property is sold and require full evaluations not brief assessments.
- **#64-66:** Garner funding or discounts that support and encourage septic system maintenance by coordinating group septic system pumping discounts, investigating grants and low-interest loans (e.g., NHDES Clean Water State Revolving Fund, Section 319 Implementation Grant) to provide cost-share opportunities for septic system inspections, installations, and upgrades, and encouraging towns, conservation commissions, or local conservation partners to reserve a portion of conservation dollars for the watershed that can be used for septic system upgrades.
- **#67-69:** Enhance awareness of proper septic system maintenance and regulations by distributing educational pamphlets on septic system function and maintenance in tax bills, and have the material available in the library (to include recommended pumping schedules, proper leach field maintenance/planting, new/alternative septic system designs such as community septic or site-limited homes, etc.). Additionally, create and distribute a list of septic service providers (designers v. pumpers) (create magnets, etc.). Host multiple "septic socials to address link between septic system maintenance and water quality. Target educational campaign in areas with minimally maintained or aging septic systems.
- **#70-73:** Develop and maintain a septic system database for the watershed/town, to be maintained by the Code Enforcement Office. Complete in-person, mail-in or online survey of septic systems to fill in any missing information in the database. Conduct voluntary dye testing of any suspected septic systems, with a goal of five systems. Hire canine scent detection team to investigate shoreline septic systems.

Table 5-1. Action Plan for the Merrymeeting River and Lake Watershed Management Plan. TP = total phosphorus.

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	CMSC	Town	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
		Water Quality Monitoring										
Enhance awareness of water quality issues in the watershed	**1**	Contact local representatives and attend selectman meetings to voice concerns and stay informed.	✓		✓			✓			2019-28	N/A
	2	Create flyers/brochures for shorefront homes regarding BMPs and septic systems. Consider also creating a "new homeowner" packet that covers water quality related issues and ordinances in the watershed. Cost does not cover printing.	✓	✓					✓		2019-28	$2,000
	3	Contribute interesting articles about water quality and watershed protection efforts to various media sources. Assumes volunteer labor.	✓								2019-28	N/A
	4	Create educational annual "report cards" about water quality, presented in a format that is approachable to lay persons. Cost assumes initial consultant setup for $2,000, then $500/yr to update for 9 additional years.	✓	✓					✓		2019-28	$6,500
Maintain and/or improve current invasives and/or weed management program	**5**	Support State legislation that increases funds for aquatic invasive plant (e.g., milfoil) eradication.	✓				✓	✓			2019-28	N/A
	6	Increase the number of volunteer inspectors for the Lake Host and Weed Watchers programs.		✓			✓	✓			2019-28	N/A
	7	Expand invasive species monitoring programs to include insects and other animals not currently monitored (e.g., spiny waterflea).	✓		✓		✓	✓			2019-28	N/A
Obtain more funding	**8**	Obtain funding from sources such as municipal contributions, NHDES grants, lake associations, targeted fundraising, and other grants related to climate change or invasive species studies.	✓	✓	✓		✓				2019-28	N/A
Establish regular lake/pond monitoring program	**9**	Conduct at least three annual sampling events at the deep spot of Merrymeeting Lake, Marsh Pond, Jones Pond, Downing Pond, and Mill Pond in July, August, and September (prior to Sept 15) to include DO and temperature profile readings, Secchi Disk Transparency readings, hypolimnion and metalimnion grab samples for total phosphorus (if applicable), and epilimnion core samples for total phosphorus, cyanobacteria, total nitrogen, total carbon, chlorophyll-a, pH, alkalinity, and color. Aim for biweekly Secchi Disk Transparency readings and monthly DO and temperature profile readings from May 24-Sept 15. Assumes volunteer labor.	✓	✓			✓				2019-28	$27,000
Establish regular tributary/river monitoring program	**10**	Sample major tributary and mainstem river sites for at least total phosphorus, and also consider turbidity, pH, total nitrogen, total carbon, and chloride 3-4 times per year from June-September. Cost assumes 10 sites. Consider adding stream gages to monitor flow.	✓	✓			✓				2019-28	$36,000
Further investigate pollutant sources to Mill Pond	**11**	Inspect the condition of the capped landfill located along the banks of Mill Pond. Determine the type and amount of buried materials and how it was capped. Devise and conduct a monitoring strategy using surface and groundwater samples to determine the extent of possible seepage coming from the landfill.	✓	✓					✓		2019-23	$50,000
	12	Complete Lake Loading Response Model for Mill Pond to quantify the amount of pollutant source contribution from atmospheric deposition, waterfowl, watershed land cover, internal loading, and septic systems. This, along with sediment sampling (#13), will help determine if Mill Pond would be a candidate for alum treatment.	✓	✓					✓		2019-23	$5,000

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	CMSC	Town	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	13	Sample bottom sediments for sediment core analyses in multiple locations to allow for historical assessment of changes in sediment particle size, organic matter content, phosphorus to aluminum and iron ratios (for internal loading estimates), and phytoplankton communities as each relates to major known natural and human events.	✓	✓					✓	✓	2019-23	$20,000
	14	Map the stormwater infrastructure draining to Mill Pond. Sample all outfalls for MS4/IDDE parameters. Design stormwater treatments throughout stormwater drainage network. Cost does not include actual BMP implementation.	✓	✓					✓		2019-23	$30,000
Further investigate internal loading in the ponds.	**15**	Sample lake/pond bottom sediments for phosphorus, iron, and aluminum and assess the risk of internal load release.				✓					2020	TBD
	16	NHDES/CMSC to complete monitoring of Marsh and Jones Ponds in 2019 using a combination of grab samples and continuous loggers to measure changes in water quality parameters (especially dissolved oxygen) over time and space (vertically and longitudinally).	✓			✓					2019	TBD
	17	Complete a dye test of the Powder Mill State Fish Hatchery outfalls to evaluate the rate and dispersion of discharge water and whether some of the high TP in bottom waters of Marsh and Jones Ponds are from cold, high-TP discharge water.	✓			✓					2019-20	TBD
Update the load model following point source remediation	**18**	Update the Lake Loading Response model once additional data are collected up to and following upgrade of the Powder Mill State Fish Hatchery. Incorporate existing detailed bathymetry of Marsh Pond.	✓	✓					✓		2025	$15,000
Document changes in hatchery operations (include timeline)	**19**	Continue to collect quarterly outfall samples and consider collecting more frequent samples before and after a major change in hatchery operations (e.g., as interim fixes are implemented or if the upgrades occur in stages).	✓			✓					2019-28	TBD
Survey aquatic biological communities in key locations	**20**	Continue to work with NHDES to complete aquatic biological community studies (fish, macroinvertebrate, zooplankton, phytoplankton) of the lake, ponds, river, and tributaries in the watershed. Prioritize fish survey of Coffin Brook and several tributaries to Merrymeeting Lake that have been classified as wild brook trout habitat.	✓			✓					2019-20	TBD
		Watershed & Shorefront BMPs										
Address point source discharge from Powder Mill State Fish Hatchery.	**21**	Work with state and federal agencies to set a new permit limit on the point source discharge from the Powder Mill State Fish Hatchery and design/implement a new facility that meets the target limit. Estimated TP reduction 293 kg/yr.	✓	✓		✓		✓			2019-25	TBD
Promote healthy vegetated buffers for shoreline properties	**22**	Complete a shoreline survey of all ponds and the river. Repeat every 5-10 years. Assumes volunteer labor using the standard assessment rubric used for the Merrymeeting Lake shoreline survey. This information can be used to help prioritize technical assistance follow-up and stormwater management outreach.	✓				✓				2020, 2028	N/A
	23	Work with SOAK Up the Rain NH to implement small scale example BMPs and host concurrent residential stormwater workshops. Cost estimate does not include actual BMP implementation. Cost assumes printing, mailing to advertise events.	✓			✓	✓	✓			2020-22	$1,000
	24	Work with river/pond shoreline residents to implement at least one conservation practice on their land. Assumes $500 cost-share for 100 properties. Assumes volunteer labor. Estimated TP reduction 14 kg/yr.	✓				✓	✓			2020-25	$50,000

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	CMSC	Town	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Address priority pollutant sites identified in surveys	**25**	Implement BMPs in the top 4 areas (7 sites) identified in the watershed survey and for which conceptual designs were developed. Estimated TP reduction 4 kg/yr.	✓	✓					✓		2019-22	$260,000-$410,000
	26	Implement BMPs in the remaining 71 sites identified in the watershed survey. Estimated TP reduction 21 kg/yr.	✓	✓		✓	✓	✓			2019-28	$1.0-$1.9 million
	27	Implement BMPs at high impact sites identified in the shoreline survey. High impact is defined as Shoreline Disturbance Scores of 14 or greater. Thirteen high impact sites were identified during the Merrymeeting Lake shoreline survey. Assumes consultant labor for technical assistance and $3,000 cost-share for 13 properties. Estimated TP reduction 12 kg/yr.	✓	✓			✓		✓		2019-28	$45,000
	28	Implement BMPs at medium impact sites identified in the shoreline survey. Medium impact is defined as Shoreline Disturbance Scores of 10-13. 272 medium impact sites were identified during the Merrymeeting Lake shoreline survey. Assumes volunteer labor for technical assistance and $1,500 cost-share for 272 properties. Estimated TP reduction 39 kg/yr.	✓	✓			✓		✓		2019-28	$408,000
	29	Develop a method of tracking and monitoring BMP implementation progress (e.g., NPS Site Tracker). Assumes volunteer labor.	✓	✓							2019-28	N/A
Work with NRCS and farmers on comprehensive nutrient management plans	**30**	Work with NRCS and farms to develop comprehensive nutrient management plans for livestock operations or fields with applied manure or other fertilizer.				✓		✓			2019-25	N/A
Garner funding for action items	**31**	Create a subcommittee that develops a fundraising strategy and determines how funding is spent. Assumes volunteer labor.	✓	✓							2019-20	N/A
	32	Establish a capital reserve fund or include as a budget line item for towns to spend on BMP installation and maintenance. Cost covers labor to setup and maintain fund for 10 years by the towns.	✓	✓							2019-28	$10,000
	33	Develop a "Friends of the Watershed" program for donations from local businesses. A business can receive a sticker or plaque recognizing their support for protecting local water resources. Cost covers sticker/plaque purchase.	✓	✓				✓			2019-28	$2,000
		Road Maintenance & Training										
Coordinate road and culvert improvements	**34**	Develop a complete inventory and assessment of all public road cross culverts. Maintain a prioritized database to direct available annual funding through the culvert upgrade program more efficiently and effectively.		✓					✓		2019-25	$20,000
	35	Summarize NPS sites identified on state-maintained roads and send to NHDOT for review and remediation. Assumes volunteer labor. Cost does not include remediation.	✓	✓							2019-20	N/A
Require winter and spring maintenance training of road agents for the town	**36**	If not already in place, require training for road agents on proper road BMPs for salt, sand, and equipment use (e.g., UNH Technology Transfer Center trainings for snowplow operators). Use only treated salt, and no sand on paved surfaces, and reduce application rate by 40-50%, sweep the roadways in the spring. Review locations of snow pile areas to avoid nearby surface waters.		✓							2019-28	$5,000

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	CMSC	Town	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Update town BMP road installation and maintenance practices to better protect water quality	**37**	Review BMP road installation and maintenance practices currently used for each town and determine areas for improvement. Develop and/or update a written protocol for BMP road installation and maintenance practices.		✓					✓		2019-28	$20,000
Create and manage drainage easements on roads	**38**	Continue to work with road agents and landowners to create and manage drainage easements on private properties. This will help ensure that culverts and other drainage structures that cross private property are being properly maintained to control salt/sand and stormwater runoff from roads. The towns have already been implementing this action as needed.		✓				✓			2019-28	TBD
Host road maintenance workshops for private landowners	**39**	Hold workshops on proper road management, winter maintenance, and provide educational material for homeowners about winter maintenance and sand/salt application for driveways and walkways.	✓	✓	✓			✓		✓	2019-28	$5,000
Municipal Planning & Land Conservation/Management												
Identify opportunities for land protection and conservation within the watershed	**40**	Collaborate with local conservation partners on land conservation initiatives within the watershed. Assign a liaison to communicate with conservation groups such as Moose Mountain Regional Greenways and Southeast Land Trust.	✓	✓	✓		✓	✓			2019-28	N/A
	41	Fund tools, such as natural resource inventories, to help identify and target critical land for protection.	✓	✓	✓				✓		2019-28	$20,000
	42	Create a priority list of watershed areas that need protection based on natural resource inventory and identify potential conservation buyers and property owners interested in easements within the watershed.	✓	✓	✓				✓		2019-28	$5,000
Enhance watershed resident education and communication of local land ordinances, best management practices, and actions	**43**	Hold informational workshops for new landowners, towns, and developers on relevant town ordinances, conservation easements, and watershed goals. Goal: Host 1-2 workshops.	✓	✓	✓		✓	✓			2020, 2026	$2,000
	44	Utilize online points of contact to provide information on ordinances, LID, and BMPs for landowners (e.g., fact sheets). Assumes consultant design of fact sheets. Does not include printing costs.	✓	✓	✓				✓		2020	$3,000
	45	Reach out to residents converting camp properties to year-round single-family homes to educate on watershed issues, LID, and BMPs. Includes cost of printing materials made in other action items.	✓	✓	✓						2020	$1,000
Adopt plan recommendations	**46**	Present the watershed plan to the BOS/planning board of Alton/New Durham. Assumes volunteer labor.	✓	✓							2019	N/A
	47	Incorporate watershed plan recommendations into town master plan.	✓	✓							2019-20	N/A
Improve municipal permitting process	**48**	Create list of BMP and LID descriptions for Town Selectman, ZBA, Planning Boards, and landowners.	✓	✓					✓		2019-25	$2,000
Improve municipal ordinances	**49**	Meet with town staff to review recommendations to improve or develop ordinances addressing setbacks (how much), buffers, lot coverage, LID, steep slopes, stormwater regulations, and open space. Refer to LRPC (1989) document for water quality related improvements to regulations. See also the nine strategies discussed in Section 3.5.9 Climate Change.	✓	✓					✓		2019-25	N/A

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	CMSC	Town	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	50	a) Lot Coverage: adopt requirements on Stormwater Management Plans for subdivisions, commercial, and multi-family development, and redevelopment disturbing 20,000 sq. feet or more.	✓	✓					✓		2019-25	N/A
	51	b) Setbacks (Shoreland Zoning): increase the setback distance to 100 feet within the shoreland zone. Expand the coverage of the Shoreland Protection Overlay District to smaller lakes and ponds, streams and rivers, and surface waters of local significance, as defined by a natural resource inventory.	✓	✓					✓		2019-25	N/A
	52	c) Wetland Buffers: increase the setback distance from all wetlands (not just prime wetlands) to 100 feet. Develop and approve a Wetland Conservation Overlay District that encompasses all wetlands in Alton and establishes higher levels of protection for wetlands of local significance, wetlands contiguous to lakes or ponds, and vernal pools.	✓	✓					✓		2019-25	N/A
	53	d) Steep Slopes: require design and implementation of BMPs on all development on slopes >15%.	✓	✓					✓		2019-25	N/A
	54	e) Conservation/Cluster Subdivisions: encourage conservation subdivisions and increase the amount of land set aside in conservation subdivisions to min. 50% of the development area.	✓	✓					✓		2019-25	N/A
	55	f) LID: Amend Stormwater Management ordinances to state that the use of LID techniques is preferred and shall be implemented to the maximum extent possible.	✓	✓					✓		2019-25	N/A
Investigate additional municipal ordinances for protecting water quality	**56**	Assess if more stringent wake restrictions may have a positive impact on the lake shoreline. Currently, the lake is governed by state law (RSA 270-D:2 - boats shall maintain headway (no wake) speed within 150 ft of the shoreline, docks, and mooring fields. http://www.gencourt.state.nh.us/rsa/html/XXII/270-D/270-D-2.htm). Request more involvement of Marine Patrol on Merrymeeting Lake. Follow up with 2019 Session results for HB137 which established a commission to examine the effects of wake boats in NH (http://gencourt.state.nh.us/bill_status/billText.aspx?sy=2019&id=65&txtFormat=html).	✓	✓							2019-20	N/A
	57	Complete a full-scale ordinance review that includes working with the planning board to recommend changes, such as site plan review regulations, road and right of way standards, minimum lot sizes, minimum shore frontage per lot, and others.	✓	✓					✓		2020	$20,000
Host LID/BMP trainings for public works, road agents, code enforcement officers, and ZBAs	**58**	Host LID/BMP training and investigate certification opportunities for public works, road agents, code enforcement officers, and ZBAs in watershed towns, where applicable. Target seasonal residents and renters as well.		✓				✓			2020, 2022, 2024, 2026, 2028	$5,000
Enhance enforcement of proper land management practices	**59**	Create better enforcement of forestry rules and regulations.		✓	✓		✓	✓			2019-28	N/A
	60	Encourage easement holders to be notified and present at closings.		✓	✓		✓	✓			2019-28	N/A

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	CMSC	Town	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
		Septic Systems										
Enforce town septic system regulations	**61**	Communicate with town departments to enforce occupancy loads and have septic system inventories in Master Plans.		✓	✓						2019-28	TBD
	62	Inspect all home conversions from seasonal to permanent residences, sold properties, and property transfers for proper septic system size and design. Cost responsibility of property owner.		✓				✓			2019-28	TBD
	63	Consider septic system ordinances that require regular pump-outs and inspections to ensure proper functioning. Require a septic system to be fixed before the property is sold, and require full evaluations, not brief assessments. Cost responsibility of property owner.		✓				✓			2019-25	TBD
Garner funding or discounts that support and encourage septic system maintenance	**64**	Coordinate group septic system pumping discounts. Assumes volunteer labor to coordinate. Pump-out costs responsibility of landowners.						✓			2019-28	N/A
	65	Investigate grants and low-interest loans (e.g., NHDES Clean Water State Revolving Fund, Section 319 Implementation Grant) to provide cost-share opportunities for septic system upgrades. Cost estimate based on resources to apply for grant.	✓	✓	✓			✓	✓		2019-20	$3,000
	66	Encourage towns, conservation commissions, or local conservation partners to reserve a portion of conservation dollars for the watershed that can be used for septic system upgrades.	✓	✓	✓		✓				2019-28	N/A
Enhance awareness of proper septic system maintenance and regulations	**67**	Distribute educational pamphlets on septic system function and maintenance in tax bills, and have the materials available in the library (to include recommended pumping schedules, proper leach field maintenance/planting, new/alternative septic system designs such as community septic or site-limited homes, etc.). Cost covers printing.	✓	✓	✓						2019-20	$2,000
	68	Create and distribute a list of septic service providers (designers v. pumpers) (create magnets, etc.).	✓	✓	✓						2019-20	$1,000
	69	Host multiple "septic socials" to address link between septic system maintenance and water quality. Target educational campaign in areas with minimally maintained or aging septic systems near the lake and river. LWA to coordinate.	✓				✓	✓			2019-28	$1,500
Inventory status of septic and greywater systems in watershed	**70**	Develop and maintain a septic system database for the watershed. Code Enforcement Office for towns to maintain database.		✓							2019-20	$500
	71	Complete in-person, mail-in, or online survey of septic systems to fill in any missing information in the database. Assumes volunteer labor.	✓	✓							2019-28	N/A
	72	Conduct voluntary dye testing of any suspected septic systems. Goal: 5 systems.		✓				✓			2019-20	$1,250
	73	Hire canine scent detection team to investigate shoreline septic systems.	✓	✓			✓		✓		2019-25	$20,000

5.3 INDICATORS TO MEASURE PROGRESS

The following environmental, programmatic, and social indicators and associated numeric targets (benchmarks) will help to quantitatively measure the progress of this plan in meeting the established goal and objectives for the Merrymeeting River and Lake watershed. These benchmarks represent short-term (2020), mid-term (2023), and long-term (2028) targets derived directly from actions identified in the Action Plan. Setting benchmarks allows for periodic updates to the plan, maintains and sustains the action items, and makes the plan relevant to ongoing activities. A steering committee should review the benchmarks for each indicator on an ongoing basis to determine if progress is being made, and then determine if the watershed plan needs to be revised because the targets are not being met.

Environmental Indicators are a direct measure of environmental conditions (Table 5-2). They are measurable quantities used to evaluate the relationship between pollutant sources and environmental conditions. They assume that BMP recommendations outlined in the Action Plan will be implemented accordingly and will result in the improvement of water quality. Note that the benchmarks for environmental indicators also reflect protection of water quality from any potential impacts from future development in the watershed.

Table 5-2. Environmental Indicators for the Merrymeeting River and Lake watershed management plan.

ENVIRONMENTAL INDICATORS

Indicators	Benchmarks* 2020	2023	2028
Maintain median in-lake total phosphorus of 3.5 ppb at the deep spot of Merrymeeting Lake.	Prevent or offset **5 kg/yr** in phosphorus loading from new or existing development	Prevent or offset **10 kg/yr** in phosphorus loading from new or existing development	Prevent or offset **16 kg/yr** in phosphorus loading from new or existing development
Improve median in-pond total phosphorus to 10 ppb at the deep spot of Marsh, Jones, and Downing Ponds.	Prevent or offset **5 kg/yr** in phosphorus loading from new or existing development	Prevent or offset **10 kg/yr** in phosphorus loading from new or existing development	Achieve **293 kg/yr** reduction in phosphorus with hatchery upgrade; prevent or offset **14 kg/yr** in phosphorus loading from new or existing development
Improve median in-river total phosphorus to 10 ppb in the Merrymeeting River at Alton Bay.	Achieve **20 kg/yr** reduction in phosphorus loading from existing development; prevent or offset **25 kg/yr** in phosphorus loading from new or existing development	Achieve **40 kg/yr** reduction in phosphorus loading from existing development; prevent or offset **50 kg/yr** in phosphorus loading from new or existing development	Achieve **88 kg/yr** reduction in phosphorus loading from existing development; prevent or offset **110 kg/yr** in phosphorus loading from new or existing development
Reduce the occurrence of cyanobacteria or algal blooms.	5% fewer occurrences	10% fewer occurrences	90% fewer occurrences
Improve dissolved oxygen conditions in bottom waters by reducing the extent and duration of anoxia.	5% fewer occurrences	10% fewer occurrences	20% fewer occurrences
Improve or maintain water clarity at the deep spot of Merrymeeting Lake and ponds.	0.1 m	0.2 m	0.5 m
Prevent and/or control the introduction of invasive aquatic species to surface waters.	Absence of invasive aquatic species where they currently do not exist; 5% less coverage where they currently do exist	Absence of invasive aquatic species where they currently do not exist; 10% less coverage where they currently do exist	Absence of invasive aquatic species where they currently do not exist; 20% less coverage where they currently do exist

**Benchmarks are cumulative starting at year 1.*

Programmatic indicators are indirect measures of watershed protection and restoration activities (Table 5-3). Rather than indicating that water quality reductions are being met, these programmatic measurements list actions intended to meet the water quality goal.

Table 5-3. Programmatic Indicators for the Merrymeeting River and Lake watershed management plan.

PROGRAMMATIC INDICATORS

Indicators	Benchmarks*		
	2020	2023	2028
Amount of funding secured from municipal/private work, fundraisers, donations, and grants	$200,000	$800,000	$2,000,000
Number of high priority shoreline sites remediated (13 identified)	2	8	13
Number of medium priority shoreline sites remediated (272 identified)	6	12	24
Number of watershed survey sites remediated (78 identified)	2	15	30
Number of BMP demonstration projects completed	2	3	5
Linear feet of buffers installed in the shoreland zone	500	1,000	2,000
Percentage of shorefront properties with at least one installed conservation practice	25%	50%	75%
Percentage of culverts assessed and prioritized	50%	100%	100%
Percentage of culverts remediated	5%	25%	50%
Percentage of septic system database complete for watershed	25%	50%	100%
Number of updated or new ordinances that target water quality protection	1	2	3
Number of voluntary septic system inspections (seasonal conversion and property transfer)	3	5	10
Number of voluntary septic system dye tests and inspections (watershed residents)	5	10	20
Number of septic system upgrades	1	3	5
Number of septic/stormwater "socials" or workshops held	3	5	10
Number of informational workshops and/or trainings for landowners, town staff, and/or developers/landscapers on local ordinances, watershed goals, and/or best practices	2	5	10
Number of parcels with new conservation easements	1	2	3
Number of copies of watershed-based educational materials distributed or articles published	100	500	1,000
Percentage of shoreline parcels assessed for prioritizing technical assistance	50%	100%	100%
Number of best practices used in road BMPs	1	3	5
Number of new parcels put into permanent conservation	1	3	5
Percentage of mapped and properly managed drainage easements	25%	75%	100%

**Benchmarks are cumulative starting at year 1.*

Social Indicators measure changes in social or cultural practices and behavior that lead to implementation of management measures and water quality improvement (Table 5-4).

Table 5-4. Social Indicators for the Merrymeeting River and Lake watershed management plan.

SOCIAL INDICATORS

Indicators	Benchmarks*		
	2020	2023	2028
Number of new association members	5	15	25
Number of volunteers participating in educational campaigns	10	15	20
Number of people participating in workshops, trainings, or BMP demonstrations	20	50	75
Percentage of shorefront residents installing conservation practices on their property	25%	50%	75%
Number of farmers with approved comprehensive nutrient management plans	1	3	5
Number of representative stakeholders involved on the steering committee	5	10	20
Number of groups or individuals contributing funds for plan implementation	3	5	10
Number of new lake hosts	2	5	10
Number of newly trained VLAP/LLMP volunteers	1	3	5
Number of new weed watchers	2	5	10
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%

**Benchmarks are cumulative starting at year 1.*

5.4 ESTIMATED COSTS & TECHNICAL ASSISTANCE NEEDED

The cost of successfully implementing the plan is estimated at around $2-$3 million over the next ten or more years (Table 5-5). **However, many costs are still unknown and should be incorporated to the Action Plan as information becomes available.** Estimated costs include both structural BMPs, such as fixing roads and planting shoreline buffers, and non-structural BMPs, such as demonstration tours or workshops and ordinance revisions. Annual BMP costs were included within the cost ranges based on a ten-year total for the initial BMP installation plus ten years of maintenance.

Table 5-5. Estimated total and annual 10-year costs for implementation of the Action Plan. Note: many costs were unknown or dependent on further information; therefore, total estimated costs over the next 10 years are likely underestimated.

Category	Estimated Total Cost	Estimated Annual Cost
Water Quality Monitoring	$191,500	$19, 150
Watershed and Shorefront BMPs	$1,776,000 - $2,826,000	$177,600-$282,600
Road Maintenance & Training	$50,000	$5,000
Planning & Land Conservation	$58,000	$5,800
Septic Systems*	$29,250	$2,925
Total Cost	**$2,104,750 - $3,154,750**	**$210,475-$315,475**

**Septic system recommendations do not include design or replacement costs because these should be covered by landowners. Recommendations cover assistance to secure grant funding for those individuals who cannot afford these costs.*

Diverse funding sources and strategies will be needed to implement these recommendations. 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 (Section 319, ARM, Moose Plate, etc.), 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 formation of a funding subcommittee, as well as a steering committee, will be a key part in how funds are raised, tracked, and spent to implement and support the plan. The following list summarizes several possible outside funding options available to implement the watershed management plan:

- **USEPA/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 management plans and typically fund $50,000 to $150,000 projects over the course of two years. http://des.nh.gov/organization/divisions/water/wmb/was/categories/grants.htm
- **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.mooseplate.com/grants/
- **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 and loss of associates functions and values in a watershed. https://www4.des.state.nh.us/arm-fund/

- **New England Forest and River Grant –** 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
- **Milfoil and Other Exotic Plant Prevention Grants (NHDES)** – Funds are available each year for projects that prevent new infestations of exotic plants, including outreach, education, Lake Host Programs, and other activities. http://des.nh.gov/organization/divisions/water/wmb/exoticspecies/categories/grants.htm
- **Clean Water State Revolving Loan Fund (NHDES)** – 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 nonpoint source, watershed protection and restoration, and estuary management projects that help improve and protect water quality in New Hampshire. http://des.nh.gov/organization/divisions/water/wweb/grants.htm

5.5 EDUCATIONAL COMPONENT

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. As detailed in Sections 1.4 and 1.5, much effort is already being done in the watershed to enhance public understanding of the plan and encourage community participation in watershed restoration and protection activities. In addition to the meetings identified in Section 1.4, the following outreach events were hosted by the CMSC:

- Cyanobacteria in the Merrymeeting River to the Alton/New Durham. Rotary Club, Alton, December 2016.
- Cyanobacteria and excess phosphorus in the watershed presented as an informational session to residents of New Durham and Alton by Pat Tarpey. New Durham, April 13, 2017.
- Cyanobacteria identification by the EPA. Alton Bay, July 2017
- A threat to our watershed presented to the Regional Town Administrators Meeting. New Durham, August 2017.
- New Durham informational session on phosphorus pollution in the waterways. New Durham, September 2017
- Cyanobacteria: what it is and how it can affect you. Alton Garden Club, April 2018.
- Preparing for a watershed management plan. New Durham Board of Selectmen, May 23, 2018.
- Preparing for a watershed management plan. Alton Board of Selectmen, May 24, 2018.
- Public session on hatchery best management practices. New Durham, July 10, 2018.
- Section 319 Funding. Alton and New Durham Selectmen, Alton, March 14, 2019.
- Septic Sense informational session for residents of Alton and New Durham. Alton, June 30, 2019.

CMSC also partnered with the Lake Winnipesaukee Association (LWA) in 2019 to send AmeriCorps interns to private landowners to assess stormwater runoff and provide recommendations for stormwater management. CMSC has also supplied a collection of papers, fact sheets, and books related to water quality protection in the New Durham Public Library. The materials can be copied at the library at the expense of CMSC.

CMSC and the Towns of Alton and New Durham are the primary entities for education and outreach campaigns in the watershed and for development and implementation of the plan. These stakeholders should continue all aspects of their education and outreach programs 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 specific to the five categories are detailed in the Action Plan (Section 5.2).

ADDITIONAL RESOURCES

A Shoreland Homeowner's Guide to Stormwater Management. New Hampshire Department of Environmental Services. NHDES-WD-10-8. Online: https://www.des.nh.gov/organization/commissioner/pip/publications/wd/documents/nhdes-wd-10-8.pdf

Buffers for wetlands and surface waters: a guidebook for New Hampshire municipalities. Chase, et al. 1997. NH Audubon Society. Online: https://www.nh.gov/oep/planning/resources/documents/buffers.pdf

Conserving your land: options for NH landowners. Lind, B. 2005. Center for Land Conservation Assistance / Society for the Protection of N.H. Forests. Online: https://forestsociety.org/sites/default/files/ConservingYourLand_color.pdf

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. Online: http://www.maine.gov/dep/land/watershed/camp/road/gravel_road_manual.pdf

Gravel roads: maintenance and design manual. U.S. Department of Transportation, Federal Highway Program. November 2000. South Dakota Local Transportation Assistance Program (SD LTAP). Online: https://www.epa.gov/sites/production/files/2015-10/documents/2003_07_24_nps_gravelroads_gravelroads.pdf

Innovative land use techniques handbook. New Hampshire Department of Environmental Services. 2008. Online: https://www.nh.gov/oep/resource-library/planning/documents/innovative-land-use-planning-techniques-2008.pdf

Landscaping at the water's edge: an ecological approach. University of New Hampshire, Cooperative Extension. 2007. Online: https://extension.unh.edu/resources/files/resource004159_rep5940.pdf

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 March 2016. Online: https://www.des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-11-11.pdf

Protecting water resources and managing stormwater. University of New Hampshire, Cooperative Extension & Stormwater Center. March 2010. Online: https://extension.unh.edu/resources/files/Resource002615_Rep3886.pdf

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