


MOULTONBOROUGH BAY & WINTER HARBOR

WATERSHED MANAGEMENT PLAN

SEPTEMBER 2020


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WATERSHED MANAGEMENT PLAN

Prepared by **FB ENVIRONMENTAL ASSOCIATES**
in cooperation with the Lake Winnipesaukee Association, DK Water Resource Consulting, and Horsley Witten Group

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Cover photos taken by FBE staff during the shoreline survey and FBE staff/Lake Winnipesaukee resident Antonia Sohns.

EXECUTIVE SUMMARY

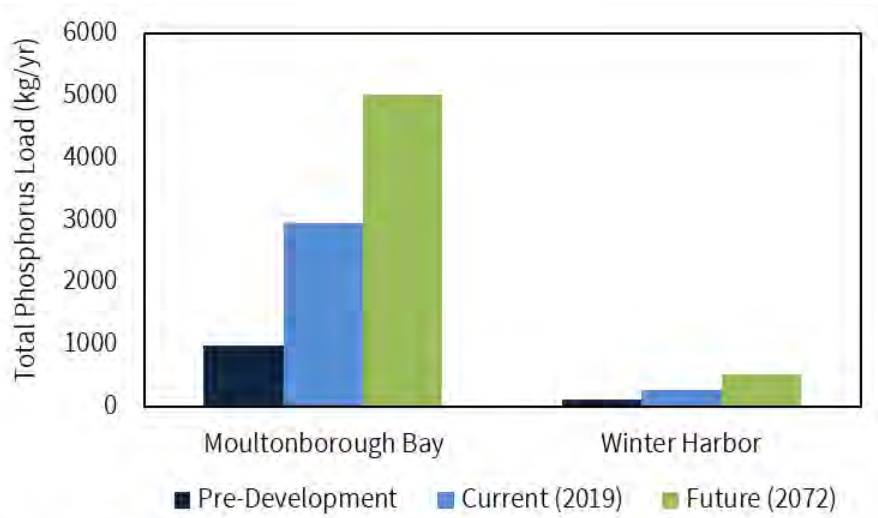
Lake Winnipesaukee is a 44,586-acre (70 sq.mi.) lake located in central NH, with a 215,133-acre (336 sq.mi.) watershed area that includes the 29,870-acre (47 sq.mi.) Moultonborough Bay watershed and the 5,095-acre (8 sq.mi.) Winter Harbor watershed (see map on page v). Lake Winnipesaukee is classified as an **oligotrophic** lake and is the second clearest lake in New Hampshire. Lake Winnipesaukee supports a thriving population of both cold and warm water species including but not limited to rainbow trout, land locked salmon, lake trout, and small and large mouth bass. The only recorded invasive aquatic plant species present in Lake Winnipesaukee is variable milfoil which was first reported in 1965. Vigilant weed watchers and boaters are helping to keep the lake and its bays and harbors free from additional invasive aquatic species. Lake Winnipesaukee is an important recreational destination for many residents and visitors for boating, fishing, hiking, swimming, and more. The Lake is host to approximately 80 registered bass tournaments annually in addition to the "Winni Derby", a three-day, open-water salmon and lake trout derby that attracts approximately 3,000 anglers (Lake Winnipesaukee Association, LWA). The Lake is alive in the winter with an annual "Meredith Rotary Ice-Fishing Derby" held in February that attracts thousands of hard-water anglers (LWA).

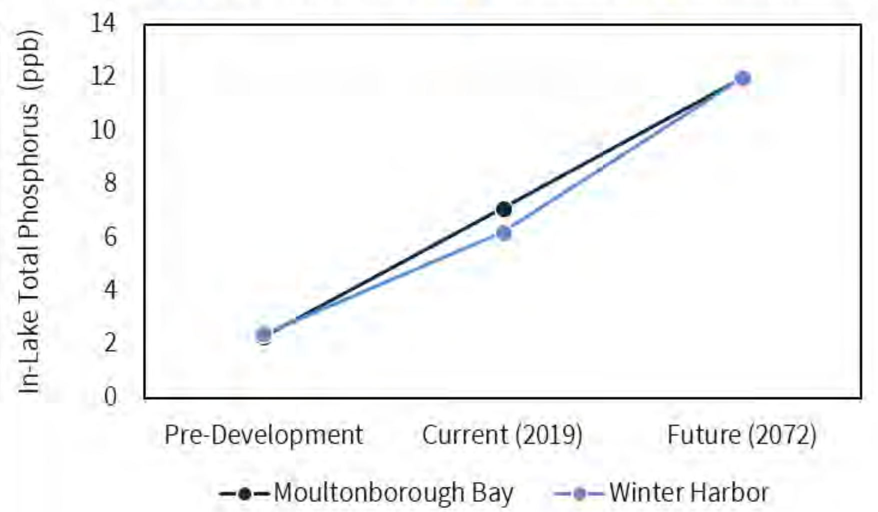
Despite its classification as an oligotrophic waterbody, the lake is currently listed on the 303(d) NH List of Impaired Waters due to the occurrence of cyanobacteria. *Gloeotrichia (Gloeotrichia echinulata)* blooms have been observed in Winter Harbor, as well as other embayments on Lake Winnipesaukee, and represent a threat to water quality and lake health. The NH Department of Environmental Services (NHDES) uses a tool called **assimilative capacity analysis** to assess water quality in the context of current state criteria. While the assimilative capacity for Moultonborough Bay and Winter Harbor indicate that all sites attain state designation for high quality waters, a closer look at near-shore sites and land use modeling indicate that both these bays are at risk for continued water quality degradation from future development under current zoning. The combined effects of increased development and climate change will likely continue to support the prevalence of potentially-toxic cyanobacteria in these waterbodies.

"The combined effects of **increased development** and **climate change** will likely continue to support the prevalence of potentially-toxic cyanobacteria in these waterbodies."

Given the importance of Lake Winnipesaukee as a recreational destination and its current cyanobacteria impairment, the Lake Winnipesaukee Association (LWA), in partnership with the Lakes Region Planning Commission, launched the "Winnipesaukee Gateway" project to bring together restoration and management of the big lake. Through the Gateway, LWA is creating Watershed-Based Management Plans (WMPs) for individual embayments along the lake. Focusing on smaller sub-sections of the big lake can tailor management recommendations to individual communities and water quality concerns. This Plan is written to address the Moultonborough Bay and Winter Harbor watersheds, located in Moultonborough, Tuftonboro, and Wolfeboro on the northern side of the lake. The Moultonborough Bay and Winter Harbor Watershed Management Plan provides a roadmap for improving the water quality of surface waters within the Moultonborough Bay and Winter Harbor watersheds and can be used as a mechanism for procuring funding (e.g., Section 319 grants) to secure actions needed to achieve the water quality goal. The United States Environmental Protection Agency (USEPA) requires that a nine-element watershed plan be created so that communities become eligible for federal watershed assistance grants.

As part of the development of this plan, a build-out analysis, Lake Loading Response Model analysis, water quality and assimilative capacity analysis, and shoreline/watershed surveys were conducted (Section 3). A buildout analysis detects areas within the watersheds with development potential and identifies how much development can occur and at what densities (Section 3.3.3). **The buildout analysis results indicated that under current zoning within Moultonborough, Tuftonboro, and Wolfeboro, 56% (16,770 acres) of the Moultonborough Bay and Winter Harbor watersheds is buildable area and has the potential to be developed.** Upon reaching full build-out – the theoretical point in time when all available land has been developed to the maximum capacity permitted by current local ordinances and current zoning standards – an estimated additional 6,385 additional buildings could be constructed within the watersheds. At a compound annual growth rate of 2.23%, full build-out in these watersheds is estimated to occur by the year 2072 (see figures to the right).

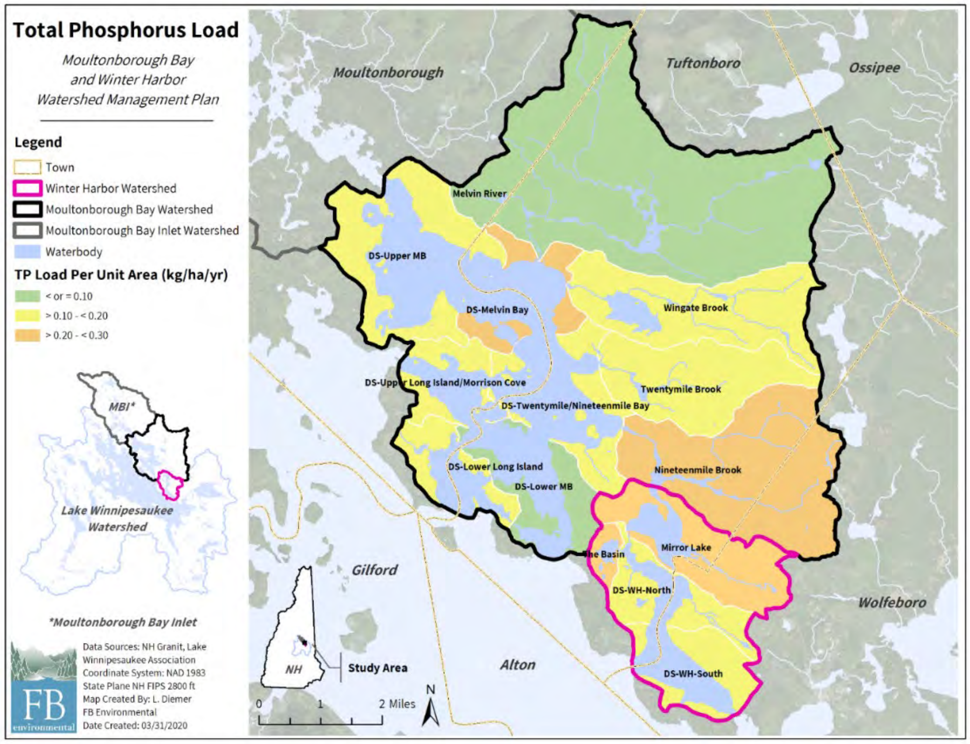




Change in total phosphorus load (kg/yr, **TOP**) and in-lake total phosphorus concentration (ppb, **BOTTOM**) for Moultonborough Bay and Winter Harbor from pre-development to current (2019) to future (2072) conditions.

Results of the build-out analysis, as well as a septic system survey 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 Moultonborough Bay and Winter Harbor (Section 3.3.2). Current modeled total phosphorus load to Moultonborough Bay is 2,951 kg/yr and is 271 kg/yr for Winter Harbor. Based on model analysis of pre-development, current, and future water quality conditions, both Moultonborough Bay and Winter Harbor are at risk for continued water quality degradation from future development under current zoning. The model results show that watershed runoff combined with baseflow was the largest phosphorus loading contribution across all sources to Moultonborough Bay and Winter Harbor. **Future loading estimation indicate that total phosphorus loading may increase by 70% at full build-out (estimated as early as 2072)** within the watershed. Water quality degradation of the basins will likely be accelerated by additional phosphorus loading from the watershed and internal sediments. Modeled total phosphorus load was highest for the direct drainage to Melvin Bay, the Nineteenmile Brook sub-watershed, the Mirror Lake sub-watershed, and the area draining to the Basin (see map on the following page). These additional model results can help watershed managers prioritize restoration efforts in areas with greater total phosphorus input to the lake.

To identify possible sources of pollution across these two watersheds, watershed and shoreline surveys of Moultonborough Bay and Winter Harbor were completed in 2019 (Section 3.5.4). The field surveys identified **107 pollutant sites** in the watershed and **717 high to medium impact rated shoreline properties**. Watershed sites have been prioritized for remediation based on the estimated total phosphorus load reduction from the recommended action, the cost, and the observed site impact. Finally, as part of development of this plan, recent water quality data for key parameters – dissolved oxygen, temperature, secchi disk transparency, total phosphorus, and chlorophyll-a – have been summarized and this summary is available in Section 3.2.



A map of modeled current total phosphorus (TP) load per unit area (kg/ha/yr) for each sub-watershed in the Moultonborough Bay and Winter Harbor watersheds. Watershed managers can use TP loading maps to help prioritize restoration.

An Action Plan (Section 5.2) with associated timeframes, responsible parties, and estimated costs was developed in collaboration with the steering committee. Completing the action items set forth in the Action Plan will help achieve the water quality goal and objectives set by the watershed community. Management strategies for achieving the water quality goal and objectives involve using a combination of structural and non-structural Best Management Practices (BMPs), as well as an adaptive management approach that allows for regular updates to the plan (refer to Section 4). More specifically, this Plan includes the following key recommendations for success:

(1) **Enhance the existing baseline lake and tributary monitoring program** with increased volunteers to ensure consistency in data collection at existing sampling stations.

(2) **Expand the water quality monitoring program** to include sample collection in the spring (immediately following ice-out) and during turnover in the fall. Consider collecting winter data under the lake ice for phytoplankton enumeration and speciation.

(3) **Support nearshore investigative studies** aimed at identifying localized sources of phosphorus in cyanobacteria hotspots.

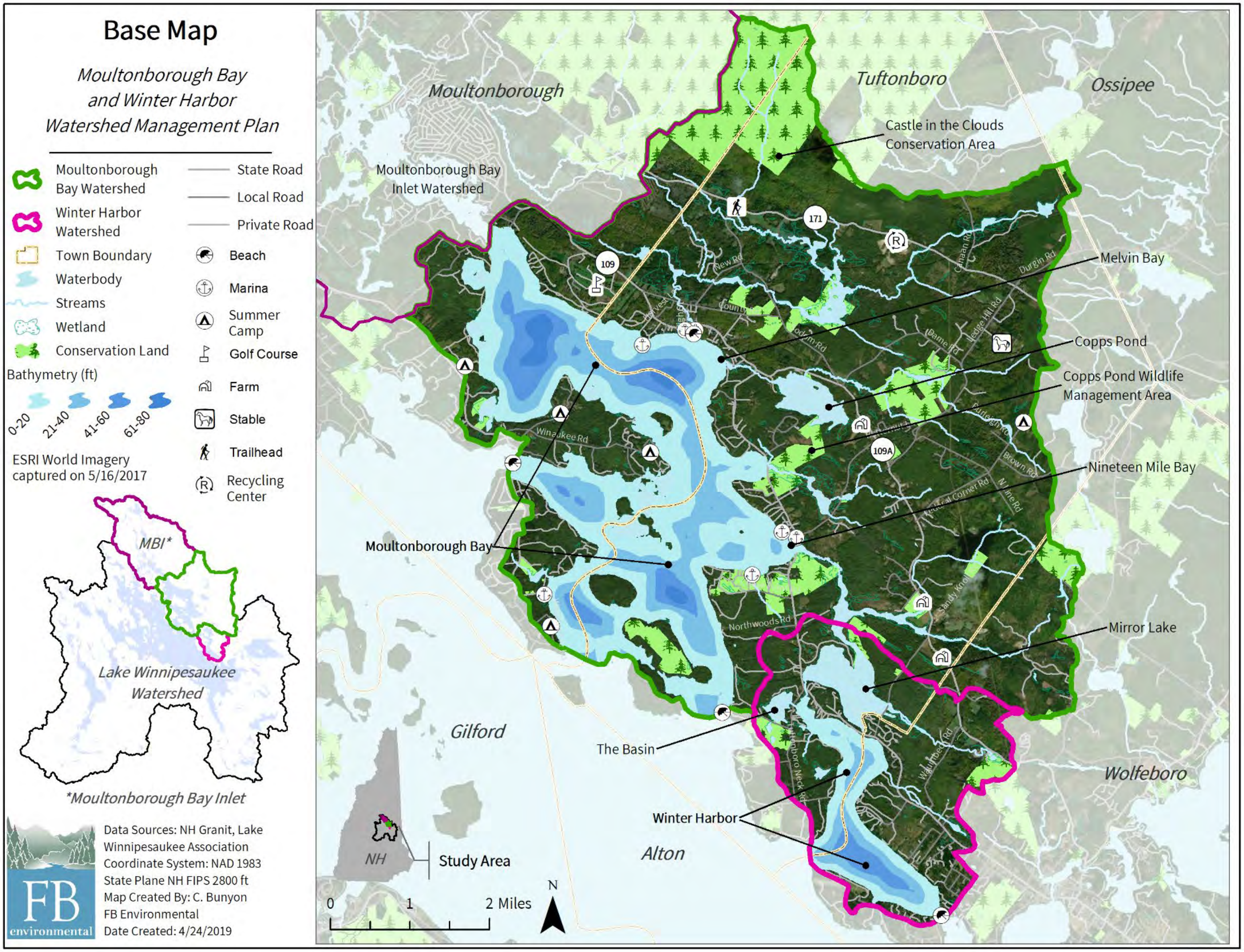
(4) **Address priority pollutant sites** and identify funding for the three conceptual BMP concept designs completed through this planning process. Identify funding for remaining high priority watershed and shoreline pollution sites.

(5) **Review the gaps in municipal ordinances**, outlined on pages 70-71, and identify strategies for strengthening town ordinances in each community that will improve natural resource protection.

(6) **Enhance watershed resident education and communication of local land ordinances** and actionable best management practices for private property.

The success of this plan is dependent on the continued effort of volunteers, and a strong and diverse steering committee that meets regularly to coordinate resources for implementation, review progress, and make any necessary adjustments to the plan to maintain relevant action items and interim benchmarks. Measurable milestones (number of BMP sites, volunteers, funding received, etc.) should be tracked by a steering committee and reported to the 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 rivers, lakes, 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.


Base Map
Moultonborough Bay and Winter Harbor Watershed Management Plan
Moultonborough Bay Watershed
Winter Harbor Watershed
Town Boundary
Waterbody
Streams
Wetland
Conservation Land
Bathymetry (ft)
0-20
21-40
41-60
61-80
ESRI World Imagery captured on 5/16/2017
State Road
Local Road
Private Road
Beach
Marina
Summer Camp
Golf Course
Farm
Stable
Trailhead
Recycling Center
MBI*
Lake Winnipesaukee Watershed
*Moultonborough Bay Inlet
Data Sources: NH Granit, Lake Winnipesaukee Association
Coordinate System: NAD 1983 State Plane NH FIPS 2800 ft
Map Created By: C. Bunyon
FB Environmental
Date Created: 4/24/2019
Moultonborough
Tuftonboro
Ossipee
Castle in the Clouds Conservation Area
Moultonborough Bay Inlet Watershed
Melvin Bay
Copps Pond
Copps Pond Wildlife Management Area
Nineteen Mile Bay
Moultonborough Bay
Mirror Lake
The Basin
Winter Harbor
Gilford
Alton
Wolfeboro
NH
Study Area
0
1
2 Miles
N

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LIST OF ABBREVIATIONS

ACRONYM	DEFINITION
ALI	Aquatic Life Integrity
ARM	Aquatic Resource Mitigation fund
BMP	Best Management Practice
CALM	Consolidated Assessment & Listing Methodology
CHL-A	Chlorophyll-a
CWA	Clean Water Act
CWSRLF	Clean Water State Revolving Loan Fund
DO	Dissolved Oxygen
EMD	Environmental Monitoring Database
ESRI	Environmental Systems Research Institute
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
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
PCS	Potential Contamination Source
ppb, ppm	parts per billion, parts per million
PS	Point Source Pollution
RCRA	Resource Conservation and Recovery Act
RIB	Rapid Infiltration Basin
SCC	State Conservation Committee
SDT	Secchi Disk Transparency
TP	Total Phosphorus
UNH	University of New Hampshire
USEPA	United States Environmental Protection Agency
USLE	Universal Soil Loss Equation
VLAP	Volunteer Lake Assessment Program
VRAP	Volunteer River Assessment Program
WWTP	Wastewater Treatment Plant

DEFINITIONS

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

Anoxia is a condition of low dissolved oxygen.

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

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

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

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

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

Cyanobacteria are photosynthetic bacteria that can grow prolifically as blooms when enough nutrients are available. Some cyanobacteria can fix nitrogen and/or produce toxins harmful to humans and other life forms., 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 can experience periods of low oxygen during stratification, is colder, 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 typically released back into the water column during periods of anoxia. The phosphorus can be used as fuel for plant and algae growth, creating a positive feedback to eutrophication.

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

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

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

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

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

Riparian 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 mass of algae or amount of algal growth 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 & PURPOSE

Lake Winnipesaukee is a 44,586-acre lake located in central New Hampshire (NH), with a 215,133-acre watershed area that includes the 29,870-acre Moultonborough Bay watershed and the 5,095-acre Winter Harbor watershed. The lake and its embayments are currently listed on the NHDES 303(d) List of Impaired Waters as impaired for primary contact recreation due to elevated levels of **cyanobacteria** hepatoxic microcystins. *Gloeotrichia (Gloeotrichia echinulata)* (a species of cyanobacteria) blooms have been observed in Winter Harbor, as well as other embayments on Lake Winnipesaukee, and represent a threat to water quality and lake health. A cyanobacteria warning for Winter Harbor was issued by NHDES from August 30, 2018 to September 21, 2018 when areas along the southern shoreline near Whitegate Road showed evidence of a *Gloeotrichia* bloom. Based on modeling and field surveying presented in this plan, both Moultonborough Bay and Winter Harbor are at risk for continued water quality degradation from future development under current zoning. The combined effects of increased development and climate change will likely continue to exacerbate the prevalence of potentially-toxic cyanobacteria in these waterbodies. 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 Moultonborough Bay and Winter Harbor watersheds. These actions will ensure continued ecosystem health and recreational enjoyment by current and future generations.

WHAT IS non-point source (NPS) pollution? Nonpoint source pollution is pollution that enters the lake from diffuse sources throughout a watershed, such as stormwater runoff, seepage from septic systems, and gravel road erosion. One of the major components of pollution is sediment, which contains a mixture of nutrients (like phosphorus) and inorganic and organic material that stimulate plant and algae growth.

The Moultonborough Bay and Winter Harbor 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 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 federal 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 linked watershed land-use, or Lake Loading Response Model (LLRM), that estimated the pre-development, current, and projected future amount of **total phosphorus** delivered to these two embayments 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 the steering committee and the resultant annual average total phosphorus concentrations in the embayments. A public forum was initially scheduled to discuss the Action Plan and receive feedback from the community; however, this forum was canceled due to concerns with public gatherings in the face of COVID-19. The public forum was replaced with individual outreach to community members within the watershed and sharing of a homeowner's guide to assist residents with the implementation of residential BMPs.

1.2 STATEMENT OF GOAL

We have presented the water quality goals for Moultonborough Bay and Winter Harbor as two-fold.

Goal 1: To improve water quality in both Moultonborough Bay and Winter Harbor through a 5% reduction in current total phosphorus loads to meet an average seasonal (May 24-Sept 15) deep spot epilimnion concentration of 6.7 ppb and 5.9 ppb in Moultonborough Bay and Winter Harbor, respectively.

- To maintain current water quality in Moultonborough Bay, 39 kg/yr of total phosphorus must be removed to offset the anticipated increase in annual inputs over the next 10 years plus an additional 148 kg/yr to meet the 5% reduction target. <u>This sums to a reduction total of 187 kg/yr for Moultonborough Bay in the next 10 years</u>.
- To maintain current water quality in Winter Harbor, 4.7 kg/yr of total phosphorus must be removed to offset the anticipated increase in annual inputs over the next 10 years plus an additional 14 kg/yr to meet the 5% reduction target. <u>This sums to a reduction total of 18.7 kg/yr for Winter Harbor in the next 10 years.</u>

Goal 2: To assess the spatial and temporal distribution and causes of *Gloeotrichia* blooms observed in Lake Winnipesaukee (and most notably in the Winter Harbor basin) and determine geographically specific water quality objectives to reduce the occurrence of localized blooms.

- Quantify (through enumeration and speciation) the presence of *Gloeotrichia* at nearshore sites in Moultonborough Bay and Winter Harbor during bloom events (including within column, surface scum, and benthic algae).
- Identify long-term beach profiling sites to determine the contribution of shoreline erosion to localized total phosphorus concentrations in both Moultonborough Bay and Winter Harbor (Rando et. al., 2017).
- Enhance water quality monitoring at nearshore sites with sampling in spring, summer, and fall to identify the seasonal effects of localized total phosphorus.

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 Moultonborough Bay and Winter Harbor and describes the results of the watershed and shoreline surveys conducted in the summer and fall of 2019. 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 Moultonborough Bay and Winter Harbor and the amount of reduction needed to meet the water quality goal. **Section 4** describes how estimated phosphorus load reductions to Moultonborough Bay and Winter Harbor 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 Moultonborough, Tuftonboro, and Wolfeboro, NHDES, and USEPA), local groups (Lake Winnipesaukee Association (LWA)), private donations, and landowner contributions for BMP implementation on private property. The towns of Moultonborough, Tuftonboro, and Wolfeboro, and other core stakeholders, led by the LWA, should oversee the planning effort by meeting regularly and efficiently coordinating resources to achieve the Plan objectives.

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 LWA and the three towns.

F. **SCHEDULE FOR ADDRESSING PHOSPHORUS REDUCTIONS: Section 5.2** provides a list of action items and recommendations to reduce the phosphorus load to Moultonborough Bay and Winter Harbor. 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. 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 5.4** 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 Moultonborough Bay and Winter Harbor, 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 occurrence of cyanobacteria blooms. 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 LWA, NHDES, the USEPA, representatives from the towns of Moultonborough, Tuftonboro, and Wolfeboro, and private landowners (see Acknowledgments).

Five meetings were held over the duration of the plan development. The following list does not include routine annual meetings conducted separately by LWA.

- **June 20, 2018:** Held a project kick-off meeting with LWA, consultants, and steering committee members to review project objectives, timeline, and strategy.
- **March 6, 2019:** LWA presented the revised landcover analysis, subwatershed delineation, and assimilative capacity to the steering committee.
- **September 19, 2019:** FBE met with the project steering committee to review the preliminary results of the LLRM and the results of the watershed and shoreline survey work completed in the summer of 2019.
- **April 10, 2020:** FBE and LWA met with the steering committee to review the final results of the LLRM and to present the conceptual design plans for the four identified candidate sites for BMP implementation projects. BMP implementation projects were presented by sub-contracting engineers, Horsley Witten Group (HWG).
- **September 24, 2020:** The final public meeting to review the full plan was held on September 24, 2020 as a webinar.

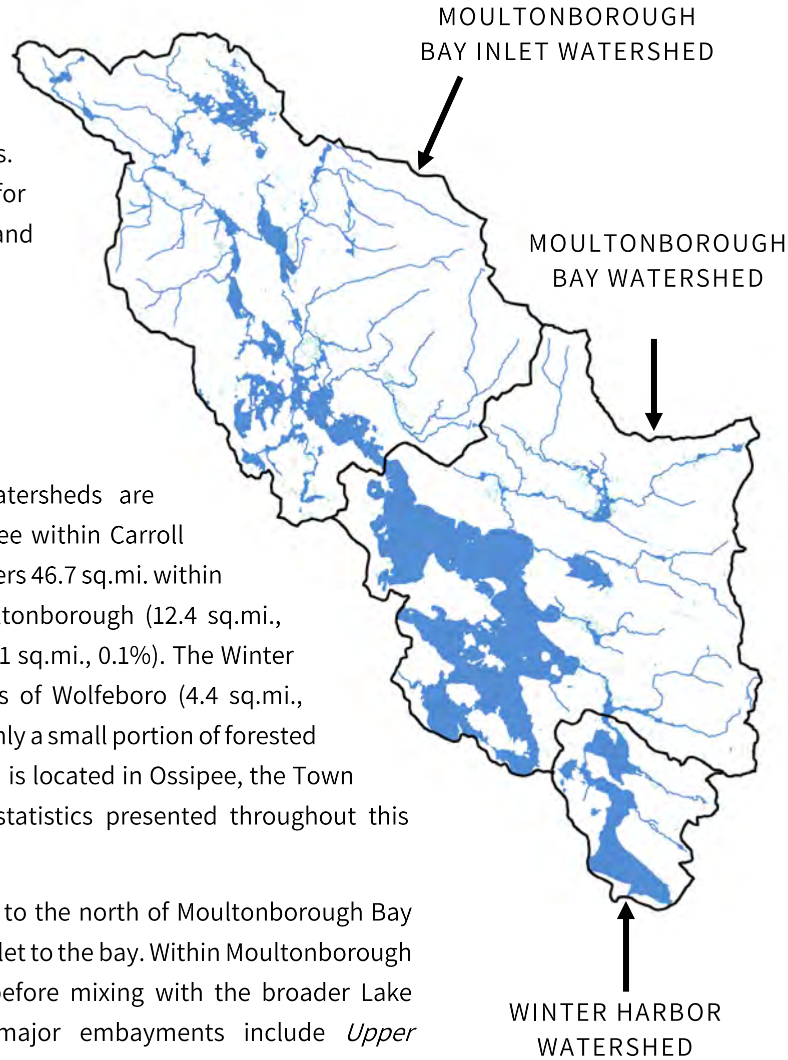
1.5 WATERSHED PROTECTION GROUPS

LWA is a non-profit organization "…dedicated to protecting the water quality and natural resources of Lake Winnipesaukee and its watershed" (Lake Winnipesaukee Association, n.d.). LWA, in partnership with the Lakes Region Planning Commission, created the "Winnipesaukee Gateway", a webpage designed to house all of the plans, reports, maps, water quality data, and recreational opportunities on Lake Winnipesaukee (Winnipesaukee Gateway, 2020). Watershed management plans for the lake are being completed on a sub-watershed basis (such as Moultonborough Bay and Winter Harbor). This approach allows geographically-specific plans that address the complex physical structure and shape of Winnipesaukee, with many different embayments, land uses, and development characteristics. At the time of this plan's publication, three plans had been completed on Lake Winnipesaukee: (1) *Meredith, Paugus and Saunders Bay*, (2) *Waukewan Winona Watershed Restoration Plan (2016)*, and (3) *Moultonborough Bay Inlet Watershed Restoration Plan (2017)*. Additionally, a plan was recently completed for the Merrymeeting Lake and River in Alton and New Durham, NH, a plan was completed for Mirror Lake (within the Winter Harbor watershed) in Tuftonboro, NH (Geosyntec, 2012), and a plan was created in 2012 for Lake Wentworth. Lake Winnipesaukee has over 25 volunteer water quality monitors responsible for 30 sampling sites on the lake. Water quality monitoring is coordinated through the University of New Hampshire Cooperative Extension "Lakes Lay Monitoring Program" (UNH LLMP).

NHDES works with local organizations to improve water quality in NH 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 and by investigating actual and potential NPS water contamination problems, among other activities.

2. WATERSHED CHARACTERIZATION

This section provides information on the local climate, demographic history, past and present land cover, underlying soil and geographical characteristics, bathometric and morphometric descriptions, and habitats and wildlife within the Moultonborough Bay and Winter Harbor watersheds. This information helped to guide goal development for protecting the water quality of Moultonborough Bay and Winter Harbor.



2.1 POPULATION, GROWTH TRENDS, AND LAND COVER

2.1.1 Watershed and Climate

The Moultonborough Bay and Winter Harbor watersheds are located on the eastern shores of Lake Winnipesaukee within Carroll County, NH. The Moultonborough Bay watershed covers 46.7 sq.mi. within the towns of Tuftonboro (31.9 sq.mi., 68.4%), Moultonborough (12.4 sq.mi., 26.6%), Wolfeboro (4.4 sq.mi., 4.9%), and Ossipee (0.1 sq.mi., 0.1%). The Winter Harbor watershed covers 8 sq.mi. within the towns of Wolfeboro (4.4 sq.mi., 55.6%) and Tuftonboro (3.5 sq.mi., 44.4%). Because only a small portion of forested land area within the Moultonborough Bay watershed is located in Ossipee, the Town of Ossipee will not be included in the summary statistics presented throughout this document.

The Moultonborough Bay Inlet watershed is located to the north of Moultonborough Bay beyond Clark's Landing and represents the primary inlet to the bay. Within Moultonborough Bay, water flows through six major embayments before mixing with the broader Lake Winnipesaukee beyond Cow Island. These six major embayments include *Upper Moultonborough Bay*, *Melvin Bay*, *Upper Long Island & Morrison Cove*, *Twentymile & Nineteenmile Bay*, *Lower Moultonborough Bay*, and *Lower Long Island*. Inlet waters for Winter Harbor include the Basin, Mirror Lake, and overland flow. Water in Winter Harbor mixes with the Lake Winnipesaukee Broads (The Broads refers to the open, central region of Lake Winnipesaukee) past Thomas and Ayers Points.

Situated within a temperate zone of converging weather patterns from the hot, wet southern regions and the cold, dry northern regions, the Lake Winnipesaukee Region experiences various natural phenomena such as severe thunder and lightning storms, and heavy snowfalls. The area experiences moderate to high rainfall and snowfall, averaging 49.2 inches of precipitation annually. Temperature generally ranges from -5 °F to 85 °F with an average of 19°F in winter and 65°F in summer (NOAA NCEI, 2019; Figure 2-1).

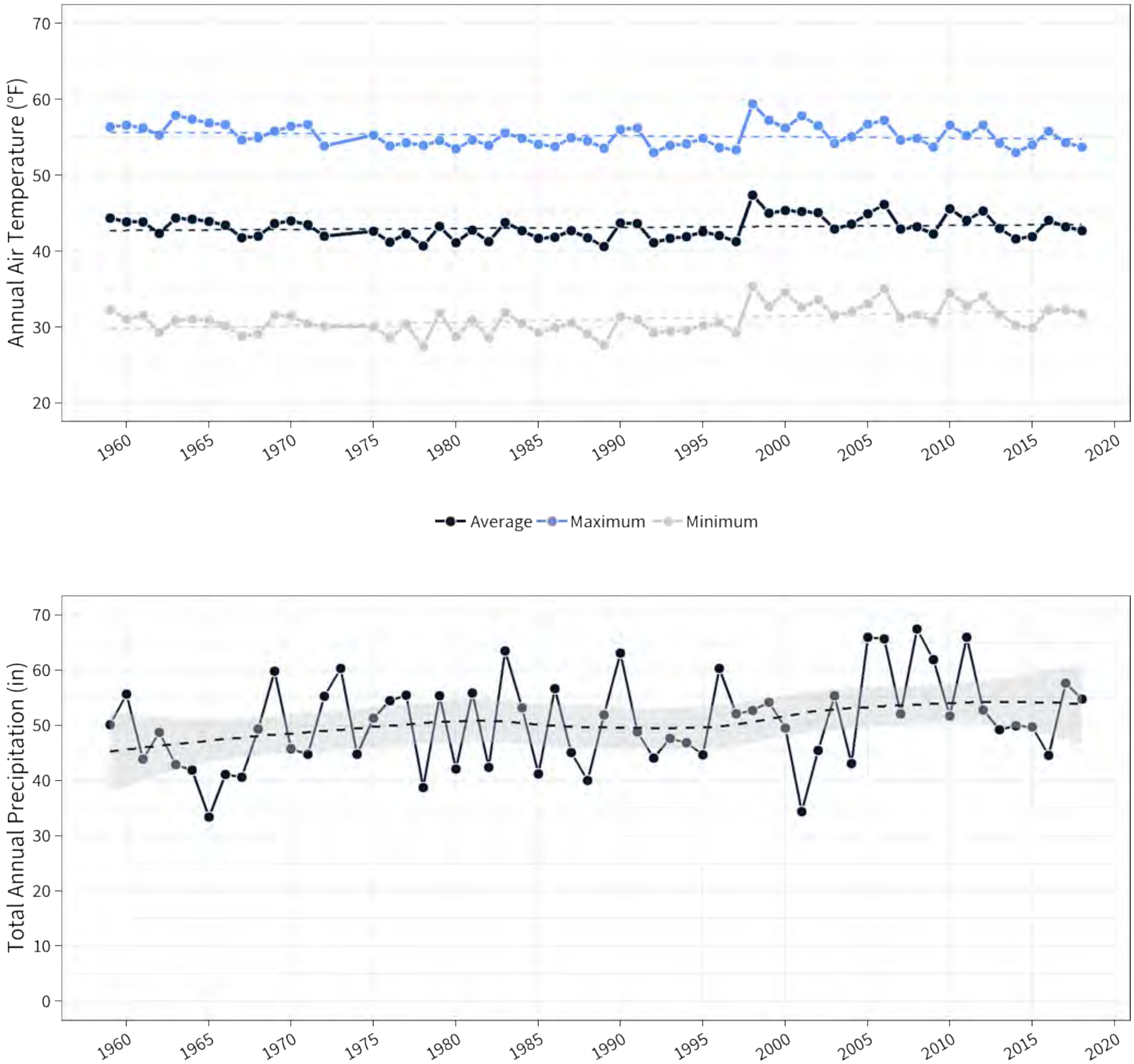


Figure 2-1. Total annual air temperature (top) and precipitation (bottom) from 1959 through 2018 for the Tamworth weather stations (Station ID: USC00278610, USC00278612, USC00278614) with data gaps covered by weather stations in Conway, NH (USUSC00271732), Lakeport, NH (USC00274480), and Rumney, NH (USC00279474) (NOAA NCEI, 2019).

2.1.2 Population and Growth Trends

Lake Winnipesauke, along with Moultonborough Bay and Winter Harbor, have been long treasured as a recreational haven for summer vacationers and year-round residents. The area is one of the oldest summer vacation spots in NH and offers lifeguarded beaches, fishing, hiking, boating, sailing, canoeing, kayaking, and swimming, in the summer, and ice fishing, cross-country skiing, snowshoeing, and snowmobiling in the winter. The Moultonborough Bay watershed makes up 65% of the total area within Tuftonboro, 17% within Moultonborough, and 4% within Wolfeboro. The Winter Harbor watershed makes up 8% of the total area within Wolfeboro and 7% within Tuftonboro. According to the most recent US census in 2010, most housing units within towns of Moultonborough (61%) and Tuftonboro (53%) support a seasonal population (Figure 2-2, Table 2-1). Wolfeboro also supports a significant seasonal population (30%). These seasonal residents continue to flock to the Moultonborough Bay and Winter Harbor watersheds (from Independence Day to Labor Day) to utilize various amenities around the lake including, private and public beaches, marinas, summer camps, cottages, a golf course, and a variety of on-lake boating activities. There is limited public transportation in the area, and most people use personal vehicles in their daily routines.

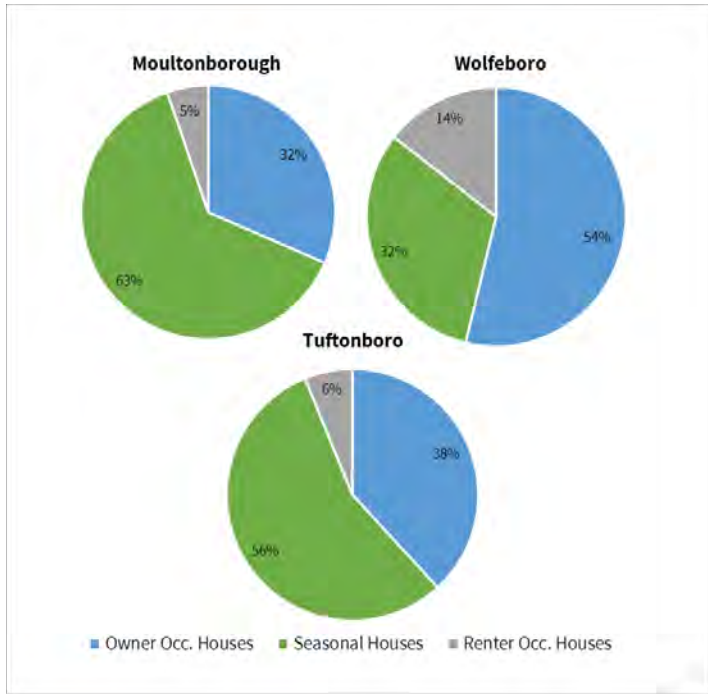


Figure 2-2. Housing unit demographics for Moultonborough, Tuftonboro, and Wolfeboro, based on total occupied houses (owner or renter occupied) plus seasonal houses.

Understanding population growth and demographics, and ultimately development patterns, provide critical insight to watershed management, particularly as it pertains to lake water quality. According to the U.S. Census Bureau, the population of Carroll County in 2010 was 47,698, representing a 9% increase in population since the 2000 census (NHOEP, 2019; Table 2-2, Figure 2-3). From 1960 to 2010, the population of Moultonborough grew exponentially at an average rate of 911 residents every decade, Wolfeboro at an average of 849 residents, and Tuftonboro at an average of 368 residents. From 2000 to 2010, the population of Moultonborough decreased by 440 residents, while the populations of Tuftonboro and Wolfeboro increased by 239 and 186 residents, respectively. The decrease in population in Moultonborough could be attributed to the dispersal of young adults out of the watershed communities. There were 602 residents in 2000 within the 10-19 age group but only 241 residents in 2010 within the 20-29 age group (NHOEP, 2011) (Table 2-1).

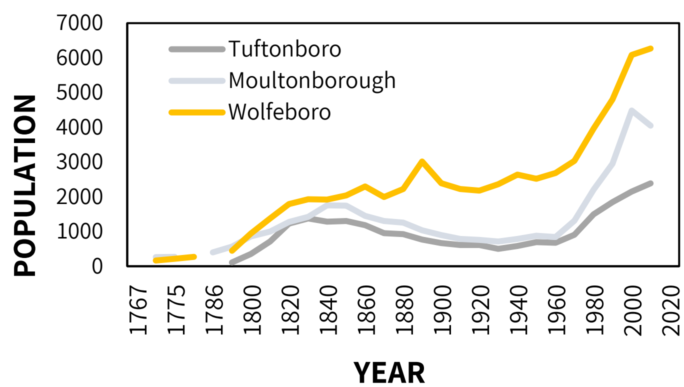


Figure 2-3. Historical demographic data for the Towns of Moultonborough, Tuftonboro, and Wolfeboro. The population of this community has grown dramatically over the last 60 years.

The desirability of the towns of Moultonborough, Tuftonboro, and Wolfeboro as seasonal destinations is congruent with many other lake front communities in the Lakes Region of NH. Growth figures show an influx of residents to the Moultonborough Bay and Winter Harbor communities from 1960 to 2000 that slowed or decreased from 2000 to 2010 (Figure 2-3, Table 2-2). Because of this historical growth pattern, communities within the watershed 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 and an increase in impervious cover raises the potential for water quality decline (refer to Section 3.3.3 for Build-Out Analysis results).

Table 2-1. 2010 population demographics for watershed communities of Moultonborough, Tuftonboro, and Wolfeboro.

State/County/ Town	Total Population	Aged 0-19	Aged 20-64	Aged 65+	Total Housing Units	Total Occ. Houses	Owner Occ. Houses	Seasonal Houses	Renter Occ. Houses
New Hampshire	1,316,470	325,802	730,446	178,268	614,754	518,973	368,316	63,910	150,657
Carroll County	47,818	9,798	24,072	9,838	39,813	21,052	16,665	16,794	4,387
Moultonborough	4,044	828	1,887	905	4,940	1,741	1,492	2,991	249
Tuftonboro	2,387	477	1,127	565	2,435	1,029	886	1,293	143
Wolfeboro	6,269	1,233	2,745	1,756	4,443	2,839	2,238	1,322	601

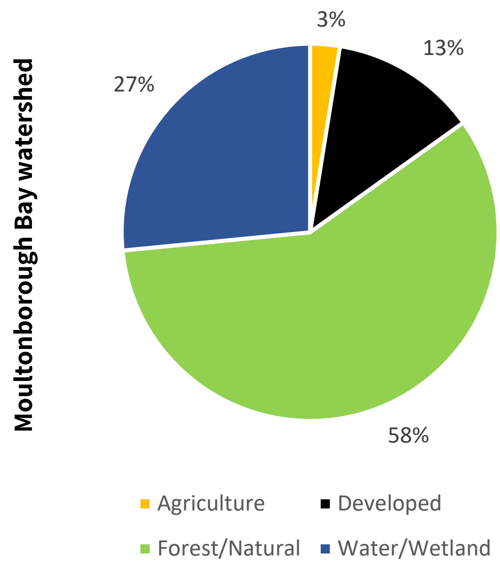
Table 2-2. Population estimates and growth rates for the communities of Moultonborough, Tuftonboro, and Wolfeboro.

TOWN	1960	1970	1980	1990	2000	2010	50-Yr Growth Rate (1960-2010)	20-Yr Growth Rate (1990-2010)	10-Yr Growth Rate (2000-2010)
Carroll County	15,821	18,548	27,929	35,410	43,608	47,698	201%	35%	9%
Tuftonboro	678	910	1,500	1,842	2,148	2,387	252%	30%	11%
Moultonborough	840	1,310	2,206	2,956	4,484	4,044	381%	37%	-10%
Wolfeboro	2,689	3,036	3,968	4,807	6,083	6,269	133%	30%	3%

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

Current land cover in the Moultonborough Bay and Winter Harbor watersheds was determined using a combination of land cover data from NH GRANIT's NH Land Cover Assessment 2001 [NHLC01], National Wetland Inventory (NWI) wetlands, National Hydrography Dataset (NHD) waterbodies, ESRI World Imagery from September 22, 2019, and Google Earth satellite images from September 3, 2018. For more details on methodology, see the Moultonborough Bay-Winter Harbor Lake Loading Response Model Report (FBE, 2020a).



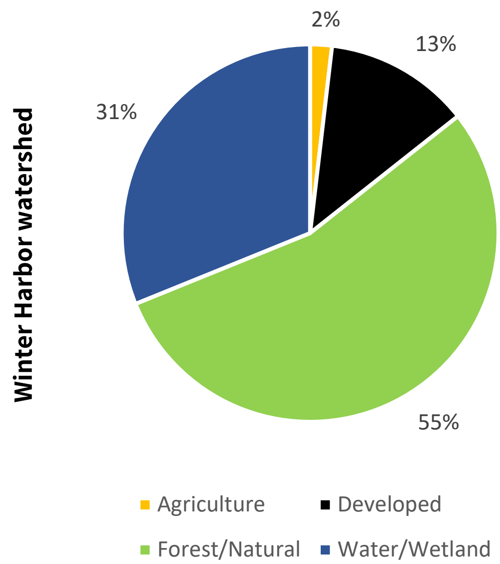


Figure 2-4. Land cover in the Moultonborough Bay (top) and Winter Harbor (bottom) watersheds. Does not include lake surface area.

Today, development accounts for 13% of both watersheds (3,758 acres in Moultonborough Bay and 637 acres in Winter Harbor), while forested and natural areas dominate at 58%, and 55%, respectively (17,429 acres in Moultonborough Bay and 2,779 acres in Winter Harbor) (Figure 2-4). Wetlands and open water represent 27% (7,929 acres) of the Moultonborough Bay watershed, and 31% (1,586 acres) of the Winter Harbor watershed. Agriculture represents 3% and 2% (761 acres in Moultonborough Bay and 95 acres in Winter Harbor) and includes row crops, hayfields, and pastureland. Developed areas within the Moultonborough Bay and Winter Harbor watersheds 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. Logged areas and excavated areas were also included into the "Developed" category (2,084 acres and 128 acres, respectively). See Appendix A Map 7 for the Moultonborough Bay and Winter Harbor map of land cover. Stormwater runoff carries pollutants that may be harmful to aquatic life to waterbodies, 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.

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. About 3,139 acres (11%) of the Moultonborough Bay watershed and 208 acres (4%) of the Winter Harbor watershed have been classified as conserved land (Figure 2-5. Conserved land covers 11% of the Moultonborough Bay watershed and 4% of the Winter Harbor watershed. Refer to Appendix A, Map 2. Appendix A, Map 2). The largest parcel of conserved land within these watersheds is part of the Castle in the Clouds Conservation Area. According to the Conserved Land layer from NH GRANIT, the portion of the Castle in the Clouds Conservation area within the Moultonborough Bay watershed spans 1,424 acres, although most of this conservation area is located outside the Moultonborough Bay watershed (5,363 acres total). Land conservation is one of many tools for protecting lake water quality for future generations.

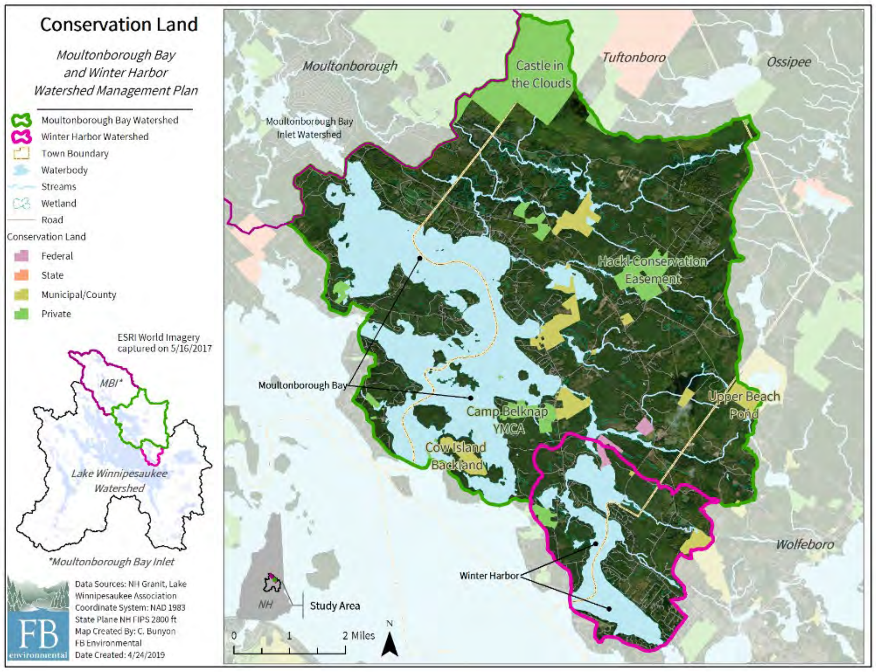


Figure 2-5. Conserved land covers 11% of the Moultonborough Bay watershed and 4% of the Winter Harbor watershed. Refer to Appendix A, Map 2.

2.2 PHYSICAL FEATURES

2.2.1 Topography

The highest elevation in both the Moultonborough Bay and Winter Harbor watersheds is the summit of Mount Shaw (approx. 2,994 feet), which is located at the northernmost point of the Moultonborough Bay watershed within the Castle in the Clouds Conservation Area. Moultonborough Bay, Winter Harbor, and their direct shoreline drainage areas are at 502 feet in elevation[1].

2.2.2 Soils and Geology

Surficial Geology

The composition of soils surrounding Moultonborough Bay and Winter Harbor reflect the dynamic geological processes that have shaped the landscape of NH over millions of years. Approximately 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 NH 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 unique geological formation in this area formed the Winnipesaukee River Basin Stratified Drift Aquifers, some of the cleanest and most productive aquifers in the region. Seventeen major aquifers comprise the Winnipesaukee River Basin Stratified Drift Aquifers; three of which are within the Moultonborough Bay watershed (Nineteenmile Brook, Coops Pond, and Melvin River Aquifers), and one of which is within the Winter Harbor watershed (Nineteenmile Brook Aquifer) (Ayotte, 1997). Moultonborough Bay and Winter Harbor are discharge points for the Winnipesaukee River Basin Stratified Drift Aquifers, by receiving water through groundwater infiltration. Any contamination in the aquifer will move quickly due to the high transmissivity of the material and enter Moultonborough Bay and Winter Harbor. Therefore, protection of the aquifer is vital to the protection of the lake.

Soils

The soils in the Moultonborough Bay and Winter Harbor watershed are a direct result of geologic processes. Of the 35 different soil series present within the Moultonborough Bay and Winter Harbor watersheds (excluding the Bay and Harbor), the most prevalent soil series in the Moultonborough Bay watershed is Metacomet fine sandy loam (3,123 acres, 11%), closely followed by Henniker-Gloucester fine sandy loams (2,703 acres, 10%) and Henniker fine sandy loam (2,299 acres, 8%; Figure 2-6; Appendix A, Map 3). The most prevalent soil series in the Winter Harbor watershed is Paxton fine sandy loam (1,196 acres, 4%), Woodbridge fine sandy loam (569 acres, 2%), and Woodstock-Brice fine sandy loam (428 acres, 2%). These soils are all classified with having moderate to excessive drainage capabilities and low surface runoff potential due to their sandy nature.

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[1] Elevation measurements estimated via GoogleEarth imagery.

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. Soils with negligible soil erosion hazard are primarily low-lying wetland areas near abutting streams. The soil erosion hazard for the Moultonborough Bay watershed was determined from the associated slope, and soil erosion factor K_w[2] used in the Universal Soil Loss Equation (USLE). The USLE predicts the rate of soil loss by sheet or rill erosion in units of tons per acre per year. A rating of "slight" specifies erosion is unlikely to occur under standard conditions. A rating of "moderate" specifies some erosion is likely and erosion-control measures may be required. A rating of "severe" specifies erosion is very likely and erosion-control measures and revegetation efforts are crucial. A rating of "very severe" specifies significant erosion is likely and control measures may be costly.

Excluding the lake area, "severe" and "very severe" erosion hazard areas account for 3% of the Moultonborough Bay watershed (967 acres) and 1% of the Winter Harbor watershed (54 acres) and are mostly concentrated on the steeper slopes

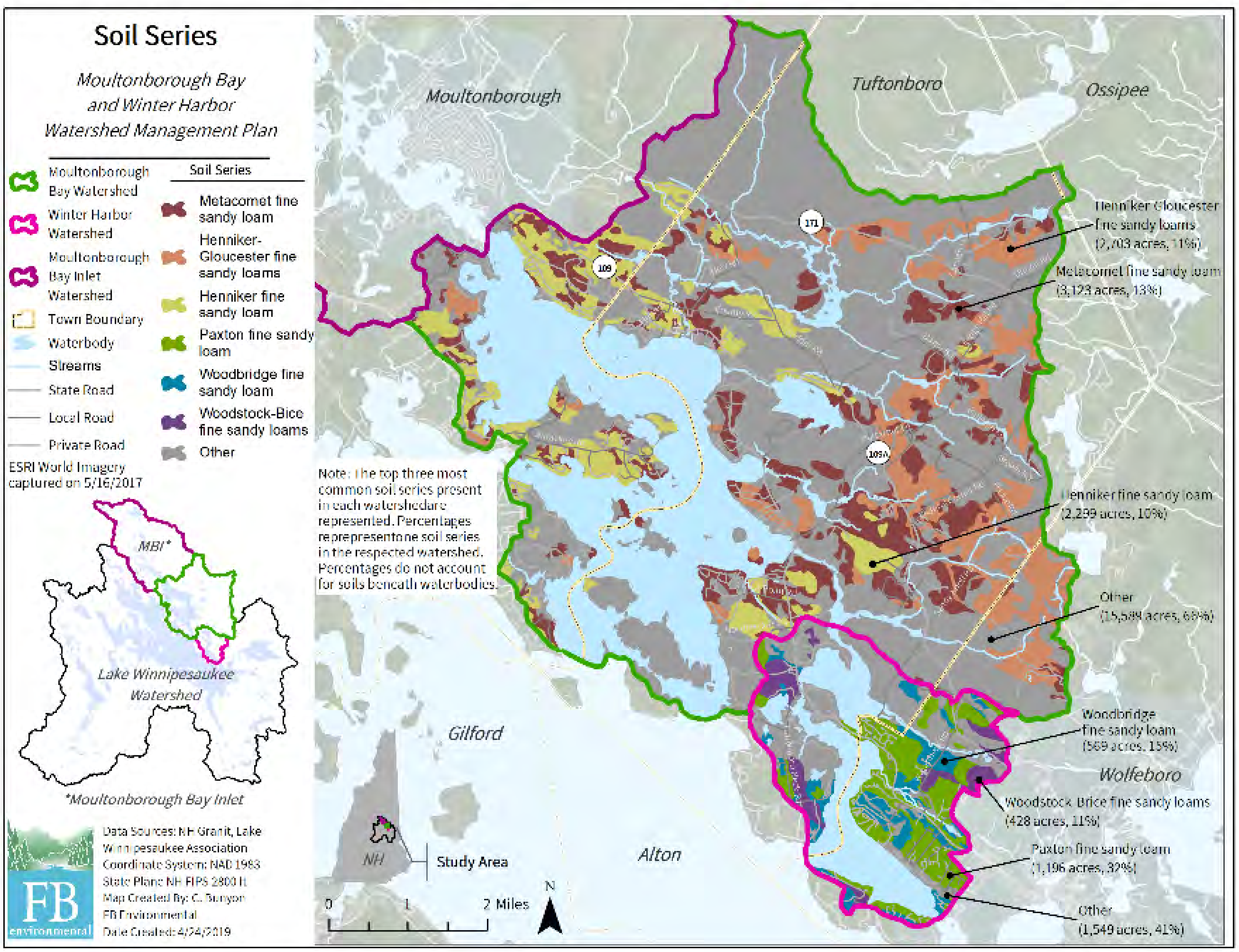

Figure 2-6. There are 35 soil series represented within the Moultonborough Bay watershed and 20 within the Winter Harbor watershed. Refer to Appendix A, Map 3.

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

of Mount Shaw (Appendix A, Map 4). Moderate erosion hazard areas account for 11% in both the Moultonborough Bay and Winter Harbor watersheds (3,415 acres and 578 acres, respectively). Slight erosion hazard areas account for 64% (19,190 acres) in the Moultonborough Bay watershed and 61% (3,085 acres) in the Winter Harbor watershed. Development should be restricted in areas with severe and very severe erosion hazards due to their inherent tendency to erode at a greater rate than what is considered tolerable soil loss. Since a highly erodible soil can have greater negative impact on water quality, more effort and investment is required to maintain its stability and function within the landscape, particularly from BMPs that protect steep slopes from development and/or prevent stormwater runoff from reaching water resources.

2.2.3 Lake Morphology and Morphometry

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

The surface area of Moultonborough Bay is 9.4 sq.mi. (6,040 acres) with a mean depth near 60 ft (18.3 m) and a maximum depth between 100 and 110 ft. The surface area of Winter Harbor is 1.5 sq. mi. (969 acres) with a mean depth near 40 ft (12.2 m) and a maximum depth between 60 and 80 ft (Figure 2-7; Appendix A, Map 5). There are 53 miles of shoreline in

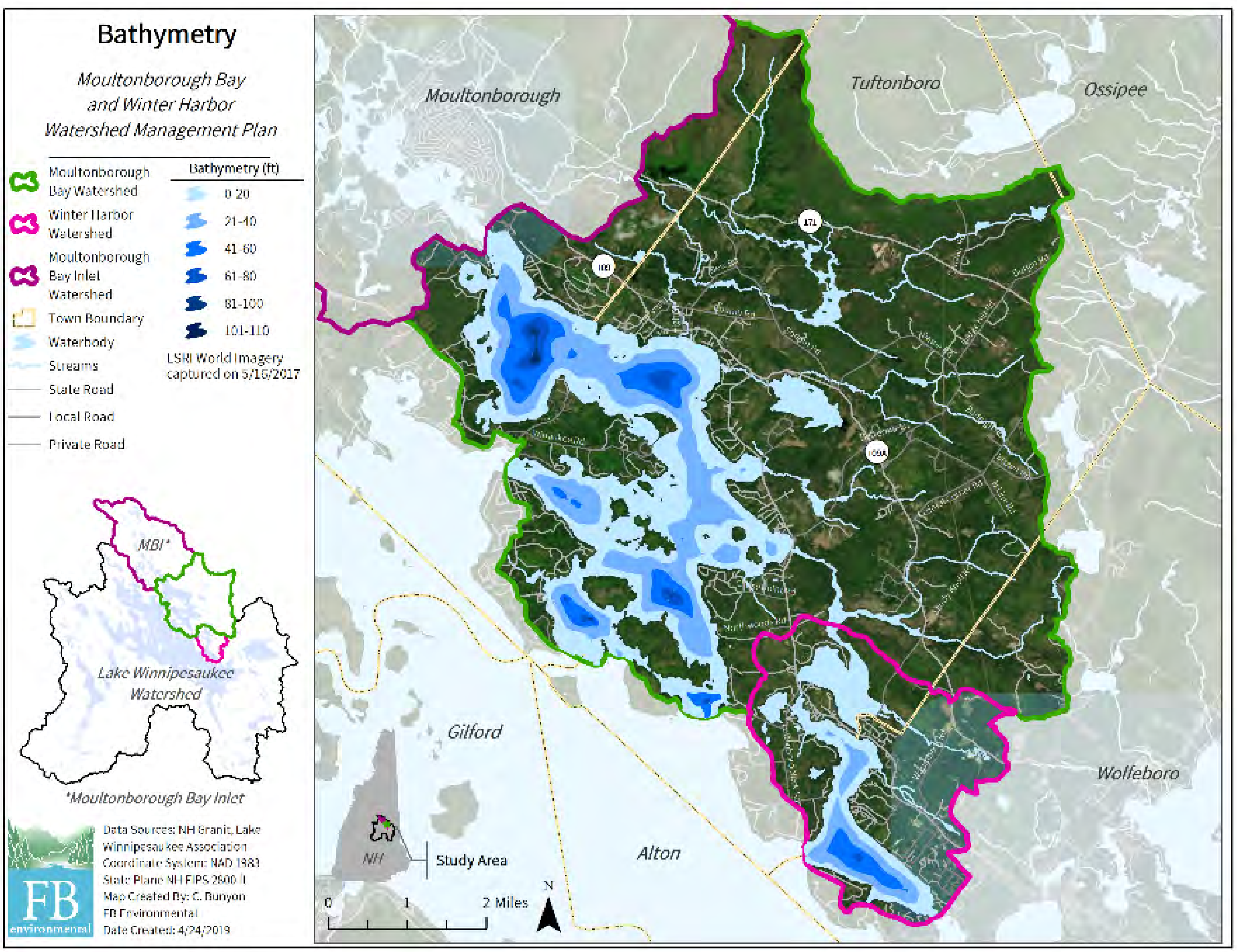

Figure 2-7. Bathymetry of Moultonborough Bay and Winter Harbor. (UNH GRANIT; Appendix A, Map 5).

Moultonborough Bay including island shorelines, and there are 9.9 miles of shoreline in Winter Harbor. The LLRM estimated the flushing rate (i.e. number of whole lake volume flushings per year) of Moultonborough Bay at 1.2 and Winter Harbor at 0.5. This means that the entire volume of Moultonborough Bay and Winter Harbor is replaced about every 10 months and 2 years, respectively.

2.2.4 Habitats and Wildlife

NH Fish and Game Department (NHFGD) ranks habitat based on 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 NH based on ecoregional subsections. The Moultonborough Bay and Winter Harbor watersheds are part of the Sebago-Ossipee Hills and Plains ecoregional subsection (NHFGD, 2015 – 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 NH. Over 12,586 acres (42%) of the Moultonborough Bay watershed and over 2,821 acres (55%) of the Winter Harbor watershed are considered Highest Ranked Habitat in NH. These habitats include Moultonborough Bay and Winter Harbor and a 200-meter buffer surrounding the waterbodies. A map of priority habitats for conservation based on the NH Wildlife Action Plan can be found in Appendix A, Map 6.

The watersheds are 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 rich forested resources include land mammals (moose, deer, black bear, coyote, bobcats, fisher, fox, raccoon, weasel, porcupine, muskrat, mink, chipmunks, squirrels, and bats), semi-aquatic mammals (muskrat, otter, and beaver), semi-aquatic reptiles and amphibians (turtles, snakes, frogs, and salamanders), various insects, and birds (herons, loons, gulls, multiple species of ducks, wild turkeys, cormorants, bald eagles, and song birds). Fish are an important natural resource for sustainable ecosystem food webs and provide recreational opportunities. Moultonborough Bay and Winter Harbor support a diversity of both warmwater and cold-water fish species. These species include rainbow trout, Landlocked Salmon, lake trout, lake whitefish, small and large mouth bass, eastern chain pickerel, brown bullhead, white perch, black crappie, bluegill, rock bass, and burbot.

2.2.5 Invasive Species

The introduction of non-indigenous invasive aquatic plant species to NH'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.

Moultonborough Bay and Winter Harbor are both located within Lake Winnipesaukee. Although no invasive species are listed explicitly for Moultonborough Bay or Winter Harbor on the NHDES list of infested waterbodies as of October 2019 (NHDES, 2019), Lake Winnipesaukee has been listed since 1965 for containing variable milfoil. Lees Pond, upstream in the Moultonborough Bay Inlet watershed, is also listed for variable milfoil. Control efforts for these infestations have included herbicide treatments, removal by hand and diving, and suction harvesting. Reductions in growth have been documented from these efforts. The NH Lakes Lake Host Program is a robust program to reduce invasive species transfer in NH lakes and has deployed the first waterless watercraft cleaning unit in the Northeast – the CD3 Clean, Drain, Dry, & Dispose Unit, pictured below (Figure 2-8). Native to the Great Lake, Lake Champlain, and the Mississippi river watersheds, rock bass (*Ambloplites rupestris),* have been introduced to New Hampshire waterbodies including Lake Winnipesaukee. Disliked by anglers, these fish often inhabit the same shallow portions of the lake as small mouth bass with which they compete for food. As a management effort, an angler can catch and keep an unlimited number of rock bass without adhering to size restrictions.

PULL THE PLUG on Aquatic Hitchhikers!
Arrive
CLEANED, DRAINED & DRY!
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NH LAKES

Figure 2-8. The NH Lakes Lake Host Program works with lake communities to ensure that invasive species are not transported between lakes by cleaning, draining, and drying before leaving any boat launch area.

3. ASSESSMENT OF WATER QUALITY

This section provides an overview of the water quality standards that apply to Moultonborough Bay and Winter Harbor, 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 NH 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 NH. These regulations form the basis for NH'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 NH, 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, 2018a). 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. **Moultonborough Bay and Winter Harbor, as part of Lake Winnipesaukee, is classified as Class B waters in the State of NH**. Lake Winnipesaukee is listed as not supporting for its designated use of primary contact recreation due to the occurrence of cyanobacteria hepatoxic microcystins.

Table 3-1. Designated uses for NH surface waters. Descriptions taken directly from the 2018 NH Consolidated Assessment and Listing Methodology (NHDES, 2018a).

Designated Use	NHDES Definition	Applicable Surface Waters
Aquatic Life Integrity (ALI)	The surface water can support aquatic life, including a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of the region.	All surface waters
Fish Consumption	The surface water can support a population of fish free from toxicants and pathogens that could pose a human health risk to consumers.	All surface waters
Shellfish Consumption	The tidal surface water can support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers.	All tidal surface waters
Potential Drinking Water Supply	The surface water could be suitable for human intake and meet state and federal drinking water requirements after adequate treatment.	All surface waters
Swimming and Other Recreation in and on the Water	The surface water is suitable for swimming, wading, boating of all types, fishing, surfing, and similar activities. **Primary Contact Recreation** (i.e. swimming) – Waters suitable for recreational uses that require or are likely to result in full body contact and/or incidental ingestion of water and **Secondary Contact Recreation** (i.e. boating) – Waters that support recreational uses that involve minor contact with the water.	All surface waters
Wildlife	The surface water can provide habitat capable of supporting any life stage or activity of undomesticated fauna on a regular or periodic basis.	All surface waters

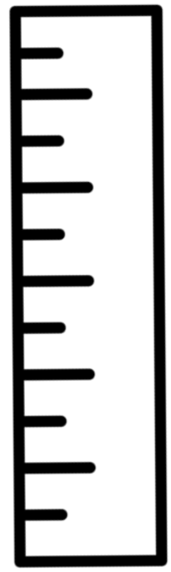
Table 3-2. NH surface water classifications. Descriptions taken directly from the 2018 NH Consolidated Assessment and Listing Methodology (NHDES, 2018a).

Classification	Description (RSA 485-A:8)
Class A	These are generally of the highest quality and are considered potentially usable for water supply after adequate treatment. Discharge of sewage or wastes is prohibited to waters of this classification.
Class B	Of the second highest quality, these waters are considered acceptable for fishing, swimming and other recreational purposes, and, after adequate treatment, for use as water supplies.

3.1.2 Lake Water Quality Criteria

NH'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 NH can be found in RSA 485 A:8, IV and in the state's surface water quality regulations. Aquatic Life Integrity (ALI) and Primary Contact Recreation (PCR) are the two major uses for lakes.



WHAT IS THE YARDSTICK FOR ASSESSING WATER QUALITY?

The NHDES uses a set of water quality criteria to protect lakes. These criteria look at indicator parameters such as chlorophyll-a, total phosphorus, and dissolved oxygen. Using these parameters, scientists can identify how healthy the lake is.

Primary Contact Recreation (PCR)

For PCR, NH has a narrative criterion with a numeric translator or threshold for the primary indicator *E. coli.* The narrative criteria for PCR (Env-Wq 1703.03) states that "All surface waters shall be free from substances in kind or quantity which float as foam, debris, scum or other visible substances, produce odor, color, taste or turbidity which is not naturally occurring and would render it unsuitable for its designated uses or would interfere with recreation activities." Nutrient response indicators, chlorophyll-a and cyanobacteria scums, are used as secondary indicators. Elevated chlorophyll-a levels or the presence of cyanobacteria scums interfere with the aesthetic enjoyment of swimming and/or may pose a health hazard. Chlorophyll-a levels greater than or equal to 15 ppb or the presence of cyanobacteria scums are considered "not supporting" for PCR. These secondary indicators can provide reasonable evidence to classify PCR as "not supporting," but cannot result in a "fully supporting" designation.

Aquatic Life Integrity (ALI)

Criteria for ALI ensure that waters provide suitable habitat for the survival and reproduction of desirable fish, shellfish, and other aquatic organisms. For ALI 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 or cyanobacteria concentrations, which can be estimated by measuring chlorophyll-a levels in the lake. More algae or cyanobacteria 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, ALI criteria vary by lake trophic state; each trophic state has a certain phytoplankton 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 ALI 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 ALI 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 Lake Winnipesaukee, the trophic state was determined to be oligotrophic** during all four completed surveys (1979, 1984, 1990, 2001). This means that in-lake water quality was consistent with the standards for oligotrophic lakes. However, it is important to note that this classification is based on the chlorophyll-a and total phosphorus thresholds listed in Table 3-3 and does not represent trends over time and/or water quality indicators outside of these two parameters.

Table 3-3. Aquatic life integrity (ALI) nutrient criteria ranges by trophic class in NH. 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 integrity (ALI) assessment in NH. 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 NH'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 & Data Acquisition

Water quality data were gathered through a coordinated effort among the UNH LLMP, LWA, and local volunteers. Sampling has been conducted at the deep spots in the bays with varying frequency by LLMP and LWA for dissolved oxygen-temperature profiles, **Secchi disk transparency** readings, and total phosphorus. LWA also performs sampling for targeted studies in conjunction with LLMP long-term efforts. Local volunteers either through LLMP or alone collect samples largely in coves and shoreline areas to supplement localized water quality data.

A summary of recent sampling data for key parameters of interest are provided for lake stations in Table 3-5. Lake station locations are shown in Figure 3-1. The LLMP and volunteers regularly monitor multiple stations in Moultonborough Bay, including Langdon Cove, Melvin Bay, Twentymile Bay, Nineteenmile Bay, and Long Island, and two stations in Winter Harbor, including the deep spot and Libby Museum. Many surface grab samples are regularly collected from Winter Harbor along the shoreline in the north and south ends, as well as the outlet to the Basin.

Minimal tributary data have been collected from the major inflows to Moultonborough Bay. LWA collected three samples for total phosphorus in 2019 at four of the major tributaries – Melvin River, Nineteenmile Brook, Twentymile Brook, and Wingate Brook – to supplement the modeling effort. The Town of Wolfeboro has conducted water quality monitoring along

Nineteenmile Brook from 2006-2008 (before the Rapid Infiltration Basin (RIB) system was installed in 2009) and for ten years post-installation. The Town of Tuftonboro contracted Normandeau Associates to complete a baseline study of Nineteenmile Brook in 2009 (before the RIB was activated) and a follow-up study in 2019. There are no distinct tributaries to Winter Harbor except for the inflows from the Basin and Mirror Lake.

Table 3-5. Summary of recent sampling data for epilimnion or surface grab total phosphorus (TP), dissolved oxygen (DO)-temperature profiles, chlorophyll-a (Chl-a), and Secchi disk transparency (SDT) (2009-2018, except for Johnsons Cove which was only sampled since 2019). Sites with * indicate some hypolimnion total phosphorus data available.

Site ID	Depth (ft)	Site Name	Years Sampled TP (*n*)	Years Sampled DO/Temp (*n*)	Years Sampled Chl-a (*n*)	Years Sampled SDT (*n*)
Moultonborough Bay						
WINMOUD	80	Moultonborough Deep	2010-15 (3)	NA	NA	NA
WMO03LL*	27	Langdon Cove	2010-18 (49)	2014-17 (3)	2010-17 (47)	2010-18 (50)
WMO07SL	30	Senter Cove	2017 (6)	NA	2017 (6)	2017 (6)
WMO05ML*	55	Melvin Bay	2009-17 (65)	2009-17 (9)	2009-17 (67)	2009-17 (68)
WMO20ML*	50	Twentymile Bay	2009-17 (120)	2009-17 (9)	2009-18 (116)	2009-18 (123)
WMO19AL	43	Nineteenmile Bay-Site A	2017 (2)	2017 (2)	2009-18 (114)	2009-18 (115)
WMO19BL	23	Nineteenmile Bay-Site B	2017 (2)	2017 (1)	2009-18 (112)	2009-18 (114)
WLI42EL	61	Long Island-42 ENE LI	NA	NA	NA	NA
WLI49GL	35	Long Island – GB	2009-18 (58)	NA	2009-18 (143)	2009-18 (140)
WINTUFD*	80	Cow Island Deep	2010-15 (2)	2010 (1)	NA	NA
Winter Harbor						
WWHBSNL	1	Basin Outlet	2010-18 (71)	NA	NA	NA
WWH10ML	35	Libby Museum	2010-18 (4)	2015-16 (2)	2010-18 (71)	2010-18 (74)
WWH15WL*	50	WH Deep	2010-18 (22)	2016 (1)	2009, 2016-17 (24)	2009, 2016-17 (24)
WWHMLOL	1	Mirror Lake Outlet	2010-13 (30)	NA	NA	NA
WWHWAYL	1	Winter Harbor Way	2010-18 (70)	NA	NA	NA
WWHWGTL	1	Wingate	2010-18 (72)	NA	NA	NA
WWHBVRL	1	Beaver Pond Outlet	2010-18 (71)	NA	NA	NA
Johnsons Cove	1	Johnsons Cove	2019 (5)	NA	2019 (5)	NA
Port Wedeln	1	Port Wedeln	2017-18 (11)	NA	2017-18 (15)	NA
Nary Shore	1	Nary Shore	2017-18 (15)	NA	2017-18 (15)	NA
Carry Beach	1	Carry Beach	2017-18 (13)	NA	2017-18 (13)	NA
Whitegate	5	Winter Harbor below Whitegate Drainage	2017-18 (33)	NA	2017-18 (17)	NA

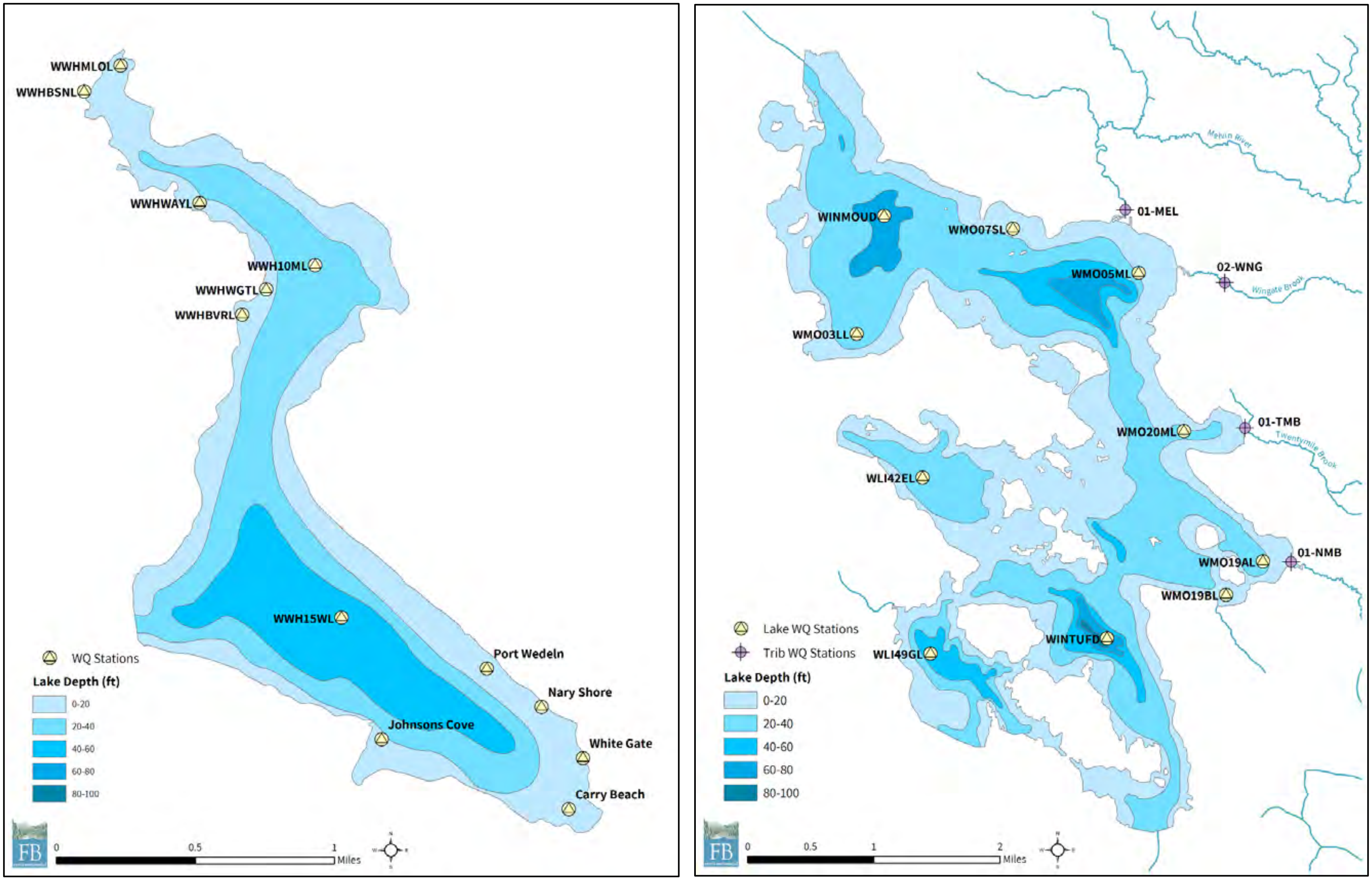


Figure 3-1. Bathymetric maps with water quality monitoring stations for Winter Harbor (left) and Moultonborough Bay (right).

3.2.2 Trophic State Indicator Parameters

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

Total Phosphorus

Median total phosphorus in the **epilimnion** of Moultonborough Bay during the summer season ranges from 5.73 to 8.50 ppb, with the lowest median total phosphorus at Langley Cove (WMO03LL) and the highest median total phosphorus at Senter Cove (WMO07SL; Table 3-6). Median total phosphorus at the two deep spot locations in Winter Harbor, WWH10ML in the northern end of Winter Harbor at the Libby Museum and WWH15WL in the southern end of Winter Harbor, are 4.75 ppb and 4.50 ppb, respectively (Table 3-6). Senter Cove is the only site with existing median total phosphorus above the oligotrophic water quality criterion set by NHDES (see Table 3-3).

Chlorophyll-a

Median chlorophyll-a in the epilimnion of Moultonborough Bay during the summer season ranges from 1.30 to 2.00 ppb, with the lowest median chlorophyll-a at Long Island (WLI49GL) and the highest median chlorophyll-a at Senter Cove (WMO07SL; Table 3-6). Median chlorophyll-a at the two deep spot locations in Winter Harbor, WWH10ML in the northern end of Winter Harbor at the Libby Museum and WWH15WL in the southern end of Winter Harbor, are 1.10 ppb and 0.95 ppb, respectively (Table 3-6). No sites exceeded the oligotrophic water quality criterion set by NHDES (see Table 3-3).

Secchi Disk Transparency

Secchi disk transparency (or water clarity) has been collected at eight sites in Moultonborough Bay and two sites in Winter Harbor (Figure 3-2). The deepest median water clarity has occurred at the deep spot in Winter Harbor (WWH15WL) in July (10 m), October (9.6 m), and September (9.5 m). The shallowest median water clarity has occurred at site WMO19AL in Moultonborough Bay, ranging from 3.0-4.5 m across all months.

Table 3-6. Median total phosphorus (TP) and chlorophyll-a (Chl-a) in Moultonborough Bay and Winter Harbor. Data included were limited to the last ten years (2009 – 2018; 2019 not included to match assimilative capacity analysis completed in 2019), epilimnion samples, and samples collected during the critical period (May 24 – Sept 15).

Station ID	Station Name	Count	Median TP (ppb)	Median Chl-a (ppb)
MOULTONBOROUGH BAY				
WINMOUD	Moultonborough Bay Deep Spot	1	6.20	na
WMO03LL	Langley Cove	28	5.73	1.60
WMO07SL	Senter Cove	5	8.50	2.00
WMO05ML	Melvin Bay	60	6.35	1.90
WMO20ML	Twentymile Bay	114	6.10	1.60
WMO19AL	Nineteenmile Bay	2	5.80	1.40
WMO19BL	Nineteenmile Bay	1	5.85	1.40
WLI49GL	Long Island – Greens Boathouse	36	5.75	1.30
WINTUFD*	Cow Island Deep	0	na	na
WINTER HARBOR				
WWH10ML	Libby Museum (Upper)	4	4.75	1.10
WWH15WL	Winter Harbor Deep Spot (Lower)	20	4.50	0.95

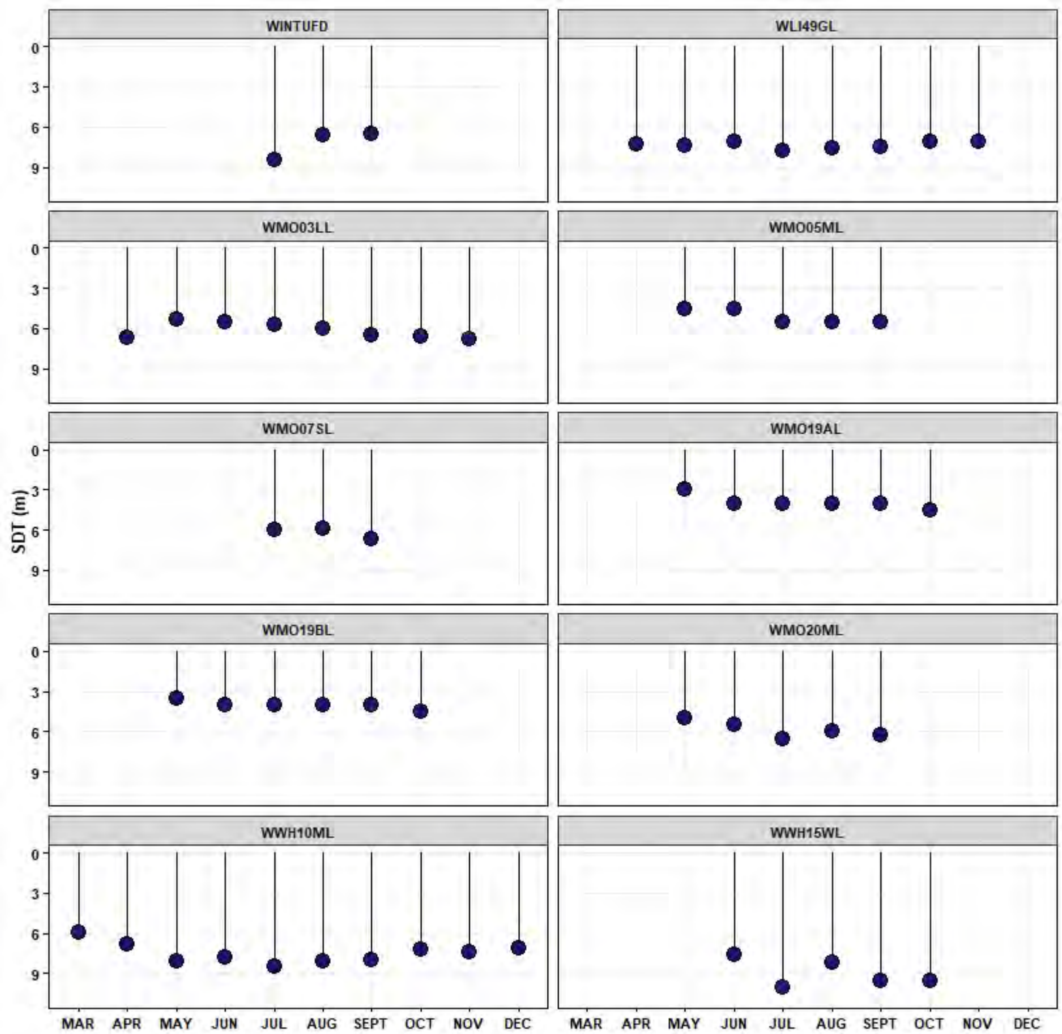


Figure 3-2. Historical median Secchi disk transparency for each month of the year across eight sites in Moultonborough Bay (WINTUFD, WLI49GL, WMO03LL, WMO05ML, WMO07SL, WMO19AL, WMO19BL, and WMO20ML) and two sites in Winter Harbor (WWH10ML and WWH15WL). Includes all historical data through 2018.

Temperature & 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 added through the interface with the atmosphere) while oxygen is consumed near the bottom of a lake (where organic matter accumulates and decomposes). These deep layers are isolated and do not receive oxygen from surface waters or the atmosphere when the lake is thermally stratified. 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, <1ppm) 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 integrity.

Dissolved oxygen and temperature profiles are presented for two sites in Moultonborough Bay (WMO05ML and WMO20ML, 6 and 2 profiles available, respectively) and two sites in Winter Harbor (WWH10ML and WWH15WL, 4 profiles available each). Sporadic dissolved oxygen and temperature profiles exist for other locations in the watersheds but not consistent enough for analysis.

Median dissolved oxygen and temperature at site WMO05ML (below Wingate Brook) shows summer 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**) between 5 and 10 m depth (Figure 3-3). Dissolved oxygen drops below 5 ppm at approximately 12 m. Water temperature is relatively uniform above 5 m, between 23°C and 24°C. Site WMO20ML (below Twentymile Brook) displays a similar pattern of summer thermal stratification; however, dissolved oxygen drops below 5 ppm higher in the profile, at approximately 9-10 m. Dissolved oxygen then drops below 1 ppm around 15 m.

Dissolved oxygen and temperature at the deep spot in the southern end of Winter Harbor ((WWH15WL) also show summer thermal stratification, with dissolved oxygen dropping to 5 ppm at 15 m depth[3]. The northern end (WWH10ML) is much shallower, at 35 feet, and median dissolved oxygen and temperature profiles suggest that there is no thermal stratification in this embayment. Dissolved oxygen is relatively uniform through the profile between 7 and 8 m, and temperature remains above 22°C throughout the profile. These warm temperatures throughout the water column limit coldwater refugia for fish and aquatic organisms.

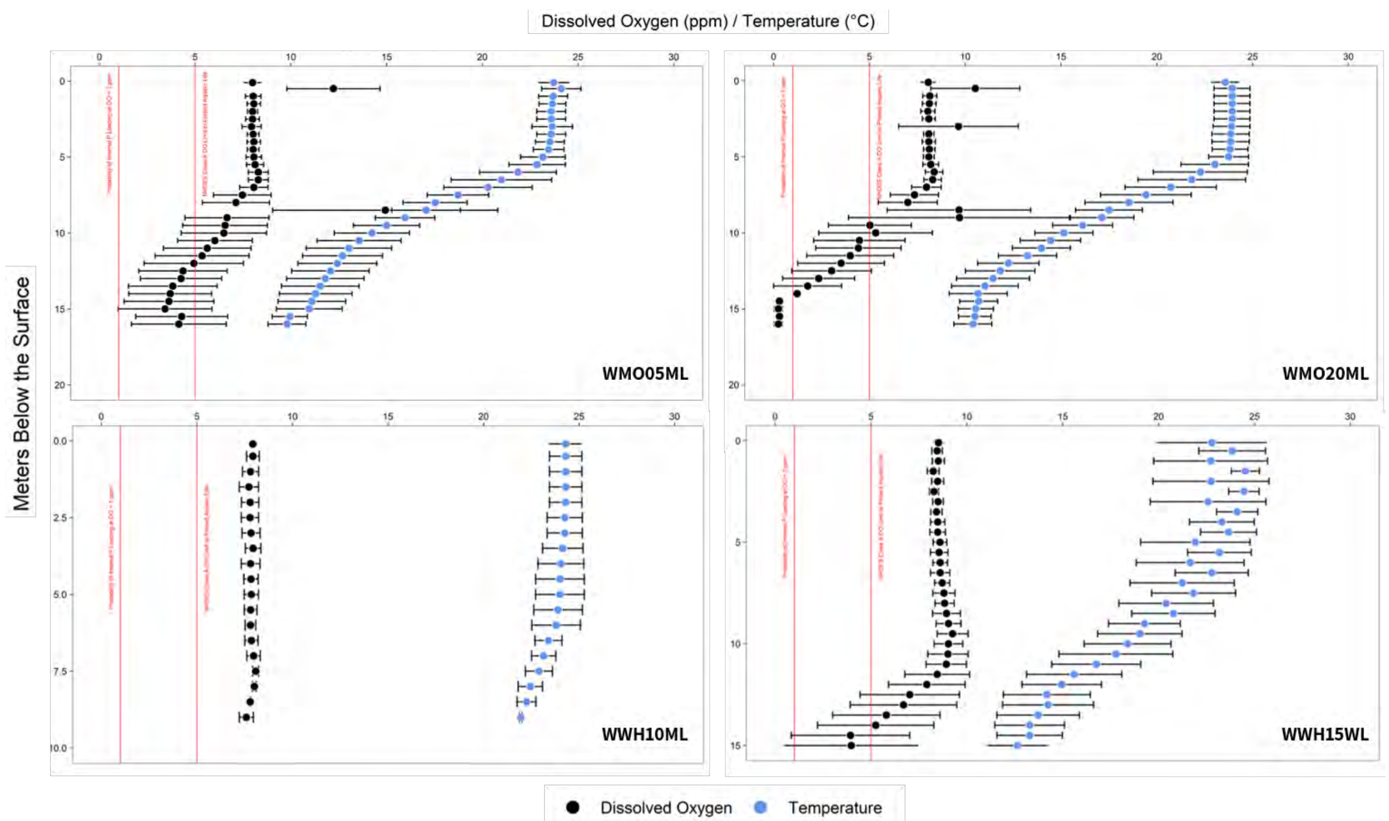


Figure 3-3. Average dissolved oxygen and temperature profiles at WMO05ML (below Wingate Brook) and WMO20ML (below Twentymile Brook) in Moultonborough Bay and at sites WWH10ML (Winter Harbor northern end) and WWH15WL (Winter Harbor southern end/deep spot). Vertical red lines denote dissolved oxygen thresholds for Class B Aquatic Life Integrity at 5

[3] Data collected below 15 m was discarded because it is assumed that these points were collected in or near the sediments and were not accurately reflecting dissolved oxygen in the water column.

ppm and probability of internal phosphorus loading at 1 ppm. Averaged profiles included only those that were stratified for each site (WMO05ML, n=6; WWH10ML, n=2; WMO05ML, n=4, and WMO20ML, n=4).

3.2.3 Localized and Nearshore Monitoring

Analyzing water quality at the deep spot is a helpful tool for tracking long-term water quality trends. However, this approach can overlook nuances in water quality observed in nearshore locations or semi-isolated embayments. The following series of boxplots is intended to offer a snapshot of nearshore monitoring conducted by residents in the Winter Harbor watershed. Residents have been collecting total phosphorus data from nearshore sites located at Carry Beach, Johnsons Cove, Nary Shore, Port Wedeln, and Whitegate, located in the southern end of Winter Harbor. Data are presented alongside sites WWH10ML (the deep spot site in the northern end of Winter Harbor) and WWH15WL (the deep spot site in the southern end of Winter Harbor).

It is difficult to compare all data across seasons for the sites since the number and distribution of those data vary site to site. Whitegate has the most data outside of the summer months; other sites, namely Carry Beach, Nary Shore, Port Wedeln, and WWH15WL, were limited to a few data points collected in October. Several data points were also collected in the spring at WWH10ML. Winter Harbor shows higher total phosphorus concentrations in spring and fall compared to winter and summer, likely as a result of the large influx of material from the landscape during the rainier spring and fall times of year when land based plants are not actively growing and when the lake mixes and brings up phosphorus from deep parts of the basin (Figure 3-4). Comparison of median total phosphorus binned by season does not account for event-specific fluctuations in total phosphorus, but rather can represent seasonal variability based on the frequency of events and their influence on water chemistry. These seasonal variations in nutrient concentrations can also be caused by changes in biological communities both throughout the water column and on the bottom of the lake (in the benthic zone).

Overall, the available data indicate minimal differences across sites, but analysis is limited by data availability and frequency of collection. Differences may exist at a storm-level scale as material is washed into the nearshore areas prior to dilution with the greater lake basin water.

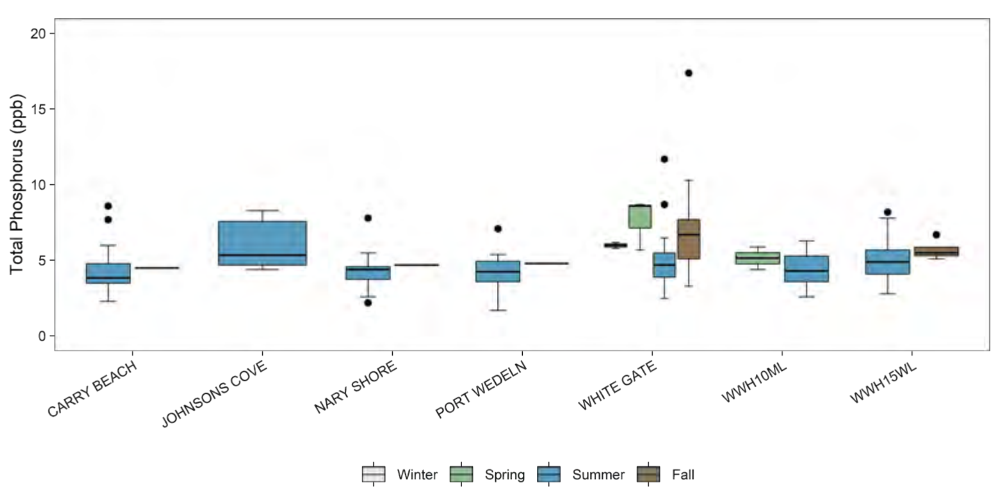


Figure 3-4. Seasonal all data summary distribution of total phosphorus concentrations measured from 2009-2019 in the epilimnion or near-surface of the lake at several sites in Winter Harbor. Carry Beach, Johnsons Cove, Nary Shore, Port Wedeln, and Whitegate are nearshore sites located in the southern end of Winter Harbor. WWH10ML is the deep spot site in the northern end of Winter Harbor. WWH15WL is the deep spot site in the southern end of Winter Harbor. The top and bottom of the box area in each boxplot represent the 75th and 25th percentiles of the data, respectively. The solid horizontal line in each box represents the median or 50th percentile of the data. The blue asterisk in each box represents the mean of the data. The

top and bottom whiskers represent the maximum and minimum non-outliers of the data, respectively. Any points above or below the whiskers are outliers, defined as 1.5 times the interquartile range (or the length of the box). Single horizontal lines represent only a single data point.

3.2.4 Internal Phosphorus Loading

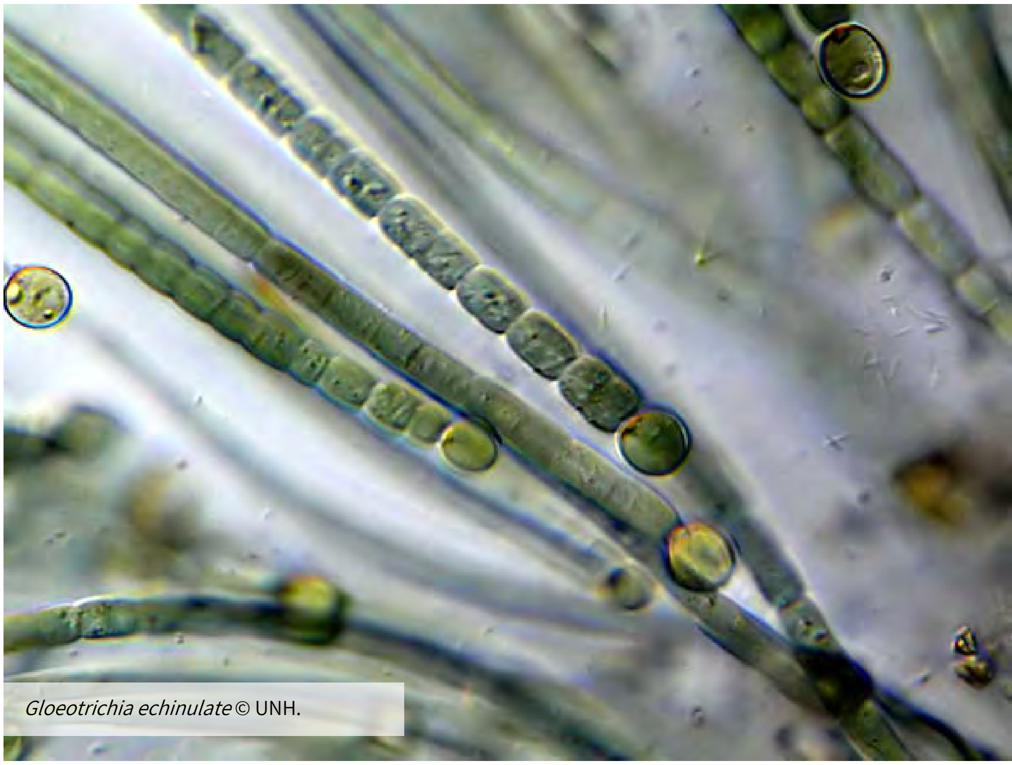
Phosphorus that enters the lake and settles to the bottom can be re-released from sediment under anoxic conditions, providing a nutrient source for algae and other plants. Internal phosphorus loading can also result from wind-driven wave action or physical disturbance of the sediment (boat props, aquatic macrophyte management activities). We were unable to calculate a possible internal phosphorus load for the Basin due to a lack of water quality data at the deep spot; although the Basin's shallow nature may minimize the formation of a bottom anoxic layer (due to mixing from wind and wave action), the Basin may be susceptible to mechanical disturbance of and release of phosphorus from bottom sediments as a result of boat propeller action. Limited water quality data were available for stations in Moultonborough Bay and Winter Harbor. Using Navionics®, we estimated the **hypolimnion** volume for only deep spot areas with data showing anoxia. For Moultonborough Bay, we used Melvin Bay (WMO05ML), Twentymile Bay (WMO20ML), and Nineteenmile Bay (WMO19AL). For Winter Harbor, we used the deep spot in the southern end (WWH15WL). It is possible that the internal load estimates for both Moultonborough Bay and Winter Harbor are underestimated and do not reflect the behavior of *Gloeotrichia*, which can regulate their buoyancy to capture phosphorus from bottom sediments in shallow waters and transport that phosphorus up into the water column.

Internal loading was determined to be 1% of the total phosphorus load in Moultonborough Bay and 6% in Winter Harbor. Internal loading is currently a minor source but still a concern for Moultonborough Bay-Winter Harbor given that low dissolved oxygen in bottom waters is causing a release of phosphorus from bottom sediments (as evidenced by the moderate difference between bottom and surface phosphorus concentrations (5-28 ppb)). 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.

3.2.5 Gloeotrichia

Gloeotrichia echinulata or "Gloeo" is a freshwater planktonic cyanobacteria, ranging from 1-3mm in diameter (Carey et al., 2012). *Gloeotrichia* have been found to group together with other individuals to form colonies. This colonial cyanobacterium can range in color from off white to bright green and often appears fuzzy. Beginning in June and peaking in August, *Gloeotrichia* blooms have been seen in a handful of lakes across New England, including Lake Winnipesaukee, and have subsequently been the subject of many studies focused on understanding their causes and possible management measures.

Gloeotrichia is naturally present in many lakes in the region in minimal concentrations. When excess nutrients are introduced into the water column, a bloom of *Gloeotrichia* colonies may be triggered which can accelerate lake eutrophication. However, *Gloeotrichia* has been seen in many low nutrient lakes across North America. Specifically, a study published in 2012 by lead author Cayelan Carey showed that many low nutrient lakes in New England had *Gloeotrichia* (Carey et al., 2012). *Gloeotrichia* can not only survive but thrive in low nutrient oligotrophic lakes because of two striking abilities. First, *Gloeotrichia* can fix nitrogen. Nitrogen fixation is the process by which atmospheric nitrogen is taken up and chemically combined with other elements into more "usable" forms for biological processes such as ammonia (NH_3), nitrate (NO_{3-}), or nitrite (NO_{2-}) (Augustyn, 2019). Second, *Gloeotrichia* cells can become dormant during the winter months on the lake sediment (Carey et al., 2012). When water temperatures rise and sunlight increases in the late spring, *Gloeotrichia* emerge from their dormant state to grow and absorb nutrients such as phosphorus that were stored in the lake sediment. Using their ability to regulate their depth in the water column using gas vesicles, *Gloeotrichia* cells then rise towards the surface, transporting the stored phosphorus with them (Tymowski & Duthie, 2000). Therefore, although Winter Harbor, Moultonborough Bay, and Lake Winnipesaukee might have low nutrient concentrations and are classified as oligotrophic, *Gloeotrichia* blooms can still occur. Once established in a lake, *Gloeotrichia* may become a regular aquatic resident and may lead to a decrease in property values surrounding the lake if the water becomes less appealing, shows a decrease in clarity, and/or becomes unsafe for recreation.



Gloeotrichia echinulate © UNH.

Gloeotrichia has taken the spotlight because of its ability to produce the toxin microcystin-LR and its greater prevalence within the last decade. Concentrations of microcystins may reach levels high enough to affect the health of both aquatic species and humans (Carey, et al., 2012). The microcystin-LR has shown to cause skin irritation in swimmers amongst other affects (Backer, 2002) and may perturb food webs by affecting primary producers and consumers within the lake (Carey et al., 2012). *Gloeotrichia*, along with other toxin producing cyanobacteria, do not always produce toxins. The NHDES Limnology Center offers free analysis of cyanobacteria samples which includes an identification of which species are present, a count, and the level of toxicity. To find out more information on these services provided by the NHDES see https://www.des.nh.gov/organization/divisions/water/wmb/beaches/faq_cyanobacteria.htm or contact beaches@des.nh.gov.

Identifying the "cause" of *Gloeotrichia* blooms remains an exceedingly difficult pursuit. *Gloeotrichia* blooms are easily moved to alternate locations within a lake by wind and water currents which may cluster *Gloeotrichia* colonies in coves displaced from their site of occurrence. Blooms may also occur as small clusters and are frequently very flashy (McQuaid, 2020). It is likely that climate change is influencing the increased occurrence of *Gloeotrichia* blooms. An increase in extreme weather with stronger winds and greater amounts of precipitation may increase the mixing of in-lake nutrients, thus supporting the growth of cyanobacteria (Stockwell, et al., 2020). Contributing factors may include, but are not limited to, the amount of phosphorus in sediment, in-lake nitrogen concentrations, light availability, temperature, dissolved oxygen concentration, and lake depth (Carey et al., 2012).

SUMMARY OF CYANOBACTERIA COMPLAINTS & SIGHTINGS ON LAKE WINNIPESAUKEE

(data available through 2018)

NHDES issues cyanobacteria advisories when blooms are confirmed to be cyanobacteria, samples are identified to taxa, and cells are enumerated, exceeding 70,000 cells/mL. Lake Winnipesaukee has been issued three cyanobacteria advisories by NHDES since from 2011 through 2018. These can be viewed via the NHDES Lake Mapper (link below) which also contains links to the UNH LLMP water quality reports. On June 28, 2011, there was a bloom of *Anabaena* (now called *Dolichospermum*), lasting three days at 500,000 cells/mL (near Governors Island) on the lake in Meredith. In 2018, two cyanobacteria blooms were recorded. The first was in Weirs Channel, Laconia with a dense bloom of decaying *Microcystis*, estimated at 3 million cells/mL. This advisory was specific to the channel and lasted 41 days. The second advisory was due to a very common type of cyanobacteria to Lake Winnipesaukee known as *Gloeotrichia*. The advisory was issued August 30, 2018 for Winter Harbor in Wolfeboro and lasted 22 days. Other cyanobacteria complaints were also first recorded in 2011. Though blooms or cyanobacteria presence has been often noted, the accumulations do not typically last longer than a few hours. About a dozen complaints were filed between 2011 and 2019 and half of those were confirmed to be cyanobacteria. Most of the reports were due to *Gloeotrichia*, which often is observed in late August into Labor Day each year. Green filamentous algae was often the source of the other sightings and complaints. While the records by NHDES only go back to 2011, there have been other notable blooms for the lake. For example, prior to 2011, there was a bloom of *Planktothrix rubescence* in Alton Bay that could be seen by aerial views as the bay turned a reddish-purple from the cyanobacteria. It is also known from recent plankton studies by NHDES that there are a variety of cyanobacteria taxa in the lake. The noted types of cyanobacteria include *Anabaena/Dolichospermum, Gloeotrichia, Microcystis, Woronichinia, Coelosphaerium, Pseudoanabaena, Snowella, Picocyanobacteria, Oscillatoria, Planktothrix, benthic Anabaena and Stigonema*.

The NHDES Lake Mapper:
https://nhdes.maps.arcgis.com/apps/webappviewer/index.html?id=1f45dc20877b4b959239b8a4a60ef540

Table 3-7. Cyanobacteria blooms that triggered a posted warning or advisory in Lake Winnipesaukee.

Date	Location	Town	Species	Cells/mL
8/30/18	Wolfeboro Bay	Wolfeboro	Gloeotrichia	>70,000 cells/mL
6/29/18	Paugus Bay	Laconia	Microcystis	3,000,000 cells/mL
6/28/11	Governors Island	Meredith	Anabaena	500,000 cells/mL

3.2.6 Tributary Water Quality Analysis

Moultonborough Bay

There are four major rivers that enter Moultonborough Bay, listed here from upstream to downstream: Melvin River, Wingate Brook, Twentymile Brook, and Nineteenmile Brook. Table 3-8, below, shows sampling results for dissolved oxygen, water temperature, and total phosphorus from LWA across three dates in 2019 (08/30/19, 09/20/19, and 10/15/19). Prior to 2019, limited data exist for these tributaries aside from the intensive monitoring being completed on Nineteenmile Brook to monitor the Wolfeboro Rapid Infiltration Basin (RIB) system. Previous total phosphorus data is summarized in Table 3-9 and was collected by the Volunteer River Assessment Program (VRAP) in 2004 and 2005.

Dissolved oxygen at all sites and across sampling days was adequate for supporting aquatic life. It is important to note, however, that measurements were taken in the mid to late afternoon for all sample dates. Dissolved oxygen is typically lowest in the early morning following increased respiration over the night and before photosynthesis begins the following day. Therefore, it is likely that these data overestimate minimum dissolved oxygen and future measurements should include early morning readings. Water temperature was lowest in Wingate Brook and highest in Twentymile Brook across all sampling events. Water temperature greater than 20°C was noted in August in all streams except Wingate Brook and in September remained elevated above 20°C in Twentymile and Nineteenmile brooks. Elevated water temperatures can stress aquatic organisms, particularly coldwater species such as trout. Total phosphorus in the four major rivers in 2019 was slightly elevated compared to natural background for the ecoregion (~ 10 ppb) in the Melvin River, Wingate Brook, and Nineteenmile Brook.

Table 3-8. Tributary data collected by LWA from the main tributaries to Moultonborough Bay in 2019. Parameters include dissolved oxygen (DO), water temperature, and total phosphorus (TP). Sampling sites represent the outlet of each tributary.

Stream	Site ID	Date	DO (mg/L) *	Water Temp (°C)	TP (ppb)
Melvin River	01-MEL	08/30/19	8.83	20.4	24.7
Melvin River	01-MEL	09/20/19	9.86	15.9	13.8
Melvin River	01-MEL	10/15/19	10.36	11.8	16.1
		Average (01-MEL)	**9.68**	**16.0**	**18.2**
Wingate Brook	02-WNG	08/30/19	8.34	19.7	16.8
Wingate Brook	02-WNG	09/20/19	9.15	14.5	13.6
Wingate Brook	02-WNG	10/15/19	9.62	11.2	12.1
		Average (02-WNG)	**9.04**	**15.1**	**14.2**
Twentymile Brook	01-TMB	08/30/19	8.26	24.7	8.4
Twentymile Brook	01-TMB	09/20/19	8.88	21.3	7.9
Twentymile Brook	01-TMB	10/15/19	9.57	16.0	12.0
		Average (01-TMB)	**8.90**	**20.7**	**9.4**
Nineteenmile Brook	01-NMB	08/30/19	7.90	22.5	14.0
Nineteenmile Brook	01-NMB	09/20/19	9.08	20.3	16.6
Nineteenmile Brook	01-NMB	10/15/19	9.57	14.7	17.5
		Average (01-NMB)	**8.85**	**19.2**	**16.0**

*Samples were taken in the mid to late afternoon for all sample dates so likely do not represent the lowest DO (highest stress on aquatic life).

Table 3-9. Historic total phosphorus (TP) data for the Melvin River, Wingate Brook, Twentymile Brook, and Nineteenmile Brook. Data were collected by the NH Volunteer River Assessment Program (VRAP).

	Year(s)	Count	TP (ppb)
Melvin River	2004-2005	15	19.2
Wingate Brook	2005	7	15.8
Twentymile Brook	2004-2005	13	9.2
Nineteenmile Brook	2004-2005	12	18.3

Winter Harbor

Winter Harbor does not have significant river or stream inflows aside from the outlet of Mirror Lake and the Basin. However, steep slopes and increased development have concentrated drainage in the watershed to create drainage pathways (i.e., headwater streams) to the bay. One major drainage originates in the Whitegate Road neighborhood and enters the south side of the bay just above Carry Beach. Data collected by local residents in the bay near the outlet of this drainage show episodic exceedances of the oligotrophic total phosphorus threshold (8 ppb, six total exceedances) but no documented exceedances of the chlorophyll-a threshold (3.3 ppb; Figure 3-5). In addition to these data collected in the bay, a small set of samples collected from within these drainages during and after storm events suggests significant total phosphorus delivery to the lake.

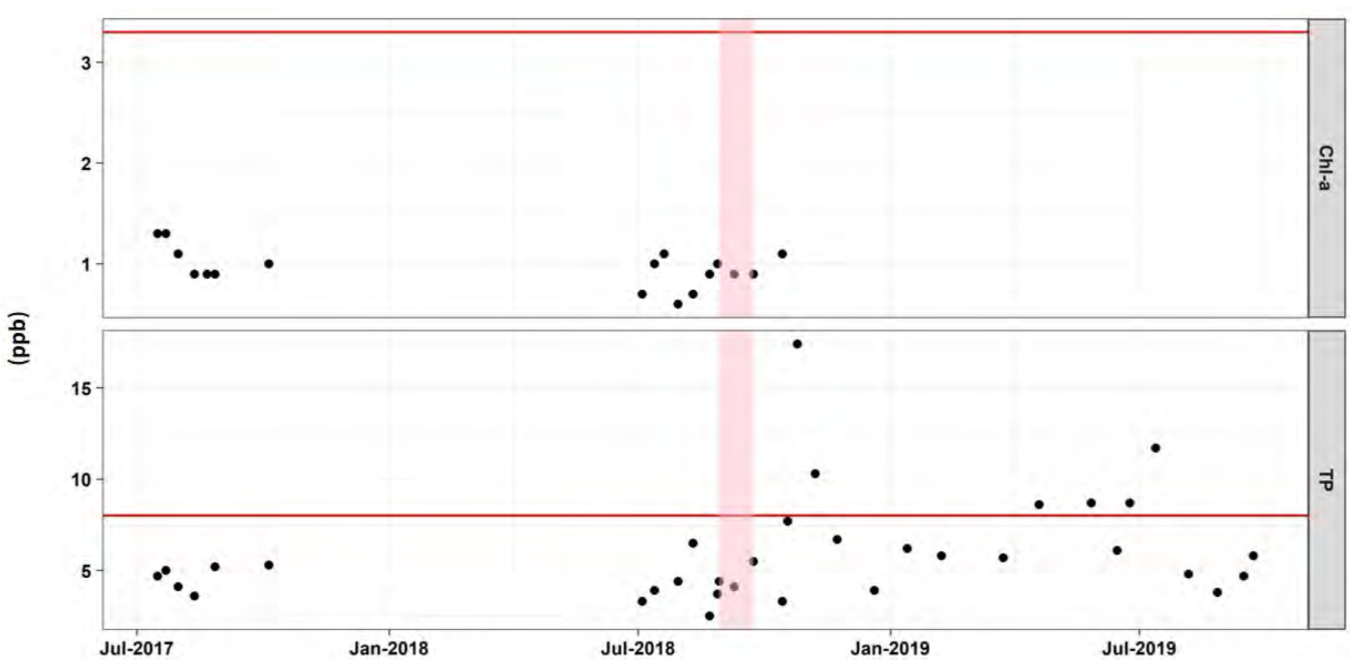


Figure 3-5. Chlorophyll-a (Chl-a) and total phosphorus (TP) data collected from the bay below the Whitegate Road neighborhood drainage in Winter Harbor. The red lines represent oligotrophic water quality thresholds for Chl-a (3.3 ppb) and TP (8 ppb). The pink shaded area represents the duration of a *Gloeotrichia* bloom advisory in Winter Harbor.

Residents have also collected data at Carry Beach. Carry Beach is a public beach for Wolfeboro residents, their families, and friends, located on the eastern shore of Winter Harbor. Available data from 2017, 2018, and 2019 show no exceedances of chlorophyll-a and one exceedance of total phosphorus in 2019 (06/24/19; Figure 3-6). Data collection was limited to the summer season when residents were using the beach.

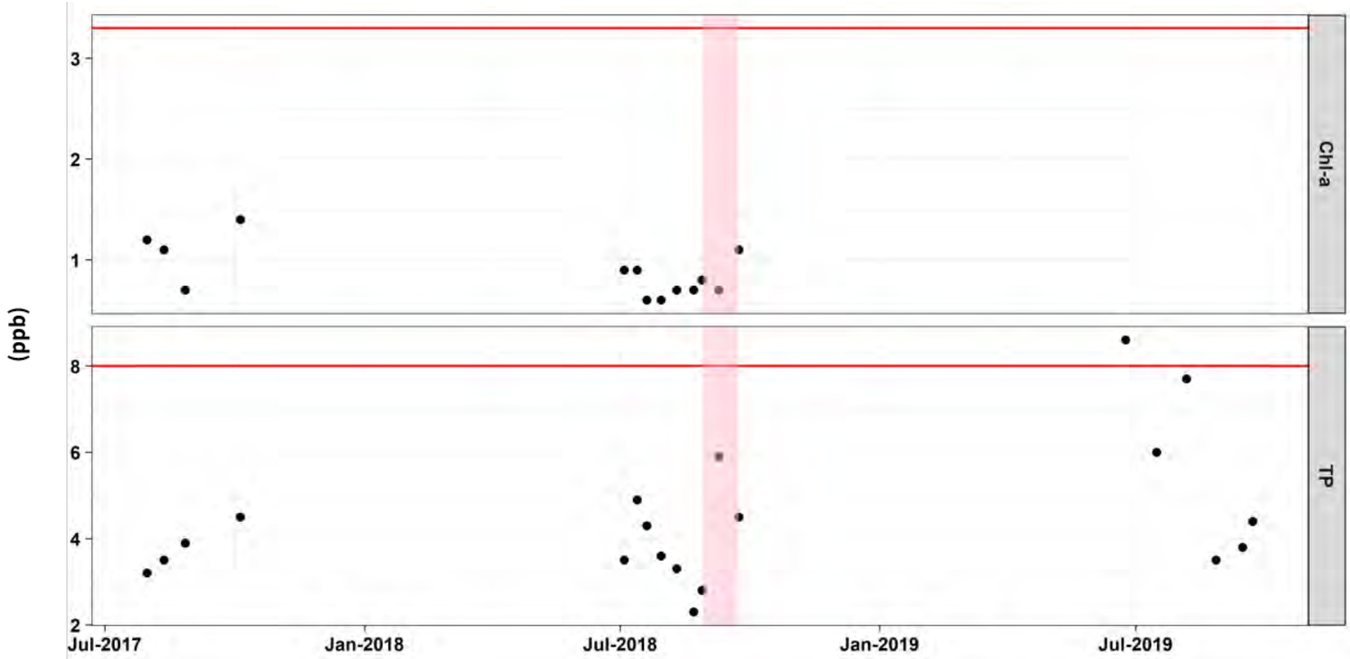


Figure 3-6. Chlorophyll-a (Chl-a) and total phosphorus (TP) data collected from Carry Beach on the eastern shore of Winter Harbor. The red lines represent oligotrophic water quality thresholds for Chl-a (3.3 ppb) and TP (8 ppb). The pink shaded area represents the duration of a *Gloeotrichia* bloom advisory in Winter Harbor.

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

One of the initial exercises that can be performed to assess water quality in the context of current state criteria is an assimilative capacity analysis of total phosphorus and chlorophyll-a in surface waters. Chlorophyll-a is a surrogate measure for the amount of algae and cyanobacteria in the water and generally increases in response to increases in total phosphorus availability.

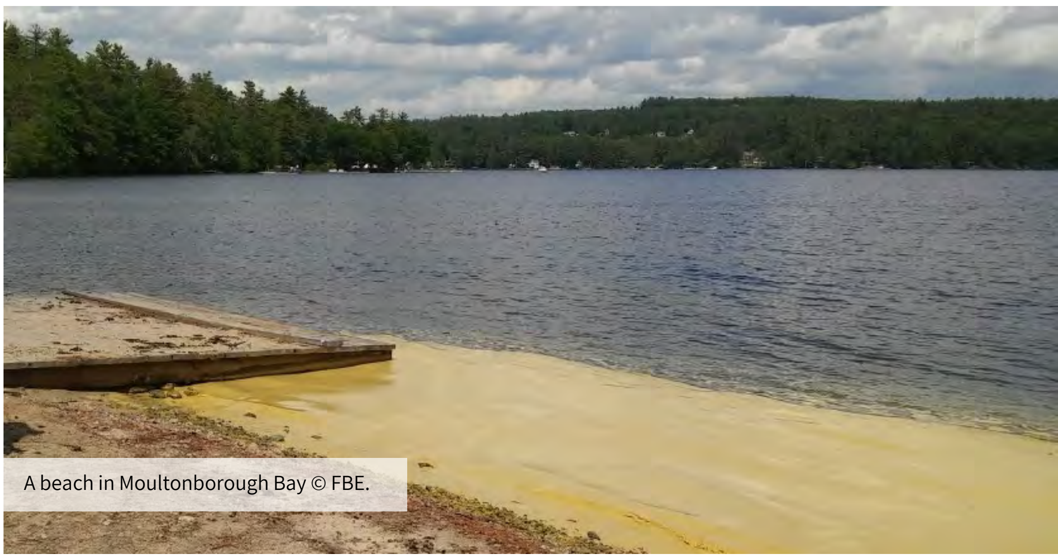
The assimilative capacity analysis for Moultonborough Bay and Winter Harbor follows the methods outlined in the 2018 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology (NHDES, 2018b) (2018 CALM) to identify the tier status and assimilative capacity of these two embayments. Assimilative capacity analysis was completed for total phosphorus and chlorophyll-a at all sites in Moultonborough Bay and Winter Harbor with epilimnion samples collected during the critical period (May 24 – Sept 15) within the last ten years (2009 – 2018). Results of the assimilative capacity analysis for Moultonborough Bay and Winter Harbor indicate that all sites obtained Tier 2 designation for high quality waters except for the Senter Cove site (WMO07SL) for total phosphorus and chlorophyll-a (Table 3-10; Table 3-11).

However, the state criteria used to assess results from the assimilative capacity analysis are based on average lake water quality conditions and responses across the state and may not well represent localized conditions of individual waterbodies. In this case, the use of the assimilative capacity analysis for Moultonborough Bay and Winter Harbor as a method for assessing the interaction of total phosphorus and chlorophyll-a falls short in capturing nuanced changes in water quality.

*The **assimilative capacity** of a waterbody describes the amount of a pollutant that can be added to a waterbody without causing a violation of the water quality criteria. For oligotrophic waterbodies such as Lake Winnipesaukee (including all embayments), the water quality criteria are set at 8 ppb for total phosphorus and 3.3 ppb for chlorophyll-a. NHDES requires 10% of the criteria be kept in reserve; therefore, median total phosphorus and chlorophyll-a must be at or below 7.2 ppb and 3.0 ppb, respectively, to achieve Tier 2 High Quality Water status. Support determinations are based on the nutrient stressor (phosphorus) and response indicator (chlorophyll-a), with chlorophyll-a dictating the assessment if both chlorophyll-a and total phosphorus data are available and the assessments differ.*

Phosphorus is often the most limiting nutrient in freshwater lakes. As such, excess inputs of total phosphorus can cause an imbalance in the system, stimulating the overgrowth of algae and cyanobacteria (i.e., blooms), as well as aquatic plants. **By using average summer total phosphorus and chlorophyll-a concentrations in the epilimnion of deep spot and nearshore sites throughout these bays as the sole indicators of high-quality water designations according to the state criteria, we are overlooking the unique characteristics of the species comprising the observed blooms.**

Lake Winnipesaukee and specifically Winter Harbor have seen *Gloeotrichia* blooms in the summer season. *Gloeotrichia* is a colonial cyanobacterium that grows in response to increased light and temperature. *Gloeotrichia* has been observed across New England in low nutrient lake systems over the past decade (Carey et. al., 2012). This is likely in part due to *Gloeotrichia's* ability to use stored phosphorus from the lake sediments before deploying gas vesicles that move the bacterium into the upper water column where it can access light for growth. Thus, legacy phosphorus stored in bottom sediments, especially in the nearshore areas impacted by localized nutrient runoff, represent the greatest risk for and a better indicator of cyanobacteria blooms. This legacy phosphorus that settles to the bottom enters these waterbodies throughout the year, with the highest loads generally occurring outside the summer season during spring precipitation and snowmelt events, fall storm events, and under-ice processes.



A beach in Moultonborough Bay © FBE.

Table 3-10. Assimilative capacity analysis update for total phosphorus in Moultonborough Bay and Winter Harbor. Data included were limited to the last ten years (2009 – 2018), epilimnion samples, and samples collected during the critical period (May 24 – Sept 15).

STATION ID	STATION NAME	COUNT	MEDIAN TP (ppb)	RESERVE ASSIMILATIVE CAPACITY	REMAINING ASSIMILATIVE CAPACITY	TIER DESIGNATION
MOULTONBOROUGH BAY						
WINMOUD	Moultonborough Bay Deep Spot	1	6.20	0.8	1.00	Tier 2**
WMO03LL	Langley Cove	28	5.73	0.8	1.47	Tier 2
WMO07SL	Senter Cove	5	8.50	0.8	-1.30	Impaired**
WMO05ML	Melvin Bay	60	6.35	0.8	0.85	Tier 2
WMO20ML	Twentymile Bay	114	6.10	0.8	1.10	Tier 2
WMO19AL	Nineteenmile Bay	2	5.80	0.8	1.40	Tier 2**
WMO19BL	Nineteenmile Bay	1	5.85	0.8	1.35	Tier 2**
WLI49GL	Long Island – Greens Boathouse	36	5.75	0.8	1.45	Tier 2
WINTUFD*	Cow Island Deep	0	na	0.8	Na	na
WINTER HARBOR						
WWH10ML	Libby Museum (Upper)	4	4.75	0.8	2.45	Tier 2**
WWH15WL	Winter Harbor Deep Spot (Lower)	20	4.50	0.8	2.70	Tier 2

Table 3-11. Assimilative capacity analysis update for chlorophyll-a in Moultonborough Bay and Winter Harbor. Data included are limited to the last ten years (2009 – 2018), epilimnion samples, and samples collected during the critical period (May 24 – Sept 15).

STATION ID	STATION NAME	COUNT	MEDIAN CHL-A (ppb)	RESERVE ASSIMILATIVE CAPACITY	REMAINING ASSIMILATIVE CAPACITY	TIER DESIGNATION
MOULTONBOROUGH BAY						
WINMOUD*	Moultonborough Bay Deep Spot	0	na	0.3	na	na
WMO03LL	Langley Cove	27	1.60	0.3	+1.4	Tier 2
WMO07SL	Senter Cove	5	2.00	0.3	+1.0	Tier 2**
WMO05ML	Melvin Bay	65	1.90	0.3	+1.1	Tier 2
WMO20ML	Twentymile Bay	116	1.60	0.3	+1.4	Tier 2
WMO19AL	Nineteenmile Bay	106	1.40	0.3	+1.6	Tier 2
WMO19BL	Nineteenmile Bay	104	1.40	0.3	+1.6	Tier 2
WLI49GL	Long Island – Greens Boathouse	90	1.30	0.3	+1.7	Tier 2
WINTUFD*	Cow Island Deep	0	na	0.3	na	na
WINTER HARBOR						
WWH10ML	Libby Museum (Upper)	35	1.10	0.3	+1.9	Tier 2
WWH15WL	Winter Harbor Deep Spot (Lower)	20	0.95	0.3	+2.1	Tier 2

* = no data exists between May 24 and September 15.
** = less than ten samples included in analysis. Tier designation is preliminary.

3.3.2 Lake Loading Response Model (LLRM) Results

A second analysis was used to link watershed loading conditions with in-lake total phosphorus and chlorophyll-a concentrations to predict past, current, and future water quality in Moultonborough Bay and Winter Harbor. It is important to note that the two LLRM models (one for Moultonborough Bay and one for Winter Harbor) represent simplified, single-basin, whole-lake mixing at the average annual time scale and do not represent localized conditions in individual embayments throughout the basins. Physical characteristics such as basin morphology (shape), bathymetry (depth), underlying soil/geology, atmospheric deposition, and riparian vegetation can alter localized water chemistry and hydrology within the lake. For example, shallow nearshore areas may be more susceptible to external inputs of phosphorus from drainage pathways and/or shoreline erosion. Lake mixing and stratification may also not be uniform across basins with unique morphology and position that alter water circulation and wind patterns, which can create spatial heterogeneity in the extent and duration of anoxic and hypoxic conditions that promote internal loading in the hypolimnion. Cyanobacteria blooms that reach the surface of the lake may also be susceptible to wind patterns and concentrate along shorelines in the direction of the prevailing wind.

However, the model can still provide useful information about the major sources of phosphorus to each basin and help guide management efforts. Modeled current total phosphorus load to Moultonborough Bay is 2,951 kg/yr and is 271 kg/yr for Winter Harbor (Table 3-12). The model results shows that watershed runoff combined with baseflow (83% and 61%) was the largest phosphorus loading contribution across all sources to Moultonborough Bay and Winter Harbor, respectively, followed by atmospheric deposition (9% and 16%), septic systems (4% and 12%), waterfowl (3% and 6%), and internal loading (1% and 6%) (Figure 3-7, Table 3-12). Development in the watershed is most concentrated around the shoreline where septic systems or holding tanks are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures, which leach untreated, nutrient-rich wastewater effluent to the lake. A closer look at development in drainage areas to localized problem areas may reveal significant nutrient sources that should be addressed. For instance, the 2018 cyanobacteria bloom in the southern portion of Winter Harbor near Whitegate Road (coupled with elevated phosphorus concentrations measured in stormwater outfalls from the area) led to an investigation and subsequent re-engineering of the stormwater drainage in the Whitegate Road neighborhood.

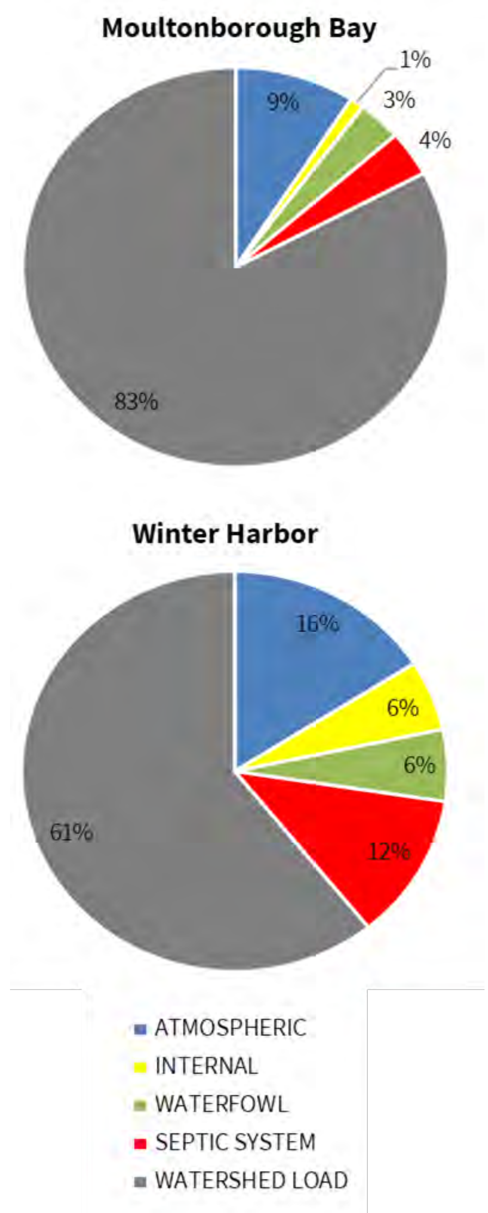


Figure 3-7. Summary of total phosphorus loading by major source for Moultonborough Bay and Winter Harbor. The loads from the Basin, Moultonborough Bay Inlet, Mirror Lake, and exchange with Lake Winnipesaukee are included in the watershed load.

Pre-development loading estimation showed that since European settlement, total phosphorus loading increased by 204% for Moultonborough Bay and by 160% for Winter Harbor. These additional phosphorus sources are coming from development in the watershed (especially from Moultonborough Bay Inlet, Nineteenmile Brook, and Melvin River for Moultonborough Bay and from the direct shoreline of Winter Harbor North for Winter Harbor), septic systems, atmospheric dust, and internal loading (Figure 3-8, see Figure 3-10 on page 35 for a map of current total phosphorus loads by sub-basin). The increase in phosphorus loading to these basins since European settlement represents a potentially significant accumulation of legacy phosphorus in bottom sediments that can be utilized by cyanobacteria.

Future loading estimation showed that total phosphorus loading may increase by 70% at **full build-out** (2,072) under current zoning for Moultonborough Bay and by 93% for Winter Harbor (Figure 3-9, following page). Additional phosphorus will be generated from more development in the watershed (especially from Moultonborough Bay Inlet, Melvin River, and Nineteenmile Brook for Moultonborough Bay and from Mirror Lake for Winter Harbor), greater atmospheric dust, more septic systems, and enhanced internal loading. The model predicted significantly higher (worse) phosphorus (12.0 ppb), higher (worse) chlorophyll-a (3.2 ppb), and lower (worse) water clarity (3.4 m) compared to current conditions for both Moultonborough Bay and Winter Harbor. Any further increases in phosphorus to these basins can disrupt the ecological balance in favor of increased algal and cyanobacteria growth, resulting in a continued degradation of water clarity.

Based on model analysis of pre-development, current, and future water quality conditions, both Moultonborough Bay and Winter Harbor are at risk for continued water quality degradation from future development under current zoning. Additional phosphorus loading from the watershed and internal sediments will likely accelerate water quality degradation of the basins. Given the area's recreational and aquatic habitat value in the region, it will be crucial to both maximize land conservation of intact forestland and consider zoning ordinance amendments that encourage LID techniques and proper septic system siting and replacement on existing and new development.

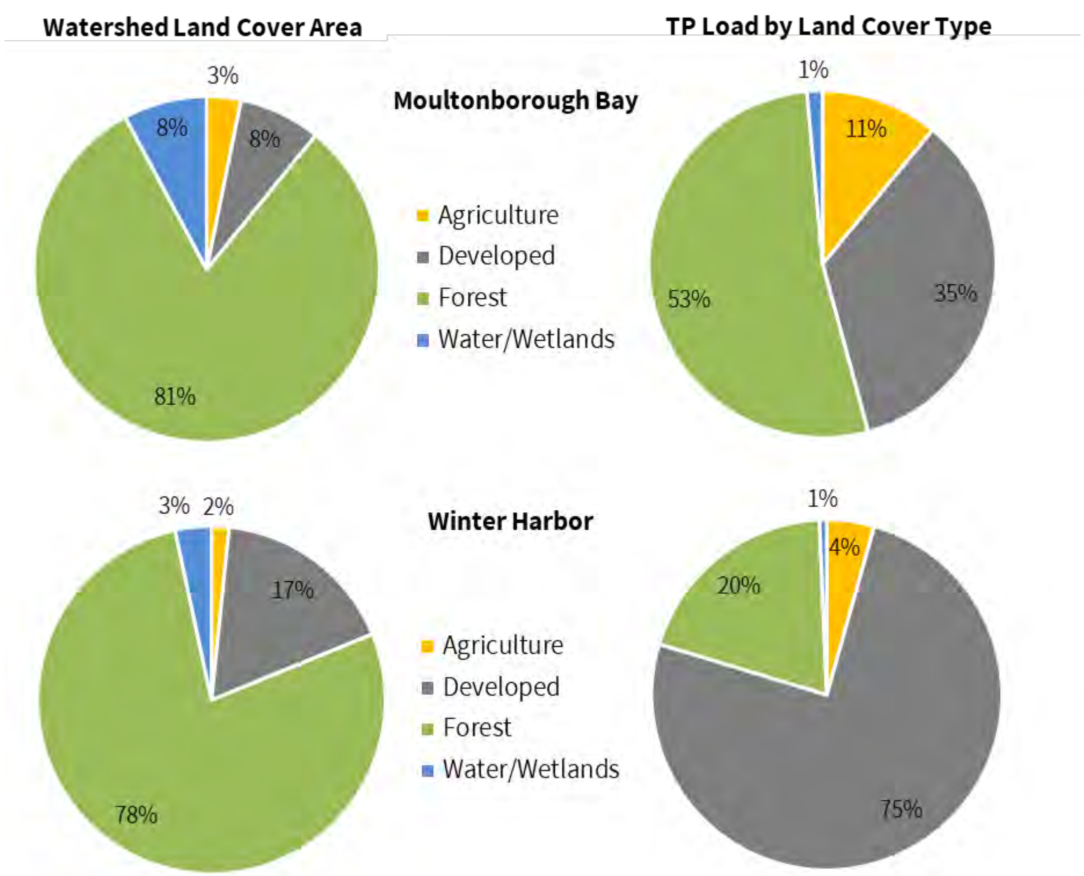


Figure 3-8. Watershed land cover area by general category (developed, agriculture, forest, and water/wetlands) and total phosphorus (TP) watershed load by general land cover type. This shows that developed areas cover 8% and 17% of the watershed and contribute 35% and 75% of the TP watershed load to Moultonborough Bay and Winter Harbor, respectively.

Table 3-12. Total phosphorus (TP) and water loading summary by source for Moultonborough Bay and Winter Harbor. Italicized sources sum to the watershed load.

SOURCE	PRE-DEVELOPMENT			CURRENT (2019)			FUTURE (2072)		
	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)
Moultonborough Bay									
ATMOSPHERIC	171	18%	18,183,287	269	9%	18,183,287	612	12%	18,183,287
INTERNAL	0	0%	0	31	1%	0	53	1%	0
WATERFOWL	98	10%	0	98	3%	0	98	2%	0
SEPTIC SYSTEM	0	0%	0	109	4%	85,631	143	3%	111,745
WATERSHED LOAD	702	72%	192,343,553	2,443	83%	192,667,487	4,102	82%	193,251,685
RIWDS	--	--	--	*0*	*0%*	*497,403*	*0*	*0%*	*497,403*
MBI	*222*	*23%*	*76,441,784*	*846*	*29%*	*76,219,714*	*1,273*	*25%*	*76,697,288*
Exchange with Main Lake	*194*	*20%*	*54,000,000*	*292*	*10%*	*54,000,000*	*497*	*10%*	*54,000,000*
Direct Land Use Load	*286*	*29%*	*61,901,769*	*1,306*	*44%*	*61,950,371*	*2,332*	47%	*62,056,995*
TOTAL LOAD TO LAKE	**971**	**100%**	**210,526,840**	**2,951**	**100%**	**210,936,405**	**5,008**	**100%**	**211,546,717**
Winter Harbor									
ATMOSPHERIC	27	26%	2,912,447	43	16%	2,912,447	98	19%	2,912,447
INTERNAL	0	0%	0	15	6%	0	30	6%	0
WATERFOWL	16	15%	0	16	6%	0	16	3%	0
SEPTIC SYSTEM	0	0%	0	32	12%	24,030	42	8%	31,826
WATERSHED LOAD	61	59%	12,659,817	165	61%	12,664,414	336	64%	12,667,455
The Basin	*3*	*3%*	*762,060*	*9*	*3%*	*763,729*	*15*	*3%*	*763,761*
Mirror Lake	*25*	*24%*	*3,955,000*	*42*	*15%*	*3,955,000*	*120*	*23%*	*3,955,000*
Exchange with Main Lake	*11*	*10%*	*3,000,000*	*16*	*6%*	*3,000,000*	*28*	*5%*	*3,000,000*
Direct Land Use Load	*23*	*22%*	*4,942,757*	*98*	*36%*	*4,945,685*	*173*	*33%*	*4,948,694*
TOTAL LOAD TO LAKE	**104**	**100%**	**15,572,264**	**271**	**100%**	**15,600,892**	**521**	**100%**	**15,611,729**

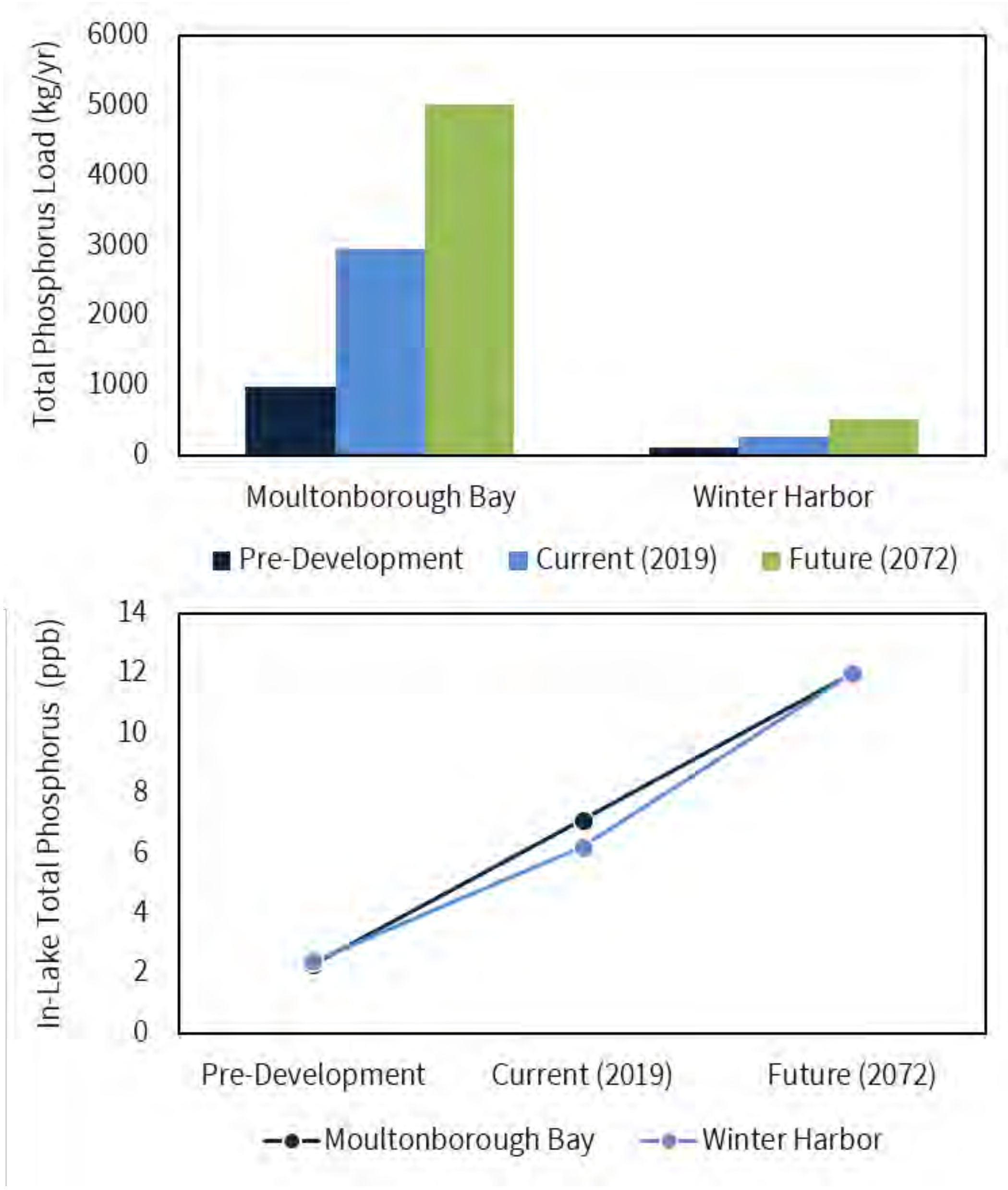


Figure 3-9. Change in total phosphorus load (kg/yr, **TOP**) and in-lake total phosphorus concentration (ppb, **BOTTOM**) for Moultonborough Bay and Winter Harbor from pre-development to current (2019) to future (2072) conditions.

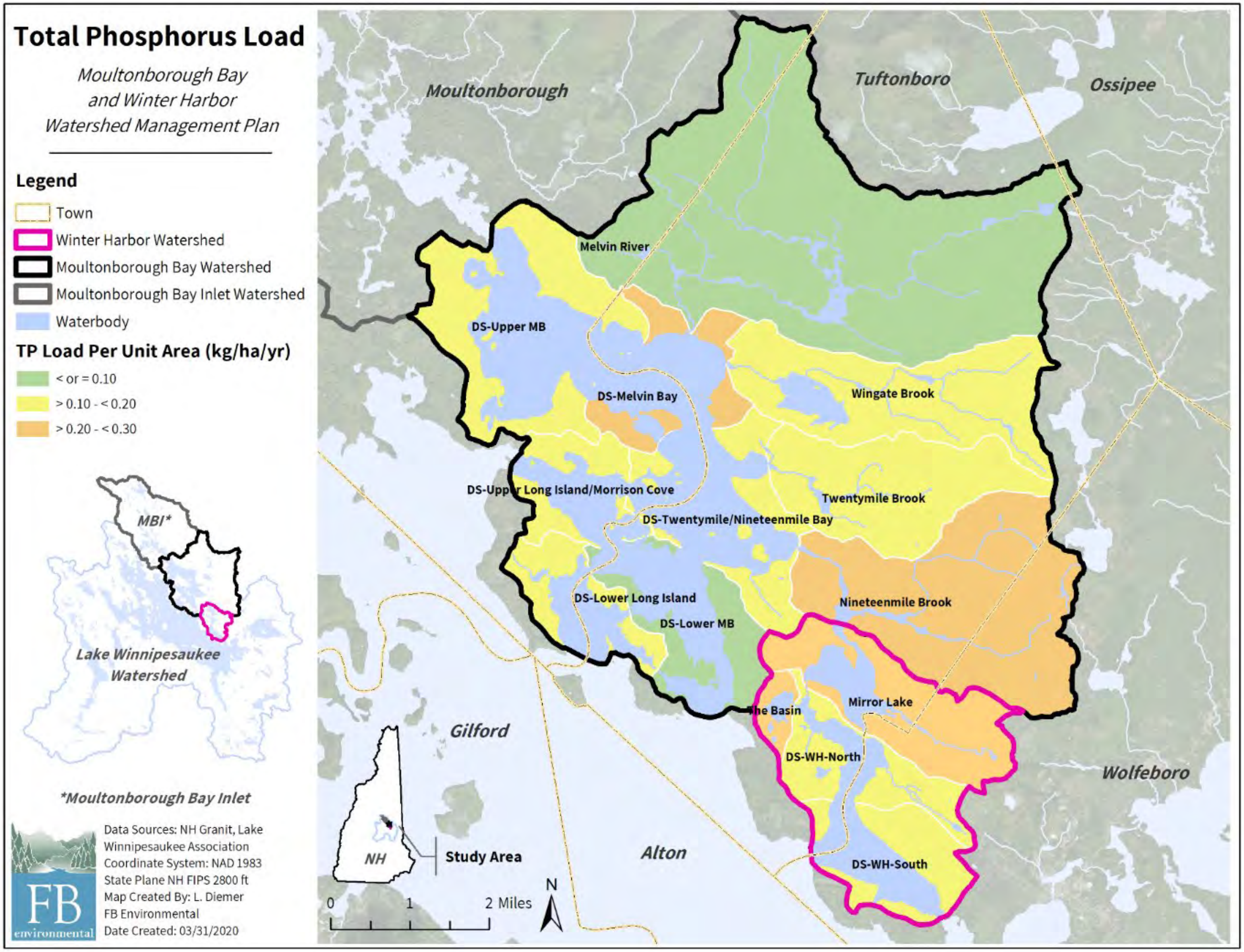


Figure 3-10. Map of current total phosphorus load per unit area (kg/ha/yr) for each sub-watershed in the Moultonborough Bay and Winter Harbor watersheds.

3.3.3 Historical & Future Phosphorus Loading: Build-out Analysis

A build-out analysis identifies areas with development potential and projects future development based on a set of conditions (e.g., zoning regulations, environmental constraints) and assumptions (e.g., population growth rate). A build-out analysis shows what land is available for development, how much development can occur, and at what densities. “Full Build-out” is a theoretical condition representing the moment in time when all available land suitable for residential, commercial, and industrial uses has been developed to the maximum capacity permitted by current local ordinances and current zoning standards. Local ordinances and zoning standards are subject to change and therefore the following results of the build-out analysis should be viewed as estimates only. The build-out analysis includes the portions of the watersheds in the towns of Moultonborough, Tuftonboro, and Wolfeboro (FBE, 2020b). The Town of Ossipee was not included because only 0.11% of the watershed area is part of the Town of Ossipee.

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

To determine where development may occur within the study area, the build-out analysis first subtracts land unavailable for development due to physical constraints, including environmental restrictions (e.g., wetlands, conserved lands, hydric soils), zoning restrictions (e.g., shoreland zoning, street Right-of-Ways (ROWs), and building setbacks), and practical design considerations (e.g., lot layout inefficiencies). Existing buildings also reduce the capacity for new development (Appendix A, Map 9). Under current zoning regulations, 56% (16,770 acres) of the Moultonborough Bay and Winter Harbor watersheds is buildable (Figure 3-11) (Appendix A, Map 10). The Moultonborough Bay and Winter Harbor watersheds consist of approximately 5,262 parcels, ranging in size from less than one acre to 830 acres. Approximately 2,910 existing buildings were identified within the watershed area. Upon reaching full build-out, an estimated 6,385 additional buildings could be constructed, resulting in a total of 9,295 buildings (Appendix A, Map 11).

According to the US Census Bureau, Moultonborough, Tuftonboro, and Wolfeboro have experienced steady population growth since the middle part of the 20th century, increasing from a combined total of 5,256 people in 1970 to 12,700 people in 2010. The TimeScope Analysis was run under three different iterations. This tool for facilitating analysis of change over time was run using compound annual growth rates for 20-, 30- and 40-year periods from 1990-2010 (1.41%), 1980-2010 (1.69%), and 1970-2010 (2.23%), respectively. Therefore, full build-out is projected to occur in 2102 at the 20-year growth rate, 2089 at the 30-year growth rate, and 2072 for the 40-year growth rate. Moultonborough Bay and Winter Harbor watersheds will reach full build-out by the late 21st century to early-22nd century, given growth rates, zoning, and other development constraints remain constant (Figure 3-12).

The Tuftonboro Low Density Residential zone has the greatest amount of land available for development (6,817 acres of its total 11,645 available acres) and the largest number of projected buildings (2,177 buildings). The Wolfeboro Rural Residential District has the highest percentage (72%) of buildable land within the study area, and the Open Space/Forestry zone in Tuftonboro has the highest percent increase from existing buildings to projected buildings at 4,725% (Table 3-12).

Table 3-13. Amount of buildable land within the Moultonborough Bay and Winter Harbor watersheds.

Zone	Total Area (Acres)	Buildable Area (Acres)	Percent Buildable Area	No. Existing Buildings	No. Projected Buildings	Total No. Buildings	Total No. Buildings Percent Increase
Moultonborough							
Residential/Agricultural	4,690	2,406	51	733	1,562	2,295	213
Tuftonboro							
Low Density Residential	11,645	6,817	59	557	2,177	2,734	391
Medium Density Residential	1,963	1,294	66	276	769	1,045	279
Islands' Conservation	630	214	34	171	191	362	112
Lakefront Residential	867	293	34	429	224	653	52
Open Space/Forestry	2,891	1,227	42	4	189	193	4,725
Neighborhood Business	346	234	68	81	151	232	186
Manufactured Housing/Low Density Residential	487	235	48	44	81	125	184
Manufactured Housing/Medium Density Residential	51	8	16	8	16	24	200
Manufactured Housing/Open Space/Forestry	63	37	59	3	5	8	167
Wolfeboro							
Residential	1,435	813	57	326	574	900	176
Rural Residential*	3,717	2,663	72	127	230	357	181
Shorefront Residential	382	208	54	139	96	235	69
General Residential	452	318	70	12	120	132	1,000
Residential/Agricultural	71	3	4				
Municipal Watershed	23	2	9				
Total	**29,713**	**16,772**	**56**	**2,910**	**6,385**	**9,295**	**219**

**Wolfeboro Rural Residential Zone includes Manufactured Housing Overlay.*

The Municipal Watershed and Residential Agricultural Zone have small buildable area and no projected buildings.
Note: The portion of the watershed in the Town of Ossipee is not included in the summary tables. This portion is 32 acres and composes 0.11% of the watersheds.

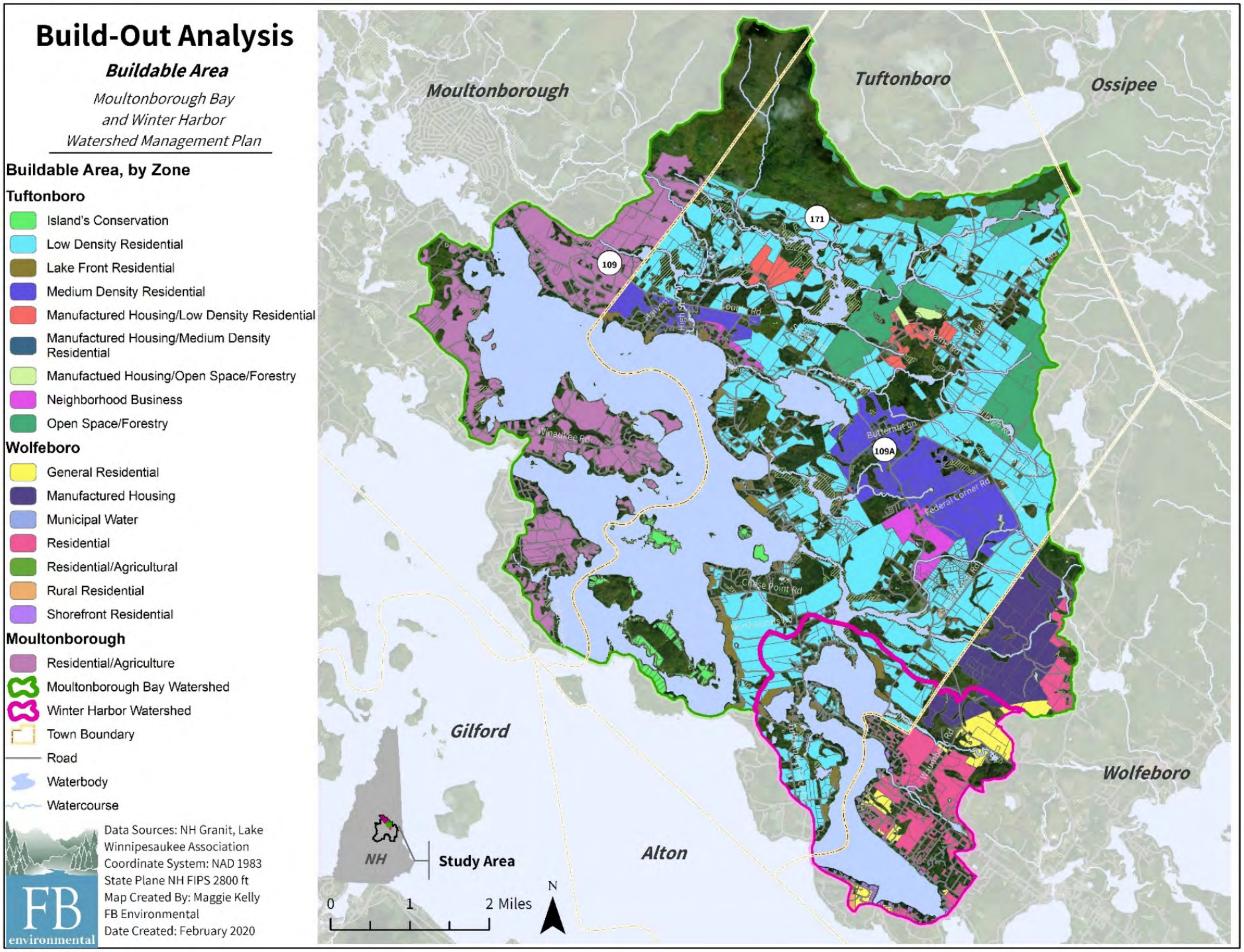


Figure 3-11. Buildable area in the Moultonborough Bay and Winter Harbor Watersheds, displayed by town zone.

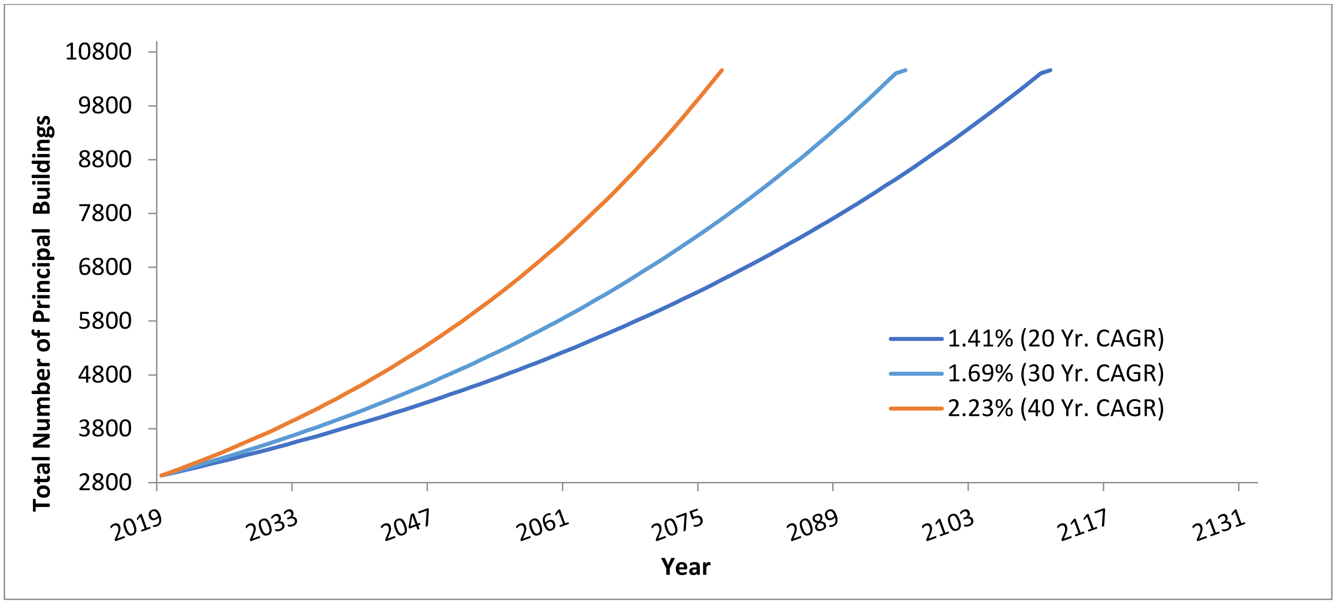


Figure 3-12. Full build-out projections of the Moultonborough Bay and Winter Harbor watersheds (based on compound annual growth rates).

3.4 ESTABLISHMENT OF WATER QUALITY GOAL

The analyses revealed that both Moultonborough Bay and Winter Harbor are at great risk for continued water quality degradation as a result of existing and future development in the watersheds. Addressing watershed runoff and baseflow sources of phosphorus in both existing and new development will be critical to reducing the accumulation of legacy phosphorus in bottom sediments that cyanobacteria can readily access. The committee met to discuss the water quality goal and objectives on April 10, 2020 and agreed that the observation of localized cyanobacteria blooms requires further investigation of those areas so that more geographically specific objectives can be set for the plan. In the meantime, watershed-wide reductions in phosphorus load to the basins will be helpful to improving and protecting water quality in the long-term. Local hotspots of phosphorus loading and associated benthic and free-floating algal growth are early warning signs of water quality degradation on a basin-wide scale. Addressing the local sources of phosphorus associated with these local hotspots will help prevent water quality decline in the greater basins and ultimately throughout Lake Winnipesaukee. We have presented the water quality goals for Moultonborough Bay and Winter Harbor as two-fold.

Goal 1: To improve water quality in both Moultonborough Bay and Winter Harbor through a 5% reduction in current total phosphorus loads to meet an average seasonal (May 24-Sept 15) deep spot epilimnion concentration of 6.7 ppb and 5.9 ppb in Moultonborough Bay and Winter Harbor, respectively.

- To maintain current water quality in Moultonborough Bay, 39 kg/yr of total phosphorus must be removed to offset the anticipated increase in annual inputs over the next 10 years plus an additional 148 kg/yr to meet the 5% reduction target. This sums to a reduction total of 187 kg/yr for Moultonborough Bay in the next 10 years.
- To maintain current water quality in Winter Harbor, 4.7 kg/yr of total phosphorus must be removed to offset the anticipated increase in annual inputs over the next 10 years plus an additional 14 kg/yr to meet the 5% reduction target. This sums to a reduction total of 18.7 kg/yr for Winter Harbor in the next 10 years.

Goal 2: To assess the spatial and temporal distribution and causes of *Gloeotrichia* blooms observed in Lake Winnipesaukee (and most notably in the Winter Harbor basin) and determine geographically specific water quality objectives to reduce the occurrence of localized blooms.

- Quantify (through enumeration and speciation) the presence of *Gloeotrichia* at nearshore sites in Moultonborough Bay and Winter Harbor during bloom events (including within column, surface scum, and benthic algae).
- Identify long-term beach profiling sites to determine the input of shoreline erosion on localized total phosphorus concentrations in both Moultonborough Bay and Winter Harbor (Rando et. al., 2017) .
- Enhance water quality monitoring at nearshore sites with sampling in spring, summer, and fall to identify the seasonal effects of localized total phosphorus.

It is important to set interim milestones for each goal to 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 ten or more years (Table 3-13). 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.

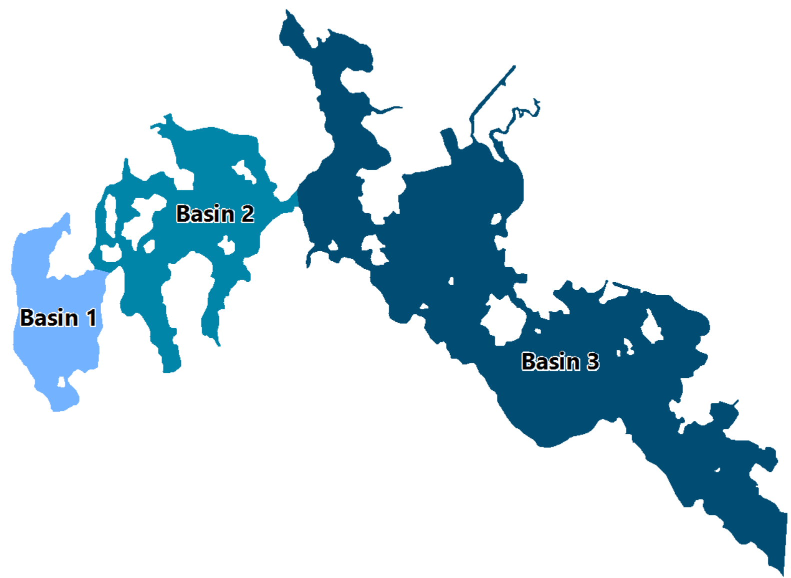
Table 3-14. Water quality goals for Moultonborough Bay and Winter Harbor with interim goals/benchmarks to guide success.

	Interim Goals/Benchmarks		
Water Quality Goal	**2021**	**2025**	**2030**
1. To improve water quality in both Moultonborough Bay and Winter Harbor through a 5% reduction in current total phosphorus loads to meet an average seasonal (May 24-Sept 15) deep spot epilimnion concentration of 6.7 ppb and 5.9 ppb in Moultonborough Bay and Winter Harbor, respectively.	<u>Moultonborough Bay:</u> Achieve 50 kg/yr reduction in TP loading; prevent or offset 10 kg/yr in TP loading from new development <u>Winter Harbor:</u> Achieve 5 kg/yr reduction in TP loading; prevent or offset 2 kg/yr in TP loading from new development.	<u>Moultonborough Bay:</u> Achieve 100 kg/yr reduction in TP loading; prevent or offset 20 kg/yr in TP loading from new development <u>Winter Harbor:</u> Achieve 10 kg/yr reduction in TP loading; prevent or offset 3 kg/yr in TP loading from new development. Re-evaluate water quality and track progress.	<u>Moultonborough Bay:</u> Achieve 148 kg/yr reduction in TP loading; prevent or offset 39 kg/yr in TP loading from new development <u>Winter Harbor:</u> Achieve 14 kg/yr reduction in TP loading; prevent or offset 4.7 kg/yr in TP loading from new development. Re-evaluate water quality and track progress.
2. To assess the spatial and temporal distribution and causes of *Gloeotrichia* blooms observed in Lake Winnipesaukee (and most notably in the Winter Harbor basin) and determine geographically specific water quality objectives to reduce the occurrence of localized blooms.	Complete study designs and identify funding for enhanced nearshore monitoring, including algae and cyanobacteria enumeration/speciation and shoreline erosion profiling.	Evaluate first three years of enhanced monitoring (2022, 2023, and 2024). Identify any needed design modifications. Prioritize drainage areas to hotspot nearshore sites for implementation action.	Complete 10-yr study and re-evaluate water quality and track progress. Identify action items to address any results identified in these studies. Continue to prioritize drainage areas to hotspot nearshore sites for implementation action.

3.5 POLLUTANT SOURCE IDENTIFICATION

3.5.1 Moultonborough Bay Inlet

Located just upstream, the Moultonborough Bay Inlet is the largest inlet to the Moultonborough Bay watershed, totaling 50 sq. mi. (32,246 acres). The Moultonborough Bay Inlet watershed includes three distinct basins (Basins 1, 2, and 3). Like the Moultonborough Bay and Winter Harbor watersheds, the Moultonborough Bay Inlet is classified as part of the Lake Winnipesaukee system and therefore is listed as oligotrophic in the NHDES database. However, when considered individually, Basin 1 is impaired for both total phosphorus and chlorophyll-a and is at risk for elevated nutrient input and blooms. Basins 2 and 3 are potential non-support but available data were insufficient at the time of the plan. The Moultonborough Bay Inlet Watershed Restoration Plan was written in 2017 and stated interim water quality goals and milestones to reduce current median in-lake total phosphorus to 7.2 ppb for Basins 1, 2, and 3, which would require a phosphorus loading reduction of 42% (26 kg/year) in Basin 1, 31 % (27 kg/year) in Basin 2, and 20% (242 kg/year) in Basin 3. Protecting the water quality of Moultonborough Bay is reliant on strong implementation of the Moultonborough Bay Inlet Watershed Restoration Plan and improved water quality in the inlet.



3.5.2 Mirror Lake

Mirror Lake is a 321-acre (0.5 sq. mi.) lake in the towns of Tuftonboro and Wolfeboro in the Winter Harbor watershed. The Mirror Lake watershed is 1,460 acres in total (2 sq. mi.). A watershed management plan for Mirror Lake was written in 2012 by the Mirror Lake Protective Association and Geosyntec consultants because of its impairment for primary contact recreation due to recurring cyanobacteria blooms (Geosyntec Consultants, 2012). The plan estimated an annual total phosphorus load of 320 lbs/year to Mirror Lake, with 52% from watershed runoff, 24% from atmospheric deposition, 17% from internal loading, 7% from septic systems, and 0.6% from the wastewater treatment plant (WWTP). Mirror Lake has an estimated flushing rate of 0.7 and a hydraulic residence time of 1.4 years. Historic total phosphorus data for Mirror Lake (1990-2012) show an increasing trend in total phosphorus concentrations. Mirror Lake outlets to Winter Harbor through a 0.28 km channel at the eastern edge of the lake near the crossing with Governor Wentworth Highway near its intersection with Tuftonboro Neck Road. For the purposes of this plan, the results of the 2012 modeling from Mirror Lake were input as point sources into the Winter Harbor LLRM results.

3.5.3 Rapid Infiltration Basin System

Rapid infiltration (i.e., a rapid infiltration basin, RIB) is a treatment technique for wastewater where wastewater is applied to highly porous soils via flooding or sprinklers. The wastewater is applied to shallow basins where it percolates through the soil until it is discharged to surface waters or groundwater. As the wastewater infiltrates through the basin soils, it is treated through filtration, adsorption, ion exchange, precipitation, and microbial decomposition in the soil matrix (USEPA, 2016).


The RIB site. © GoogleEarth Imagery.

The RIB system in Wolfeboro, near the Tuftonboro border, was developed in 2009 on a 35-acre parcel and includes a series of five (5) basins that serves as a groundwater discharge area for treated effluent from the Wolfeboro Effluent Storage Pond. Nineteenmile Brook is located downgradient of the site and an Unnamed Brook that flows into Nineteenmile Brook is located to the north and east of the site. Following initial introduction of treated wastewater effluent to the RIB system in March 2009, unanticipated issues developed, including groundwater breakouts on the slopes below the RIB, erosion and slope failure, and sediment deposition in wetlands. It was identified that the original consultant incorrectly modeled the RIB site which caused the issues and damage to wetlands, as well as violation of the groundwater permit. The Town was awarded $7 million in damages and negotiated an Administrative Order by Consent (AOC No. 15-011 WD) with NHDES in May 2015. Following this AOC negotiation, the Town of Wolfeboro retained consultants at Underwood Engineers to test, study, and identify a plan to achieve compliance with wastewater disposal rules and regulations at the RIB site.

In 2016, Underwood Engineers and the Town constructed and piloted three solutions (two natural systems and one engineered natural system). An additional Engineered Natural System was piloted in 2017. In 2018 – 2019, four cut-off trenches of varying depth, width, and elevation were constructed.

Because of its location downgradient of the RIB system, Nineteenmile Brook was monitored three years prior and for 10 years post-installation of the RIB system. Model results from the LLRM presented in this plan identified a negligible difference in total phosphorus between the upstream control site and the downstream impacted site on Nineteenmile Brook below the RIB system, suggesting that given current available data, the RIB system is not contributing a significant phosphorus load to stream. An analysis by Normandeau Associates published in January 2019 concluded that there was evidence of surface water quality impacts (primarily chloride and nitrate), likely resulting from the RIB discharge (Normandeau Associates, 2019). This plan does not address other possible contaminants from the RIB system.

3.5.4 Watershed Survey

Following the completion of the watershed survey, FBE created a BMP Prioritization Matrix of all 107 identified sites. This matrix prioritized sites based on the estimated total phosphorus load reduction from the recommended BMP, cost, and observed site impact. From this list, contracting engineers at HWG visited the six highest priority sites and recommended conceptual BMP designs for the top four sites. The top four sites are listed below. Of these four sites, HWG completed final designs for the top three sites. It is important to note that final designs did not include permitting and as such may need to be updated following final permitting requirements from NHDES.

<u>Melvin Village Boat Launch (Site 1-01)</u>

This site is in Melvin Village at the boat launch on Lake Road off Governor Wentworth Highway/Route 109. Stormwater Runoff is evident along the eastern edge of the pavement on Lake Road. An existing conveyance channel on the western edge captures stormwater from Route 109 and the neighboring Melvin Village Community Church. To stay within town property lines, HWG prepared a recommended BMP along the edge of Lake Road. This site consists of a series of two roadside rain gardens with a sediment forebay check dam and two paved inlet flumes. A natural stone check dam would be installed at the end of the first rain garden and a broad-crested spillway would be installed at the end of the second in-series rain garden. A site design was also included for a more comprehensive stormwater management plan for the launch that would include work on the adjacent private property and parking. See Appendix C for more details.

<u>New Road Culvert Restoration (Site 1-12A)</u>

The second site is located on New Road and the crossing with the Melvin River. Because the culvert exists at a lower elevation than New Road, it receives road runoff from both directions that is causing erosion (photo to right, © HWG). The erosion is most severe on the east side of the culvert. Recommendations for this site include a roadside rain garden with a paved inlet flume, an emergency spillway, and stone splash pad on the northwest side of the culvert and a vegetated conveyance swale with emergency spillway, paved inlet flume, stabilized inlet swale, and plantable concrete pavers on the northeast side of the culvert.

<u>Northwoods Road (Site 4-07)</u>

Northwoods Road is a gravel road in Tuftonboro that leads to Moultonborough Bay off Route 109. The Boston YMCA Camping Branch is located along this section of roadway. There are no formal stormwater controls on this roadway and country drainage is present. A small, unnamed stream crosses underneath Northwoods Road before entering Moultonborough Bay. There is evidence of stormwater runoff from Northwoods Road entering directly into the stream. HWG designed a 160 sq. ft. rain garden along the edge of the roadway with a sediment forebay that includes plantable concrete pavers. A natural stone check dam would be installed between the forebay and the rain garden. A compacted earth berm would be built along the forested edge of the sediment forebay. The end of the rain garden would include an emergency spillway.

Tuftonboro Neck Road (Site 4-05)

Tuftonboro Neck Road passes between the main Winter Harbor embayment and the Basin via a large corrugated metal culvert. At this crossing, exposed shoulders exist on both embankments with predominantly bare ground and little to no vegetation. Preliminary recommendations for this site from HWG include the re-establishment of native, low-growing vegetation to stabilize the shoreline. The existing shoreline boulders and steel guardrail would remain in place with the addition of native rock channels to embrace the current flowpath. HWG recommends planting bunch grasses and grain drilled seed mix before amending the soil with jute mating. Constriction of the channel is a concern for water quality in the Basin; however, these BMP recommendations are intended only to address stormwater runoff. This site was not selected for final BMP designs.

3.5.5 Shoreline Survey

Field assessments were completed from a boat using handheld tablet computers with GPS and GIS software for data collection and cameras to document the existing conditions of each parcel with lake frontage. The survey uses a scoring system that evaluates vegetated buffer, presence of bare soil, extent of shoreline erosion, distance of structures to the lake, and slope. The sum of these scores generates a “shoreline disturbance score” for each parcel. Vegetated buffer was scored from one to five, with one being an excellent natural buffer with a mix of trees and shrubs, and five being all lawn or bare ground with no buffer. Presence of bare soil was scored from one to four, with one being no bare soil and four being large amounts of exposed soil. Extent of shoreline erosion was scored from one to three, with one being no erosion visible and three being moderate to severe shoreline erosion. Distance to shore was scored from one to three, with one being a structure more than 150 feet from the shoreline, and three being a structure closer than 75 feet to the shoreline. Slope was scored from one to three, with one being little to no slope, and three being a steep slope. These data were then downloaded and entered into a compiled dataset with the scores, notes, and photographs of all parcels. Surveys completed by LWA AmeriCorps members used paper versions of the field forms and data were sent to FBE staff for inclusion in the dataset.

A total of 1,306 parcels were surveyed along the shoreline. The shoreline disturbance scores ranged from four to 18, with lower scores indicating a lesser impact on lake quality (minimal erosion or runoff issues) and higher scores indicating greater impact (significant erosion or runoff issues (Figure 3-7). The average shoreline disturbance score across all parcels was 9.8, with an average score of 9.6 in Moultonborough Bay and 10.4 in Winter Harbor (Table 3-14). A total of 717 parcels were rated as either “high” (scored 15-18) or “medium (scored 10-14).

Certain site characteristics, such as slope, can cause shorelines to be naturally more vulnerable to erosion. For example, parcels along the Winter Harbor shoreline scored higher for slope, indicating that the Winter Harbor shoreline is more steeply sloped, and thus, more vulnerable to stormwater runoff and erosion. Other site characteristics, such as buffer, are often a direct consequence of the development on that parcel. These factors are more easily changed to strengthen the resiliency of the shoreline to disturbance in the watershed.

Table 3-15. Summary of shoreline disturbance scores for parcels in Moultonborough Bay and Winter Harbor. Shoreline disturbance scores represent an analysis of the vegetated buffer (1-5), bare soil on the parcel (1-4), the distance of any structures to the shoreline (0-3), and the slope of the parcel (1-3).

	Average Scores Per Parcel					
	Buffer (1-5)	**Bare Soil (1-4)**	**Shoreline Erosion (1-3)**	**Distance (0-3)**	**Slope (1-3)**	**Shoreline Disturbance Score (0-18)**
Moultonborough Bay	2.6	1.9	1.4	2.3	1.4	9.6
Winter Harbor	2.9	2.3	1.2	2.4	1.7	10.4
Average of All Scores	**2.7**	**2.0**	**1.3**	**2.3**	**1.5**	**9.8**

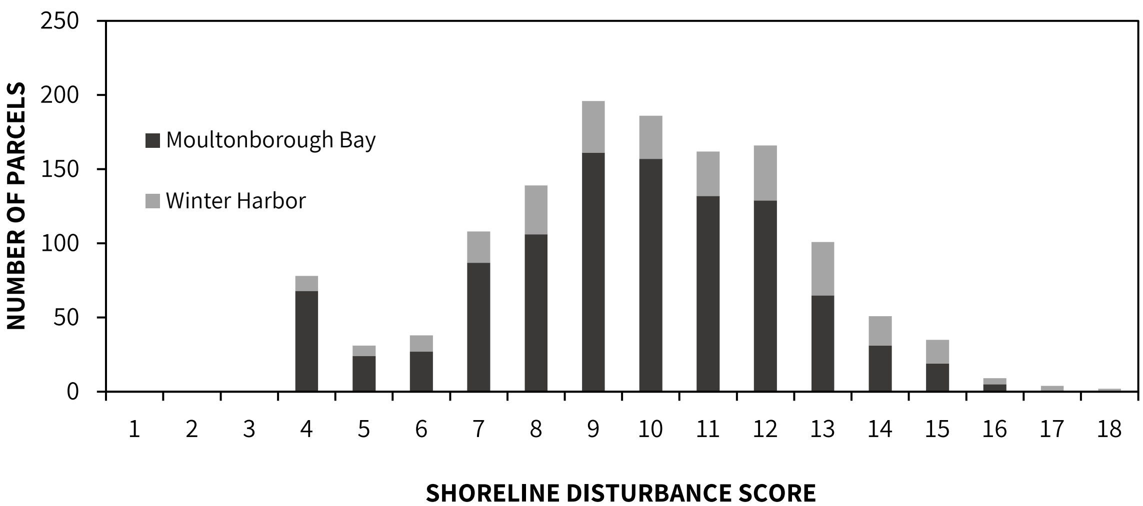


Figure 3-13. Shoreline disturbance scores for Moultonborough Bay (black) and Winter Harbor (light grey). A total of 1,306 parcels were surveyed with 717 parcels rated as “high” (scored 15-18) or “medium” (scored 10-14).

Figure 3-14. (top)Two properties with trees and shrubs between the shoreline and structure creating a natural buffer, and (bottom) two properties vulnerable to stormwater runoff because of limited shoreline buffers. Examples not from Moultonborough Bay - Winter Harbor shoreline survey to protect landowner privacy.

3.5.6 Septic System Survey

In 2019, LWA completed a septic system risk analysis for properties located within 250 feet of Moultonborough Bay and Winter Harbor. Using GIS and parcel data from the towns of Moultonborough, Tuftonboro, and Wolfeboro, LWA determined that 870 parcels with primary dwellings on septic systems are within the 250 feet of Moultonborough Bay and 265 parcels are within 250 feet of Winter Harbor (Table 3-15). Further analysis of the parcels indicates that 533 parcels out of the 870 parcels around Moultonborough Bay and 177 out of the 265 parcels around Winter Harbor contain buildings that were built prior to 1994; the date used to determine the number of systems older than 25 years (the average life span of a septic system). Verification of the age of the septic system is difficult. Tax records were reviewed for each property as well as the NHDES Subsurface One Stop online database to determine whether construction or operational approval permits had been issued for the property. NHDES records of construction and operational approval permits can be found online back to 1986. Prior to 1986, records are archived, and require individual research requests.

Table 3-16. Total parcels identified within 250 feet of Moultonborough Bay and Winter Harbor listed by subwatershed. Work conducted by LWA.

Subwatershed	Total Parcels
Moultonborough Bay	
DS-Twentymile/Nineteenmile	179
DS-Melvin Bay	80
DS-Upper MB	174
DS-Upper Long Island	147
DS- Lower Long Island	102
DS- Lower MB	188
Moultonborough Total	**870**
Winter Harbor	
DS-WH-South	99
DS-WH-North	135
Basin-WH	31
Winter Harbor Total	**265**

Individual tax records for each parcel were reviewed to determine whether the property is occupied year-round or seasonally. Properties with mailing addresses outside of Moultonborough, Tuftonboro, and Wolfeboro were assumed to be seasonal. These data were then inputted to the LLRM (see Section 3.3.2) to provide an improved estimation of the contribution of septic systems to phosphorus loading to the lake.

3.5.7 Potential Contamination Sources

Identifying the types and locations of potential contamination sources (PCS) within the watersheds may help identify sources of pollution and or areas to target for restoration efforts. There are two solid waste facilities within the Moultonborough Bay and Winter Harbor watersheds. One of which, the Tuftonboro Municipal Landfill, is a closed, unlined landfill no longer under operation, while the other is the Tuftonboro Transfer Station which is currently under operation. Hazardous waste generating facilities are identified through the USEPA's Resource Conservation and Recovery Act (RCRA). Only one of the nine hazardous waste generating facilities within the Moultonborough Bay and Winter Harbor watersheds is listed as active. There are eight aboveground storage tanks, four of which are operated by marinas, and one each for commercial, recreational, utilities, and other. Twenty-two storage tanks lie underground, and there are 75 remediation project sites to clean up contaminated sites within the watersheds (Appendix A, Map 8).

3.5.8 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 in the Oyster River in Durham, NH, three of the four highest floods occurred in the past 10 years (Ballestero et al., 2017). Average annual air temperature in New England has risen by 1°C to 2.3 °C since 1895 with greater increases in winter air temperature (IPCC, 2013). Lake ice-out dates are occurring earlier as warmer winter air temperature melts the snowpack and lake ice; earlier ice-out allows a longer growing season and increases the duration of anoxia in bottom waters. Increasing storm frequencies will flush more nutrients to surface waters for algae to feed on and flourish under warmer air temperatures.

These trends will likely continue into the future to impact both water quality and quantity. Climate change models predict a 10-40% increase in stormwater runoff by 2050, particularly in winter and spring and an increase in both flood and drought periods as seasonal precipitation patterns shift. Adding to this stress is population growth and corresponding development in NH. The build-out analysis for the watershed showed that about 16,770 acres is still developable and up to 6,385 new buildings could be added to the watershed at full build-out based on current zoning standards. Moultonborough Bay and Winter Harbor 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 the 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 for preservation because wetlands hold water, recharge groundwater, and mitigate water pollution.
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, 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 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.

4. MANAGEMENT STRATEGIES

The goal of the Moultonborough Bay and Winter Harbor Watershed Management Plan is to improve water quality in these embayments and their tributaries to eliminate the presence of blooms that impair these waterbodies. 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, the 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) POLLUTION

One hundred and seven (107) watershed NPS sites and 717 high to medium priority shoreline properties around Moultonborough Bay and Winter Harbor 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 reductions 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

A watershed survey was completed to identify hotspots of pollutant loading to Moultonborough Bay and Winter Harbor. The survey focused on areas of significant sediment erosion. Sediment can carry nutrients, such as phosphorus, to surface waters during runoff events. Treatment of the 107 sites identified would reduce phosphorus loading to Moultonborough Bay and Winter Harbor by an estimated 61 kg/yr. It is important to note that the watershed survey identified erosion sites from public access points (e.g., roads, common areas) unless information was provided by private landowners; it can be assumed that a significant amount of the phosphorus-laden sediment entering these basins likely comes from the cumulative impact of private shoreline properties. To estimate this contribution, a shoreline survey was completed for Moultonborough Bay and Winter Harbor by FBE, volunteers, LWA, and most significantly, by LWA AmeriCorps members Alison Baranovic and Gloria Norcross. All shoreline parcels were evaluated; 717 total parcels were scored as a "high" or "medium". Estimated total phosphorus reduction from these high and medium sites is 290 kg/yr (Table 4-1).

The strategy for reducing pollutant loading to the lake 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) (Table 4-1). Another significant but difficult to quantify strategy for reducing phosphorus loading to the lake is revising local ordinances to set LID requirements on new construction. With a dedicated stakeholder group in place and with the help of grant funding, it is possible to achieve target phosphorus reductions and meet the established water quality goal for both Moultonborough Bay and Winter Harbor in the next 10 years.

Table 4-1. Estimated pollutant reduction (TP) in kg/year and estimated cost for watershed survey sites (107) and high and medium impact shoreline sites (717).

BMP Site Categories	TP Reduction (kg/yr)	Estimated Cost
Watershed Survey Sites (107)*	61	$1,100,000 - $1,600,000
High-Medium Impact Shoreline Sites (717)**	290	$537,750 - $1,075,500
Total	**351**	**$1,637,750 - $2,675,500**

*Estimated TP load reduction from watershed survey sites calculated using a combination of the NHDES Simple Method and the USEPA Region 5 pollutant load models. Estimates should be used for planning purposes only. Thirteen of these sites did not include TP reduction estimates because they represent preventative maintenance or monitoring.

**Medium impact sites were given total rating scores of 10-14 in the shoreline survey. High impact sites were given total rating scores of 15-18 and represent 50 of the total sites. TP load reduction calculations were estimated using the USEPA Region 5 pollutant load model. The estimates assume fine sandy loam for all sites. Medium impact sites used a 5-ft length by 3-ft height and moderate lateral recession rate of 0.1 ft/yr. High impact sites used a 100-ft length by 5-ft height and a moderate lateral recession rate of 0.2 ft/yr. Cost estimates represent $750 - $1,500 for implementation at each site. Estimates should be used for planning purposes only.

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.)

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

4.2.1 Buildout Potential

“Full Build-out” is a theoretical condition which represents the period when all available land suitable for residential, commercial, and industrial uses has been developed to the maximum conditions permitted by local ordinances. A build-out analysis identifies areas with development potential and projects future development based on a set of conditions (e.g., zoning regulations, environmental constraints) and assumptions (e.g., population growth rate). **The results of the build-out analysis can be used as a planning tool to help guide future development activities in a given study area, as well as target specific areas for conservation.**

The Moultonborough Bay and Winter Harbor watersheds consist of approximately 5,262 parcels, ranging in size from less than one acre to 830 acres. **The build-out analysis shows that, under current zoning regulations, 56% (16,770 acres) of the Moultonborough Bay and Winter Harbor watersheds is buildable.** The Tuftonboro Low Density Residential zone has the greatest amount of land available for development at 6,817 acres. FBE identified 2,910 existing buildings within the watershed area, and the build-out analysis projected that an additional 6,385 buildings could be constructed in the future, resulting in a total of 9,295 buildings.

Three iterations of the TimeScope Analysis (a tool facilitating analysis of change over time) were run using compound annual growth rates for 20-, 30- and 40-year periods from 1990-2010 (1.41%), 1980-2010 (1.69%), and 1970-2010 (2.23%), respectively. Full build-out is projected to occur in 2102 at the 20-year growth rate, 2089 at the 30-year growth rate, and 2072 for the 40-year growth rate. This analysis shows that if growth rates, zoning, and other development constraints remain constant, the Moultonborough Bay and Winter Harbor watersheds will attain full build-out by the late 21st century to early-22nd century.

4.2.2 Zoning and Ordinances

Table 4-2 summarizes the results of existing zoning and ordinances for the three primary communities (Moultonborough, Tuftonboro, and Wolfeboro) in the Moultonborough Bay and Winter Harbor watersheds. A full ordinance review is needed for these communities.

Table 4-2. Ordinance summaries for the towns of Moultonborough, Tuftonboro, and Wolfeboro. These summaries are broken down by “regulatory tools”, “conservation funding strategies”, and “non-regulatory tools”. A full ordinance review is needed for these communities.

	STRATEGY	MOULTONBOROUGH	TUFTONBORO	WOLFEBORO
REGULATORY TOOLS	Shoreland zoning.	"Waterfront Property" [Article IV, effective 2008] addresses impervious surfaces and tree cutting/buffers for waterfront properties within 250 feet of all lakes, ponds, rivers, and streams.	"Lakefront Residential" zone for lakefront of Lake Winnipesaukee, Mirror Lake, Dan Hole Pond, and Lower Beech Pond.	"Shorefront Residential District" [last amended 03/11/2014] addresses minimum lot area and frontages, setbacks, permitted uses, buffers, in the shorefront.
	Cluster development and/or open space provisions for subdivisions.	Article VII "Multi-Family and Cluster Development" with the purpose to "…preserve the natural beauty of existing undeveloped land and to encourage less intensive residential development, to allow diversity of housing opportunities with open space areas and increased pedestrian and vehicle safety, and to allow efficient use of land, streets, and utility systems."	As part of the zoning ordinance section VIII "Cluster Developments" [published March 2019].	"Conservation Subdivision" [last amended 03/09/2010] to allow alternatives to conventional subdivision practices to encourage protection of natural resources.
	Septic pump-out ordinance or regulation of septic and sewer systems.	New or replacement water and sewer systems in flood hazard areas are regulated through Article VIII "Floodplain Development". Septic systems are not permitted on slopes of 25% or greater.	New or replacement water and sewer systems proposed in special flood hazard area must provide the CEO with assurance of design per "Floodplain Development Ordinance" [Section XIV]	New or replacement water and sewer systems proposed in flood-prone areas must be designated to minimize or eliminate infiltration of floodwaters. Section § 175-50 addresses leach field and septic tank setbacks from the high-water mark of all waterbodies and watercourses.
	Zoning districts address environmental protection.	Zoning districts addressing environmental protection: "Waterfront Property", "Floodplain Development", "Wetland Resources Conservation Overlay District", "Stormwater Management", "Groundwater Protection Ordinance", "Steep Slope Protection Ordinance".	Zoning districts addressing environmental protection: "Floodplain Development Ordinance", "Open Space/Forestry", "Islands' Conservation", "ISC Wetlands Conservation".	Two zoning districts addressing environmental protection: "Municipal Watershed District" and "Shorefront Residential District".

STRATEGY	MOULTONBOROUGH	TUFTONBORO	WOLFEBORO
Zoning overlay districts that address wetland conservation.	"Overlay Districts (A" Wetland Resources Conservation Overlay District" [Article IX] applicable to wetlands that are greater than 20,000 sq. ft. and wetlands of any size contiguous to a river, brook, lake or pond, except as exempted. Addresses setbacks, permitted uses, and prohibited uses.	As part of the zoning ordinance section XIII "Wetlands Conservation District" [published March 2019].	"Wetlands Conservation Overlay District" [last amended 03/13/2001] that protects areas defined in §175-10.4 and certified by a NHDES certified wetland scientist. Includes setback requirements for wetlands, perennial and intermittent streams, and poorly drained soils.
Zoning overlay districts that protect groundwater.	"Groundwater Protection Ordinance" [Article XIII, effective 2010] establishes a groundwater protection overlay district that includes performance standards for pollution prevention, recharge, BMPs for animal manure and fertilizer storage, sanitary sewer design, and storage of regulated substances.	None identified.	"Groundwater Protection Overlay District" includes current USGS stratified drift aquifer map and wellhead protection areas of community and municipal wells. Includes requirements for a Stormwater Management Plan and a Spill Prevention, Control, and Countermeasure Plan (SPCC).
Protection of steep slopes.	"Steep Slopes Protection Ordinance" [Article XIV, effective 2011] applicable to development with a slope of 15% or greater where the proposed site disturbance is greater than 20,000 sq. ft. Addresses performance standards such as preserving existing natural and topographic features, preventing negative impact to water quality, requiring proper stormwater management design.	"Cluster Developments" [Section VIII] lists the avoidance of development of land which has "…poor soil conditions, high water tables, is subject to flooding, or has excessively steep slopes."	Steep Slope Protection [added 3/13/2012] applied to disturbance of greater than 20,000 sq. ft. on slopes greater than 15% and addresses disturbance to streams and lakes from erosion.
Nutrient loading analysis required for fresh waterbodies.	None identified. Nutrient loading to surface waters identified in Master Plan.	None identified.	None identified.
Low impact development requirements and standards.	None identified.	None identified.	Stormwater Management Plan must meet design and performance standards for Low Impact Development Site Planning and Design (among others).

	STRATEGY	MOULTONBOROUGH	TUFTONBORO	WOLFEBORO
	Fertilizer and/or pesticide ordinances.	None identified (fertilizer storage regulated in groundwater ordinance).	None identified.	None identified.
	Implement and enforce a Stormwater Management Plan.	"Stormwater Management Ordinance" [Article XII, effective 2010] requires a Stormwater Management Plan for developments that disturb 20,000 sq. ft. or more.	None identified.	Stormwater Management Plan [2014] required if development disturbs 10,000 or more square feet (an approved AOT permit satisfies this requirement) OR if less than 10,000 sq. ft. with a possible water quality threat. The Planning Board reserves the right to request a Plan if potential for degradation of local resources.
CONSERVATION FUNDING STRATEGIES	Development transfer overlay district.	None identified.	None identified.	None identified.
	Conservation impact fees.	None identified.	None identified.	None identified.
	Wetland mitigation funds.	Participate in state wetland mitigation program.	Participate in state wetland mitigation program.	Participate in state wetland mitigation program.
	Fee in lieu of land dedication.	None identified.	None identified.	None identified.
	Stormwater utility district.	None identified.	None identified.	None identified.
	Open space or non-lapsing conservation fund.	None identified.	Yes.	Yes.
	Has a Land Use Change Tax per RSA 79-A:25.	None identified.	Yes. A portion of the Land Use Change Tax is allocated to the Conservation Fund.	Yes. 100% of Land Use Change Tax is allocated to the Conservation Fund.
	Participate or collaborate with a local watershed association.	Lake Winnipesaukee Association.	Lake Winnipesaukee Association.	Lake Winnipesaukee Association.
	Participate or collaborate with a local land trust.	Lakes Region Conservation Trust.	Lakes Region Conservation Trust.	Lakes Region Conservation Trust.

	STRATEGY	MOULTONBOROUGH	TUFTONBORO	WOLFEBORO
NON-REGULATORY TOOLS	Open space plan.	None identified.	None identified.	None identified.
	Master plan addresses natural resources and environmental protection.	Yes [2008]. Sub-chapters relevant to environmental protection include (Ch. 1, updated 2019) Natural Resources, (Ch.2) Land Use and Development.	Yes [2006]. Sub-chapters relevant to environmental protection include (Ch. 3) Resources: Natural, Historic and Scenic, and (Ch. 5) Tuftonboro's Land Use.	Sub-chapters related to environmental protection include (1) Natural Resources, (2) Energy, and (3) Existing & Future Land use.
	Conduct a town-wide natural resources inventory.	Yes, completed in 2016.	None identified.	Yes, completed in 2011.
	Incentive-based programs for voluntary low impact development implementation.	None identified.	None identified.	None identified.
	Incentive-based programs for stormwater reduction efforts.	None identified.	None identified.	None identified.
	Have established conservation commission.	Yes.	Yes.	Yes.
	Incentivize and/or encourage property owners to implement low impact development stormwater practices.	None identified.	None identified.	None identified.
	Encourage property owners to put land into farmland/tree growth programs.	None identified.	None identified.	None identified.

Adapted from draft York River watershed study: draft regulatory and non-regulatory recommendations report, SMPDC, May 2018 and Wells National Estuarine Research Reserve ordinance review for the Kennebunk River watershed, January 2020.

4.3 ADAPTIVE MANAGEMENT APPROACH

An adaptive management approach, to be employed by a steering committee, is highly recommended for protecting the Moultonborough Bay and Winter Harbor watersheds. 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 towns of Moultonborough, Tuftonboro, and Wolfeboro, 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 5.5 for a list of potential funding sources.
- **Determining Management Actions.** This plan provides a unified watershed management strategy with prioritized recommendations for restoration using a variety of methods. The proposed actions in this plan should be used as a starting point for grant proposals. Once a funding mechanism is established, designs for priority restoration actions on a project-area basis can be completed and their implementation scheduled. Refer to Section 5.2: 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.
- **Continuing the Long-Term Monitoring Program.** A water quality monitoring program is necessary to track the health of surface waters in the watershed. Information from the monitoring program will provide feedback on the effectiveness of management practices. Refer to Section 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 5.4: 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 LWA, 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 and the support of LWA (Table 5-1). The Action Plan outlines responsible parties, approximate costs[4], 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.

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

Table 5-1. Action Plan for the Moultonborough Bay and Winter Harbor Watershed Management Plan. TP = total phosphorus. All costs are presented as total costs for ten years except for "Water Quality Monitoring" which is presented on an annual basis.

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	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 and collaborate with other sub-watershed residents and stakeholders	1	Contact local representatives and attend select board meetings to voice concerns and stay informed.	✓		✓			✓			2020-30	N/A
	2	Share the "Residential BMP Homeowners Guide" document with residents on the lake. Work directly with landowners to provide them technical assistance through AmeriCorp volunteers.	✓								2020-30	LWA In-house
	3	Enhance outreach program to landowners through newly established "Director of Development" position at the LWA (Kate Bishop).	✓								2020-30	N/A
	4	Identify a University research group to partner on large-scale analysis and modeling of Lake Winnipesaukee, such as UNH.	✓	✓						✓	2020-30	N/A
	5	Unify stakeholders across the lake to create a lake-wide steering committee for developing Education & Outreach strategies and creating unified messaging and marketing.	✓	✓			✓	✓	✓		2020-30	N/A
Maintain and/or improve current invasive and/or weed management program	6	Support State legislation that increases funds for aquatic invasive plant (e.g., milfoil) eradication.	✓			✓					2020-30	N/A
	7	Increase the number of volunteer inspectors for the Lake Host and Weed Watchers programs.		✓			✓	✓			2020-30	N/A

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	8	Expand invasive species monitoring programs to include insects and other animals not currently monitored (e.g., spiny water flea).	✓		✓		✓	✓			2020-30	N/A
Obtain more funding	9	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.	✓	✓	✓		✓				2020-30	N/A
Expand baseline lake monitoring through UNH LLMP.	10	At a minimum at least 3 times per year in the critical growing season (July-September) at lake deep spot sites, collect samples for epilimnion and hypolimnion total phosphorus and epilimnion chlorophyll-a. Aim for biweekly Secchi Disk Transparency readings and monthly dissolved oxygen-temperature profile readings from May 24-Sept 15. Continue to collect surface grab samples for total phosphorus and chlorophyll-a at the nearshore sites or outlets for Winter Harbor (depth = 1 ft).	✓	✓					✓	✓	2020-30	$15,000 - $25,000 (annually)
	11	Consider also collecting total nitrogen, dissolved organic carbon, and chloride as part of baseline sampling efforts. Consider including the deep spot of the Basin in regular lake monitoring.	✓	✓					✓	✓	2020-30	$2,500 - $5,000 (annually)
Consider expanding lake/tributary monitoring to the early spring and	12	Following summer lake and tributary procedures, collect samples immediately following ice-out in April through early May and again following fall turnover in October through early November.	✓	✓					✓		2020-30	$5,000 - $7,500 (annually)

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
late fall to capture turnover periods.												
Consider collecting winter data under the lake ice.	13	Following summer lake procedures, collect samples under the ice in February or whenever the ice is solid. Send samples for phytoplankton enumeration and speciation.	✓	✓					✓			$2,500 - $5,000 (annually)
Continue/establish regular cyanobacteria monitoring.	14	Bloom samples should be sent to a qualified laboratory for enumeration and speciation. If cyanobacteria are present, then samples should also be screened for toxins. NHDES can usually accept and process samples. Volunteers should collect as much information as possible about weather conditions leading up to the bloom (rainfall, wind patterns, etc.). These data may be useful in predicting under what conditions blooms typically occur.	✓			✓		✓			2020-30	TBD
	15	Encourage residents to use the EPA "Bloom Watch" app to identify and photograph blooms on the lake.	✓					✓			2020-30	N/A
Establish regular tributary/river monitoring program for Moultonborough Bay.	16	At a minimum at least 3 times per year in the growing season (May-October) at major tributary outlets to Moultonborough Bay, collect surface grabs samples for total phosphorus and measure/estimate flow at the time of collection. Major tributaries include the Melvin River, Nineteenmile Brook, Twentymile Brook, and Wingate Brook. Consider adding staff gauges to	✓	✓	✓				✓		2020-30	$15,000 - $25,000 (annually)

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
		major tributaries and calibrating them to allow calculation of loads from concentration data.										
	17	Consider also collecting turbidity, pH, total nitrogen, dissolved organic carbon, and chloride as part of baseline sampling efforts. Sample tributaries near the outlet but far enough upstream where it appears the possibility of backflow from the larger bay is minimal.	✓	✓	✓				✓		2020-30	$5,000 - $15,000 (annually)
Continue regular sampling and 10-year intensive studies assessing the impact of the RIB on Nineteenmile Brook.	18	Continue funding regular sampling and intensive studies assessing the water quality and biological integrity of Nineteenmile Brook downstream of the RIB. This monitoring is critical to assessing the proper functioning of the RIB over time.	✓	✓		✓			✓		2020-30	TBD

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Complete nearshore investigative studies for localized sources of phosphorus in cyanobacteria hotspots.	19	Collect sediment samples to assess the ratio of phosphorus, iron, and aluminum, the risk of internal loading, and the possibility of any spatial patterns in these elements. Collect surface and bottom grab samples for total phosphorus, chlorophyll-a, phytoplankton and periphyton enumeration and speciation, total nitrogen, and dissolved organic carbon at several spatially-representative areas within the area(s) of interest under a variety of conditions during the growing season to capture before, during, and after bloom events. The study should be designed to highlight important spatial and temporal patterns in cyanobacteria bloom occurrence that can better home in on management efforts.	✓	✓		✓			✓	✓	2020-23	$10,000 - $20,000 (annually)
Quantify shoreline erosion and explore impact of wakes on shoreline erosion processes.	20	Establish regular evaluations of shoreline bank heights and undercutting severity using shoreline profiling methods to quantify change around Winter Harbor and possibly Moultonborough Bay to document and track evidence of shoreline erosion and retreat. Assess if changes to local boating regulations could remediate shoreline erosion due to wake action. Cost based on holding training sessions. Assumes volunteer labor for monitoring.	✓	✓				✓	✓		2020-21	$2,000 (annually)

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	21	Assess if more stringent wake restrictions may have a positive impact on the lake shoreline through an intensive research study. 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).	✓	✓					✓		2020-23	N/A
Work with NHDES to complete regular 5- to 10-year biological assessments of the major tributaries to Moultonborough Bay.	22	Fish and macroinvertebrate studies should be completed in representative sites along each of the major tributaries to Moultonborough Bay to establish a baseline from which to judge any future changes in biological assemblages. Sensitive organisms can serve as a sentinel for a change in habitat conditions, possibly due to new contamination sources or pressures.	✓			✓					Every 5- to 10-years	TBD
Watershed & Shorefront BMPs												
Address priority pollutant sites identified in surveys	23	Identify funding for three (3) conceptual BMP designs developed in through this planning process (Melvin Village boat launch, New Road stream crossing, and Northwoods Road rain garden).	✓	✓					✓		2020-21	Included in Action #27 estimate.
	24	Identify funding for planting project on Tuftonboro Neck Road at crossing with the Basin.	✓	✓					✓		2020-21	Included in Action #27 estimate.

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	25	Complete permitting for four sites listed above and update designs to accommodate permitting requirements before putting out to bid for contractors.	✓	✓					✓		2020-21	$2,500 - $7,500 (total cost)
	26	Work with Wolfeboro and Underwood Engineers to ensure that the Whitegate Neighborhood BMPs are completed and installed.	✓	✓	✓	✓			✓		2020-21	N/A
	27	Implement BMPs in the remaining 103 sites identified in the watershed survey.	✓	✓				✓	✓		2020-30	$1.6 - $2.7 million (total cost)
	28	Implement BMPs at high impact sites identified in the shoreline survey. Assumes consultant labor for technical assistance and $3,000 cost-share for 50 properties. Estimated TP reduction 96 kg/yr.	✓	✓					✓		2020-2025	Included in Action #29 estimate.
	29	Implement BMPs at medium impact sites identified in the shoreline survey. Medium impact is defined as Shoreline Disturbance Scores of 10-14. 667 medium impact sites were identified during the Lake Winnipesaukee shoreline survey. Assumes volunteer labor for technical assistance and $1,500 cost-share for 667 properties. Estimated TP reduction 193 kg/yr.	✓	✓					✓		2019-28	$537,750 - $1,075,500 (total cost)
	30	Develop a method of tracking and monitoring BMP implementation progress (e.g., NPS Site Tracker). Assumes volunteer labor.	✓	✓							2019-28	N/A

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Promote healthy vegetated buffers for shoreline properties	31	Repeat shoreline survey every 5-10 years. Assumes volunteer labor using the standard assessment rubric used for the 2019 shoreline survey. This information can be used to help prioritize technical assistance follow-up and stormwater management outreach.	✓						✓		2029	N/A
	32	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 (total cost)
Garner funding for action items	33	Create a subcommittee that develops a fundraising strategy and determines how funding is spent. Assumes volunteer labor.	✓	✓							2020-21	N/A
	34	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.	✓	✓							2020-30	$10,000 (total cost)
	35	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 purchase.	✓	✓				✓			2020-30	$2,000 (total cost)
Road Maintenance & Training												

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Coordinate road and culvert improvements	36	Connect with the NH Geological Survey Stream Crossing Team to query the SADES database for stream crossing information in the watersheds. Use the NH survey team's physical prioritization model to identify vulnerable crossings and develop a local prioritization model that includes non-structural/social prioritization. Recommended contact: Shane Csiki, PhD (shane.csiki@des.nh.gov).		✓					✓		2020-25	N/A
	37	Identify high priority vulnerable crossings through the method above and then contact NHDOT to discuss schedule of repair for crossings in the watershed.	✓	✓		✓					2025	N/A
Require winter and spring maintenance training of road agents for the town	38	If not already in place, require training for road agents on proper road BMPs for salt, sand, and equipment use through the NH Green Snow Pro program (UNH Technology Transfer Center). This includes techniques such as pre-wetting and pre-brining, proper calibration and application rates, and proper application (e.g. salt vs sand). $60 per person for municipalities for initial training and $25 each year for refresher.		✓							2020	$5,000 - $7,500 (total cost)
Update town BMP road installation and maintenance practices to better protect water quality	39	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.		✓					✓		2020-21	$20,000 (total cost)

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Create and manage drainage easements on roads	40	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.		✓				✓			2020-30	TBD
Host road maintenance workshops for private landowners	41	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. Particularly for gravel roads around the shoreline.	✓	✓	✓			✓			2020-22	$5,000 (total cost)
Municipal Planning & Land Conservation/Management												
Identify opportunities for land protection and conservation within the watershed	42	Collaborate with local conservation partners on land conservation initiatives within the watershed. Assign a liaison to communicate with conservation groups such as the Lakes Region Conservation Trust.	✓	✓	✓		✓	✓			2020-30	N/A
	43	Update Moultonborough and Wolfeboro town-wide Natural Resource Inventories in 2026 and 2021 (respectively). Complete town-wide NRI for Tuftonboro.	✓	✓	✓				✓		2020-26	$40,000 - $50,000 (total cost)
	44	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.	✓	✓	✓		✓				2020-25	$5,000 (total cost)

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	45	Continue to apportion the Land Use Change Tax (per RSA 79-A:25) to a Conservation Fund and explore current practices in each community.		✓	✓			✓			2020-25	N/A
	46	Consider conservation funding strategies such as development transfer overlay districts, conservation impact fees, stormwater utility districts.		✓	✓			✓			2020-25	N/A
Enhance watershed resident education and communication of local land ordinances, best management practices, and actions	47	Hold informational workshops for new landowners, towns, and developers on relevant town ordinances, conservation easements, and watershed goals. Goal: Host 1-2 workshops.	✓	✓	✓		✓	✓			2021, 2027	$2,000 (total cost)
	48	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.	✓	✓	✓				✓		2021	$3,000 (total cost)
	49	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.	✓	✓	✓						2021	$1,000 (total cost)
Adopt plan recommendations	50	Present the watershed plan to the select board and/or planning board in Moultonborough, Tuftonboro, and Wolfeboro. Assumes volunteer labor.	✓	✓							2020-21	N/A
	51	Incorporate watershed plan recommendations into town master plans.	✓	✓							2019-20	N/A

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
Improve municipal ordinances	52	Consider incentive-based programming for stormwater reduction efforts, low impact development, and farmland/tree growth programs.		✓	✓			✓			2020-25	N/A
	53	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.	✓	✓					✓		2020-25	N/A
	54	Setbacks (Shoreland Zoning): Create Shoreland Protection Overlay District to increase the setback distance to 100 feet within the shoreland zone. Expand the coverage to smaller lakes and ponds, streams and rivers, and surface waters of local significance, as defined by a natural resource inventory.	✓	✓					✓		2020-25	N/A
	55	Wetland Buffers: ensure that Wetland Protection Overlay/Conservation Districts protect smaller wetlands not contiguous to surface water.	✓	✓					✓		2020-25	N/A
	56	Enforce Steep Slope Ordinances in Moultonborough and Wolfeboro for slopes 15% or greater where proposed site disturbance is greater than 20,000 sq. ft. Strengthen steep slope protections in Tuftonboro by creating an ordinance.	✓	✓					✓		2020-25	N/A

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	57	Conservation/Cluster Subdivisions: encourage conservation subdivisions and increase the amount of land set aside in conservation subdivisions.	✓	✓					✓		2020-25	N/A
	58	Establish a Stormwater Management Ordinance in Tuftonboro. Ensure that Stormwater Management Plans are reviewed and enforced in Moultonborough and Wolfeboro.	✓	✓					✓		2020-25	N/A
	59	Complete a full-scale ordinance review in each community 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.	✓	✓					✓		2021	$30,000 (total cost)
Enhance enforcement of proper land management practices	60	Create better enforcement of forestry rules and regulations.		✓	✓		✓	✓			2020-30	N/A
	61	Encourage easement holders to be notified and present at closings.		✓	✓		✓	✓			2020-30	N/A
Septic Systems												
Enforce town septic system regulations	62	Communicate with town departments to enforce occupancy loads and have septic system inventories in Master Plans.		✓	✓						2020-30	TBD
	63	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.		✓				✓			2020-30	TBD

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	64	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.		✓				✓			2020-23	TBD
Garner funding or discounts that support and encourage septic system maintenance	65	Coordinate group septic system pumping discounts. Assumes volunteer labor to coordinate. Pump-out costs are the responsibility of landowners.						✓			2020-30	N/A
	66	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.	✓	✓	✓			✓	✓		2020-22	$3,000 (total cost)
	67	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.	✓	✓	✓		✓				2020-30	N/A
Enhance awareness of proper septic system maintenance and regulations	68	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.	✓	✓	✓						2020-21	$2,000 (total cost)

ACTION ITEM	#	RECOMMENDATIONS TO ACHIEVE ACTION ITEM	LWA	Town(s)	Cons. Comm.	Fed./State Agency	Nonprofits	Landowners	Consultant	University Partners	SCHEDULE	ESTIMATED COST
	69	Create and distribute a list of septic service providers (designers v. pumpers) (create magnets, etc.).	✓	✓	✓						2020-21	$1,000 (total cost)
	70	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.	✓				✓	✓			2020-30	$1,500 (total cost)
Inventory status of septic and greywater systems in watershed	71	Develop and maintain a septic system database for the watershed. Code Enforcement Office for towns to maintain database.		✓							2020-21	$500 (total cost)
	72	Complete in-person, mail-in, or online survey of septic systems to fill in any missing information in the database. Assumes volunteer labor.	✓	✓							2020-30	N/A
	73	Conduct voluntary dye testing of any suspected septic systems. Goal: 5 systems.		✓				✓			2020-21	$1,250 (total cost)
	74	Hire canine scent detection team to investigate shoreline septic systems.	✓	✓			✓		✓		2020-25	$20,000 (total cost)

5.3 NEXT STEPS FOR WATER QUALITY MONITORING

Water quality data are gathered through a coordinated effort among the UNH LLMP, LWA, and local volunteers. However, 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. The following recommendations build on the current monitoring program.

Continue/establish regular lake monitoring through LLMP. At a minimum of 3 times per year in the critical growing season (July-September) at lake deep spot sites, collect samples for epilimnion and hypolimnion total phosphorus and epilimnion chlorophyll-a. Aim for biweekly Secchi Disk Transparency readings and monthly dissolved oxygen-temperature profile readings from May 24-Sept 15. Continue to collect surface grab samples for total phosphorus and chlorophyll-a at the nearshore sites or outlets for Winter Harbor (depth = 1 ft). Consider also collecting total nitrogen, dissolved organic carbon, and chloride as part of baseline sampling efforts. Consider including the deep spot of the Basin in regular lake monitoring.

Continue/establish regular cyanobacteria monitoring. Encourage and train volunteer bloom watchers to record and sample blooms as they occur. Samples should be sent to a qualified laboratory for enumeration and speciation. If cyanobacteria are present, then samples should also be screened for toxins. NHDES can usually accept and process samples. Volunteers should collect as much information as possible about weather conditions leading up to the bloom (rainfall, wind patterns, etc.). These data may be useful in predicting under what conditions blooms typically occur.

Establish regular tributary monitoring for Moultonborough Bay. At a minimum of 3 times per year in the growing season (May-October) at major tributary outlets to Moultonborough Bay, collect surface grabs samples for total phosphorus and measure/estimate flow at the time of collection. Major tributaries include the Melvin River, Nineteenmile Brook, Twentymile Brook, and Wingate Brook. Consider also installing stream gages, collecting turbidity, pH, total nitrogen, dissolved organic carbon, and chloride as part of baseline sampling efforts. Sample tributaries near the outlet but far enough upstream where it appears the possibility of backflow from the larger bay is minimal.

Complete nearshore investigative studies for localized sources of phosphorus in cyanobacteria hotspots. Collect sediment samples to assess the ratio of phosphorus, iron, and aluminum, the risk of internal loading, and the possibility of any spatial patterns in these elements. Collect surface and bottom grab samples for total phosphorus, chlorophyll-a, phytoplankton and periphyton enumeration and speciation, total nitrogen, and dissolved organic carbon at several spatially-representative areas within the area(s) of interest under a variety of conditions during the growing season to capture before, during, and after bloom events. The study should be designed to highlight important spatial and temporal patterns in cyanobacteria bloom occurrence that can better home in on management efforts.

Complete long-term shoreline bank profiling to document shoreline erosion. Establish regular evaluations of shoreline bank heights and undercutting severity around Winter Harbor and possibly Moultonborough Bay to document and track evidence of shoreline erosion and retreat. Assess if changes to boating rules could remediate erosion due to wake action.

Consider expanding lake/tributary monitoring to the early spring and late fall to capture turnover periods. Lake turnover events are important for resetting lake systems through mixing processes that bring nutrients to the top and oxygen to the bottom. These turnover events are already shifting due a changing climate. It will be important to understand when these shifts occur and how these shifts impact summer lake conditions that may be more suitable for blooms. Following summer lake and tributary procedures, collect samples immediately following ice-out in April through early May and again following **fall turnover** in October through early November.

Consider collecting winter data under the lake ice. Lakes are active even in winter. Algae can grow under the ice and in some cases deplete dissolved oxygen concentrations which can affect nutrient and oxygen availability in the following summer. Following summer lake procedures, collect samples under the ice in February or whenever the ice is likely solid. Send samples for nutrient analysis, and phytoplankton enumeration and speciation.

Complete a study of water current movement throughout the bays. The movement of water throughout Moultonborough Bay and Winter Harbor is complex and mixes regularly with the larger Lake Winnipesaukee system. It is likely that water moves bi-directionally and unequally through multiple outlets depending on the time of year (driven by wind and flow patterns). We recommend collecting depth and flow velocity measurements at set intervals across a transect at each of the major connecting channels of Moultonborough Bay and Winter Harbor at least twice in each season (including winter, if possible) to confirm flow direction and velocity.

Continue regular sampling and 10-year intensive studies assessing the impact of the RIB on Nineteenmile Brook. Continue funding regular sampling and intensive studies assessing the water quality and biological integrity of Nineteenmile Brook downstream of the RIB. This monitoring is critical to assessing the proper functioning of the RIB over time.

Work with NHDES to complete regular 5- to 10-year biological assessments of the major tributaries to Moultonborough Bay. Fish and macroinvertebrate studies should be completed in representative sites along each of the major tributaries to Moultonborough Bay to establish a baseline from which to judge any future changes in biological assemblages. Sensitive organisms can serve as a sentinel for a change in habitat conditions, possibly due to new contamination sources or pressures.

5.4 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 Moultonborough Bay and Winter Harbor watersheds. These benchmarks represent short-term (2021), mid-term (2025), and long-term (2030) 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 Moultonborough Bay and Winter Harbor watershed management plan.

ENVIRONMENTAL INDICATORS

Indicators	Benchmarks*		
	2021	2025	2030
Achieve an average seasonal (May 24-Sept 15) deep spot epilimnion concentration of 6.7 ppb and 5.9 ppb in Moultonborough Bay and Winter Harbor, respectively.	5% of goal reduction	50% of goal reduction	100% of goal reduction
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.	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	Absence of invasive aquatic species	Absence of invasive aquatic species

**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 Moultonborough Bay and Winter Harbor watershed management plan.

PROGRAMMATIC INDICATORS

Indicators	Benchmarks*		
	2021	**2025**	**2030**
Amount of funding secured from municipal/private work, fundraisers, donations, and grants	$500,000	$1,000,000	$3,000,000
Number of high priority shoreline sites remediated (50 identified)	10	25	50
Number of medium priority shoreline sites remediated (667 identified)	50	250	667
Number of watershed survey sites remediated (107 identified)	15	50	107
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 Moultonborough Bay and Winter Harbor watershed management plan.

SOCIAL INDICATORS

Indicators	Benchmarks*		
	2021	**2025**	**2030**
Number of new association members	1,000	1,500	2,000
Number of volunteers participating in educational campaigns	50	100	150
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%

SOCIAL INDICATORS

Indicators	Benchmarks*		
	2021	**2025**	**2030**
Number of representative stakeholders involved on the steering committee	15	18	20
Number of groups or individuals contributing funds for plan implementation	3	5	10
Number of trained VLAP/LLMP volunteers (Final number based on 40 stations and two volunteers per station)	40	60	80
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.*

5.5 ESTIMATED COSTS & TECHNICAL ASSISTANCE NEEDED

The cost of successfully implementing the plan is estimated at $2.8-$4.9 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	$570,000 - $1,045,000	$57,000 - $104,500
Watershed and Shorefront BMPs	2,153,250 - 3,787,000	$215,325 - $378,700
Road Maintenance & Training	$30,000 - $32,500	$3,000 - $3,250
Planning & Land Conservation	$81,000 - $91,000	$8,100 - $9,100
Septic Systems*	$29,250	$2,925
Total Cost	**$2,863,500 - $4,984,750**	**$286,350 - $498,475**

**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. 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 NPS pollution prevention, watershed protection and restoration, and estuary management projects that help improve and protect water quality in NH. http://des.nh.gov/organization/divisions/water/wweb/grants.htm

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

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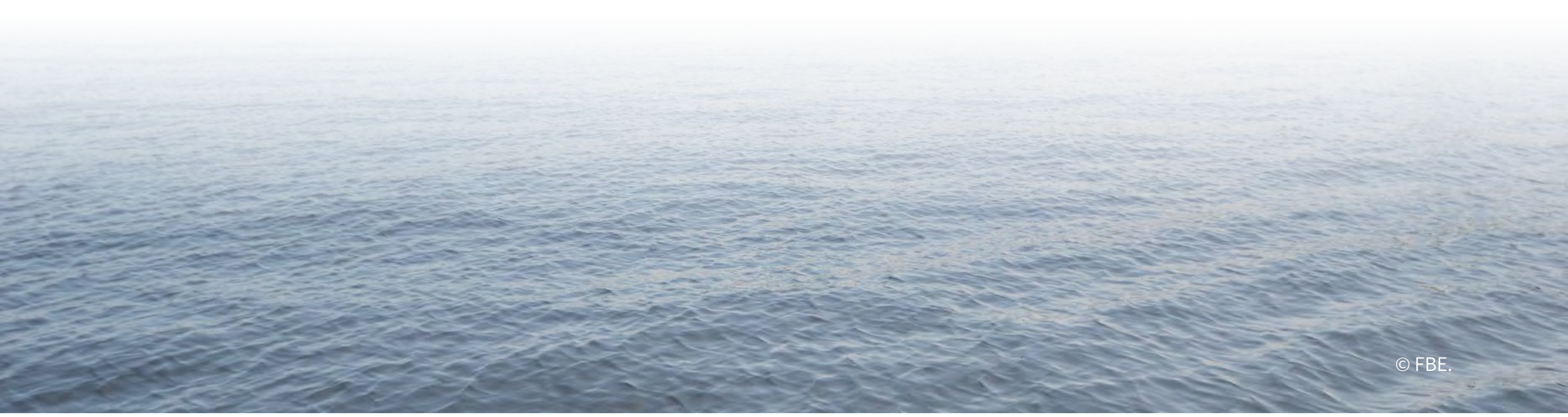

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