LAKE WARREN WATERSHED MANAGEMENT PLAN

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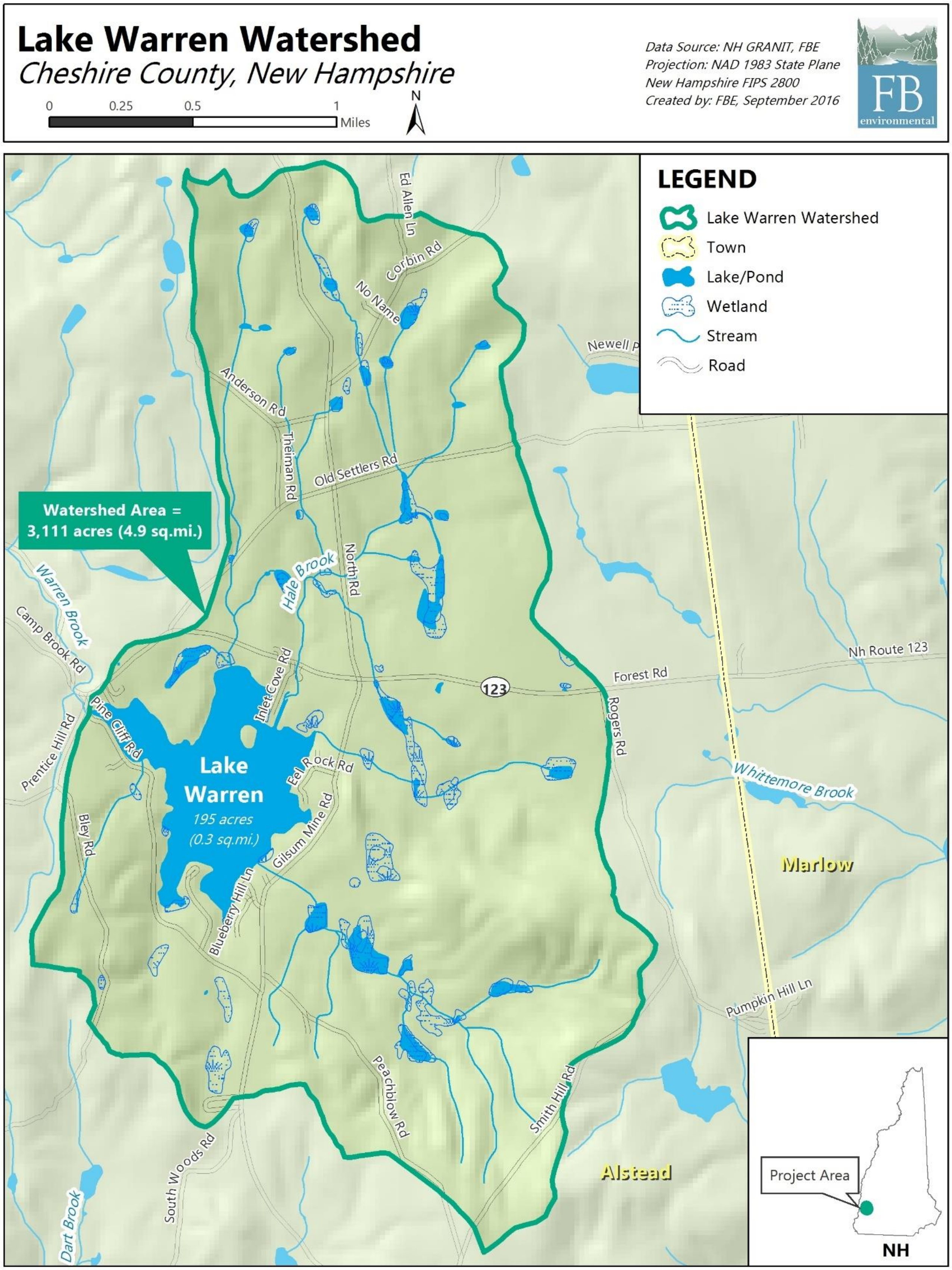
Lake Warren Watershed
Cheshire County, New Hampshire
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, September 2016
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Road
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
195 acres
(0.3 sq.mi.)
Ed Allen Ln
Corbin Rd
No Name
Newell P
Anderson Rd
Theiman Rd
Old Settlers Rd
North Rd
Hale Brook
Warren Brook
Camp Brook Rd
Inlet Cove Rd
Forest Rd
Nh Route 123
123
Pine Cliff Rd
Prentice Hill Rd
Rogers Rd
Eel Rock Rd
Whittemore Brook
Gilsum Mine Rd
Bley Rd
Blueberry Hill Ln
Marlow
Pumpkin Hill Ln
Peachblow Rd
Smith Hill Rd
South Woods Rd
Dart Brook
Alstead
Project Area
NH

Lake Warren

Watershed Management Plan

Prepared by FB Environmental Associates

in cooperation with the Southwest Region Planning Commission, the Lake Warren Association, the Lake Warren Watershed Steering Committee, and the New Hampshire Department of Environmental Services.

December 2016

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NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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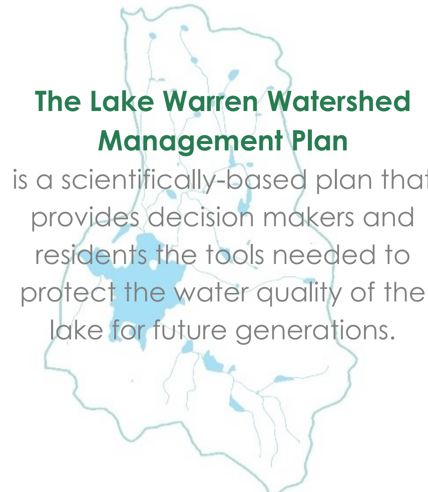
EXECUTIVE SUMMARY

Located in southwestern New Hampshire, Lake Warren has been an important natural resource in the Town of Alstead for over 200 years. As the headwaters of Warren Brook, the lake was initially dammed to provide a source of water to downstream mills. With time, the lake has also become a highly valued recreational resource to both residents and visitors who enjoy its scenic beauty and calm, quiet character. The lake also provides critical habitat for a diverse abundance of plants, wildlife, and aquatic life. The water quality of lakes and streams can decline rapidly because of stormwater runoff from watershed development (including roads, agriculture, and residences). Taking proactive steps to properly manage and treat stormwater runoff to protect these important water resources is essential for continued ecosystem health, including resources valued by humans.



The Lake Warren Watershed Management Plan is a scientifically-based plan that provides decision makers and residents the tools needed to protect the water quality of the lake for future generations.

The Lake Warren Watershed Management Plan is the culmination of several years of effort by the many individuals who care about the long-term protection of water quality in the lake. The Lake Warren Association (LWA) was formed in 1985 with the goal of protecting the lake. By partnering with the Southwest Region Planning Commission (SWRPC), the New Hampshire Department of Environmental Services (NHDES) awarded the group both a Water Quality Planning Grant (Section 604 (b) of the Clean Water Act) and a Watershed Assistance Grant for implementation (Section 319 of the Clean Water Act) with funds from the United States Environmental Protection Agency (USEPA). Stakeholders from the local to state level have collaborated on this effort, including the Town of Alstead, New Hampshire Fish and Game Department (NHFGD), the Soak Up the Rain program, the Cold River Local Advisory Committee (CRLAC), and numerous watershed residents.

The Lake Warren Watershed

The Lake Warren watershed covers approximately 4.9 square miles (3,111 acres) in southwestern New Hampshire, and is entirely within the Town of Alstead. The lake itself is 0.3 square miles (195 acres), surrounded by moderate to steep hills. The watershed is mostly forested and is home to a diverse community of fish, birds, mammals, and plants that are dependent on clean water for survival. Based on available data from NH GRANIT, conservation land around Lake Warren covers approximately 8% (234 acres) of the watershed. The surrounding landscape includes 42 acres of open waters and wetlands and more than 13 miles of mapped streams. Major tributaries to the lake include Smith Hill Brook, Hale (Carmen Cove) Brook, and the Spruce River, among others in the watershed. These tributaries and the contributing land cover of their watersheds are important to the water quality of Lake Warren.

Why Develop a Watershed Management Plan?

Lake Warren is currently listed as impaired for Aquatic Life Use (ALU) due to high levels of Chlorophyll-a (Chl-a) and total phosphorus (TP), and low pH. Excess TP can stimulate algae growth, which typically results in a decrease in Secchi disk transparency (i.e., a decrease in water clarity) due to the additional algae. This relationship between nutrients, algae, and transparency holds true in Lake Warren, where TP and Chl-a have increased since 1980 while Secchi disk transparency has decreased.

Due to the relationship between phosphorus and algae (Chl-a), as well as the potential for unmitigated sources of pollution (i.e., phosphorus) from watershed development in the coming years, phosphorus is the focus of this management plan. **The Steering Committee has set interim water quality goals that would reduce current median in-lake total phosphorus by 25% (44.4 kg/year) to 8.3 ppb in Lake Warren.** Achieving these goals will help reduce current in-lake phosphorus and Chl-a over time and help safeguard against increased phosphorus loading from the landscape as a result of development (e.g., septic systems, paved surfaces, sediment, etc.). The ultimate goal is to improve the water quality to the point that the lake is no longer impaired.

This comprehensive watershed plan provides a roadmap for preserving the water quality of Lake Warren, and provides a mechanism for procuring funding (i.e., Section 319 grants) to secure action needed to achieve water quality goals. USEPA requires that a Watershed Management Plan be created for communities to be eligible for watershed assistance implementation grants. In addition, this plan sets the stage for ongoing dialogue among key stakeholders in many facets of the community, and promotes coordinated action to address future development in the watershed. The success of this plan is dependent on the continued concerted effort of volunteers, and 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, water quality and assimilative capacity analyses and watershed and septic surveys were completed in 2013-2014. Results of these efforts were used to run a land-use model, or Lake Loading Response Model (LLRM), that estimated the current and historical amount of phosphorus being delivered to the lake from the watershed. An additional analysis of water quality data conducted by CRLAC (referenced in the 2012 Lake Warren Comprehensive Lake Inventory and Management Plan) was also consulted in drafting the Watershed Management Plan. The Steering Committee and other volunteers provided vital on-the-ground support and technical review throughout the process.

Plan Components

The Lake Warren Watershed Management Plan includes nine key planning elements to address nonpoint source (NPS) pollution (Section 1.3). These guidelines, set forth by the USEPA, highlight important steps in protecting water quality for waterbodies impacted by human activities, including specific recommendations for guiding future development, and strategies for reducing the cumulative impacts of NPS pollution on lake water quality. Below is a summary of information presented by Section:

SECTION 1– INTRODUCTION

Section 1 introduces the plan by describing the problem, the goals and objectives, the community-based planning process, and applicable federal regulations. Section 1 also provides background information, including watershed survey results and current watershed efforts in phosphorus reduction and awareness.

SECTION 2– WATERSHED CHARACTERIZATION

Section 2 describes the watershed, providing detailed information about climate, population and demographics, land cover, topography, soils and geology, wetlands and riparian habitat, lake morphology and morphometry, and drainage areas or tributaries.

SECTION 3– ASSESSMENT OF WATER QUALITY

Section 3 describes water quality standards, highlights the estimated sources of phosphorus to Lake Warren, and provides a summary of current classification based on the water chemistry assessment and water quality goals. Identification of nonpoint source pollution is also included in this section.

SECTION 4– MANAGEMENT STRATEGIES

Section 4 outlines the necessary management strategies (both structural and non-structural BMPs) to reduce phosphorus inputs to Lake Warren. Current and future sources of phosphorus are discussed and an adaptive management strategy is presented.

SECTION 5– PLAN IMPLEMENTATION

Section 5 describes who will be carrying out this plan and how the action items will be tracked to ensure that necessary steps are being taken to protect and improve the water quality of Lake Warren over the next ten years. This section also provides estimated costs and technical assistance needed to successfully implement the plan and a description of the evaluation plan to assess the effectiveness of restoration and monitoring activities.

Funding the Plan

Reducing phosphorus inputs from existing and future development in the Lake Warren watershed will require significant financial and technical resources on the order of $386,000 over the next ten years, including the financial support of private, town, state, and federal partners. Section 5.5 lists the costs associated with successfully implementing this ten-year watershed plan, including both structural and non-structural management measures. A sustainable funding plan should be developed within the first year of this plan and revisited on an annual basis to ensure that the major planning objectives can be achieved over the long-term. This funding strategy would outline the financial responsibilities at all levels of the community (landowners, towns, community groups, and state and federal governments).

Administering the Plan

This watershed management plan should be carried out by a steering committee like the one established during the development of this plan. Local participation is an integral part of the success of this plan, and should include the leadership of the Town of Alstead. This task will also require the support of other stakeholders, including NHDES, schools and community groups, local businesses, and individual landowners. The primary stakeholder group will need to meet regularly and be diligent in coordinating resources to implement practices that will reduce NPS pollution in the Lake Warren watershed.

Next Steps

The success of the plan can be measured in many ways, as outlined in Section 5.4, Indicators to Measure Progress. Much of this progress weighs heavily on the cooperation of the Town of Alstead and other key stakeholders to support the plan, and the ability of the Steering Committee to develop a sustainable funding strategy.

ACKNOWLEDGMENTS

Lake Warren Watershed Management Plan Steering Committee

Ellen Chase, Dan Curll, Joyce Curll, David Deen, Michael Heidorn, Annie Isacco, Bruce Montgomery, Nan Montgomery, Bob Quaglin, Philip Sanford, Lisa Tusveld, Sarah Webb.

Watershed and Septic Survey Volunteers

Ellen Chase, Dan Curll, Joyce Curll, Ray Davey, David Deen, Rosemarie Dowling, Mike Heidorn, Des Hinman, Annie Isacco, Bill Jahos, Mark Kingwell, John Mann, Bruce Montgomery, Molly Montgomery, Nan Montgomery, Bob Quaglin, Philip Sanford, Lisa Tusveld.

Pine Cliff Road Buffer Planting Volunteers

Margaret Chase, Joyce Curll, Tom Dowling, Katie Koster, John Mann, Bob Quaglin, Lisa Tusveld, Sarah Webb.

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Additional Partners

David Crosby, Town of Alstead Road Agent

ACRONYMS

ACRONYM	DEFINITION
ALU	Aquatic Life Use
BMP	Best Management Practice
CCSWCD	Cumberland County (ME) Soil and Water Conservation District
Chl-a	Chlorophyll-a
CLI	Comprehensive Lake Inventory
CRLAC	Cold River Local Advisory Committee
CWA	Clean Water Act
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
FBE	FB Environmental Associates
GIS	Geographic Information Systems
IC	Impervious Cover
LID	Low Impact Development
LLRM	Lake Loading Response Model
LWA	Lake Warren Association
NCDC	National Climatic Data Center
NH GRANIT	New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GIS Clearinghouse)
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
RGA	Rapid Geomorphic Assessment
SCC	State Conservation Commission
SDT	Secchi Disk Transparency
SOAK NH	Soak Up the Rain New Hampshire
SSPP	Site Specific Project Plan
SWRPC	Southwest Region Planning Commission
TP	Total Phosphorus
UNHSWC	University of New Hampshire Stormwater Center
USEPA	United States Environmental Protection Agency
USLE	Universal Soil Loss Equation
VLAP	Volunteer Lake Assessment Program
VRAP	Volunteer River Assessment Program

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1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

Located in southwestern New Hampshire, Lake Warren has been an important natural resource in the Town of Alstead for over 200 years. As the headwaters of Warren Brook, the lake was initially dammed to provide a source of water to downstream mills. With time, the lake has also become a highly valued recreational resource to both residents and visitors who enjoy its scenic beauty and calm, quiet character. The lake also provides critical habitat for a diverse abundance of plants, wildlife, and aquatic life. The water quality of lakes and streams can decline rapidly because of stormwater runoff from watershed development (including roads, agriculture, and residences). Taking proactive steps to properly manage and treat stormwater runoff to protect these important water resources is essential for continued ecosystem health, including resources valued by humans.

The Lake Warren Watershed Management Plan is the culmination of several years of effort by the many individuals who care about the long-term protection of water quality in the lake. The Lake Warren Association (LWA) was formed in 1985 with the goal of protecting the lake. By partnering with the Southwest Region Planning Commission (SWRPC), the New Hampshire Department of Environmental Services (NHDES) awarded the group both a Water Quality Planning Grant (Section 604 (b) of the Clean Water Act) and a Watershed Assistance Grant for implementation (Section 319 of the Clean Water Act) with funds from the United States Environmental Protection Association (USEPA). Stakeholders from the local to state level have collaborated on this effort, including the Town of Alstead, New Hampshire Fish and Game Department (NHFGD), the Soak Up the Rain program, the Cold River Local Advisory Committee (CRLAC), and numerous watershed residents.

Lake Warren on a sunny afternoon. Photo: FBE

This comprehensive watershed plan provides a roadmap for preserving the water quality of Lake Warren, and provides a mechanism for procuring funding (i.e., Section 319 grants) for actions needed to achieve water quality goals. USEPA requires that a Watershed Management Plan be created for communities to be eligible for watershed assistance implementation grants. In addition, this plan sets the stage for ongoing dialogue among key stakeholders in many facets of the community, and promotes coordinated action to address future development in the watershed. The success of this plan is dependent on the continued concerted effort of volunteers, and 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, water quality and assimilative capacity analyses and watershed and septic surveys were completed in 2013-2014. Results of these efforts were used to run a land-use model, or Lake Loading Response Model (LLRM), that estimated the current and historical amount of phosphorus being delivered to the lake from the watershed. An additional analysis of water quality data conducted by CRLAC was also referenced and consulted. The Steering Committee and other volunteers provided vital on-the-ground support and technical review throughout the process.

The Lake Warren Watershed Management Plan synthesizes these data into a comprehensive plan that includes the nine key planning elements to address **nonpoint source (NPS) pollution** in impaired waters. These guidelines, set forth by the USEPA, highlight important steps in protecting water quality for waterbodies impacted by human activities, including specific recommendations for guiding future development, and strategies for reducing the cumulative impacts of NPS pollution on lake water quality.

1.2 STATEMENT OF GOAL

Lake Warren is currently listed as impaired for Aquatic Life Use (ALU) due to high levels of Chlorophyll-a (Chl-a) and total phosphorus (TP), and low pH (NHDES, 2014b). Excess TP can stimulate algae growth, which typically results in a decrease in Secchi disk transparency (SDT; i.e., a decrease in water clarity) due to the additional algae. This is evident in Lake Warren, where TP and Chl-a have increased since 1980 while Secchi disk transparency has decreased.

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

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/permanent) BMPs for existing and new development to ensure long-term restoration success.

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.

LWA volunteers learn how to identify nonpoint source pollution sites. Photo: FBE

Due to the relationships between phosphorus and Chl-a (described in further detail in Section 3), as well as the potential for unmitigated sources of pollution (i.e., phosphorus) from watershed development in the coming years, phosphorus is the focus for the water quality assessment and goal setting that is described in this section of the plan.

This plan provides short and long-term goals for improving and protecting the water quality of Lake Warren over the next ten years (2017-2026). **The Steering Committee has set interim water quality goals that would reduce current median in-lake total phosphorus by 25% (44.4 kg/year) to 8.3 ppb in Lake Warren.** The interim goal was designed to meet the mesotrophic ALU standards, but approach the oligotrophic standards. This should reduce phosphorus concentrations to a level that will diminish algae growth and thus Chl-a concentrations. Achieving these goals will help reduce current in-lake phosphorus and Chl-a over time and help safeguard against increased phosphorus loading from the landscape as a result of development (e.g., septic systems, paved surfaces, sediment, etc.). It is important to act now as Lake Warren is ranked "medium" for recovery potential on the Lake Watersheds Recovery Potential Ranking list for New Hampshire (NHDES, 2014c). Recovery will become increasingly difficult if current phosphorus trends and degradation in water quality continue.

This target reduction in phosphorus can be achieved through the following structural (engineered treatment options) and non-structural objectives:

- Form smaller "action committees" within the Steering Committee or LWA for more efficient implementation of the action plan items (Section 5.3.1). For example, a smaller committee can be formed to focus on Outreach and Education, to maintain momentum and "buzz" for the project.

- Implement **best management practices (BMPs)** throughout the watershed to reduce sediment and phosphorus runoff from existing development, with a focus on high-priority shoreline properties (Sections 3.7.1, 4.2, 5.3.2).

- Work with local road managers, state agencies, and private road residents to maintain watershed roads in proper condition (Sections 3.7.1, 5.3.3)

- Increase awareness of proper septic system maintenance/replacement and identify opportunities for wastewater improvement (Sections 3.7.2, 5.3.4).

- Interface with local government (Town of Alstead) to advocate for greater controls on future and re-development, increased use of **low impact development (LID)** in site plans, and enforcement of local wastewater laws (Section 5.3.5).

- Collaborate with local conservation and land management groups to identify conservation priorities within the watershed (Sections 2.1.4 and 5.3.5).

- Continue and/or expand the water quality monitoring and aquatic invasive plant control programs (Sections 2.4, 3.2, and 5.3.6).

These objectives and more are discussed in greater detail in the Action Plan (Section 5.3).

1.3 INCORPORATING EPA'S NINE ELEMENTS

USEPA Guidance lists nine components that are required within a watershed management plan to restore waters impaired or likely to be impaired by NPS pollution. These guidelines highlight important steps in 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: Sections 1.5**, **3.7.1**, and **3.7.2** highlight known sources of NPS pollution in the watershed of Lake Warren and describe the results of the 2013 watershed survey and follow-up from 2015. These sources of pollution must be controlled to achieve load reductions estimated in this plan, as discussed in item (B) below.

B. **Estimate of Load Reductions Expected from Management Measures**: **Section 3.5** describes the estimation of the current and historical phosphorus load to Lake Warren using the Lake Load Response Model (LLRM). **Section 3.6** describes the selected water quality goal and the reduction in phosphorus load needed to meet this goal. To meet these target pollution reductions, **Section 4.2** describes the expected reductions in annual phosphorus loading to Lake Warren as a result of implemented management measures including both structural BMPs for existing development (e.g., installing vegetated buffers or rain gardens, improving and maintaining roads, managing fertilizer) and non-structural BMPs. (e.g., reviewing and improving zoning ordinances, promoting the use of

LID designs for future development, educating watershed citizens about activities to reduce phosphorus at home).

C. **Description of Management Measures: Section 5.3** identifies 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: watershed planning, shoreline BMPs, road BMPs, septic systems, municipal planning and land conservation, and water quality monitoring. 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 5.3** and **5.5** 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 state and federal granting agencies (USEPA and NHDES), local groups (Town of Alstead and LWA), private donations, and landowner contributions for BMP implementation on private property. LWA and other core stakeholders, led by a steering committee, should oversee the planning effort by meeting regularly and efficiently coordinating resources to achieve the goals set forth in this plan.

E. **Information & Education & Outreach: Sections 1.5.3** describes how Education and Outreach is already implemented to enhance public understanding of the watershed because of leadership from SWRPC and LWA. **Section 5.6** describes how these efforts can be augmented in the future.

F. **Schedule for Addressing Phosphorus Reductions: Section 5.3** provides a list of objectives and action items to reduce stormwater and phosphorus runoff to Lake Warren. Each item has a set schedule that defines when the action should begin. The schedule should be adjusted by the Steering Committee on an annual basis (see **Section 4.4** on Adaptive Management).

G. **Description of Interim Measurable Milestones: Sections 5.4** and **5.7** outline indicators of implementation success that should be tracked annually. Using indicators to measure progress makes the plan relevant and helps sustain the action items. The indicators are divided into three different categories: Environmental, Programmatic, and Social Indicators. Environmental indicators are a direct measure of environmental conditions, such as improvement in water clarity or reduced median in-lake phosphorus concentration. Programmatic indicators are indirect measures of restoration activities in the watershed, such as how much funding has been secured or how many BMPs have been installed. Social indicators measure change in social behavior over time, such as the number of new stakeholders on the Steering Committee or number of new lake monitoring volunteers.

H. **Set of criteria: Section 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 5.3.6** describes the long-term water quality monitoring strategy for Lake Warren, 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 ultimate goal of this plan is to improve the water quality of the lake by lowering the in-lake phosphorus and Chl-a concentrations. 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

A public presentation was given by the SWRPC to explain the development of the watershed management plan on July 4, 2015 at the LWA annual meeting. This presentation provided interested stakeholders an introduction to the main purpose of the plan and to explain how watershed residents could utilize this information to protect Lake Warren.

On August 25, 2015, lead consultants FB Environmental (FBE) and the SWRPC met with the Steering Committee to kick off the development of the Lake Warren Watershed Management Plan. The meeting included an overview of the process of developing a watershed plan and the role of the Steering Committee in that process.

The Steering Committee met again in October 2015 to prioritize the initial 2014 Action Plan. A total of 13 committee members provided feedback. Members ranked items 1-5 or 1-10 depending on the number of items in the category; not every action item received a ranking. Action items were prioritized in a way that accounted for how many members considered the item in the "top ten" or "top five", as well as how high that item ranked within those "top" items. From group discussions and additional actions provided by FBE, a total of 62 action items were identified and prioritized, including ordinance development or refinement, public outreach program development, and water quality monitoring improvement (Section 5.3).

On April 5, 2016, the Steering Committee met to discuss the demonstration project on Pine Cliff Road. Members determined that early June would be the most feasible time to get the plantings in and established. Types of plants were also part of the discussion. In addition to the demonstration project, the committee discussed potential topics for presentations to be held in the summer.

An additional Steering Committee meeting took place on May 24, 2016. At this meeting, the SWRPC presented preliminary results of the LLRM to the Steering Committee. The objective of the meeting was to familiarize the Steering Committee with the model results and help guide the Steering Committee toward establishing a water quality goal for the watershed.

This plan was developed through the collaborative efforts of numerous Steering Committee meetings and conference calls between FBE and outside technical staff, including SWRPC, LWA, and NHDES (see Acknowledgments). Public feedback was also received following the presentation of the draft plan in November 2016.

1.5 CURRENT WATERSHED EFFORTS

1.5.1 *WATERSHED ORGANIZATIONS*

The Lake Warren Association (LWA) was founded in 1985 so that Alstead residents, some owning property around the lake or in the watershed, and other friends of the lake, could work together to protect the lake from various encroachments. To that end, LWA has been testing water quality through the NHDES Volunteer Lake Assessment Program (VLAP) since 1990, as well as participated in the Lake Host program (boat inspections to prevent spread of invasive species) and the Weed Watchers program (weed surveys to track exotic species). The goals of these programs are to:

1) protect the water quality in the lake and to prevent the introduction and proliferation of exotic invasive plants, both in the water and along the shoreline;
2) keep the lake viable as a valuable recreational resource for the people of Alstead and for visiting fishermen and boaters.

The LWA had been involved with other issues relating to the lake, including property owners contributing to the repair of the dam when it was privately owned, the transfer of dam ownership from private owners to the Town of Alstead, invasive shoreline plants, swimming rights for residents, and water quality monitoring. LWA was actively involved in the development of the 2012 Lake Management Plan, now incorporated into the Town Master Plan. The group also runs numerous educational programs, including a program on wildlife in the environs of the lake. As part of development and initial implementation of the Watershed Management Plan, nearly 20 volunteers from LWA participated in the Watershed Survey (Section 3.7), and nine volunteers planted a demonstration project showing how property owners can engage in projects that can reduce stormwater runoff into the lake. Currently, water quality issues relating to stormwater runoff from a section of Pine Cliff Road which runs along the shoreline of the lake, dust raised from vehicles traveling along that gravel stretch of the road, and pedestrian safety in this same area, are additional concerns for the LWA.

Cold River Local Advisory Committee (CRLAC) is also an active organization in the area. Lake Warren is within the Cold River watershed, which is a tributary to the Connecticut River on the border between Vermont and New Hampshire. The Cold River became a Designated River through the New Hampshire Rivers Management and Protection Program in 1999 "due to its significant natural, cultural, scenic and scientific resources." Designated Rivers are managed and protected under RSA 483. CRLAC has previously been involved with work in the Lake Warren watershed through the 2012 Lake Warren Comprehensive Lake Inventory and Management Plan.

1.5.2 *PREVIOUS STUDIES AND PLANS*

LAKE WARREN COMPREHENSIVE LAKE INVENTORY AND MANAGEMENT PLAN

In 2012, a Comprehensive Lake Inventory (CLI) and Management Plan was completed for Lake Warren. This work was funded by a grant through Section 604(b) of the Clean Water Act. CRLAC, LWA, SWRPC, and many other stakeholder groups were involved in drafting this plan. The CLI provided a baseline profile for the lake, including an assessment of 10 attributes for their 1) recreational value and 2) susceptibility to impairment. The document also included an assessment of water quality data over the preceding decade, a phosphorus prioritization of subdrainages, and a list of perceived threats to the lake and recommended actions. The CLI and Management Plan were adopted by the Town of Alstead and incorporated into the town's Master Plan in 2014. The current Watershed Management Plan builds on this initial effort by providing more detailed analyses, such as a land-use based phosphorus model of the watershed, and identifying specific nonpoint source pollution sites. This Watershed Management Plan also meets USEPA guidelines which will make Lake Warren eligible for future Section 319 funding.

WATERSHED AND SEPTIC SURVEY

A combination watershed and septic survey was conducted in September 2013 by LWA volunteers with the help of trained technical staff from FBE and SWRPC. A watershed survey is designed to locate potential sources of NPS pollution in an area that drains to a waterbody and is essential for watershed management planning. Septic surveys are also important tools as provide information on septic system maintenance practices within a watershed. Methodology and results for these surveys is presented in Section 3.7.

HALE BROOK SEDIMENT SOURCE STUDY

On December 7, 2015, an FBE technical team conducted a stream walk and geomorphic survey of Hale Brook (FBE, 2016a). Beginning at its outlet to Lake Warren, the team walked up Hale Brook and completed rapid geomorphic assessments (RGAs) of identified reaches (wherever there was a major change in stream habitat or morphology as a result of natural or man-made structures, such as road crossings and culverts). The team assessed eleven stream reaches (1-11). Special attention was paid to sediment particle size and distribution, condition of banks (e.g., undercutting), in-stream sediment deposition (e.g., sand bars), etc. Each stream reach was rated on its condition. This helped provide insight to the sediment and flow dynamics of the stream and showed where major sediment issues may be occurring along the stream. NPS pollution sites were also noted; these were added to the list of sites from the 2013 Watershed Survey.

1.5.3 *PUBLIC OUTREACH*

The LWA provides information on activities in the watershed through its newsletter, which provides updates on the Lake Host and Weed Watchers programs, lake events, and other watershed activities. Activities such as the Lake Host program (see Section 2.4 Invasive Species), help educate the community about what can be done to protect, preserve and improve the water quality of Lake Warren. Educational materials are also available at the Lake Warren Boat Launch kiosk and the Alstead Town Hall. Flyers and brochures highlight the demonstration BMPs (see Section 1.5.4 below), recommend conservation practices for homeowners, and showcase current efforts to complete the watershed management plan.

SOAK NH provides information about how our homes create stormwater pollution and how to prevent it with rain gardens, infiltration trenches, and other conservation practices. Graphic: http://soaknh.org/

Additionally, an event with the Soak Up the Rain program was hosted by SWRPC and LWA at the Second Congregational Church in East Alstead on August 17, 2016. Soak Up the Rain New Hampshire (SOAK) is a voluntary program, managed by NHDES, with the goal of protecting and restoring clean water in the state's lakes, streams, and coastal waters from the negative impacts of stormwater pollution. The SOAK program helps property owners who want to be part of the solution. The event in August 2016 focused on "Do-It-Yourself" stormwater solutions for homeowners, such as rain gardens, vegetated buffers, and infiltration trenches.

A meeting of the LWA on August 27, 2016 was devoted to a presentation by a member of the Granite State Septic System Designers and Installers Association. The presentation highlighted innovative solutions to difficult settings for septic systems, especially those located on small properties near lakes and streams. Thirty people attended the meeting.

1.5.4 *BMP IMPLEMENTATION*

As part of the development of the watershed management plan, two demonstration best management practices (BMPs) were installed to reduce stormwater runoff and erosion to Lake Warren and to demonstrate to residents and visitors the actions that they can take to protect the lake.

PINE CLIFF ROAD BUFFER PLANTING

On June 18, 2016, nine volunteers helped install a buffer planting along Pine Cliff Road. Previously, there was almost no vegetated buffer along a 26-ft stretch of this road, with patches of dirt and grass (see below). Signs of erosion from large volumes of stormwater were visible along the road fill slope.

The unvegetated area was planted with over 40 hardy plants, including native sweet fern (*Comptonia peregrina*), to stabilize the slope and encourage infiltration of road runoff. Erosion control mulch was spread between plantings and along a footpath to the lake to help stabilize the bare soil and protect the plantings. These BMPs reduced the pollutant load to the lake by 0.1 lbs/yr of phosphorus, 0.2 lbs/yr of nitrogen, and 200 lbs of sediment/yr.


Before (left) and after (right) condition of vegetated buffer along Pine Cliff Road.

BOAT LAUNCH MAINTENANCE

The Lake Warren Boat Launch and its access road are state property, but the Town of Alstead maintains the road (grading and plowing). On November 18, 2015, several members of the Steering Committee, including a representative from the SWRPC, met with a representative of the NH Fish and Game, NH Department of Environmental Services, and the Alstead Road Agent, David Crosby. The access road to the boat launch had significant erosion along the roadside and evidence of sediment being carried into the lake near the boat ramp. A design was prepared; however, an alternative solution was discussed during the site walk. In 2015 the road agent re-graded the access road to provide better drainage of water off the road (instead of down the road toward the lake).

2. WATERSHED CHARACTERIZATION

This section details the historic and current conditions of the Lake Warren watershed, which helped guide the development of goals and objectives to protect and improve Lake Warren water quality. The characterization includes watershed-specific information on the local climate, demographic history, underlying soil and geographical characteristics, and past and present land use.

2.1 CLIMATE, POPULATION, AND LAND USE

2.1.1 *DESCRIPTION, LOCATION, AND CLIMATE*

The Lake Warren watershed covers approximately 4.9 square miles in southwestern New Hampshire, and is entirely within the Town of Alstead. From the dam outlet in the northwest corner of the lake, water from Lake Warren flows into Warren Brook, which converges with the Cold River in northwest Alstead and ultimately drains to the Connecticut River along the Vermont-New Hampshire border.

Lake Warren is situated within a temperate zone of converging weather patterns from the hot, wet southern regions and the cold, dry northern regions, which causes various natural phenomena such as severe thunder and lightning storms, hurricanes, and heavy snowfalls. Climate records from nearby Keene, NH[1] were used to assess historical climate in the Lake Warren watershed from 1900 (NCDC, 2016). The area experiences moderate rainfall and snowfall, averaging 43.6 inches of precipitation annually (climate normal, 1981-2010; NCDC, 2016). Monthly precipitation (1900-2016) averages 3.7 inches (Figure 2-1). Winter temperatures average 23.3 °F while summer temperatures average 67.5 °F (climate normal, 1981-2010; NCDC, 2016).

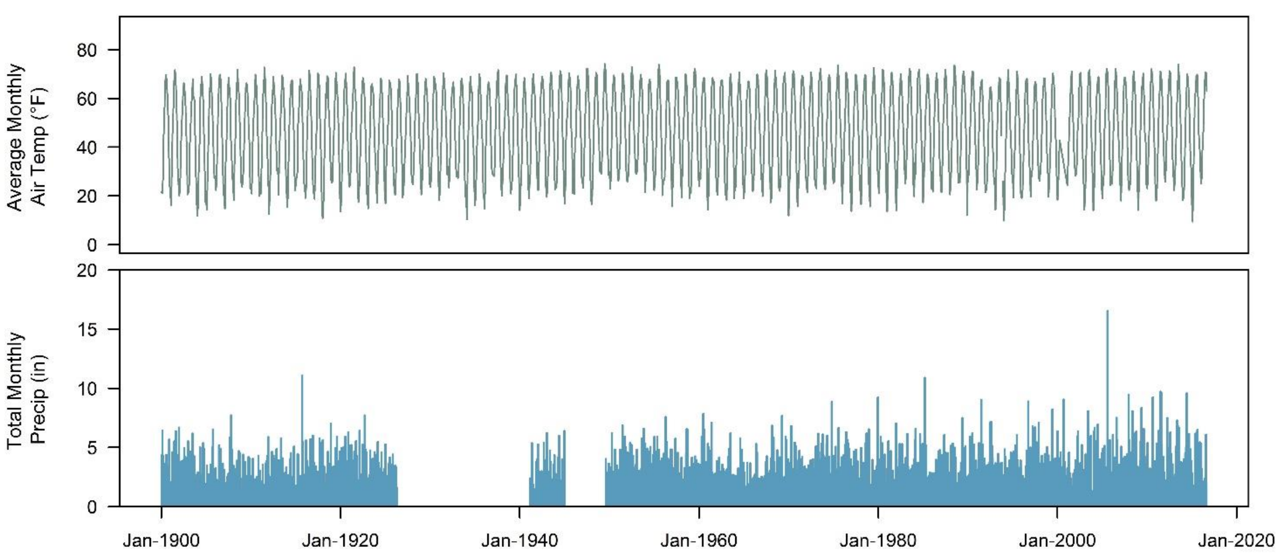


Figure 2-1. Average monthly temperature and monthly precipitation history for Keene, NH weather station.

[1] *Station ID: USC00274399*

2.1.2 *HISTORY AND POPULATION DEMOGRAPHICS*

Understanding population growth and demographics, and ultimately, development patterns provides critical insight into watershed management, particularly as it pertains to lake water quality. The history of Alstead and Lake Warren is deeply connected to the local water resources, as the Cold River and Warren Brook (at the outlet of Lake Warren) powered numerous mills in the area throughout the late 1700s to 1800s. Consequently, Alstead was sometimes known as "Paper Mill Village" during this time. Lake Warren was dammed around 1770 to provide power to the downstream mills, including the mills in the "Mill Hollow" area just below the dam. In later years, Alstead also supported a commercial mining industry for minerals such as mica[2,3]. The flood of October 2005 was also a significant event in Alstead history. Over 10" of rain fell in a 30-hour period, and Lake Warren breached its dam. Warren Brook swelled and flooded many parts of Alstead, resulting in loss of life and property.

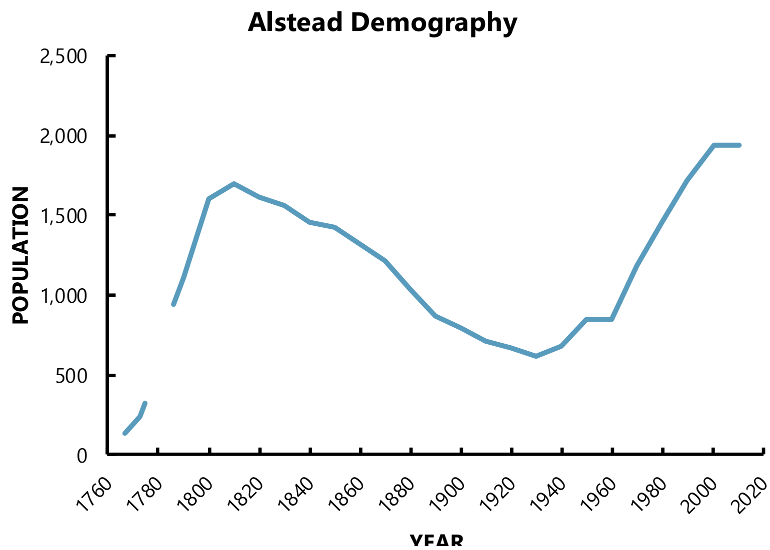


Figure 2-2. Historical demographic data for Alstead, NH. The population of this community has grown since 1960, though it has slowed down in the last decade.

Census records for Alstead date back to 1767, and records continue in ten-year intervals from 1790 to 2010. The community grew until 1820 when the population began to decline to a low in the 1930s and 40s (Figure 2-2, NHOEP, 2016). The town then experienced steady population growth since the middle part of the last century (Table 2-1). The population of Alstead has grown from 843 people in 1960 to 1,937 people in 2010 – a 130% increase.

The most recent demographic data (US Census Bureau, 2010) showed a roughly even split between the under 19, 20-44, and 45-64 age categories. Seasonal (13%) and renter-occupied (19%) homes comprise small percentages of the residencies in Alstead (Table 2-2), though the percentages are likely higher within the watershed area.

[2] *http://www.coldriver.org/ColdRiverAtlasBack.pdf*
[3] *http://www.nh.searchroots.com/documents/History_Alstead_NH.txt*

Table 2-1. US Census Bureau population estimates for Alstead, NH, 1960-2010.

Town	1960	1970	1980	1990	2000	2010	30 yr. Avg. Compound Annual Growth Rate (1980-2010)	20 yr. Avg. Compound Annual Growth Rate (1990-2010)	10 yr. Avg. Compound Annual Growth Rate (2000-2010)
Cheshire County	43,342	52,364	62,116	70,121	73,825	77,117	--	--	--
Alstead	843	1,185	1,461	1,721	1,944	1,937	0.94%	0.59%	-0.04%

Table 2-2. 2010 population demographics for Alstead, NH.

State/County /Town	Total Pop.	Aged 0-19	Aged 20-44	Aged 45-64	Aged 65+	Total Housing Units	Total Occ. Houses[1]	Owner Occ. Houses[1]	Seasonal Houses[1]	Renter Occ. Houses[1]
New Hampshire	1,316,470	325,802	408,196	404,204	178,268	614,754	84%	60%	10%	25%
Cheshire County	77,117	18,697	24,175	22,903	11,342	34,773	87%	61%	8%	26%
Alstead	1,937	444	538	654	301	991	82%	63%	13%	19%

[1]*Percentage of total housing units.*

2.1.3 *LAND USE*

Characterizing land use 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 use is also the essential element in determining how much phosphorus is contributing to a lake from the watershed (see Section 3.5: Watershed Modeling).

Current land use in the Lake Warren watershed was determined using a combination of land use data from NH GRANIT's New Hampshire Land Cover Assessment 2001 [NHLC01], National Wetland Inventory (NWI) wetlands, National Hydrography Dataset (NHD) waterbodies, and aerial imagery (see Lake Warren Nutrient Modeling report for details (FBE, 2014a)). Twelve different land use types were differentiated in the watershed (Figure 2-3).

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

Forests, including deciduous, evergreen, mixed habitats, and forested wetlands account for approximately 75% of the land use (2,338 acres). Agriculture is the second largest land cover in the watershed, accounting for 10.5% (327 acres) of the land area. Developed areas such as residential properties, lawns, and roads total 209 acres or 7% of the watershed (Figure 2-4). Wetland habitat and open water (including the surface area of Lake Warren) represent 7.5% of the land use (237 acres).

Developed areas within the Lake Warren watershed include **impervious cover (IC)**, such as asphalt, concrete, and rooftops, that force rain and snow that would otherwise soak into the ground to runoff as stormwater. Stormwater runoff carries pollutants to waterbodies that may be harmful to aquatic life, including sediments, nutrients, pathogens, pesticides, hydrocarbons, and metals. Studies have shown a link between the amount of impervious area in a watershed and water quality conditions (CWP, 2003). Developed area and associated impervious cover is relatively low at 7% in the Lake Warren watershed, but includes many areas along the lake shoreline and along major routes through the watershed. Agricultural areas are also important to watershed and lake health, as runoff from these areas may contain pesticides, nutrients (from fertilizers), or bacteria from animal wastes.

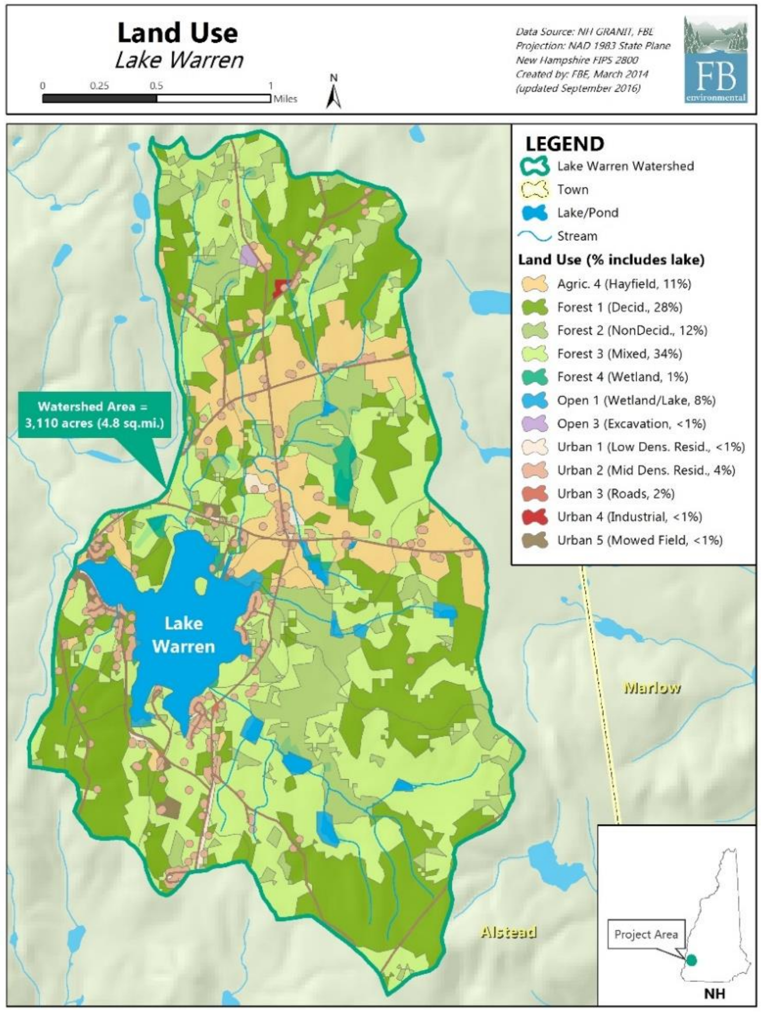


Figure 2-3. Land use within the watershed of Lake Warren. Refer to Appendix A, Map 2.

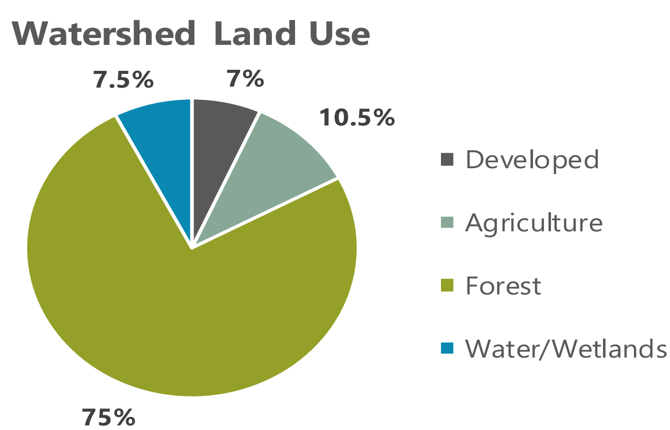


Figure 2-4. Watershed land use in the Lake Warren watershed.

2.1.4 *LAND CONSERVATION*

In 2008 and 2009, citizens of Alstead developed a Land Conservation Plan for the Town to further the vision and goals set out in Alstead's 2007 Master Plan update. The vision statement in this update describes core values held by Alstead residents: rich cultural past, pristine natural environment, dynamic sense of community, and passion for rural character. The Land Conservation Plan was adopted into the Master Plan in 2009.

A number of large pieces of land are under land conservation easements, four of which are along the shores of Lake Warren, and which comprise approximately 53 acres and approximately 7700 feet of shoreline. Another 50 acres in the watershed have had conservation easements placed on them since the Land Conservation Plan was put in place, adding to approximately 132 acres already under conservation easements. In total, approximately 8% of the watershed is conserved land today (Appendix A, Map 3). Most easements are held by the Monadnock Conservancy or the Society for the Preservation of New Hampshire Forest (SPNHF). These conserved areas provide important wildlife habitat and ecological benefits, as well as educational opportunities. For example, activities organized by Kroka Expeditions take place on a privately-owned, conserved island on Lake Warren.

2.2 PHYSICAL FEATURES OF THE WATERSHED

2.2.1 *TOPOGRAPHY*

Lake Warren sits at 1,200 feet above sea level (fasl; NHDES, 2005). The lake is surrounded by hills with steep to moderate slopes. The highest peak, Smith Hill, is located in the southeast corner of the watershed at approximately 1,791 fasl (Appendix A, Map 4). Other notable peaks are located along the northern boundary (~1,600-1,700 fasl).

2.2.2 *SOILS & GEOLOGY*

BEDROCK AND SURFICIAL GEOLOGY

Early fall color around Lake Warren. Photo: LWA

The composition of soils surrounding Lake Warren reflects the dynamic geological processes that have shaped the landscape of New Hampshire over millions of years. Important events in the formation of parent material (bedrock) in the Lake Warren area include the Taconic Orogeny, a mountain building event near the end of the Ordovician Period (~445-480 million years ago) which lifted much of New England out of the sea[4]. Around 400 million years ago, the area was once again under a shallow sea; layers of sediment deposits compressed to form sedimentary layers of shale, sandstone, and limestone known as the Littleton Formation (Goldthwait, 1951). As the sea

[4] *http://www.coldriver.org/Geology.htm*

retreated again, the Earth's crust 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; the granite for which the state is famous originated from these "bursts" (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. A glacial lake (Lake Hitchcock) formed in the Connecticut River Valley as glacial meltwater was blocked by a terminal moraine near Middletown, Connecticut[5]. Glacial meltwater from the Lake Warren watershed would have drained to this lake via Warren Brook and the Cold River. During its retreat, the glacier deposited glacial till (mix of coarse sand, silt, and clay), laying the foundation for invading vegetation and meandering streams as the depression basins throughout New England began to fill with water (Goldthwait, 1951).

The surficial geology of the Lake Warren watershed is dominated by glacial till (Appendix A, Map 5). Glacial till is composed of unsorted material deposited directly by the glacial ice sheet, with particle sizes ranging from loose and sandy to compact and silty to gravely. The majority of this area is classified as thin glacial till (R, r, sr). In these areas, bedrock exposures are common and the till is typically less than 6 feet thick. Isolated areas of organic material (Qs) and gravel/alluvium (Qcp, Qal) are concurrent with hydrologic features (i.e., wetlands, streams). A small area of anthropogenic/artificial fill (fd) is also present near the Lake Warren dam.

SOILS

Twenty-two different soil series (and 44 soil phases) are present in the Lake Warren watershed (Appendix A, Map 6). Many of these soil series contain phases with rock outcrops or are described as very stony. Combined, the Cardigan-Kearsarge and Cardigan-Kearsarge-Rock outcrop complexes comprise 24% (758 acres) of the watershed. This soil series is mostly located along the steeper slopes of the watershed.

Table 2-3. Dominant soil series found in the Lake Warren watershed. Source: USDA, 2016.

Soil Series Name	Soil Erosion Potential (K Factor)	Parent Material	Available Water Storage (in profile)	Permeability (Ksat)	Drainage Class
Bernardston	Low (0.15 - 0.24)	Basal till	Low	Moderately Low to Moderately High	Well drained
Cardigan-Kearsarge	Moderate (0.37)	Till	Low to Very Low	Moderately High to High	Well drained
Pittstown	Low (0.17)	Till	Low	Moderately Low to Moderately High	Moderately well drained
Stissing	Low (0.20)	Found in depressions	Low	Moderately Low to Moderately High	Poorly drained; partially hydric
Ossipee	not rated	Organic material over till; bogs	Very High	Moderately High to High	

The Pittstown silt loam series covers the second largest area in the watershed (21%, 654 acres) and is located at the base of the hills or on less steep slopes. Bernardston silt loam (16%, 512 acres) underlays many of the agricultural areas. Stissing silt loam (12%, 372 acres) and Ossipee mucky peat (4%, 125 acres) are generally found along the stream and wetland corridors throughout the watershed. A full list of soil series found in the watershed can be found in Appendix B.

SOIL EROSION POTENTIAL

Soil erosion potential 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 potential should be a primary factor in determining the rate and placement of development within a watershed. The soil erosion potential for the Lake Warren watershed was determined from the associated erosion factor K (whole soil) used in the Universal Soil Loss Equation (USLE) that predicts rate of soil loss by sheet or rill erosion in units of tons per acre per year. There are no high soil erosion potential areas located within the Lake Warren watershed. However, moderate soil erosion potential is prevalent, accounting for 873 acres (28%) of land within the watershed (Figure 2-5). These areas should be monitored closely for erosion during and after any development projects to ensure that eroding soil is not degrading downstream water quality. 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.

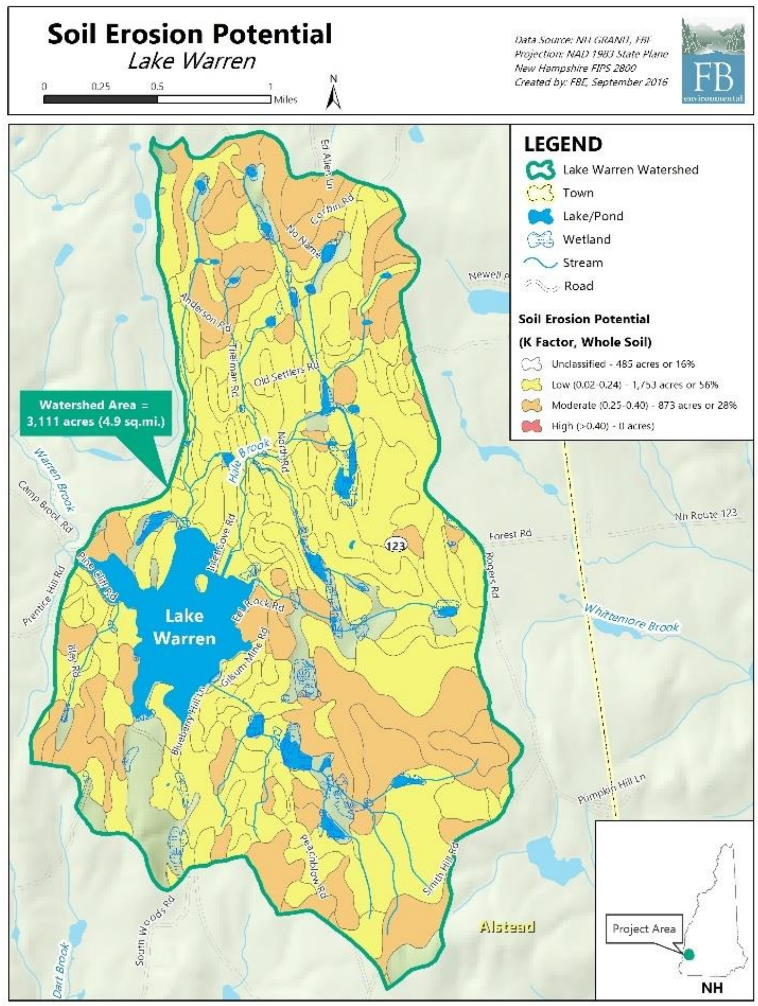


Figure 2-5. Areas of moderate soil potential cover 28% of the Lake Warren watershed. Refer to Appendix A, Map 7.

2.2.3 *WETLANDS, STREAMS, OPEN WATER, AND WILDLIFE HABITAT*

The Lake Warren watershed is rich in water resources beyond the 195-acre lake, including 42 acres of other open waters and wetlands, over 23 acres of forested wetland, and more than 13 miles of mapped streams.

Surrounding these water resources are over 2,000 acres of forest, primarily mixed forest that includes both conifers (e.g., white pine and eastern hemlock) and deciduous tree species (e.g., beech, red oak, and maple). These resources are important as both wildlife habitat and as functional resources to protect water quality: a variety of fish, birds, mammals, and plants thrive in the **riparian habitat** of the lake and surrounding water resources, and wetlands help maintain water quality by acting as a filter of nutrients and sediments from incoming stormwater runoff.

Riparian habitat refers to the type of wildlife habitat found along the banks of a lake, river or stream, and associated waterbodies. Not only are these areas ecologically diverse, but they also help protect water quality by preventing erosion and filtering polluted stormwater runoff by trapping nutrients and sediments.

NHFGD ranks habitat based on value to the state, biological region, and supporting landscape. These habitat rankings are published in the state's 2015 Wildlife Action Plan, which serves as a blueprint for prioritizing conservation actions to protect Species of Greatest Conservation need in New Hampshire. Seventy-two acres (2%) of the Lake Warren watershed is considered Tier 1 habitat (highest ranked habitat in New Hampshire). In other areas of the state, Tier 1 habitat typically includes shoreland zones and lakes, though Lake Warren's shoreland is not included in any habitat ranking. The Tier 1 habitat in the watershed are grasslands that overlap with agricultural areas. Nearly all the Smith Hill Brook and Eastern Tributary drainages are considered Tier 2 (highest ranked habitat in the biological region) or Tier 3 (supporting landscapes), consisting of northern hardwood-conifer or hemlock-hardwood-pine forests. A map detailing priority habitats for conservation based on the NH Wildlife Action Plan can be found in Appendix A, Map 3.

The fauna that enjoy these water and forest resources have been documented in the Lake Warren Comprehensive Lake Inventory and Management Plan (SWRPC, 2012). Notable species include the common loon and bald eagle. Fish are also an important natural resource for sustainable ecosystem food webs and provide recreational opportunities. The shallow lake serves as a warmwater fishery for species such as largemouth bass, smallmouth bass, yellow perch, sunfish, pickerel, and brown bullhead. Additionally, beaver activity has had a large impact on water flow within the watershed, particularly in the Hale Brook subdrainage.

2.2.4 *LAKE MORPHOLOGY AND MORPHOMETRY*

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

The surface area of Lake Warren is 0.3 square miles (195 acres or 79 ha) with a mean depth of 7.1 feet (2.1 m) and maximum depth of 13.8 feet (4.2 m) at the deep spot (Section 3: Figure 3-1; Appendix A, Map 9)[5]. The lake has approximately 3.4 miles (5,500 m; NHDES, 2005) of shoreline and over 1,600,000 m^3 of water. The **areal water load** is 10.6 m/year, and the water in Lake Warren flushes approximately 4.9 times each year.

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

2.3 DIRECT AND INDIRECT DRAINAGE AREAS

The most significant tributary drainage area to Lake Warren is the Hale Brook (Carmen Cove) subdrainage, which discharges to the north end of the lake. This drainage area accounts for 28% of the watershed input to the lake (runoff and tributary flow, excluding atmospheric and septic systems). The Smith Hill Brook subdrainage accounts for an additional 26% of the water input. Five mapped tributaries exist within the watershed: Hale Brook (Carmen Cove), Colburn Hill Brook, Smith Hill Brook, the Eastern Tributary, and a tributary which discharges at the Scotland Yard monitoring site. There are two additional smaller named subdrainages: Spruce River and Pickerel Cove (Figure 2-6).

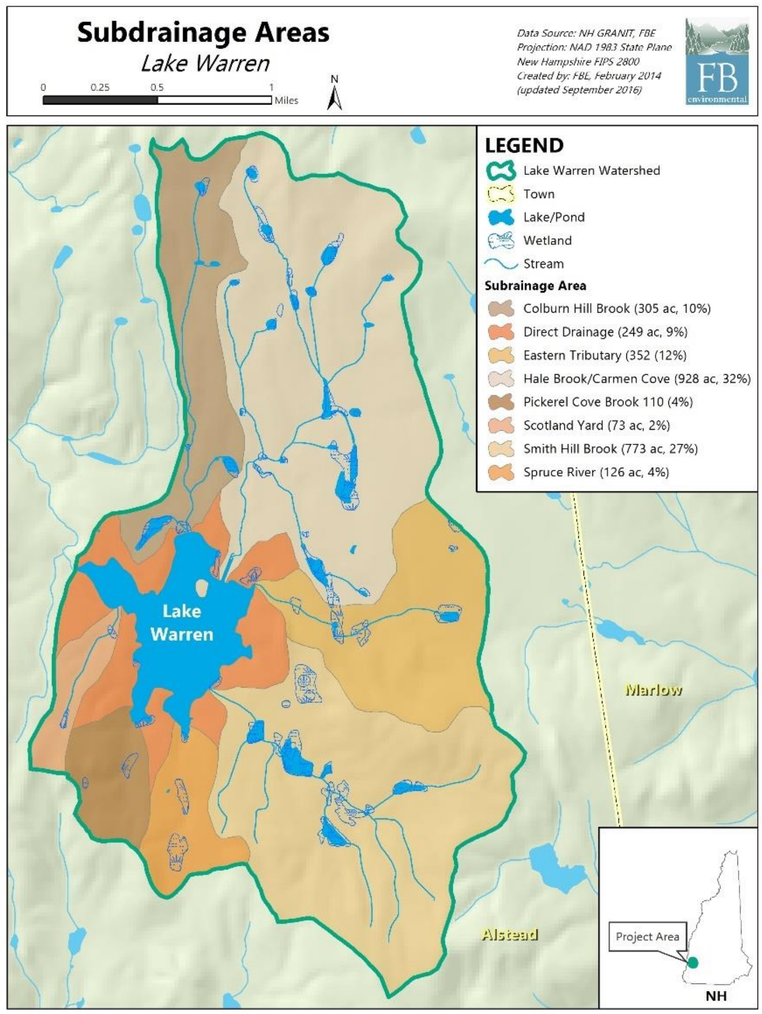


Figure 2-6. Sub-basin delineations for the Lake Warren watershed, including area and percent of watershed. Refer to Appendix A, Map 8.

Watershed load (runoff and tributary flow) accounts for 94% of the water entering Lake Warren, which makes the condition of tributaries and their associated land covers critical to water quality. Rainfall makes up the additional water input to the lake (6%; septic is a minor

[5] Lake area was calculated from National Hydrography Dataset Waterbody shapefile and GIS desktop analysis of watershed land use (including shoreline). Lake volume was calculated based on the most recent NHDES bathymetry data available from NH GRANIT. Using the hydrologic budget determined by the Lake Loading Response Model, new flushing rates were calculated for the lake. The 2005 NHDES Trophic Study reported lake volume as 1,503,500 cubic meters, flushing rate as 4.2 times per year, lake area as 75.1 ha (185 acres), mean depth as 2.0 m, and maximum depth as 4.2 m. FBE's calculations differ slightly from those listed by NHDES.

water load component). The large volume of water entering the lake directly or indirectly via tributary streams makes phosphorus loading from these subdrainages of major importance for lake management. A detailed summary of the nutrient loading analysis for the Lake Warren subdrainages is provided in Section 3.5.2.

2.4 INVASIVE SPECIES

The introduction of non-indigenous invasive aquatic plant species to New Hampshire's waterbodies has been on the rise. These invasive aquatic plants are responsible for habitat disruption, loss of native plant and animal communities, reduced property values, impaired fishing and degraded recreational experiences, and financial burden of removal. Once established, invasive species are difficult and costly to remove. Lake Warren is fortunate to have an active group of volunteers to protect the lake from these invaders.

LWA has participated in the NH Lakes Association Lake Host program since 2002 with both volunteer and paid lake hosts greeting incoming boats and conducting courtesy inspections for approximately 30 hours per week during the summer. Lake Hosts help prevent the transfer of invasive species into the lake, such as variable-leaved milfoil (*Myriophyllum heterophyllum*). Additionally, LWA began participation in the NHDES Weed Watcher program in the 1990s, with an average of approximately 20 volunteers, each taking responsibility for conducting weed surveys within a territory around the lake.

3. ASSESSMENT OF WATER QUALITY

This section provides an overview of the water quality standards that apply to Lake Warren, the methodology used to assess water quality, the current state of the water quality based on that assessment, and recommendations for managing the lake to prevent future degradation of water quality. Lake Warren presents a unique situation for water quality assessment and management, as the lake is very shallow, meaning water quality is susceptible to minute changes in chemistry, but also that the flushing rate is high enough to frequently export nutrient inputs from the system. Despite flushing an estimated 3.7 to 4.9 times per year, the lake has been listed on the Section 303(d) list as impaired for **Aquatic Life Use (ALU)** due to high levels of **Chlorophyll-a (Chl-a)** and **total phosphorus (TP)**, and low pH. Due to the relationships between phosphorus and Chl-a described in the sections below, as well as the potential for unmitigated sources of pollution (i.e., phosphorus) from watershed development in the coming years, phosphorus is the focus for the water quality assessment and goal setting that is described in this section of the plan.

Aquatic Life Use (ALU) ensures that waters provide suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms.

Chlorophyll-a (Chl-a) is a measure of the green pigment found in all plants, including microscopic plants such as algae. It is used as an estimate of algal biomass.

Total Phosphorus (TP) is one of the major nutrients needed for plant growth. In general, as the amount of TP increases, algae (and Chl-a) also increase.

The **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.

3.1 APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

The State of New Hampshire is required to follow federal regulations under the **Clean Water Act (CWA)** with some flexibility as to how those regulations are enacted. The main components of water quality regulations include designated uses, water quality standards and criteria, and anti-degradation provisions. The Federal CWA, the NH *RSA 485-A Water Pollution and Waste Control*, and the NH Surface Water Quality Regulations (Env-Wq 1700) are the regulatory bases for governing water quality protection in New Hampshire. These regulations form the basis for New Hampshire's regulatory and permitting programs related to surface water. 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 for surface waters include aquatic life, fish consumption, shellfish consumption, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating and fishing), and wildlife. Lakes can have multiple designated uses.

In New Hampshire, all surface waters are legislatively classified as Class A or Class B, most of which, including Lake Warren, are Class B. A brief description is provided in Table 3-1 (NHDES, 2014a); however, a more detailed discussion of these classifications can be found in the State statute RSA 485-A:8. Further review and interpretation of the regulations (Env-Wq 1700) reveals that the general rules can be expanded and refined to include the seven specific designated criteria (Table 3-2). Class B waters are the second highest quality waterbodies, considered acceptable for fishing, swimming, and other recreational purposes (RSA 485-A:8 I). Class B waters are also acceptable for use as water supply after adequate treatment.

Table 3-1. New Hampshire surface water classifications (adapted from NHDES, 2014a).

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

Table 3-2. Designated uses for New Hampshire surface waters (adapted from NHDES, 2014a).

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

3.1.2 *LAKE NUTRIENT CRITERIA*

New Hampshire's water quality criteria provide a baseline measure of water quality that surface waters must meet to support their designated uses. These criteria are the "yardstick" for identifying water quality problems and for determining the effectiveness of state regulatory pollution control and prevention programs. If the existing water quality of various parameters meets or is better than the water quality criteria, the water body supports its designated use. If the waterbody does not meet water quality criteria, it is considered impaired for the designated use.

Water quality criteria for each classification and designated use in New Hampshire can be found in RSA 485 A:8, IV and in the State's surface water quality regulations (NHDES, 2008). Primary Contact Recreation (PCR) and Aquatic Life Use (ALU) are the two major uses of concern for Lake Warren.

AQUATIC LIFE USE

The State has a narrative nutrient criterion with a numeric translator or threshold for ALU assessment, consisting of a "nutrient indicator" or TP and a "response indicator" or Chl-a (see also: Env-Wq 1703.03, Env-Wq 1703.04, Env-Wq 1703.14, and Env-Wq 1703.19). The nutrient indicator and response indicator are intricately linked since increased TP loading frequently results in increased algae levels, which can be estimated by measuring Chl-a levels in the lake. Increased algae may lead to decreased **dissolved oxygen (DO)** at the bottom of most lakes, but Lake Warren is shallow enough that the water column is well-mixed and low DO bottom waters are not typically a concern. Increased algae may also lead to decreased water quality and possibly changes in aquatic species composition.

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

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

Trophic State is the degree of eutrophication of a lake as assessed by the transparency, Chl-a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion.

Table 3-3. Aquatic life nutrient criteria ranges by trophic class in New Hampshire.

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

Table 3-4. Decision matrix for aquatic life use assessment (ALU) determinations in New Hampshire.

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

From 1974 through 2010, NHDES conducted trophic surveys on lakes to determine trophic state. The trophic surveys evaluated physical lake features and chemical and biological indicators. Trophic state may be designated as: oligotrophic, mesotrophic, or eutrophic. These are broad categories used to describe how productive a lake is. Generally, oligotrophic lakes are less productive or have less nutrients (i.e., low levels of TP and Chl-a), deep **Secchi disk transparency (SDT)** readings, and high DO levels throughout the water column. In contrast, very 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.

Based on trophic studies completed in 1980, 1991, and 2005, Lake Warren has been classified as both a mesotrophic and oligotrophic waterbody. However, impairment status uses the threshold for the highest classification given to a waterbody. Therefore, Lake Warren is held to the standards set for oligotrophic lakes (Table 3-3).

PRIMARY CONTACT RECREATION

For PCR, New Hampshire has a narrative criterion with a numeric translator or threshold for Chl-a. 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 Chl-a and cyanobacteria scums are used as secondary indicators. These indicators can provide reasonable evidence to classify the designated use as "not supporting," but cannot result in a "fully supporting" designation. ***E. coli*** is the primary indicator for "fully supporting" designations. Elevated Chl-a levels or the presence of cyanobacteria scums interfere with the aesthetic enjoyment of swimming and may pose a health hazard. Chl-a levels greater than or equal to 15 ppb or presence of cyanobacteria scums are considered "not supporting" for this designated use.

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).

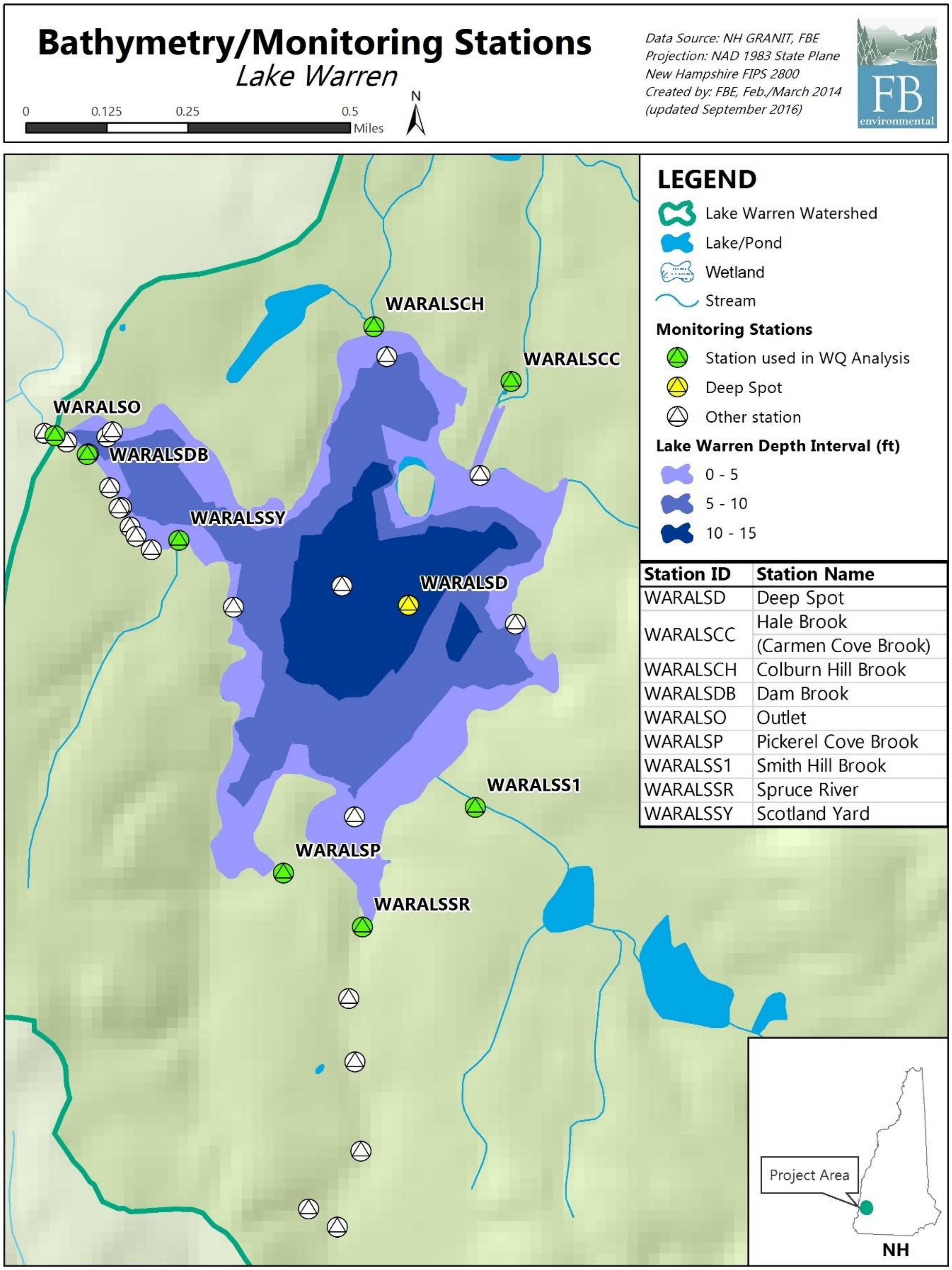
Escherichia coli (E. coli) are bacteria present in the intestinal tracts of warm-blooded animals and are used to indicate the presence of fecal contamination in waterbodies.

3.1.3 *ANTIDEGRADATION*

The Antidegradation Provision (Env-Wq 1708) in New Hampshire's water quality regulations serves to protect or improve the quality of the State's waters. The provision outlines limitations or reductions for future pollutant loading. The Antidegradation Provision is often invoked during the permit review process for certain development projects adjacent to waters that are designated impaired, high quality, or outstanding resource waters. Antidegradation of a high-quality water requires that a permitted activity cannot use more than 20% of the remaining assimilative capacity (see Section 3.5.1) on a parameter-by-parameter basis. Antidegradation for impaired waters requires that permitted activities discharge no additional loading of the impaired parameter.

3.2 SUMMARY OF EXISTING WATER QUALITY DATA

FBE analyzed historical water quality monitoring data to assess the state of Lake Warren and determine the assimilative capacity. Lake Warren was first monitored by NHDES during a trophic survey in 1980 at the deepest spot on the lake (Station ID: WARALSD). Data were obtained from NHDES OneStop Environmental Monitoring Database. With the exception of three years of trophic surveys conducted by NHDES, the remainder of the data were collected by volunteer monitors through the NHDES Volunteer Lake Assessment Program (VLAP) from 1991-2015. Water quality data for two of Lake Warren's tributaries was collected by the NH Volunteer River Monitoring Program (VRAP). Data were collected for water clarity (SDT), Chl-a, color, TP, turbidity, DO, and temperature. Figure 3-1 shows all Lake Warren monitoring stations. A detailed summary of all available data, including sources and years of collection, can be found in Appendix C of this plan as well as Appendix A of the Lake Warren Water Quality Analysis Update (FBE, 2016b).



Station ID	Station Name
WARALSD	Deep Spot
WARALSCC	Hale Brook (Carmen Cove Brook)
WARALSCH	Colburn Hill Brook
WARALSDB	Dam Brook
WARALSO	Outlet
WARALSP	Pickerel Cove Brook
WARALSS1	Smith Hill Brook
WARALSSR	Spruce River
WARALSSY	Scotland Yard

Figure 3-1. Bathymetry and monitoring site locations in the Lake Warren watershed.

3.3 STUDY DESIGN AND DATA ACQUISITION

Figure 3-2. Lakes stratify into different thermal layers during the summer months. These layers are referred to by name throughout the water quality sections. Mixing of water typically occurs within layers, but not between layers.

Water quality monitoring data were accessed and analyzed by FBE for several key water quality parameters, including water clarity (SDT), Chl-a, color, TP, turbidity, DO, and temperature. Data acquisition and analysis for Lake Warren followed protocols set forth in the Site Specific Project Plan (SSPP) in Appendix E. Analysis included a comparison of historical (2005 and earlier) and recent (2006-2015) seasonal (collected between May 24 and September 15) water quality data, statistical analysis of historical water quality trends, determination of **epilimnion** (Figure 3-2) median in-lake phosphorus concentration, determination of current trophic state, and modeling of the assimilative capacity for Lake Warren. Detailed descriptions of analysis methods and assessment of all water quality parameters can be found in the Lake Warren Water Quality Analysis (FBE, 2014b) and Update (FBE, 2016b). Below, the discussion focuses on TP, Chl-a, SDT, and DO.

3.4 WATER CHEMISTRY ASSESSMENT

Overall, water quality in Lake Warren over the last 36 years has degraded with respect to three key parameters: TP, Chl-a, and SDT.

- **Total phosphorus (TP)** has increased since 1980. However, data are limited prior to 1990 and indicate high inter-annual variability in TP over the last 15 years. Median TP for both recent and historical data exceeds the threshold for oligotrophic lakes and is within the threshold for mesotrophic lakes, but the medians over the last 10 years have exceeded the mesotrophic threshold on several occasions.

- **Chlorophyll-a (Chl-a)** has also increased since 1980. Median Chl-a of recent data exceeds the mesotrophic lake threshold and is more than double the oligotrophic lake threshold.

- **Secchi disk transparency (SDT)** has decreased since 1980, indicating degradation in water clarity over the collection period.

- **Dissolved oxygen (DO)** and **temperature** profiles from the deep site in Lake Warren show little change with depth (typical for shallow, non-stratified lakes). Low levels of DO in the hypolimnion sometimes occur mid-summer (June and July), but are generally uncommon in this shallow, well-mixed lake. Low DO can trigger internal phosphorus loading (a chemical release of phosphorus from bottom sediments). In shallow lakes, like Lake Warren, continuous mixing can also stir up sediment, mechanically releasing phosphorus into the water column.

- **pH** levels indicate that the lake is slightly acidic, but similar to state and regional medians.
- The following sections provide more detailed analyses of trophic state, TP, SDT, Chl-a, and DO.

3.4.1 *TROPHIC STATE*

Lake Warren was determined mesotrophic in 1980 and 2005, and oligotrophic in 1991. The NHDES survey reports indicate that the lake may have been borderline oligotrophic-mesotrophic in both 1980 and 1991. To examine any potential changes in trophic state over the last 10 years, we recalculated the trophic classification for Lake Warren using the NHDES Trophic Classification System for New Hampshire Lakes and Ponds. Based on water quality data from the last 10 years at Lake Warren, the trophic classification of mesotrophic would be in-line with the 2005 NHDES trophic survey. Table 3-5 provides a summary of the scoring.

Table 3-5. NHDES Trophic Classification for Lake Warren.

WQ Parameter	Mean WQ Value (2006-2015)	Trophic Score
Summer Bottom DO (ppm)	NA	NA
Mean SDT (m)	2.4	3
Aquatic Plant Abundance*	Common	3
Mean Chl-a (ppb)	7.4	1
Total	**7 → Mesotrophic (5-9 pts)**	

*Based on 2005 NHDES survey

Additional analysis, including running an alternative Trophic State Index (the Carlson TSI), is a practice commonly used to characterize trophic state in lakes and may be helpful for this discussion. The Carlson TSI varies slightly from the NHDES Trophic Classification System in that only SDT, Chl-a, and TP are used. The Carlson TSI also classifies Lake Warren as mesotrophic for SDT and TP, but eutrophic for Chl-a. Additional background information on these metrics is available in the Lake Warren Water Quality Analysis Update (FBE, 2016b).

3.4.2 *TOTAL PHOSPHORUS, CHLOROPHYLL-A, AND SECCHI DISK TRANSPARENCY*

TP, Chl-a, and SDT are interrelated and together provide insight to potential causes of water quality impairment. In freshwater systems, phosphorus is the limiting nutrient for algae and plants. Excess TP can stimulate growth of these organisms, which contain chlorophyll for photosynthesis. As TP increases, Chl-a typically increases, followed by a decrease in SDT (i.e., a decrease in water clarity) due to the additional algae.

In Lake Warren, recent (2006-2015) median TP in the epilimnion is above the NHDES ALU threshold for oligotrophic lakes and is just below the threshold for mesotrophic lakes; median Chl-a exceeds both trophic thresholds (Figure 3-3). If the ALU assessment for Lake Warren was based on the thresholds set for mesotrophic lakes (vs. current oligotrophic), TP would fall within the acceptable range but the lake would still be considered impaired as Chl-a is not within range (see Table 3-4 for decision matrix). Trends for TP and Chl-a were also statistically significant, and indicated that these metrics have both degraded since 1980 (Figure 3-4).

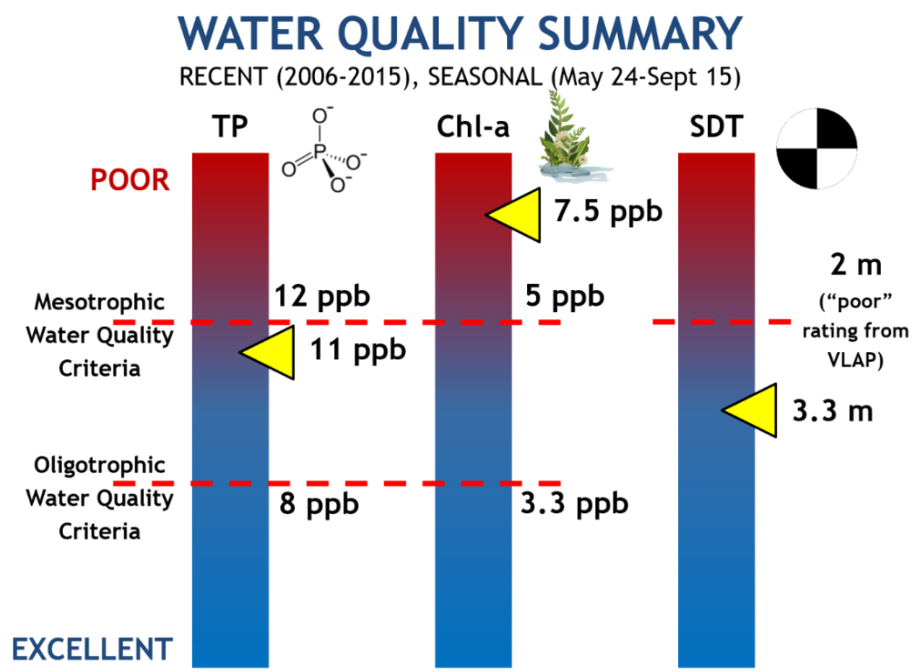


Figure 3-3. Existing water quality in Lake Warren (median TP, Chl-a, SDT with viewscope). Yellow triangles indicate existing water quality compared to state water quality criteria.

SDT records were separated into those collected with and without a viewscope, as the use of a viewscope can increase SDT; this is the general pattern in few years for which viewscope data is available (Figure 3-5). As was indicated in previous water quality reports, SDT has been steadily declining in Lake Warren (Figure 3-5). Moderate interannual variability in SDT likely reflects year-to-year weather influences. Wetter years may increase the amount of sediment delivered to the lake and cause lower SDT readings.

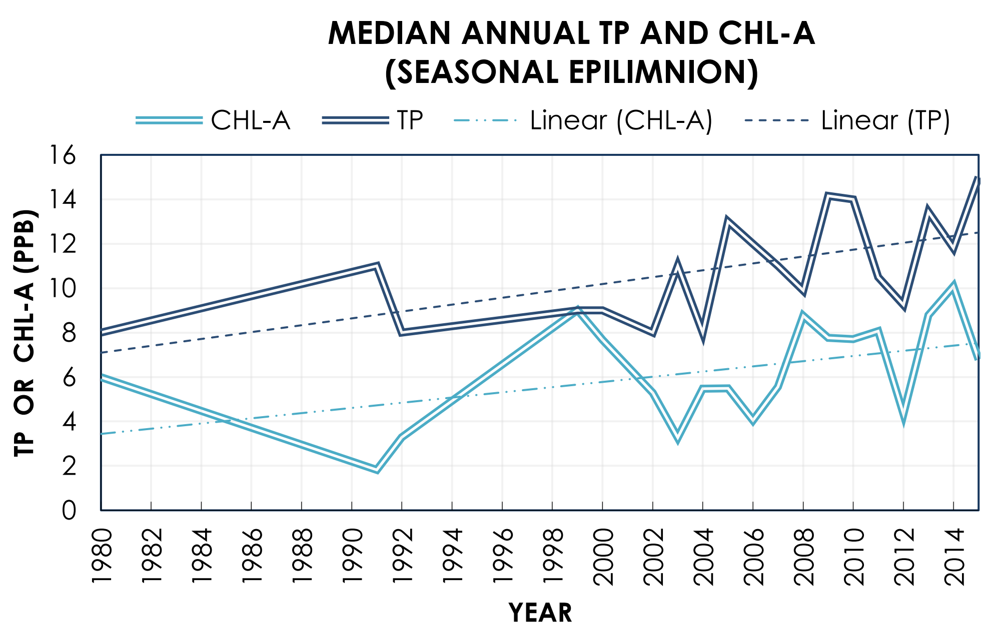


Figure 3-4. Annual median epilimnetic TP and Chl-a for Lake Warren Deep Spot (WARALSD, 1980-2015). Dashed lines represent trendlines for each dataset.

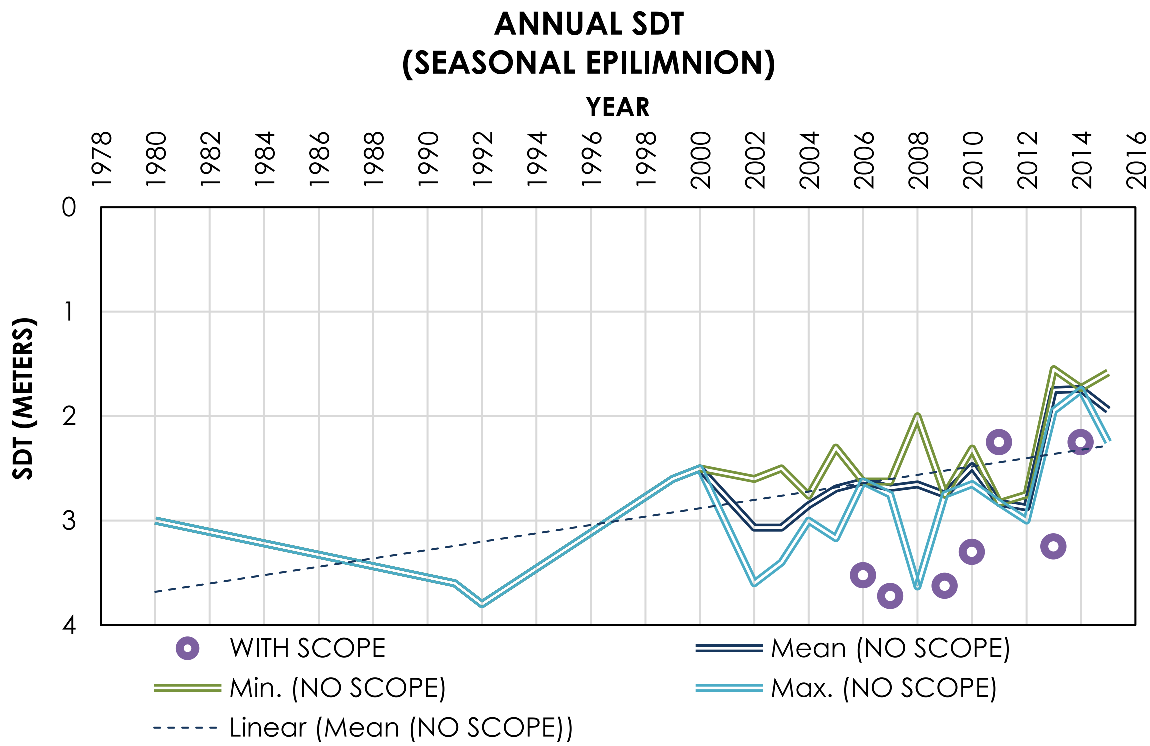


Figure 3-5. Annual SDT with and without use of a viewscope for Lake Warren Deep Spot (WARALSD, 1980-2015). Dashed line represents trend line for mean SDT (no scope). Dashed lines represent trend lines for each dataset.

3.4.3 *DISSOLVED OXYGEN, HYPOLIMNION TOTAL PHOSPHORUS, AND pH*

DO and temperature profiles from the deep spot in Lake Warren show little change with depth, which is typical of a shallow, non-stratified lake (Figure 3-6; see Appendix D for temperature figure). Oxygen is produced in the top portion of a lake, where sunlight drives photosynthesis by algae and plants and is consumed near the bottom of a lake, where organic matter accumulates and decomposes. Low oxygen in bottom waters can thus be a natural phenomenon when thermal stratification in late summer separates oxygenated surface waters from bottom waters. However, wind action mechanically mixes the water column in lakes as shallow as Lake Warren. Relatively few instances of low DO (<5 mg/L) have occurred during the monitoring period, though this condition has occurred more frequently in the last few years (2013-2015) (Figure 3-6).

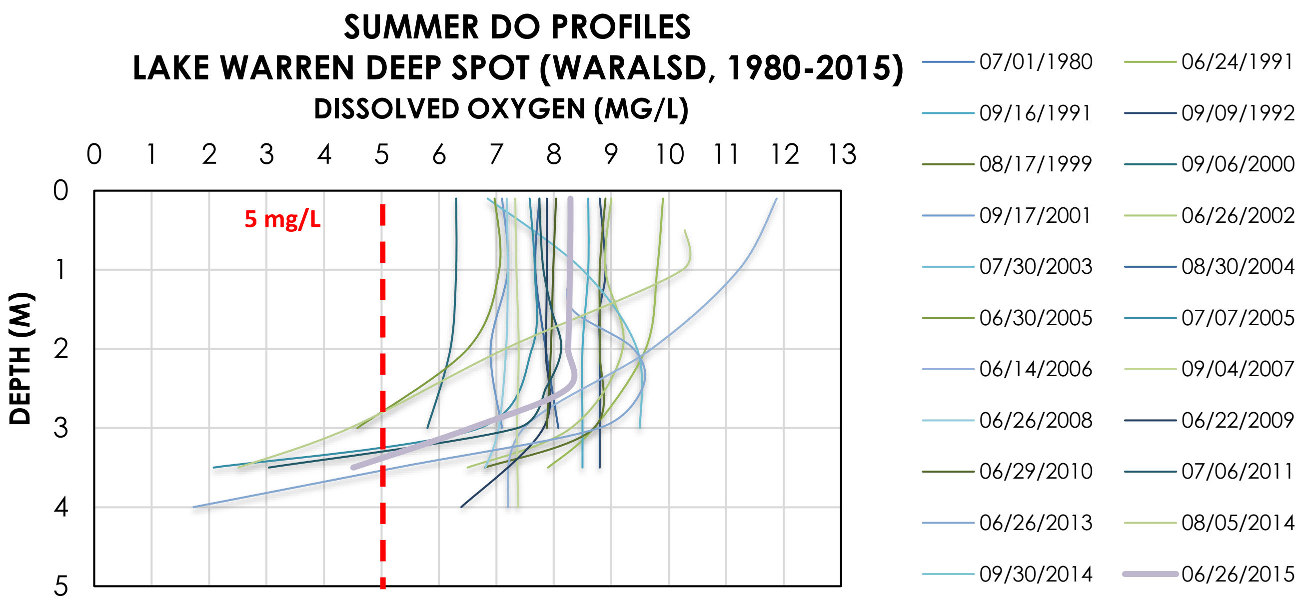


Figure 3-6. DO profiles for Lake Warren's deep site (WARALSD) from 1980-2015. Red vertical line marks the 5 mg/L DO threshold, below which can stress aquatic life.

In lakes, a cyclical relationship can exist between TP and persistently low DO, in part due to TP's effect on algae growth. Decomposition of algae in the hypolimnion can lead to continual low dissolved oxygen at depth, while extremely low DO (<1 mg/L), or anoxia, in the hypolimnion can trigger a release of additional phosphorus from sediments, also known as internal loading. Internal loading is assumed to be small due to lack of persistent low DO in bottom waters. Available TP data show that hypolimnetic (bottom waters) phosphorus concentrations are occasionally higher than in the epilimnion (Figure 3-7), indicating some internal phosphorus loading in Lake Warren. However, this may also be due to sediments becoming re-suspended into the water column from wind action and boating activity on the shallow lake.

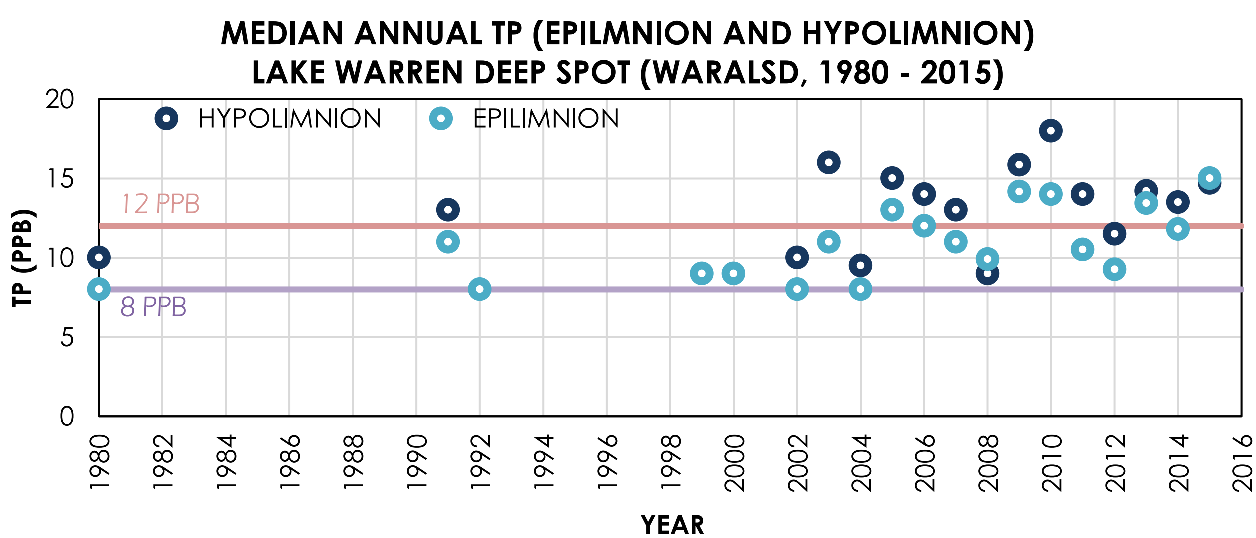


Figure 3-7. Median annual TP in the epilimnion and hypolimnion of Lake Warren. Purple line represents the TP threshold (8 ppb) for aquatic life use in oligotrophic lakes; pink line is the threshold for mesotrophic lakes.

3.4.4 *TRIBUTARY WATER QUALITY ANALYSIS*

Since 1999, six major tributaries (Spruce River since 2003) that flow to Lake Warren have been monitored consistently for TP, turbidity, specific conductivity, and pH, as well as chloride from 2010 to 2015 (Appendix C). Analysis of tributary water quality can help to identify which tributaries may be contributing to the water quality impairment of Lake Warren. Determination of median TP for these tributaries also helps inform the land use model (Section 3.5.2).

Over the last few decades, high median TP (across all historical data) was common for all tributaries (Table 3-6). TP from Spruce River and at Scotland Yard is slightly higher than other tributaries, but Spruce River may be a minimal contributor of TP overall due to its small drainage area and wetlands located upstream (FBE, 2014b). TP for Scotland Yard is also based on a set of 8 samples, so more investigation and monitoring in this drainage is recommended to confirm these results. Given typical New England geology, specific conductance >100 μS/cm generally indicates some human disturbance, possibly from sewerage; this was observed in the Spruce River tributary. High chloride was found in this same tributary, though all chloride concentrations fell below the chronic exposure limit of 230 ppm (NHDES, 2011). Mean turbidity was also relatively high in some tributaries, including Carmen Cove (Hale) Brook and Scotland Yard, indicating higher sediment (and potentially nutrient) transport from those areas.

pH in all tributaries is considered acidic (<7.0), half of those are also considered of poor quality for aquatic life (<6.5), reaching a low of 5.6 in Smith Hill Brook and a high of 6.7 in Dam Brook. Given the low buffering capacity of Lake Warren, the acidic contributions of these tributaries may further decrease pH in the lake.

From these data, **Spruce River, Scotland Yard, and Carmen Cove (Hale) Brook** should be prioritized for future monitoring and land use investigations of potential NPS pollution.

Table 3-6. Summary data for Lake Warren tributaries and outlet. Values represent the mean or median of annual means or medians for all available data (see Appendix C for years sampled). Bold and italicized text highlights parameters and sites of concern (based on VRAP program guidelines where applicable; NHDES, 2011).

STATION ID	TRIBUTARY	# of samples	MEDIAN TP (PPB)	MEAN TURBDITY (NTU)	MEAN PH	MEAN SPCOND (μS/CM)	MEAN CHLORIDE (PPM)
WARALSCC	Hale (Carmen Cove) Brook	48	14	***5.5***	6.5	77	13
WARALSCH	Colburn Hill Brook	37	11	1.6	6.6	80	6
WARALSDB	Dam Brook	27	13	2.7	6.7	56	2
WARALSO	Outlet	13	14	1.7	6.5	64	--
WARALSP	Pickerel Cove Brook	38	15	0.6	6.0	41	6
WARALSS1	Smith Hill Brook	48	18	2.2	***5.6***	24	2
WARALSSR	Spruce River	45	20	1.2	6.1	***174***	42
WARALSSY	Scotland Yard	8	***26***	***3.9***	6.7	46	2

3.5 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 **Lake Loading Response Model (LLRM)**, can make predictions about Chl-a concentrations and SDT under different pollutant loading scenarios. These types of models play a key role in the watershed planning process, and EPA guidelines for watershed management plans require that both pollutant loads from the watershed *and* the assimilative capacity of the waterbody be estimated.

3.5.1 *ASSIMILATIVE CAPACITY*

A lake receives natural inputs of phosphorus in the form of runoff from its watershed. This phosphorus will be taken up by aquatic life within the lake, settle in the bottom sediments, or flow out of the lake to downstream waterbodies. In this sense, there is a natural balance between the amount of phosphorus flowing in and out of a lake system, also known as the ability of a lake to "assimilate" phosphorus. The **assimilative capacity** is based on factors such as lake volume, watershed area, and precipitation runoff coefficient. If a lake is receiving more phosphorus from the watershed than it can assimilate, then its water quality will decline over time as algal blooms become more frequent. In relation to water quality criteria, the assimilative capacity of a waterbody describes the amount of pollutant that can be added to a waterbody without causing a violation of the water quality criteria.

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

Oligotrophic waterbodies have water quality criteria of 8 ppb for TP and 3.3 ppb for Chl-a. NHDES requires 10% of the criteria be kept in reserve; therefore, median TP and Chl-a must be at or below 7.2 ppb and 3.0 ppb, respectively, to achieve Tier 2 High Quality Water status. Tier 2 waters have some assimilative capacity remaining, whereas Tier 1 and Impaired Waters do not. Support determinations are based on the nutrient indicator (TP) and response indicator (Chl-a), with the latter dictating the assessment if the two differ.

Based on the NHDES assimilative capacity analysis, Lake Warren falls in the Impaired category for oligotrophic lakes and Tier 1 category for mesotrophic lakes; under both classifications, there is no remaining assimilative capacity for additional phosphorus inputs to Lake Warren. To meet the oligotrophic AC threshold, TP would need to be reduced by 35%; for mesotrophic, TP would need to be reduced by 2%.

Table 3-7. Summary of assimilative capacity analysis results for Lake Warren. Existing data reflects seasonal (May 24 – September 15) and recent (2006-2015) data.

Lake and Station	Existing Median TP (ppb)	TP WQ Threshold (ppb)	AC Threshold (ppb)	Remaining AC (ppb)	Analysis Results
Lake Warren Deep Spot (WARALSD)	11.0	8.0 (oligotrophic)	7.2	-3.8	Impaired
		12.0 (mesotrophic)	10.8	-0.2	Tier 1

3.5.2 LAKE LOADING RESPONSE MODEL (LLRM) RESULTS

A second analysis, the LLRM, was used to estimate the water budget and phosphorus load to Lake Warren based on land use, population, precipitation, watershed boundaries, wastewater treatment, bathymetry, waterfowl, and other information about the Lake Warren watershed. The LLRM is an Excel-based model which requires detailed information about land uses in the watershed for several inputs. The model uses data combined with many coefficients and equations from scientific literature on lakes and nutrient cycles to trace water and phosphorus loads (in the form of mass and concentration) from these various pollutant sources in the watershed, through tributary basins, and into the lake. Ultimately, the model develops a water and phosphorus loading budget for the lake and its tributaries. The model also makes predictions about Chl-a concentrations and SDT readings based on the estimated phosphorus loading. Full details of LLRM methodology and updates are available in the Lake Warren Nutrient Modeling Report (FBE, 2014a) and Lake Warren LLRM Update memo (FBE, 2016c). Results presented in this plan are from the finalized update.

Table 3-8. Total phosphorus and water loading summary for Lake Warren (both current and historical (pre-development)).

	CURRENT				HISTORICAL	
Predicted Median In-Lake TP	***13.1***				***6.8***	
Loads to Lake Warren	**TP (kg/year)**	**TP (%)**	**Water (m^3/year)**	**Water (%)**	**TP (kg/year)**	**TP (%)**
Atmospheric Deposition	8.2	5%	490,885	6%	8.2	9%
Internal Loading	4.0	2%	NA	NA	0	0%
Waterfowl	3.0	2%	NA	NA	3.0	3%
Septic Systems	25.5	14%	21,933	<1%	0	0
Watershed Runoff	136.7	77%	7,409,873	93%	84.1	88%
Developed Land	*37.5*	*21%*	--	--	--	--
Agriculture	*28.8*	*16%*	--	--	--	--
Forest	*69.4*	*39%*	--	--	--	--
Wetlands	*1.0*	*1%*	--	--	--	--
Total Load To Lake Warren	**177.4**	**100%**	**7,922,691**	**100%**	**95.3**	**100%**

As shown in Table 3-8, the results of this model indicate that the greatest phosphorus load comes from watershed runoff, which accounts for 77% of the total phosphorus loading to Lake Warren. Among watershed runoff land use categories, developed land accounts for the largest percentage of total phosphorus load after forests. Wastewater systems (septic and other types) were the second largest source at 14% (see Section 3.7.1 for additional details on the septic system survey). Direct atmospheric deposition accounts for 4.6% of the TP loading. Waterfowl inputs comprise less than 2% of the TP entering the lake. Internal loading (possibly from boat disturbances to the bottom of the shallow lake or low dissolved oxygen at lake bottom, though not frequent in Lake Warren) was calculated to contribute about 2.3% of the TP load. Table 3-8 also shows results for estimated TP loading prior to development of the Lake Warren watershed. The modeled in-lake TP for this "historical" condition is 6.8 ppb, which is in line with the borderline oligotrophic-mesotrophic classification for Lake Warren.

The model estimates the phosphorus loading from each of the subdrainage areas (tributaries and direct shoreland drainage) in the watershed, highlighting areas of largest phosphorus input and therefore most in need of phosphorus reduction efforts. The largest per hectare land use loading, based on the model, comes from the direct drainage area of Lake Warren, where runoff and other pollutants can flow directly to the lake with little attenuation (Figure 3-8). This small catchment area contributes the most phosphorus per unit area, and should be a high priority for lake protection efforts. Direct shoreline drainages are typically among the highest load areas for most lakes given their proximity to the lake (i.e., higher density of development). The direct shoreline of the lake deserves special attention in any lake protection plan.

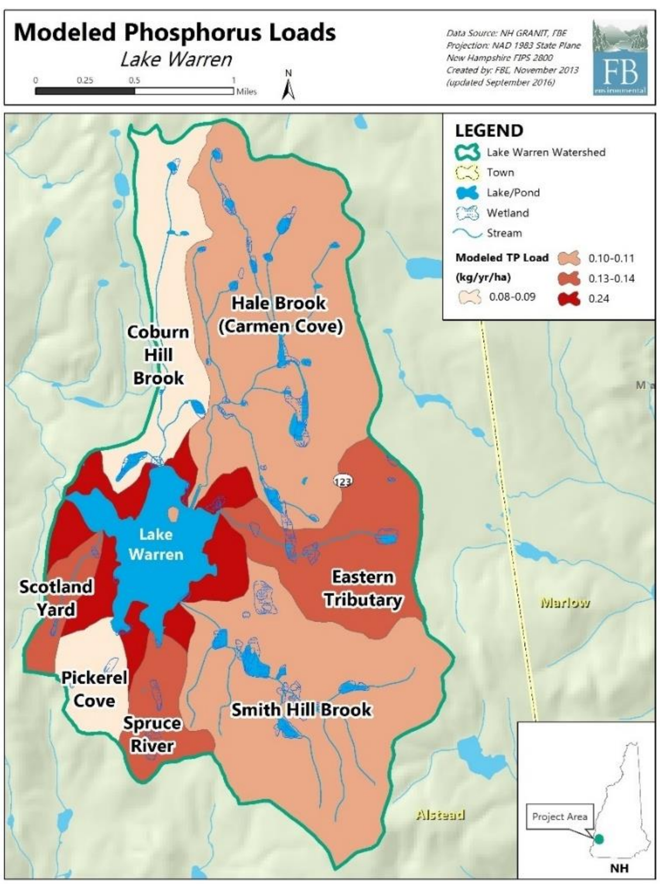


Figure 3-8. The direct shoreline area of Lake Warren contributes the most phosphorus per ha per year compared to the other subdrainages.

Among the tributary subdrainages, the largest per hectare land use loadings come from Scotland Yard, Spruce River, and Eastern Tributary. The Spruce River subdrainage was also previously identified as a potential phosphorus priority area under different methodology (SWRPC, 2012). Further investigation may be warranted to confirm these results (due to lack of monitoring data for the Eastern Tributary) and to locate potential phosphorus sources in these subdrainages. A more detailed breakdown of loading by subdrainage can be found in Appendix F.

3.6 ESTABLISHMENT OF WATER QUALITY GOALS

The purpose of setting a water quality goal in a phosphorus-focused watershed management plan is to quantify the amount of reductions in phosphorus loading needed to achieve desired water quality conditions. The phosphorus concentration in Lake Warren exceeds the threshold for oligotrophic lakes and is below the threshold for mesotrophic lakes, but has no remaining reserve capacity to assimilate additional phosphorus inputs. The overarching goal for the watershed is to improve water quality conditions at Lake Warren, which show signs of decline in water quality parameters over the last 30 years, including chlorophyll-a (Chl-a) and Secchi disk transparency (SDT).

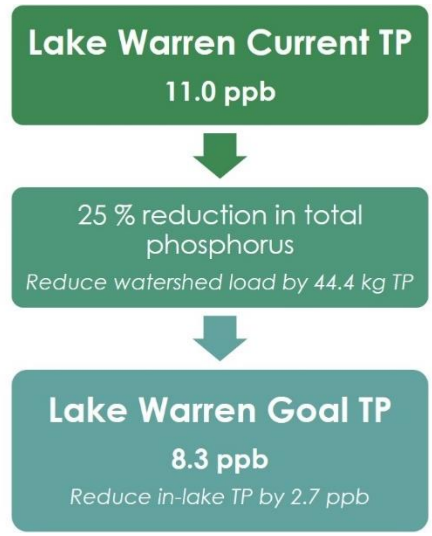


Figure 3-9. Lake Warren water quality goals.

In February 2016, FBE (after consultation with NHDES) provided the Lake Warren Steering Committee with a recommendation for an interim water quality goal based on the results of the water quality analysis and assimilative capacity analysis (Figure 3-8). The interim goal was designed to meet the mesotrophic Aquatic Life Use standards, but approach the oligotrophic standards. This should reduce phosphorus concentrations to a level that will diminish algae growth and thus Chl-a concentrations.

The ultimate goal is to improve the overall water quality in Lake Warren such that it is no longer impaired. As a means to make progress towards that goal, the phosphorus load to Lake Warren will need to be reduced by 25% over the next 10-15 years. Median total phosphorus concentrations will need to be reduced from the current level of 11.0 ppb to 8.3 ppb, by preventing 97.6 lbs. (44.4 kg) of phosphorus from entering the lake annually. **If in-lake summer phosphorus is reduced to 8.3 ppb, Chl-a concentrations should also decrease in response to between 2.0 to 5.1 ppb** (see FBE, 2014a for chlorophyll model citations). This reduction would improve Chl-a concentrations from eutrophic to mesotrophic. A 25% reduction is no easy task, and because there are many diffuse sources of phosphorus getting into the lake 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. These goals will be discussed further in Sections 4 and 5.

3.7 OTHER WATERSHED FACTORS AFFECTING WATER QUALITY

3.7.1 *NPS SITES – WATERSHED SURVEY AND HALE BROOK SEDIMENT SOURCE STUDY*

WATERSHED SURVEY

A watershed survey is designed to locate potential sources of NPS pollution in an area that drains to a waterbody. Watershed surveys are an excellent education and outreach tool, as they raise public awareness by documenting types of problems, engage volunteers, and provide specific information to landowners about how to reduce NPS pollution on their properties. Results of these surveys are essential to the watershed planning process because they identify individual NPS sites and prioritize BMP implementation projects throughout the watershed.

The 2013 Lake Warren watershed survey was conducted by volunteers, with the help of trained technical staff from FBE and SWRPC (FBE, 2014c). During a classroom workshop on September 24, 2013, over 20 volunteers were trained in survey techniques. Following the classroom training, volunteers and technical leaders spent the remainder of the day documenting erosion on the roads, properties, driveways, and trails in their assigned sectors using cameras, Global Positioning System (GPS) units, and standardized forms. Because soil contains phosphorus, soil erosion sites were the focus of the survey. "Hotspots" of pollution were identified and documented, solutions were recommended, and costs of improvements were estimated. Thirty-six sites were identified and rated for impact level based on location, slope, amount of soil eroded, and proximity to water. The results from the watershed survey were compiled and prioritized. A follow-up visit by FBE staff in October 2015 was conducted to fill in data gaps for better pollutant load estimates and to refine the site list (e.g., to remove duplicate sites or sites that had been addressed since 2013).

Of the 36 identified sites, 13 sites were threatening the lake water quality along town roads, often due to shoulder erosion (Figure 3-10). Residential areas accounted for 9 of the documented erosion sites. Below are examples of the most common problems seen at these sites, and recommended conservation practices to prevent soil erosion from affecting water quality in Lake Warren (Table 3-9). Estimated costs and pollutant reductions from recommended BMPs are in Section 4.2.1, and full descriptions of identified sites can be found in Appendix G.

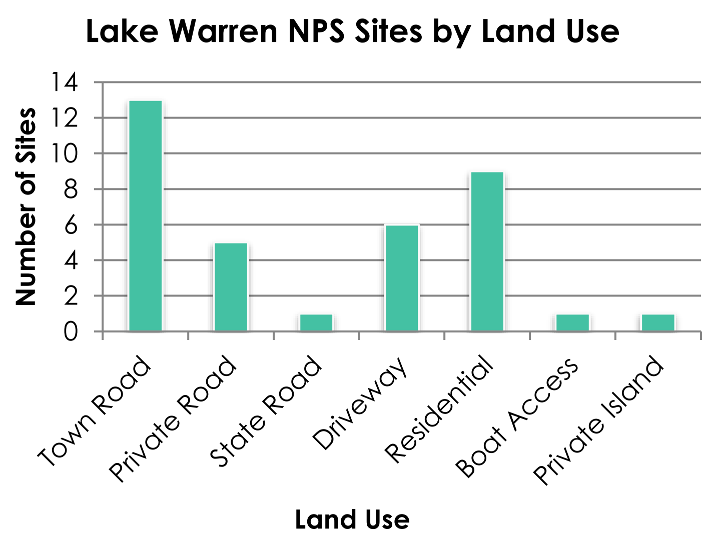


Figure 3-10. NPS sites noted in the Lake Warren watershed survey.

HALE BROOK SEDIMENT SOURCE STUDY

Seven unusual conditions or NPS pollution sites were noted during the Hale Brook geomorphic survey and stream walk (FBE, 2016a). Four of these sites were determined to be contributing sediment (and thus phosphorus) to Hale Brook. Unstable and eroding banks were the most common problem observed (three out of four NPS sites). Phosphorus load and cost estimates were calculated for the four sites, and sites were then added to the BMP matrix (Section 4.2.1 and Appendix G) for prioritization.

Table 3-9. Select examples of nonpoint source pollution in the Lake Warren watershed.

Roads: Road Shoulder & Ditch Erosion
Severe road shoulder erosion causes sediment to run off directly into streams, which lead to Lake Warren. Recommendations for these sites include removing road berms. Roads should be reshaped and resurfaced with new material. Runoff could be redirected to run off directly into forested buffer areas. Additionally, similar sites shown in the photo would benefit from installation of plunge pools. Roadside ditches suffering from erosion problems can be treated in many of the same ways, but should also be lined with rocks and vegetation for stability.

Residences: Rooftop Runoff & Unstable Access
Runoff from impervious surfaces, like rooftops, can cause erosion gullies where the water flows. Control this powerful runoff with infiltration trenches at the rooftop dripline, vegetate or armor ditches with stone, and install erosion control mulch in areas with exposed soils. Water running off the landscape and into the lake across unstable surfaces can cause sedimentation to Lake Warren. Install water bars to divert water and stop sediments from reaching the lake or establish vegetated buffers at shorelines to filter out pollutants.

Driveways: Surface Erosion
Six NPS sites were found along driveways in the Lake Warren watershed. These sites can typically be remediated at low to medium cost. Dirt or sand driveways are conducive to sediment running off to streams and lakes. A simple remedial solution would be to install rubber razors or water bars across these driveways to divert water into vegetated areas. A costlier solution would be to re-grade and resurface driveways with hard-packing, cohesive material.

3.7.2 *SEPTIC SYSTEM SURVEY*

Septic systems, outhouses, and even portable toilets help us to manage our wastewater to prevent undo harm to human health, aquatic life, and water resources. Septic system effluent typically stores a thousand times the concentration of phosphorus in lake waters (Gilliom and Patmont, 1983), which means that a small amount of effluent could have a major impact on small lakes such as Lake Warren.

Within a septic system, approximately 20% of the phosphorus is removed in the septic tank (due to settling of solid material) and a further 23-99% is removed in the leach field and surrounding soils (Lombardo, 2006, Lusk *et al.*, 2011). The degree of phosphorus removal efficiency of a septic system depends on site-specific soil and groundwater characteristics, including pH and mineral composition. Depending on the circumstances, older systems may still retain up to 85% of the input phosphorus in the top 30 cm of the soil (Zanini *et al.*, 1998), though a slow, long-term transport of phosphate over long distances in the groundwater table can also occur in older systems (Harman *et al.*, 1996). Phosphorus generally migrates through the soil slower than other dissolved pollutants in groundwater, but studies have shown that this degree of phosphorus reduction and movement is correlated with unsaturated infiltration distance (Weiskel *et al.*, 1996), suggesting it is important to have septic systems well above the seasonal high groundwater table.

The Lake Warren Septic Survey (FBE, 2014c) was conducted during the watershed survey in 2013 (see above) by FBE with guidance from SWRPC and assistance by volunteers from LWA. Residents of the Lake Warren watershed were given advance notice of the survey and were given the option to not participate. Geographic Information Systems (GIS) maps were used to identify all properties with buildings within the shoreland zone (within 250 feet of Lake Warren and mapped tributaries). The Town of Alstead parcel and buildings data, along with in-field observations, were used to identify 173 potential properties within this shoreland zone.

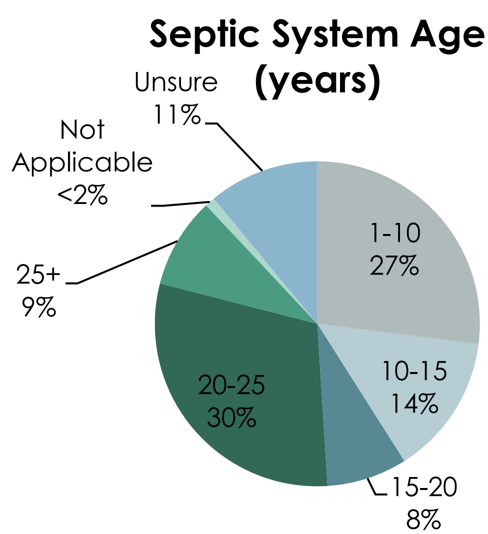


Figure 3-11. Approximately 30% of respondents with septic systems have 20 to25-year-old systems (FBE, 2014c).

Information on current septic system maintenance practices was gathered by asking a brief set of questions to each landowner during the door-to-door survey. The questionnaire included information about type of system, age of system, use (year-round or seasonal), occupancy, distance to waterbody, pumping frequency, and types of water-using machines. In addition, several questions were designed to learn more about the landowner's perceptions of water quality in the Lake Warren watershed. In instances where the landowner was not home, technical staff left a survey at the property requesting that the landowner send the information by mail, or fill out an online questionnaire on the FBE website. In situations where it was deemed ineffective to leave materials, FBE staff or volunteers sent correspondence to the landowner by mail or conducted an in-person follow-up visit to the property.

Almost all residents surveyed use septic as their primary wastewater system. Five properties use a holding tank system, and one property utilizes an outhouse/chemical toilet for waste disposal. 100% of residents know where their septic tank and leach field is located. The majority of septic systems are less than 25 years old (80%), but most of those systems fall within the 20 to 25-year-old range (31%). Old systems (> 25 years old) made up 9% of the survey respondents (Figure 3-11; FBE, 2014c).

According to the LLRM, wastewater systems, including septic systems, are the second largest source of phosphorus to Lake Warren**. Wastewater systems (both old and new) were estimated to provide 14.4% (25.5 kg/yr) of the total phosphorus load** to the lake. More information on the recommendations for addressing input from wastewater is outlined in the Action Plan (Section 5.3.4).

4. MANAGEMENT STRATEGIES

4.1 GOALS AND OBJECTIVES FOR LONG-TERM PROTECTION

The ultimate goal of the Lake Warren Watershed Management Plan is **to protect and improve water quality in Lake Warren** by reducing the amount of phosphorus delivered to the lake through implementation of items in the action plan (Section 5.3). The underlying idea is that existing and new development can be conducted in a manner that sustains environmental values, and that citizens, businesses, government, and other stakeholder groups can be responsible watershed stewards. As stated in Section 3.6, the **long-term goal is to improve the overall water quality in Lake Warren such that it is no longer impaired. To make progress towards that goal, the in-lake median total phosphorus concentration must be reduced by 25% (44.4 kg/yr reduction in current phosphorus load). In response, this is predicted to also reduce Chl-a concentrations, from eutrophic to mesotrophic.** Additionally, any phosphorus loading from future development over the next 10 years will need to be mitigated.

Structural BMPs, or engineered Best Management Practices (BMPs) are often on the forefront of most watershed restoration projects. However, **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 such as street sweeping and road sand/salt management, and targeted education and training.

The target 25% reduction in TP and additional mitigation of future development phosphorus loads can be achieved through the following broad **structural and non-structural** BMP objectives:

- Form smaller “action committees” within the Steering Committee or LWA for more efficient implementation of the action plan items (Section 5.3.1).
- Implement BMPs throughout the watershed to reduce sediment and phosphorus runoff from existing development, with a focus on high-priority shoreline properties (Sections 3.7.1, 4.2, 5.3.2).
- Work with local road managers, state agencies, and private road residents to maintain watershed roads in proper condition (Sections 3.7.1, 5.3.3)
- Increase awareness of proper septic system maintenance/replacement and identify opportunities for wastewater improvement (Sections 3.7.1, 5.3.4).
- Interface with local government (Town of Alstead) to advocate for greater controls on future and re-development, increased use of LID in site plans, and enforcement of local wastewater laws (Section 5.3.5).

- Collaborate with local conservation and land management groups to identify conservation priorities within the watershed (Sections 2.1.4 and 5.3.5).

- Continue and/or expand the water quality monitoring and aquatic invasive plant control programs (Sections 2.4, 3.2, and 5.3.6).

These objectives and more are discussed in greater detail in the Action Plan (Section 5.3). Achieving the goals and objectives for future implementation work in the Lake Warren watershed will require a comprehensive and integrated set of activities as identified below.

4.2 ADDRESSING NONPOINT SOURCE (NPS) POLLUTION

4.2.1 *STRUCTURAL NPS RESTORATION*

The 2013 watershed survey and 2015 follow-up documented 36 sites that directly impact water quality through the delivery of phosphorus-laden sediment. Four additional sites were found during the Hale Brook Sediment Source Study in 2015. Consequently, structural BMPs are a necessary and important component for the improvement and protection of water quality in Lake Warren. Hoyle, Tanner, & Associates and two Steering Committee members, along with FBE, created recommendations for the identified problem sites. The best methods for treating these sites are to:

1. Address high priority sites with an emphasis on low-cost fixes for the shoreline and residential dwellings (Appendix G, Figure G-1). 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.

2. Utilize the BMP matrix (Table 4-1; Appendix G, Table G-1) to address other watershed NPS pollution sites with the greatest phosphorus reduction to cost ratio, including high priority sites identified in the Hale Brook Sediment Source Study (FBE, 2016a).

3. Work with experienced professionals on sites that require a high level of technical knowledge (engineering) to install, and ensure proper functioning of the BMPs.

4. Measure pollutant load reduction for each BMP installed and evaluate impact (see Adaptive Management approach).

These steps will help guide the proper installation of BMPs in the watershed. Additional BMP strategies (including public outreach) are included in the Action Plan in Section 5.3. NHDES updated its Homeowner's Guide to Stormwater Management in 2016. Do-It-Yourself implementation strategies for homeowners can be found in this guide (http://des.nh.gov/organization/divisions/water/stormwater/stormwater-mgmt-homeowners.htm; NHDES, 2016).

If all sites from the watershed survey and Hale Brook survey are addressed, total phosphorus load to the lake could be reduced by a total of 19.8 kg TP/yr. Remediation will cost an estimated $103,700 (Table 4-1; refer to Section 5.4 and Appendix G). "Shoreline" sites (includes private roads, residential properties, lake shoreline, private boat launches, etc.) will reduce the largest amount of phosphorus load (approximately 9.7 kg TP/yr of the 19.8 kg TP/yr; Table 4-2). Public Road sites will address an additional 6.6 kg TP/yr. Load estimates are based on the Region 5 model for estimating pollutant load reductions (FBE, 2015).

Table 4-1. Prioritized (from highest to lowest priority) matrix of estimated cost and TP loading removal rates for recommended BMP sites. The 10-year cost is the sum of the estimated BMP installation cost plus 10 times the estimated annual cost to maintain the BMP. A map of BMP locations can be found in Appendix G. Specific details on locations and recommendations have been provided to the LWA and SWRPC.

Priority Ranking	Site	Direct Flow to	Land Use	Category	TP (kg/yr)*	BMP Cost Estimate**	Annual Cost	10-yr Cost	10-yr Cost per TP Removed ($/kg)	Recommendation
1	4-06	Stream	town road	Public Road	0.73	$225	$25	$475	$654	Riprap ditch.
2	HB7-02	Hale Brook	stream corridor	Stream Corridor	2.17	$1,800	$50	$2,300	$1,061	Vegetate with trees/shrubs to stabilize bank.
3	4-02	Stream	residential	Shoreland	3.49	$2,650	$133	$3,975	$1,138	Divert runoff into wooded areas; vegetate with live willow stakes in banks and vegetated buffer adjacent to field.
4	5-07B	Ditch	town road	Public Road	0.91	$1,163	$25	$1,413	$1,558	Riprap and reshape ditch; remove grader/plow berms.
5	3-04	Ditch	residential/town road	Shoreland	1.22	$1,700	$70	$2,400	$1,960	Install runoff diverter (water bar); armor around culvert
6	5-05	Ditch	town road	Public Road	2.31	$5,440	$544	$10,880	$4,703	Riprap and reshape ditch; install check dams and sediment pools; remove grader/plow berms; add new surface material (gravel)
7	3-06	Lake	private driveway, residential	Shoreland	0.73	$1,305	$41	$1,710	$2,356	Install vegetated buffer; armor with stone; install turnouts; building foundation threatened (may require engineering).
8	HB5-01	Hale Brook	stream corridor	Stream Corridor	0.58	$1,440	$50	$1,940	$3,354	Install 2 rootwads/log jams.
9	4-07	Lake	private land	Shoreland	0.45	$720	$36	$1,080	$2,381	Install vegetated buffer near the high erosion areas.
10	5-10	Ditch	town road	Public Road	1.45	$4,525	$110	$5,625	$3,875	Riprap ditch; remove culvert clog; install check dams.
11	3-05	Lake	private driveway	Shoreland	0.73	$2,250	$60	$2,850	$3,927	Install turnouts and runoff diverters; riprap and reshape ditch.
12	1-03	Lake	private road	Shoreland	1.18	$3,546	$187	$5,418	$4,594	Regrade and add new surface material; riprap ditch.
13	HB4-01	Hale Brook	stream corridor	Stream Corridor	0.58	$2,160	$50	$2,660	$4,599	Install 3 rootwads/log jams.

Priority Ranking	Site	Direct Flow to	Land Use	Category	TP (kg/yr)*	BMP Cost Estimate**	Annual Cost	10-yr Cost	10-yr Cost per TP Removed ($/kg)	Recommendation
14	2-04	Lake	residential/ beach access (shared/private)	Shoreland	0.27	$530	$38	$910	$3,344	Stabilize foot path with erosion control mulch; install runoff diverter.
15	2-05	Lake	residential	Shoreland	0.18	$875	$25	$1,125	$6,201	Armor culvert inlet/outlet; riprap ditch; unclog culvert pipe.
16	3-02	Lake	driveway	Shoreland	0.23	$750	$25	$1,000	$4,409	Regrade driveway; install runoff diverter.
17	4-04	Lake	private road	Shoreland	0.18	$644	$32	$966	$5,324	Install turnout; reshape ditch; reseed grassed and bare areas.
18	3-09	Lake	residential	Shoreland	0.41	$2,268	$113	$3,402	$8,333	Install vegetated buffer; install runoff diverters and turnouts.
19	5-03	Stream	town road	Public Road	0.18	$3,300	$36	$3,660	$20,172	Enlarge culvert; riprap ditch.
20	5-06	Ditch	town road	Public Road	0.09	$750	$25	$1,000	$11,023	Riprap and reshape ditch; remove grader/plow berms and add gravel to roadway.
21	5-07A	Ditch	town road	Public Road	0.05	$250	$25	$500	$11,023	Armor culvert.
22	5-04	Ditch	town road	Public Road	0.14	$1,400	$48	$1,875	$13,779	Riprap and reshape ditch; install check dams and sediment pools; remove grader/plow berms and add new surface material (gravel).
23	5-09	Stream	town road	Public Road	0.05	$200	$25	$450	$9,921	Armor culvert inlet/outlet.
24	3-08	Lake	driveway	Shoreland	0.09	$1,255	$44	$1,690	$19,329	Install plunge pool for culvert drainage; Install runoff diverter; vegetate turnout areas.
25	2-08	Stream	town road	Public Road	0.09	$1,000	$25	$1,250	$13,779	Armor culvert inlet/outlet; stabilize roadside around culvert; stabilize gully near the ditch draining to culvert.
26	5-02	Stream	town road	Public Road	0.09	$3,700	$44	$4,140	$45,636	Enlarge and stabilize culvert; riprap ditch.
27	HB10-01	Hale Brook	stream corridor	Stream Corridor	0.11	$1,800	$50	$2,300	$21,341	Install bridge for ATV crossing.
28	1-02	Lake	town road	Public Road	0.36	$16,800	$840	$25,200	$70,440	Reshape road crown and narrow the road; vegetate shoulder/add to buffer along the lake.

Priority Ranking	Site	Direct Flow to	Land Use	Category	TP (kg/yr)*	BMP Cost Estimate**	Annual Cost	10-yr Cost	10-yr Cost per TP Removed ($/kg)	Recommendation
29	2-01	Lake	private road	Shoreland	0.05	$1,635	$47	$2,101	$38,411	Reshape road crown; install runoff diverters; install detention basin.
30	4-01A	Stream	residential/ private road	Shoreland	0.18	$4,800	$240	$7,200	$40,649	Vegetate shoulder of driveway; fix gully.
31	1-04	Lake	driveway	Shoreland	0.03	$750	$25	$1,000	$33,834	Install runoff diverters (broad-based dip).
32	1-01	Lake	residential	Shoreland	0.15	$7,200	$120	$8,400	$57,357	Install vegetated buffer; stabilize seawall.
33	2-03	Lake	residential	Shoreland	0.06	$2,560	$64	$3,200	$57,852	Install vegetated buffer; stabilize seawall.
34	3-07	Stream	state road	Public Road	0.09	$8,300	$290	$11,200	$121,817	Enlarge culvert; vegetate road shoulder; riprap ditches; discontinue plowing snow into wetland area.
35	2-07	Lake	residential/ beach access	Shoreland	0.02	$1,800	$90	$2,700	$131,547	Install vegetated buffer.
36	2-06	Lake	residential	Shoreland	0.03	$4,800	$240	$7,200	$208,804	Enhance vegetated buffer.
37	4-03	Lake, Stream	private road with ROW	Shoreland	0.03	$5,420	$472	$10,140	$320,799	Regrade road; install runoff diverters.
38	3-01	Lake	residential/boat access	Shoreland	0.00	$520	$36	$884	$812,037	Install infiltration trench at dripline; add rain barrel.
39	5-08	Stream	town road	Public Road	NA	$1,500	$25	$1,750	NA	Enlarge culvert.
40	4-05	Lake	town road, boat access	Public Road	0.11	TBD	TBD	TBD	NA	Install runoff diverters; riprap road sides.
				TOTAL	**19.78**	**$103,731**	**$4,424**	**$147,969**		

** TP reduction estimates based on Region 5 model for bank stabilization, gully stabilization, or urban runoff.*

*** BMP cost estimates based on CCSWCD (2008) and UNHSWC (2012); includes labor estimate*

The top 20 BMPs from the prioritized list account for >90% of the total estimated phosphorus load per year contributed by all surveyed problem areas. On average, the top 20 BMPs will cost approximately $3,500 per kg of phosphorus removed (initial cost only). Outreach and technical assistance should be provided first to the top shoreline sites (especially residential properties), which may be able to serve as demonstration sites for others in the watershed. The strategy for reducing pollutant loading to Lake Warren will be dependent on available funding and labor resources, but will likely include a combination of approaches (i.e., larger road BMP sites and smaller residential shoreline BMP sites).

Table 4-2. Summary of total phosphorus (TP) reductions and estimated ten-year costs of BMP implementation in the Lake Warren watershed.

Waterbody	Watershed Survey	
	TP reduction (kg/yr)	Estimated 10-yr Cost
Shoreline Sites (21 identified)	9.7	$69,300
Road Sites (15 identified)	6.6	$69,400
Stream Corridor Sites (4 identified)	3.4	$9,200
TOTAL	**19.8**	**$147,900**

4.2.2 NON-STRUCTURAL NPS RESTORATION

Non-structural watershed restoration practices prevent or reduce stormwater related runoff problems by reducing the exposure and generation of pollutants and providing a regulatory framework that minimizes impervious surfaces. Non-structural approaches to watershed restoration can be the most cost-effective and holistic practices within a watershed management framework. The non-structural approaches recommended in this plan can not only improve water quality, but can also enhance watershed aesthetics (e.g., shade tree planting, landscaping, and trash reduction), streamline the permitting process (e.g., by removing conflicting stormwater codes), and reduce development costs (e.g., by minimizing impervious area development).

There are two primary components of non-structural BMPs:

1. Planning, design, and construction that minimizes or eliminates adverse stormwater impacts; and
2. Good housekeeping measures and education/training to promote awareness.

In watersheds with future development potential, it is critical for municipalities to develop and enforce stormwater management criteria to prevent any increase in pollutant loadings that may offset reduced loads as a result of plan implementation. Within the shoreland zone of Lake Warren (within 250 feet from shoreline), 44% of the land area is currently undeveloped (SWRPC, 2012), which presents considerable opportunity for continued development and potential impact to the lake. The impact of future development can be mitigated by non-structural BMPs, such as land use planning, zoning ordinances, and low impact development requirements. Though non-structural BMPs often receive little emphasis in watershed planning, these practices are extremely important components of overall restoration efforts (Clar et al., 2003).

The Town of Alstead has already taken a step in the right direction by adopting a Lake District within their Zoning Ordinance. The purpose of the Lake District is to "*preserve the special quality and character of Lake Warren* *by ensuring the protection of the natural environment, water quality and visual beauty*." Within the district, allowable land uses are limited and exclude most commercial and industrial uses. Additionally, there is a 75-foot setback from the mean high water mark for septic systems within the district. The Action Plan includes objectives for additional lake-friendly zoning and increased awareness of green development techniques in the watershed (Section 5.3.5). Non-structural objectives such as education and outreach to landowners on best management practices, septic maintenance flyers, and other awareness campaigns are also detailed in the Action Plan.

4.3 MITIGATING FUTURE POLLUTANT SOURCES

As mentioned above, the Town of Alstead has taken action in planning for the effects of future pollutant sources by adopting Lake District restrictions within their zoning ordinance. Additional planning is needed to mitigate the increased phosphorus loading to Lake Warren that may result from new development.

It is important to note that, while the focus of this plan is on phosphorus (through the treatment of sediment), the treatment of stormwater during future development will result in the reduction of many other kinds of harmful pollutants that could have a negative impact on these waters. 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)

Without a monitoring program in place to determine these pollutant levels, it will be difficult to track successful reduction efforts. However, there are various spreadsheet models available that can estimate reductions in these pollutants depending on the types of BMPs installed (e.g., Region 5, STEPL, WEPP). These reductions can be input to the LLRM model developed for this project to estimate the response of the lake to the reductions.

4.4 ADAPTIVE MANAGEMENT APPROACH

An **adaptive management approach**, to be employed by the Steering Committee, is highly recommended for protecting watersheds. Adaptive management enables stakeholders to conduct restoration activities 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 activities. This process enables efficient utilization of available resources through the combination of BMP performance testing and watershed monitoring activities. The adaptive management approach recognizes that the entire watershed cannot be restored with a single restoration action or within a short timeframe. Instead, adaptive management features establishing an ongoing program that provides adequate funding, stakeholder

The 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.

guidance, and an efficient coordination of restoration activities. Implementation of this approach would ensure that restoration actions are implemented and that surface waters are monitored to document restoration over an extended time period.

The adaptive management components for future implementation efforts should include:

- **Maintaining an Organizational Structure for Implementation.** A cooperating group representing the town, LWA, and other local associations such as land trusts should be established for the implementation of future efforts in the watershed and to help coordinate the implementation of restoration activities. In effect, this is an expanded Steering Committee. Relationships should also be fostered with other prominent groups such as Monadnock Conservancy. The watershed plan leadership should also try to involve business interests and agricultural ventures in the watershed to allow for a full consideration of all issues relevant to an effective, efficient, and cost-effective restoration program.

- **Establishing a Funding Mechanism.** A long-term funding mechanism should be established to provide financial resources for restoration actions, and should be guided by a Funding "action committee" that would include representatives from the town, lake residents, LWA, businesses, road associations, land trusts, and more. In addition to construction and organizational management costs, consideration should also be given to the type and extent of technical assistance needed to design, inspect, and maintain stormwater BMPs. Technical assistance costs for the annual water quality monitoring program should also be considered. Funding is a critical element of sustaining the restoration process, and, once it is established, the management plan can be fully vetted and restoration activities can move forward. A combination of grant funding, private donations, and municipal funding must be used to ensure completion of the plan. See section 5.4 for a list of potential outside funding sources.

- **Determining Restoration Actions.** This plan provides a unified watershed restoration strategy with prioritized recommendations for restoration using a variety of methods, including structural and non-structural restoration actions. The Steering Committee should use the proposed actions in this plan as a starting point for current proposal writing. Once a funding mechanism is established, the lake watershed restoration program should begin in earnest by developing detailed designs for priority restoration activities on a project-area basis and scheduling their implementation accordingly.

- **Continuing and Expanding the Community Participation Process.** The development of the plan has greatly benefited from the active involvement of an engaged group of watershed stakeholders with a diversity of skills and interests. Plan implementation will require their continued and ongoing participation as well as additional community outreach efforts to involve even more stakeholders throughout the watershed. A sustained public awareness and outreach campaign is essential to securing the long-term community support that will be necessary to successfully implement this project.

- **Developing a Long-Term Monitoring Program.** Although current monitoring efforts are strong, a detailed monitoring program (including ongoing monitoring of watershed tributaries) is necessary to track the health of the lake. The monitoring program will provide feedback on the effectiveness of restoration practices at the subdrainage level, and will support optimization of restoration actions through the adaptive management approach.

- **Establishing Measurable Milestones.** A restoration schedule that includes milestones for measuring restoration actions and monitoring activities in the watershed is critically important to the success of the plan. In addition to monitoring, several environmental, social, and programmatic indicators have been identified to measure the progress of the plan. These indicators are listed in Section 5.3 and are intricately tied to the action items identified in the Action Plan in Section 5.3.

5. PLAN IMPLEMENTATION

5.1 PLAN OVERSIGHT

Implementation of this Action Plan should be led by the combined efforts of LWA, SWRPC, and the Town of Alstead. Local participation is an integral part of the success of this plan, and should include the leadership of NHDES, community groups, local businesses, schools, and individual landowners. A watershed Steering Committee was formed in 2015 and includes a wide range of stakeholders within the watershed. This Steering Committee will need to meet regularly and be diligent about coordinating resources to implement the recommended actions that will reduce NPS pollution in the Lake Warren watershed.

5.2 POTENTIAL THREATS TO WATER QUALITY

Through nutrient modeling and discussions with LWA and SWRPC, it was determined that the main threats to Lake Warren include the following: shoreline development, roads and septic systems, and lack of sufficient or effective municipal ordinances and water quality monitoring. The action plan was designed to address these threats and deficiencies.

Volunteers installing a vegetated buffer along Pine Cliff Road in Alstead, 2016. Photo: FBE.

Table 5-1. Potential threats to Lake Warren water quality.

CATEGORY	DESCRIPTION OF THREATS
Shoreline Residential Properties	• Shoreline erosion • Dog waste; lack of education about effects of pet waste • Lack of knowledge of programs and threats • Large lawns at water's edge • Lack of well vegetated shoreline buffers • Uncontrolled runoff from developed features on residential lots
Roads	• Public use in sensitive shoreline areas • Lack of educational efforts (signs, pamphlets) • Improper road maintenance • Improper ditch maintenance • Poor road design • "Road dust" along Pine Cliff Road
Septic Systems	• Leaking systems (lack of awareness about problem systems), old systems • No systems – cesspools, outhouses • Water quality impacts during septic system replacement (e.g., tree removal and erosion) • Proximity to lake and tributaries • Overuse • Lack of adequate maintenance/pumping (lack of knowledge of necessity to do so)
Municipal Ordinances & Land Conservation	• Conversion of forest land to other uses • Impervious surface regulation inconsistencies; types and extent of allowable impervious (e.g. decks vs. pavement) • Stream buffer encroachment • Insufficient communication between stakeholders and planning boards • Lack of consistent septic system regulations • Conversion of camps to year-round use • Lack of funding to fix problems • Old septic systems & outhouses
Water Quality Monitoring & Assessment	• Frequency/timing of monitoring (weekday vs. weekend monitoring) • Small drainages carrying pollutants from developed land • Outhouses • Climate change • Invasive aquatic plants • Canada geese

5.3 ACTION PLAN

The Action Plan was developed and prioritized through the combined efforts of LWA, SWRPC, FBE, and the Steering Committee (see Section 1.4). The Action Plan is a critical component of the plan because it provides a list of specific strategies for improving water quality and the means to make the water quality goals a reality. The Action Plan consists of action items to help address threats identified within six major categories: (1) Watershed Planning; (2) Shoreline BMPs; (3) Road BMPs; (4) Septic Systems; (5) Municipal Ordinances and Land Conservation; and (6) Water Quality Monitoring and Lake Assessment.

The Steering Committee should work toward implementing the Action Plan and identifying improvements as needed. The Action Plan items have been placed in priority order based on feedback from the forum and the Steering Committee. The Action Plan outlines responsible parties, potential funding sources, approximate costs, and an implementation schedule for each task within each category. Current cost estimates for each action item will need to be adjusted based on further research and site design considerations.

5.3.1 *WATERSHED PLANNING*

The Steering Committee should work toward implementing this updated Action Plan and identifying improvements as needed. The formation of smaller "action committees" (e.g., for Outreach and Education, BMP Implementation, Funding) will result in more efficient implementation of the Lake Warren Action Plan.

The action items listed in the Watershed Planning table below were not prioritized by the committee as many are already in progress and will be ongoing.

Table 5-2. Watershed Planning Action Plan items.

WATERSHED PLANNING					
ACTION ITEM	DESCRIPTION	RESPONSIBLE PARTY	FUNDING SOURCE	SCHEDULE	ESTIMATED COST
Watershed Plan	Complete the Lake Warren Watershed Management Plan.	LWA, SWRPC, Town, NHDES, Citizens	Town, NHDES	Completed December 2016	$10,000
Watershed Committee	Develop the Lake Warren Watershed Management Plan Steering Committee. This committee will work towards implementing this action plan and assessing other needs as necessary.	LWA, SWRPC, Town, NHDES, Citizens	Town, NHDES, Volunteers	In progress	$10,000
Re-visit Action Plan	Develop a plan to measure progress, such as revisiting the Action Plan every three years.	LWSC, LWA, SWRPC, Town, NHDES, Citizens	Town, NHDES, Volunteers	2018	$1,500
Public Involvement	Develop a comprehensive education and outreach plan for residents in the Lake Warren watershed.	LWSC, LWA, SWRPC, Town, NHDES, Citizens	Town, NHDES, Volunteers	Began 2016	$12,000
Municipal Involvement	Conduct workshops with the municipal staff on the importance of current and future water quality issues.	LWSC, LWA, SWRPC, Town	Town, NHDES	Began 2016	$5,000

LWA = Lake Warren Association; LWSC = Lake Warren Steering Committee; NHDES = NH Dept. of Environmental Services; NHDOT = NH Dept. of Transportation; NHF&G = NH Fish and Game; SWRPC = Southwest Region Planning Commission; VLAP = Volunteer Lake Assessment Program.

5.3.2 *SHORELINE BMPs*

Direct shoreline areas are typically among the highest for pollutant loading for most lakes given their proximity to the lake and desirability for development. It is estimated that the greatest loading to Lake Warren (per unit area) is from the direct shoreline drainage area (approximately 0.24 kg TP/ha/yr, Section 3.5.2). Best Management Practices (BMPs) are restoration tools that property owners can use to minimize impacts from stormwater runoff and restore degraded shoreline areas. This could be as simple as planting vegetation along the shoreline to create vegetated buffers, installing gravel driplines along roof edges, and ensuring that paths and driveway runoff is filtered into the ground rather than running overland and into the lake. Coordination with landowners is crucial for successful implementation of BMPs identified in this Action Plan because mitigation measures will need to be implemented on private land. Roads and septic systems are not included in this portion of the Action Plan, but are addressed as their own category within the Action Plan.

Table 5-3. Shoreline BMP Action Plan items.

SHORELINE BMPs						
PRIORITY	**ACTION ITEM**	**DESCRIPTION**	**RESPONSIBLE PARTY**	**FUNDING SOURCE**	**SCHEDULE**	**ESTIMATED COST**
1	**High Priority BMPs**	Implement shoreline BMPs at high priority sites identified during the 2013 watershed survey. Includes private roads, residential properties, lake shoreline, boat launches, etc.	LWSC, Town, LWA, SWRPC	NHDES, Town, State	Began 2016	$24,836*
		Address erosion at the NHF&G boat launch.	NHF&G, Town, LWSC	NHDES, Town	Began 2015	$10,000
2	**Stream Crossings and Stream NPS Sites**	▪ Address high priority stream NPS sites identified during the Hale Brook Sediment Source Survey. ▪ Evaluate all stream crossings to identify locations for stormwater retrofits.	LWSC, LWA, SWRPC, Town	NHDES, Town	2016-2018	$9,200 (Hale Brook) + $5,000 (stream crossings)
3	**Shoreline Vegetation**	Plant vegetated buffers along lake side of roads.	LWSC, LWA, SWRPC, Towns	NHDES, LWA, Volunteers	2016-2018	TBD
4	**BMP Demonstrations**	Working with partners, set up demonstration projects with focus on high-visibility BMPs in targeted locations throughout the watershed.	LWSC, LWA, SWRPC, Town	NHDES	Began in 2015	$10,000
5	**LWA Website**	Update the Lake Warren Association website and include current information about lake conditions, water quality, and BMPs.	LWSC, LWA	NHDES, Donations, Fundraisers	Annually, beginning in 2017	$500/yr
6	**BMP Tracking & Monitoring**	Track BMPs as sites are identified and BMPs are implemented.	LWSC, LWA, SWRPC	NHDES, Other Grants	Annually, began in 2016	$1,000/yr
7	**Publicity**	Publicize events and lake water quality updates through local newspapers and LWA newsletter.	LWSC, LWA	NHDES, Donations, Fundraisers	Annually, beginning in 2016	$500/yr
8	**Long-term BMP Monitoring**	Re-survey implemented BMP sites every five years and develop a tracking system to document long-term functionality.	LWSC, LWA, SWRPC	NHDES, Other Grants	Every five years starting 2021	$1,000

SHORELINE BMPs						
PRIORITY	ACTION ITEM	DESCRIPTION	RESPONSIBLE PARTY	FUNDING SOURCE	SCHEDULE	ESTIMATED COST
9	**Municipal Staff**	▪ Conduct LID and BMP workshops for Alstead Public Works staff ▪ Conduct workshops for municipal staff about water quality and BMPs	LWSC, LWA, SWRPC	NHDES, Town	Beginning 2017	$6,000
10	**Certified Contractors**	Require contractors to have adequate training in the installation and maintenance of Low Impact Development (LID) and BMPs for all permit work.	LWSC, LWA, Town	Contractors	Beginning 2018	n/a
11	**BMP Brochure**	Develop and send letters to residents in the spring showing before/after photos of BMPs.	LWSC, LWA, SWRPC	Donations, Fundraisers	2017	$1,000
12	**Medium & Low Priority BMPs**	Prioritize and address medium and low priority shoreline BMPs.	LWSC, LWA, SWRPC	NHDES, Town	2016-2018	$44,515*
13	**Door-to-Door BMP Education**	Enlist volunteers (including neighborhood reps) to go door-to-door to inform neighbors about erosion, BMPs, and programs that can help.	LWSC, LWA	Volunteers	2016-2018	n/a
14	**Conservation/Water Quality Fund**	Develop a conservation or water quality fund.	LWSC, LWA, SWRPC, Town	N/A	Start 2017	n/a
15	**Plant Sale**	Organize and host an annual spring plant sale. Plants can be used for shoreline buffer plantings.	LWSC, LWA	N/A	Spring 2016 and ongoing	n/a
16	**Educational Signage**	Install educational signs at select locations.	LWSC, LWA, Town	NHDES, Fundraisers	2016-2018	$250/yr
17	**Self-assessment Quiz**	Develop and send/post on-line, a self-assessment quiz helping homeowners to determine whether or not they have an erosion problem.	LWSC, LWA, SWRPC	NHDES, Donations	2016 and 2021	$500/yr
18	**Youth Conservation Corps (YCC)**	Form a Youth Conservation Corps (YCC) to implement BMPs and conduct outreach activities throughout the watershed.	LWSC, LWA, SWRPC	NHDES, Town, Private Landowners	Beginning 2018	$15,000

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5.3.3 *ROAD BMPs*

The 2013 Lake Warren watershed survey and 2015 follow-up identified multiple sites along public and private roads that result in the delivery of nutrients and other pollutants to the lake. Many roads in the Lake Warren watershed are not paved, and significant erosion of sediment to the lake and its tributaries was observed. Pine Cliff and Gilsum Mine Roads were thought to be major contributors of sediment, and subsequently, phosphorus to the lake.

Table 5-4. Road BMP Action Plan items.

ROAD BMPs						
PRIORITY	**ACTION ITEM**	**DESCRIPTION**	**RESPONSIBLE PARTY**	**FUNDING SOURCE**	**SCHEDULE**	**ESTIMATED COST**
1	**Public roads**	Implement public road BMPs from the watershed survey; upgrade public roads annually using recommended BMPs from watershed survey, UNH Roads Scholar reference and Maine Camp Road Manual	Town, State	Town, NHDOT, NHDES	Annually	$69,418*, Any additional annual cost TBD
		Work with the town to address erosion on Pine Cliff and Gilsum Mine Roads.	LWSC, LWA, Town	Town, NHDOT, NHDES	Annually	TBD
2	**Roadway ditches**	Properly maintain and improve roadway ditches, including Forest Road.	Town, State	Town, NHDOT	Annually	TBD
3	**Culvert crossings**	Stabilize and enlarge culvert crossings by installing stormwater BMPs.	Town, State	Town, NHDES	Annually	TBD
4	**Roadside Vegetation**	Install stormwater Best Management Practices (e.g. vegetation) along lake side of road.	LWSC, LWA, SWRPC, Town, State	NHDES grants, state, town	Ongoing, began 2016	TBD
5	**Road Maintenance Workshop**	Educate town officials, road maintenance personnel, and contractors through roadway BMP outreach workshops.	LWSC, LWA, SWRPC	Grants, towns	Annually, beginning 2017	$1,000/yr
6	**Private Roads**	Assist private road land owners and private road associations with BMP installation on private roads.	LWSC, LWA, SWRPC	NHDES, grants	2017-2018	$10,000
7	**Road Associations**	Encourage new road associations where needed, and host a workshop for interested roads and existing associations.	LWSC, LWA, SWRPC, Town	Grants	Every 2 year, beginning 2016	$1,000 every 2 yrs

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5.3.4 *SEPTIC SYSTEMS*

Septic system effluent typically stores a thousand times the concentration of phosphorus found in lake waters, which means that a small amount of effluent could have a major impact on the lake. An old or improperly maintained septic system can also result in the delivery of disease-causing bacteria resulting in gastro-intestinal illness in swimmers. Untreated septic waste may contain chemicals and hormones used in pharmaceutical and personal care products, which can reach lake water if a system is not working properly. Inundation of systems by groundwater greatly enhances the transport of phosphorus and pathogens to the lake. Therefore, it is critical to ensure adequate setbacks and good vertical separation from the seasonal high groundwater table.

Based on the LLRM, wastewater systems, including septic systems, outhouses, and cesspools are the second largest source of phosphorus to Lake Warren (14.4%). A strong wastewater inspection and maintenance program will help reduce phosphorus loading to Lake Warren. Significant reductions in phosphorus loading to the lake will be achieved if landowners take responsibility to check their systems, and make necessary upgrades, especially to old systems, cesspools, and outhouses.

Table 5-5. Septic Systems Action Plan items.

SEPTIC SYSTEMS						
PRIORITY	ACTION ITEM	DESCRIPTION	RESPONSIBLE PARTY	FUNDING SOURCE	SCHEDULE	ESTIMATED COST
1	**Mandatory Inspections & Pumping**	• Require inspections and maintenance of septic systems and repair at time of property transfer. • Require inspections and maintenance of septic systems for all new permit requests.	LWSC, Town, LWA, Landowners	Grants, Town, Landowners	2016-2026	$250/system*
2	**Landowner Assistance**	Offer free landowner assistance (technical, permitting and grants) for septic system maintenance and upgrades.	LWSC, Town, LWA, SWRPC, Landowners	NHDES	2017-2019	$1,500
3	**Targeted Septic Outreach**	• Focus outreach on septic survey results with focus on older systems, close to the shoreline, rarely pumped, outhouses and cesspools. • Focus septic maintenance education on homeowners with high volume of seasonal use visitors.	LWSC, LWA, SWRPC	Grants, Volunteers	Workshop held in 2016; continue in 2017	$1,000
4	**Targeted Septic Installation**	Install new septic systems at high-risk sites (old systems, on slope, close to water).	LWSC, Landowners	NHDES, Grants, Landowners	2017-2019	TBD

SEPTIC SYSTEMS						
PRIORITY	**ACTION ITEM**	**DESCRIPTION**	**RESPONSIBLE PARTY**	**FUNDING SOURCE**	**SCHEDULE**	**ESTIMATED COST**
5	**Dye Testing**	Encourage and help fund voluntary dye testing for homeowners to evaluate septic system performance.	LWSC, LWA, SWRPC	NHDES, Town	2017-2019	TBD
6	**Group Discounts**	Coordinate group septic system pumping discounts (i.e. LWA member pumping discounts).	LWSC, LWA, SWRPC	NHDES	Start 2018	n/a
7	**Septic System Flyer**	Develop an educational flyer about septic systems and distribute with tax bills.	LWSC, LWA, SWRPC	Volunteers, Grants	2017-2018	$1,000
8	**Septic Provider List**	Create and distribute a list of septic service providers (create magnets, etc.).	LWSC, LWA	Volunteers, Fundraisers	2017	$500
9	**Septic Database**	Develop a system to track septic system maintenance and pumping history.	LWSC, Town, LWA, SWRPC	Town, Volunteers	Start from 2013 survey; 2017-2019	$5,000 - $10,000 initial start-up cost
10	**Cost Sharing**	Investigate grants and low-interest loans to provide cost-share opportunities for septic system upgrades.	LWSC, LWA, SWRPC	Volunteers	Immediately	n/a
11	**Septic System Fund**	Designate a single pot of conservation dollars for the lake that can be used for septic system upgrades.	LWSC, Town, LWA, SWRPC	Town, Volunteers	Beginning 2017	$1,000
12	**Community Septic Systems**	Install community septic systems for cluster developments (campgrounds & small camps with outhouses).	Town, Landowners	NHDES, Grants, Low-interest loans	2018-2021	$20-$30,000 per community for initial installation
13	**Septic Socials**	Host septic socials to focus information on a neighborhood-scale.	LWA, LWSC, SWRPC	Grants	2017-2019	$500
14	**Door to Door**	Conduct door-to-door septic education to follow-up on septic survey.	LWSC, LWA	Volunteers	2017-2018	$250

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5.3.5 MUNICIPAL ORDINANCES AND LAND CONSERVATION

Municipal land-use regulations are a guiding force for where and what type of development can occur in a watershed, and therefore, how water quality is affected because of this development. To protect the watershed from water quality issues related to future development, non-structural BMPs such as municipal ordinance adoption or revisions, especially as it relates to new development, should be implemented. Action items related to this element have been divided into those relating to septic systems, and the adoption of new ordinances or incorporation of new language (watershed-wide), including the need for a low impact development (LID) strategy (watershed-wide).

Table 5-6. Municipal Ordinance and Land Conservation Action Plan items.

MUNICPAL ORDINANCES & LAND CONSERVATION						
PRIORITY	ACTION ITEM	DESCRIPTION	RESPONSIBLE PARTY	FUNDING SOURCE	SCHEDULE	ESTIMATED COST
Septic Systems						
1	**Site Plan Review & Septic System Regulations Assessment**	Review town site plans and septic system rules.	LWSC, LWA, Town, Consultant	Grants	2017-2019	$1,500
2	**Expansions**	Improve ordinances to consider more than just number of bedrooms when doing expansions.	LWSC, LWA, Town, Consultant	Town	2017-2019	$1,500
3	**Planning Board Meetings**	Communicate regularly with the Planning Boards by attending regular meetings.	LWSC, LWA	Volunteers	Ongoing	n/a
Municipal Ordinances - New & Upgrades to Existing						
1	**Setbacks, Buffers & Lot Coverage**	Improve ordinances to include mandatory setbacks, riparian buffers between development and waterbodies, and maximum lot coverage restrictions.	LWSC, LWA, Town, SWRPC	Town, Grants	2017-2019	$1,500
2	**Low Impact Development (LID)**	Develop new policy to encourage Low Impact Development (LID) for all future development including additions.	LWSC, LWA, Town, SWRPC	Town, Grants	2017-2019	$1,500
3	**Open Space**	Encourage town to adopt open space guidelines for conservation subdivisions.	LWSC, LWA, Town, SWRPC	n/a	Beginning 2017	n/a
4	**Conservation Subdivisions**	Increase incentives for conservation subdivisions in town ordinances.	LWSC, LWA, Town, SWRPC	Town, Grants	2018-2019	$1,500
Land Conservation						
1	**Landowner Outreach**	Conduct outreach to large landowners (particularly those facing generational change) to discuss conservation options.	LWSC, LWA, Local Land Trust	Town, Grants	2017-2019	$100

MUNICPAL ORDINANCES & LAND CONSERVATION						
PRIORITY	**ACTION ITEM**	**DESCRIPTION**	**RESPONSIBLE PARTY**	**FUNDING SOURCE**	**SCHEDULE**	**ESTIMATED COST**
2	**Land Conservation Workshop**	Host a land conservation workshop for landowners in the watershed.	LWSC, LWA, SWRPC, Local Land Trust, Consultants	Grants, Donations	2017-2019	$500
3	**Prioritize Land for Conservation**	Determine key parcels of land to acquire to maximize the benefit of land conservation.	LWSC, LWA, SWRPC, Local Land Trust, Consultants	Town, Grants	Beginning 2017	$1,500

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5.3.6 *WATER QUALITY MONITORING AND LAKE ASSESSMENT*

Monitoring programs are crucial to evaluating the effectiveness of watershed planning activities, and to determine if water quality goals are being achieved over the long-term. This Action Plan includes recommendations for enhancing current water quality monitoring efforts, including sample collection from various tributaries, and continuation of the Weed Watchers and Lake Host programs. Since volunteers typically conduct many different monitoring activities, it will be critical to continue building on the success of LWA's membership participation to accomplish many of these tasks. Refer to Appendix A, Map 9 for a map showing current monitoring sites in the watershed.

Tributary Monitoring – It is recommended that LWA volunteers continue their tributary monitoring program at consistent locations through the VLAP program. Most of the current monitoring stations have been sampled at least once annually (typically three times per year) since 1999, and demonstrates the LWA's strong commitment to monitoring activities. Alterations to the current monitoring plan may include:

- **Continuing tributary monitoring at existing stations and expanding to include other tributaries in the watershed.** Current monitoring stations should continue to be sampled several times annually as their long-term record is extremely valuable for detecting any changes in tributary inputs to Lake Warren. If possible, monitoring stations should be expanded to include the Eastern Tributary to Lake Warren as no data currently exists and the LLRM indicated that this drainage area could be delivering relatively high concentrations of phosphorus to Lake Warren.

- **Include both dry and wet weather sampling events, particularly during storm events** to examine peak discharges and measure inputs of sediment and nutrients during heavy rains. These samples may be collected either by manual or automated grab sampling during storm events; these automated sampling devices are deployed at collection sites and triggered to fill when water rises to a pre-determined level (e.g., the samplers may be positioned so that they fill when the water rises 6 inches).

- **Using water level loggers.** A specific type of logger that measures continuous water level in a river, stream, or lake. In flowing waters, water level can be converted to stream discharge, which is used to measure flow during storm events as well as baseflow conditions. Coupled with water chemistry data, loading rates of nutrients may also be calculated with continuous flow data. The need for flow data was also highlighted in the water quality summary by CRLAC in 2012.

Lake Monitoring and Assessment – Water quality data from Lake Warren indicate that TP and Chl-a concentrations have been increasing and transparency has been decreasing since 1980. Recent (2006-2015) median TP in the epilimnion is just below the NHDES Aquatic Life Use criteria for mesotrophic lakes, but median Chl-a exceeds this criterion and would be classified as eutrophic. However, this analysis is based on a limited dataset of 1-3 readings per year, and extending monitoring to 4-5 readings per year (to include spring and fall conditions) may further illuminate trends in lake condition. At a minimum, it is recommended that monitoring continue at all existing lake sampling locations at the current annual frequency. Alterations to the monitoring plan may include:

- **Extending the monitoring season at the Deep Spot** to examine how nutrients are distributed in the water column and processed throughout and outside of the growing season. Current monitoring occurs about 3 times per year, which should be sustained as resource availability permits. Extensions of this monitoring may also include **weekend monitoring** to capture high-use water quality conditions.

- **Continuing Weed Watch and Lake Host programs.** These programs are important to protecting the lake from being invaded by non-native invasive species, such as purple loosestrife (*Lythrum salicaria*) and variable milfoil (*Myriophyllum heterophyllum*).

- **Adding SDT and DO measurements on a weekly or bi-weekly schedule** to collect more information about water quality between major sampling events. SDT measurements are relatively easy to collect, requiring a relatively small time and resource commitment.

- **Adding measurements of new parameters to the current monitoring program:**
    - **Begin collecting sediment core samples** to gain a better understanding of potential internal phosphorus loading. This may provide insight on future nutrient inputs in Lake Warren if low DO in bottom waters becomes more frequent.
    - **Examine the relationship between dissolved organic carbon (DOC) and metals** as they relate to phosphorus cycling in the lake. This may include collecting DOC data in major wetlands that flow to the lake.
    - **Expand collection of nitrogen data,** as limited total nitrogen (TN) data exists for Lake Warren. A close examination of TN:TP ratios may provide information relative to effects on algae communities, the source of nutrients flowing into the lake, and help answer the question of appropriate trophic classification.

- **Include collection of orthophosphate data,** which may provide a better understanding of phosphorus in Lake Warren. Orthophosphate (also known as "reactive phosphorus") is the form of phosphorus most easily used by plants, and is a component of agricultural and residential fertilizers.

- **Gathering information about the effects of historical management practices,** such as plant dredging/weed harvesting and timber harvesting. Examine how these might have affected trophic state classifications, as well as historical TP and Chl-a values. For example, a review of water quality data by CRLAC (2012) noted that logging operations in the Smith Hill Brook drainage may have affected historically-elevated TP concentrations in the brook. Information on other important land use changes throughout the watershed should be researched by the LWA.

- **Recruiting and training additional monitoring volunteers** to be trained through VLAP. This is the key to the sustainability of LWA's monitoring program. Additional volunteers may also allow for expansion of the monitoring program.

- **Investigating the possible benefits of weather monitoring.** Monitoring could include parameters on air quality, visibility, wind, and basic information such as rainfall. If feasible, monitoring should be set up using an automated personal weather station (PWS).

Table 5-7. Water Quality Monitoring and Lake Assessment Action Plan items.

WATER QUALITY MONITORING AND LAKE ASSESSMENT *Recommended Interim Water Quality Goal = [25% reduction in Total Phosphorus or 2.7 ppb]*						
PRIORITY	**ACTION ITEM**	**DESCRIPTION**	**RESPONSIBLE PARTY**	**FUNDING SOURCE**	**SCHEDULE**	**ESTIMATED COST**
1	**Tributary Monitoring**	Continue to monitor tributaries throughout the watershed, which may include expanding current program (adding eastern tributary). Assumes minimum three samples collected at each site per year using volunteer labor. Analysis includes TP, turbidity, pH, specific conductivity, and chloride.	LWSC, LWA, VLAP, Water Quality Consultant	VLAP, Town	Beginning 2016	$2,700/yr
		Include both dry and wet weather (storm) samples. Assumes manual sampling three times by volunteers (added to current monitoring regime).	LWSC, LWA, VLAP	LWA, Town	Beginning 2016	$2,700/yr
		Use water loggers to measure flow. Assumes stilling well installation at three sites using consultant labor. Includes logger purchase ($1,150), installation, and maintenance for first year.	LWA, Water Quality Consultant	LWA, Town	Beginning 2016	$6,000

WATER QUALITY MONITORING AND LAKE ASSESSMENT *Recommended Interim Water Quality Goal = [25% reduction in Total Phosphorus or 2.7 ppb]*						
PRIORITY	**ACTION ITEM**	**DESCRIPTION**	**RESPONSIBLE PARTY**	**FUNDING SOURCE**	**SCHEDULE**	**ESTIMATED COST**
2	**Extend Lake Monitoring Season**	Extend lake monitoring season from April to November to capture spring and fall turnover. Assumes volunteer labor.	LWSC, LWA, NHDES	LWA, NHDES	Beginning 2016	$500/yr
3	**Weekend Monitoring**	Add weekends in addition to standard weekday measurements to get a better sense of high-use water quality conditions. Assumes volunteer labor.	LWSC, LWA, NHDES	LWA, Town	Beginning 2016	$300/yr
4	**Weed Watchers & Lake Host Programs**	Continue the established Weed Watchers program to keep invasive species from entering Lake Warren; conduct routine surveys of dam, tributaries, and shallows during summer months.	LWSC, LWA	Volunteers	Ongoing	n/a
5	**Secchi Disk and DO Monitoring Frequency**	Extend Secchi Disk Transparency and DO monitoring frequency to weekly or biweekly (esp. for transparency). Assumes trained volunteer labor. Cost associated with purchase of DO meter.	LWSC, LWA, VLAP	Volunteers	Beginning 2016	$750
6	**Measure New Parameters**	Add measurements of new parameters such as sediment cores, DOC, orthophosphate, and nitrogen, possibly through partnerships with universities. Assumes sediment core sampling donated and DOC/TN/ortho-P added to lake monitoring program (5 sample events).	LWA, Water Quality Consultant, University Researchers	Town, LWA, Universities	Beginning 2016	$200
7	**Volunteer Monitors**	Recruit and train new VLAP volunteers.	LWSC, LWA, VLAP	Volunteers, VLAP	Ongoing	n/a
8	**Weather Station**	Investigate the benefits of weather monitoring for air quality/wind/visibility; if feasible, set up monitoring station using automated data loggers.	LWSC, LWA	Town, Universities, Grants	2017	TBD

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5.4 INDICATORS TO MEASURE PROGRESS

Establishing indicators and numeric targets (benchmarks) to quantitatively measure the progress of this plan will provide both short-term and long-term input about how successful the plan has been in meeting the established goals and objectives for the watershed.

Indicators are derived directly from tasks identified in the Action Plan. While the Action Plan provides a description of tasks, responsible party, a schedule, and estimated annual costs associated with each task, the indicators are developed to reflect how well implementation activities are working, and provides a means by which to track progress toward established goals and objectives.

The following environmental, programmatic, and social indicators and associated benchmarks will help measure the progress of this plan. These benchmarks represent short-term (2018), mid-term (2021), and long-term (2026) targets for improving water quality in Lake Warren. Setting benchmarks allows for periodic updates to the plan, maintains and sustains the action items, and makes the plan relevant to ongoing activities. The 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. 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 indirectly result in reductions in median in-lake TP concentrations and the frequency of peak flows to tributaries from unbuffered impervious or bare soil surfaces that carry phosphorus-laden sediment.

Table 5-8. Environmental Indicators for Lake Warren.

Environmental Indicators			
Indicators	Benchmarks*		
	2018	2021	2026
Reduction in median in-lake TP for Lake Warren *GOAL: 8.3 ppb (25% reduction)*	10% of goal	50% of goal	75% of goal
Reduction in median in-lake Chl-a for Lake Warren *GOAL: 5.6 ppb (25% reduction)*	10% of goal	50% of goal	75% of goal
Improvement in mean annual water clarity (Secchi disk transparency) *GOAL: 3 m*	+0.25 m	+0.5 m	+0.7 m

**Benchmarks are cumulative starting at year 1.*

Programmatic Indicators are indirect measures of watershed protection and restoration activities. Rather than indicating that water quality reductions are being met, these programmatic measurements list actions intended to meet the water quality goal.

Table 5-9. Programmatic Indicators for Lake Warren.

Programmatic Indicators			
Indicators	Benchmarks* 2018	2021	2026
Amount of funding secured for plan implementation (e.g., from fundraisers, donations, and grants)	$125,000	$225,000	$375,000
Number of high priority shoreland sites remediated (11 identified)	2	5	10
Number of Residential BMP demonstration projects completed	1	3	5
Linear feet of buffer installed in the shoreland zone (1,700 feet identified)	400	800	1600
Linear feet of public roadway addressed by BMPs (2,400 feet identified)	800	1600	2000
Number of culverts stabilized or enlarged/replaced (9 identified)	3	5	9
Number of voluntary septic system inspections and dye testing	5	20	40
Number of septic system upgrades (6 systems identified as >25 years old)	1	3	6
Number of "septic socials" held	1	3	5
Number of parcels with new conservation easements	1	3	5
Number of new road associations (if determined as feasible)	1	2	3
Number of copies of watershed-based educational materials distributed	150	300	600

**Benchmarks are cumulative starting at year 1.*

Social Indicators measure changes in social or cultural practices and behaviors that lead to implementation of management measures and water quality improvement.

Table 5-10. Social Indicators for Lake Warren.

Social Indicators			
Indicators	Benchmarks* 2018	2021	2026
Number of new LWA members	5	10	20
Number of volunteers participating in educational campaigns	10	20	30
Number of people participating in workshops or demonstrations	20	50	75
Number of new lake hosts (partner with conservation commissions)	2	5	10
Number of newly trained VLAP volunteers (partner with LWA)	1	3	5
Number of active weed watchers (partner with conservation commissions)	2	5	10
Percentage of residents making voluntary upgrades or maintenance to their septic systems (with or without free technical assistance), particularly those identified as needing upgrades or maintenance	10%	25%	50%

**Benchmarks are cumulative starting at year 1.*

5.5 ESTIMATED COSTS AND TECHNICAL ASSISTANCE NEEDED

The cost of successfully implementing this watershed plan for Lake Warren is estimated at $386,000 over the next ten years (Table 5-11). **However, many costs are still unknown and should be incorporated to the Action Plan as information becomes available.** These costs will come from a variety of stakeholders, grants, or other funding sources identified in the Action Plan. This includes both structural BMPs, such as fixing eroding roads and planting shoreline buffers, and non-structural BMPs, such as improving ordinances.

Annual BMP costs were estimated based on a ten-year total for the initial BMP installation plus ten years of maintenance.

Table 5-11. Estimated annual and ten-year costs for watershed restoration. Estimated annual cost is 10% of the ten-year cost.

Category	Estimated Annual Costs	10-year Total
Watershed Planning	$3,850	$38,500
Shoreland and Residential BMPs	$14,905	$149,051
Road BMPs and Maintenance	$9,442	$94,418
Septic Systems*	$2,575	$25,750
Municipal Ordinances and Land Conservation	$960	$9,600
WQ Monitoring and Lake Assessment	$6,895	$68,950
Total Cost	**$38,627**	**$386,269**

**Septic system action items do not include design or replacement costs or community septic installations because these should be covered by private landowners. Action items cover assistance to secure grant funding for those individuals who cannot afford these costs.*

A diverse source of funding and a funding strategy will be needed to match these implementation activities. 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, Aquatic Resource Mitigation Fund (ARM), Moose Plate grants, etc.), municipalities, and LWA. Funding to improve septic systems, roads, and shoreland zone buffers could be expected from property owners most affected by the improvements. As the plan evolves into the future, the Lake Warren Steering Committee will be a key part of 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 Lake Warren Action Plan:

- **US EPA/NHDES 319 Grants (Watershed Assistance/Restoration Grants) –** This nonpoint source (NPS) grant is designed to support local initiatives to restore impaired waters (priorities identified in the NPS Management Plan, updated 2014) and protect high-quality waters. 319 grants are available for the implementation of watershed management plans. 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: Restore, enhance, maintain or protect.
    - Wildlife Habitat: Create, restore, enhance, manage or protect.

  - Soil Conservation and Flooding: Reduce or prevent erosion, or improve soils.
  - Best Management Practices: Plan and implement for agriculture, storm water or forestry.
  - Conservation Planning: Accomplish a conservation project or outcome that includes a public involvement component.
  - Land Conservation: Permanent land protection through conservation easement or fee acquisition and / or associated transaction and stewardship costs.

  For the 2017 funding year, the total SCC grant request per application cannot exceed $24,000.
  http://agriculture.nh.gov/divisions/scc/grant-program.htm

- **Milfoil and Other Exotic Plant Prevention Grants (NHDES) –** Funds are available each year for projects to 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 collection systems and wastewater treatment plants with the ultimate goal of protecting public health and improving water quality. A portion of the CWSRF program is used to fund nonpoint source, watershed protection and restoration, and estuary management projects that help improve and protect water quality in New Hampshire."
  http://des.nh.gov/organization/divisions/water/wweb/grants.htm

5.6 EDUCATIONAL COMPONENT

As detailed in Section 1.5.3, efforts are already underway by SWRPC and LWA to communicate with watershed residents and to encourage community participation in watershed restoration and protection activities. Joint efforts between SWRPC and LWA will need to continue to execute the education and outreach campaigns highlighted in the Action Plan. LWA should consider developing new educational campaigns or improving existing ones to reach more watershed residents. Establishment of an "Outreach Committee" within the LWA can help maintain momentum for the project. Educational campaigns specific to the six Action Plan categories are detailed in their respective tables (Section 5.3).

5.7 EVALUATION PLAN

Annual Steering Committee meetings should be organized to review the status of goals and objectives presented in this watershed management plan. It is recommended that an adaptive management approach be used to assess annual progress, determine key projects for the following year, and provide a venue for sharing information with watershed stakeholders. Adaptive management is the process by which new information about the health of the watershed is incorporated to the plan. This process allows stakeholders the opportunity to evaluate the effectiveness of restoration and monitoring activities before implementing future actions. Tasks listed in the Action Plan should be tracked and recorded as they occur, and new tasks should be added to the plan as determined through the adaptive management process. All achievements, such as press releases, outreach activities, number of sites repaired, number of volunteers, amount of funding received, number of sites documented, should be tracked. Stakeholders can then use the established indicators (Section 5.4) to determine the effectiveness of the plan.

5.8 CONCLUSION

Watershed residents, landowners, farmers, business owners, and recreationalists alike should have a vested interest in protecting the long-term water quality of Lake Warren for future generations. With a goal of reducing in-lake phosphorus concentrations by 25%, water quality trends in phosphorus will likely be maintained or slowed over time and ultimately bring Lake Warren water quality closer to the oligotrophic range. At this stage, implementation of the plan over the next ten years is estimated to cost $386,000, and will require the continued dedication and hard work of the diverse group of stakeholders brought together by the development of this plan. Collaboration among these entities and active leadership will ensure that the actions identified in this plan are carried out accordingly. The Action Plan will need to be updated as the plan is implemented and new action items are added, in accordance with the adaptive management approach.

ADDITIONAL RESOURCES

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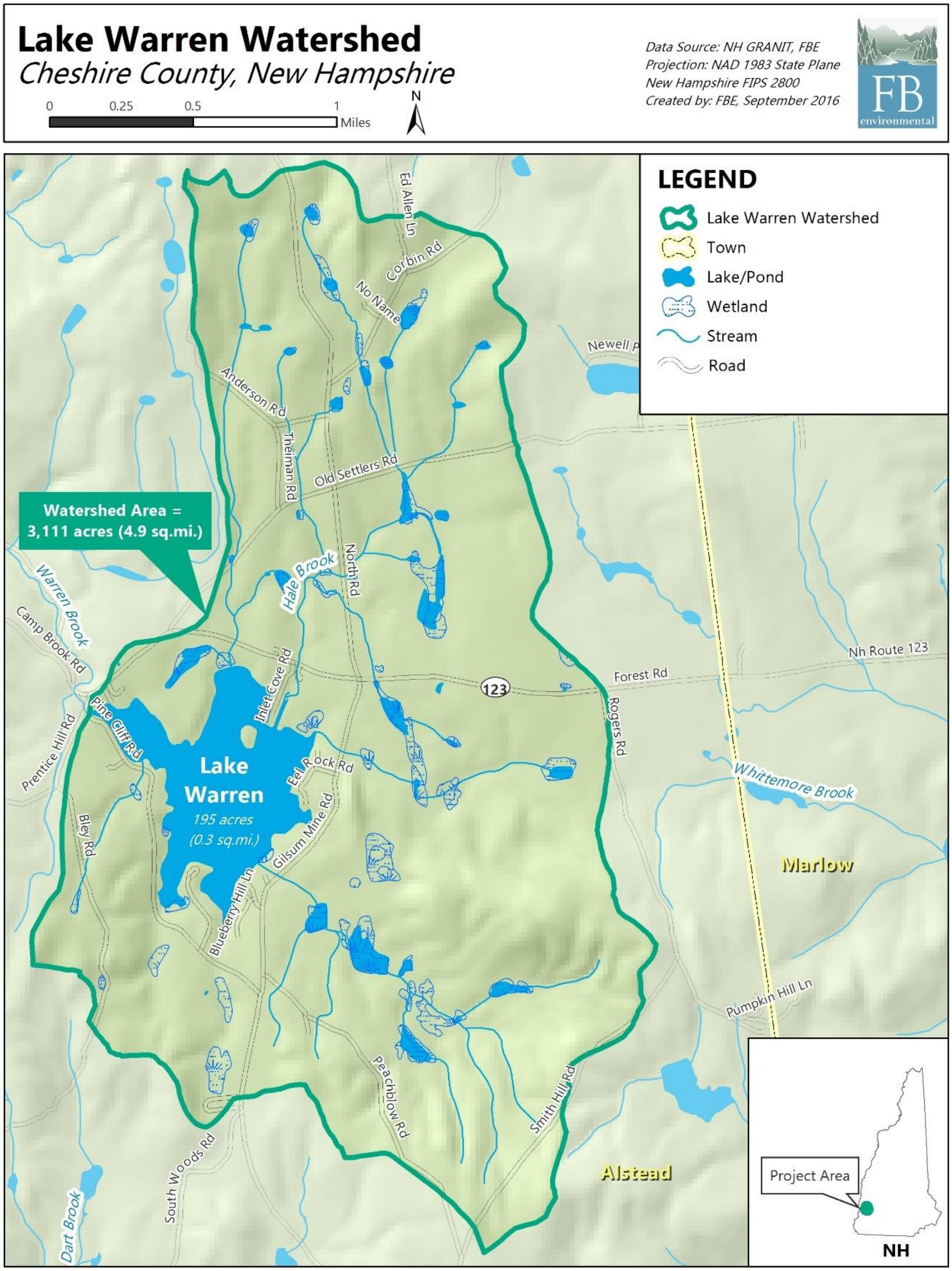
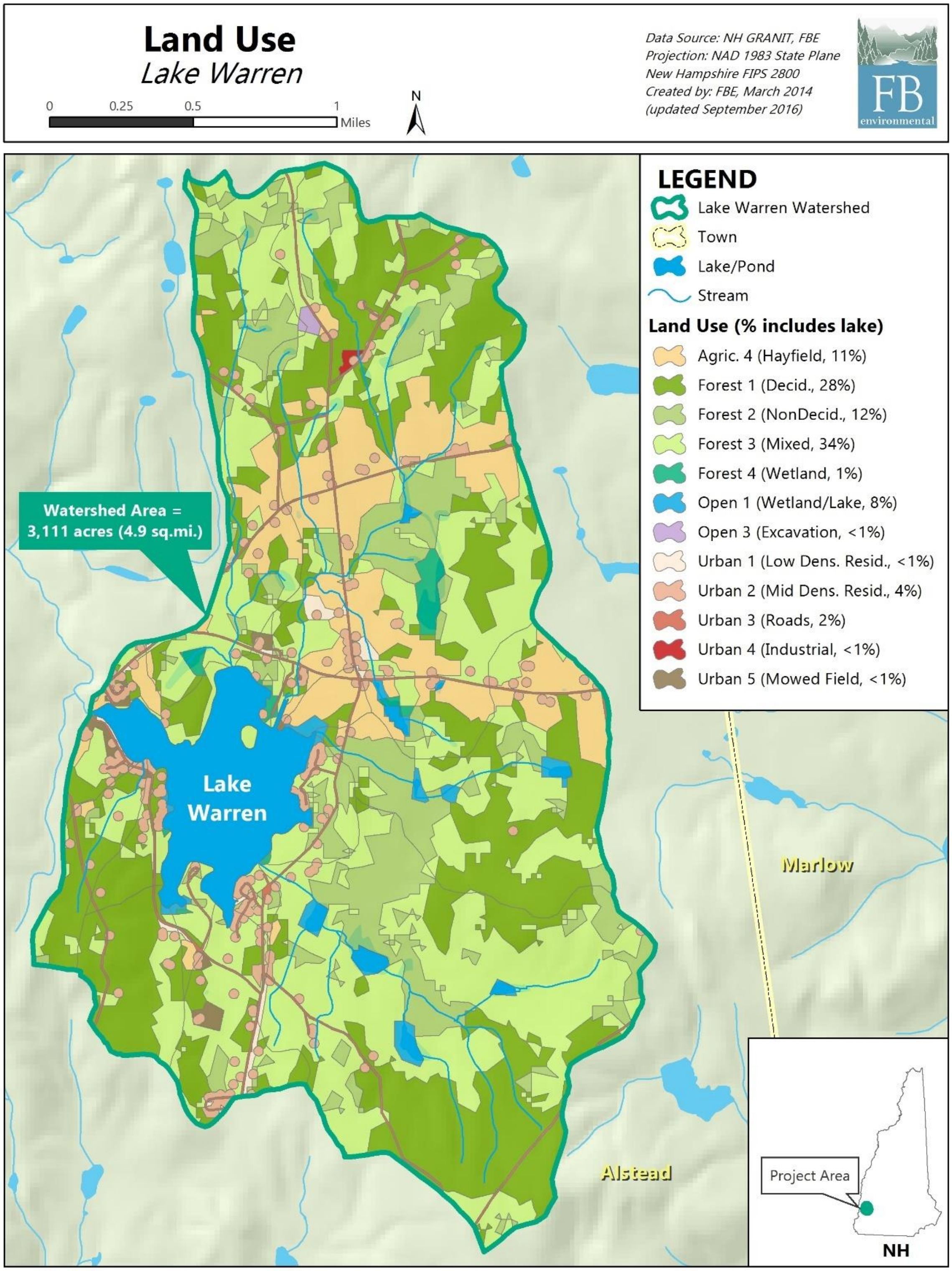
APPENDICES

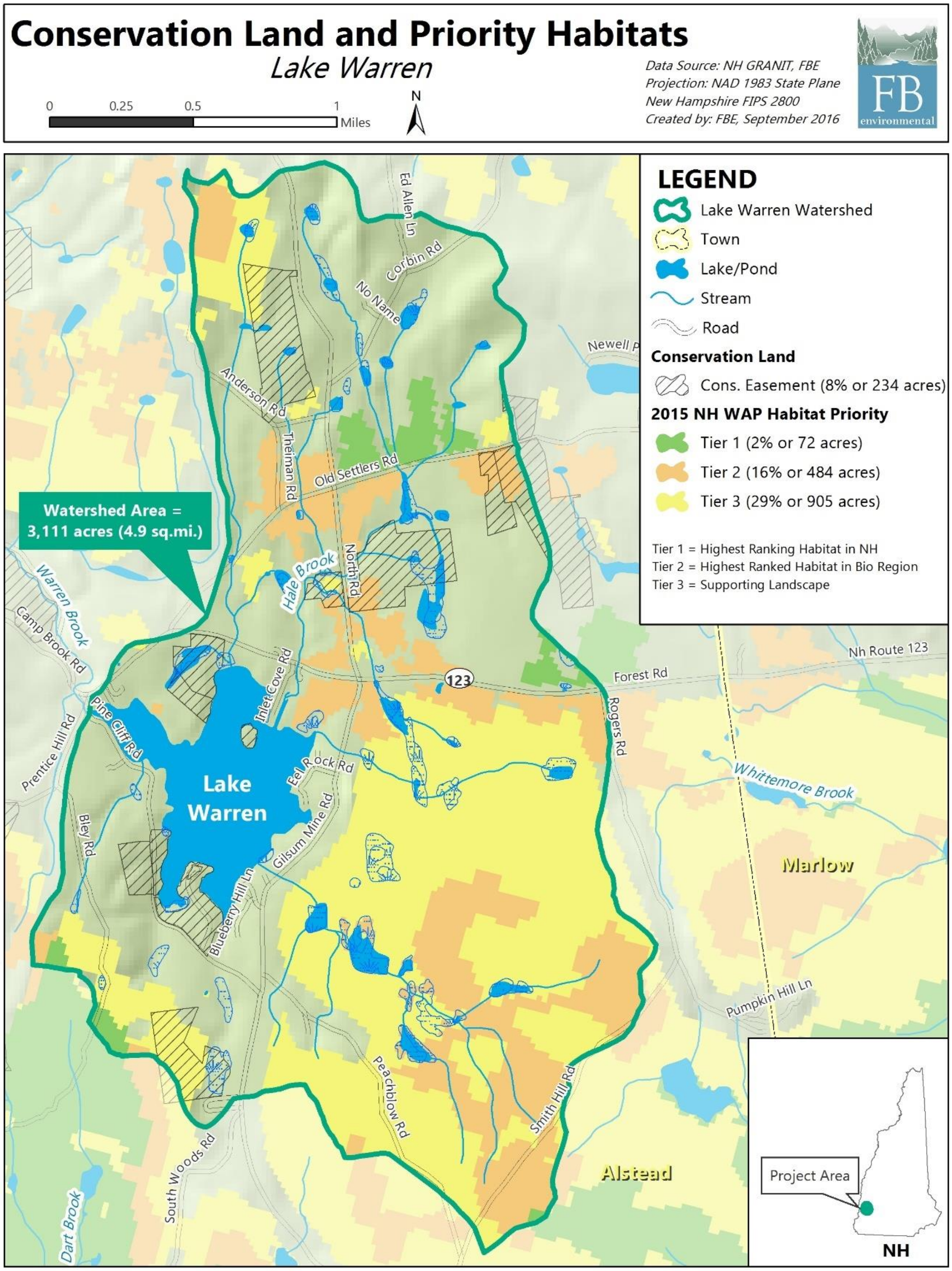


APPENDIX A: THEMATIC GIS MAPS

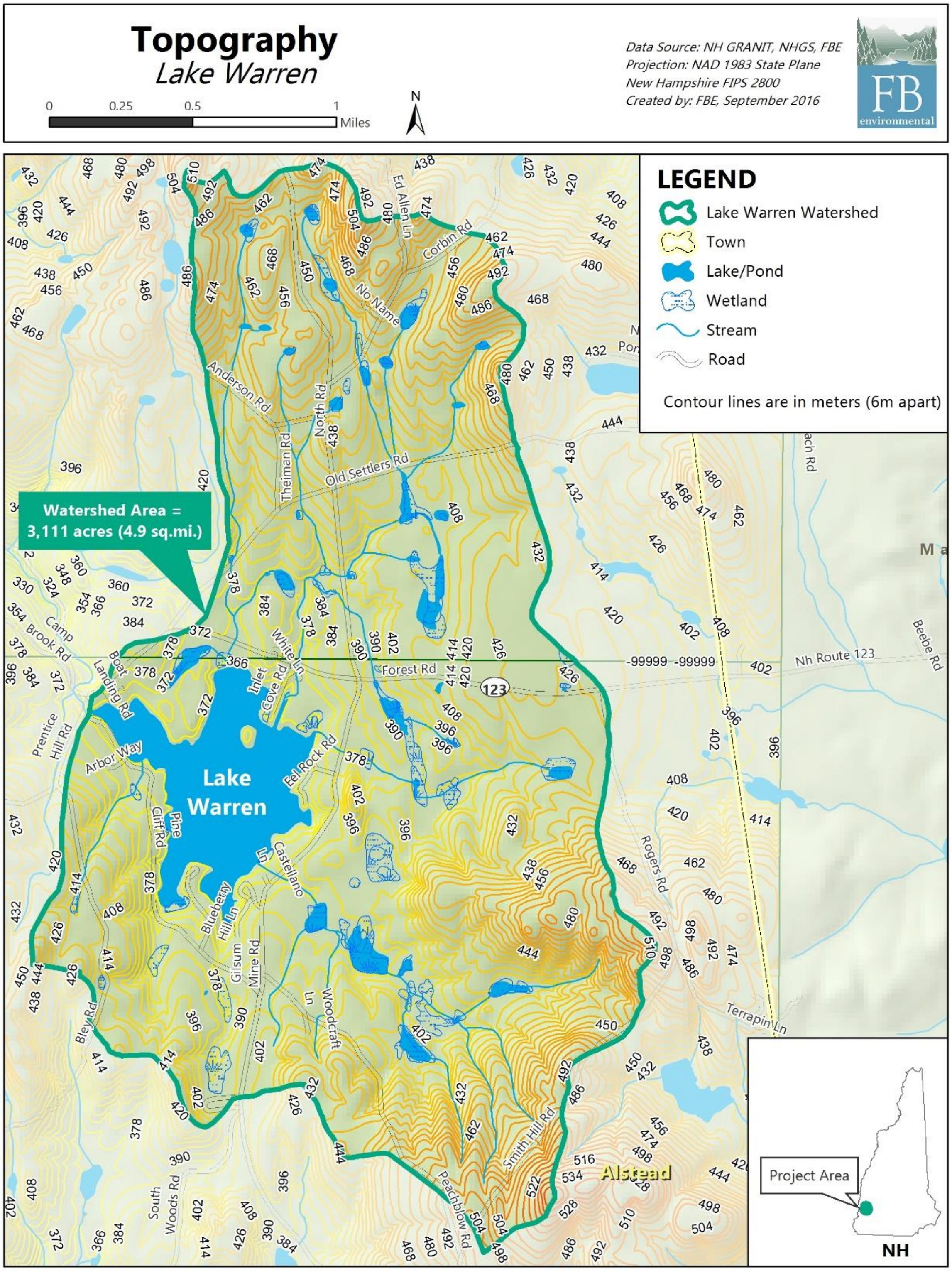
Map 1


Land Use
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, March 2014
(updated September 2016)
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Stream
Land Use (% includes lake)
Agric. 4 (Hayfield, 11%)
Forest 1 (Decid., 28%)
Forest 2 (NonDecid., 12%)
Forest 3 (Mixed, 34%)
Forest 4 (Wetland, 1%)
Open 1 (Wetland/Lake, 8%)
Open 3 (Excavation, <1%)
Urban 1 (Low Dens. Resid., <1%)
Urban 2 (Mid Dens. Resid., 4%)
Urban 3 (Roads, 2%)
Urban 4 (Industrial, <1%)
Urban 5 (Mowed Field, <1%)
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
Marlow
Alstead
Project Area
NH

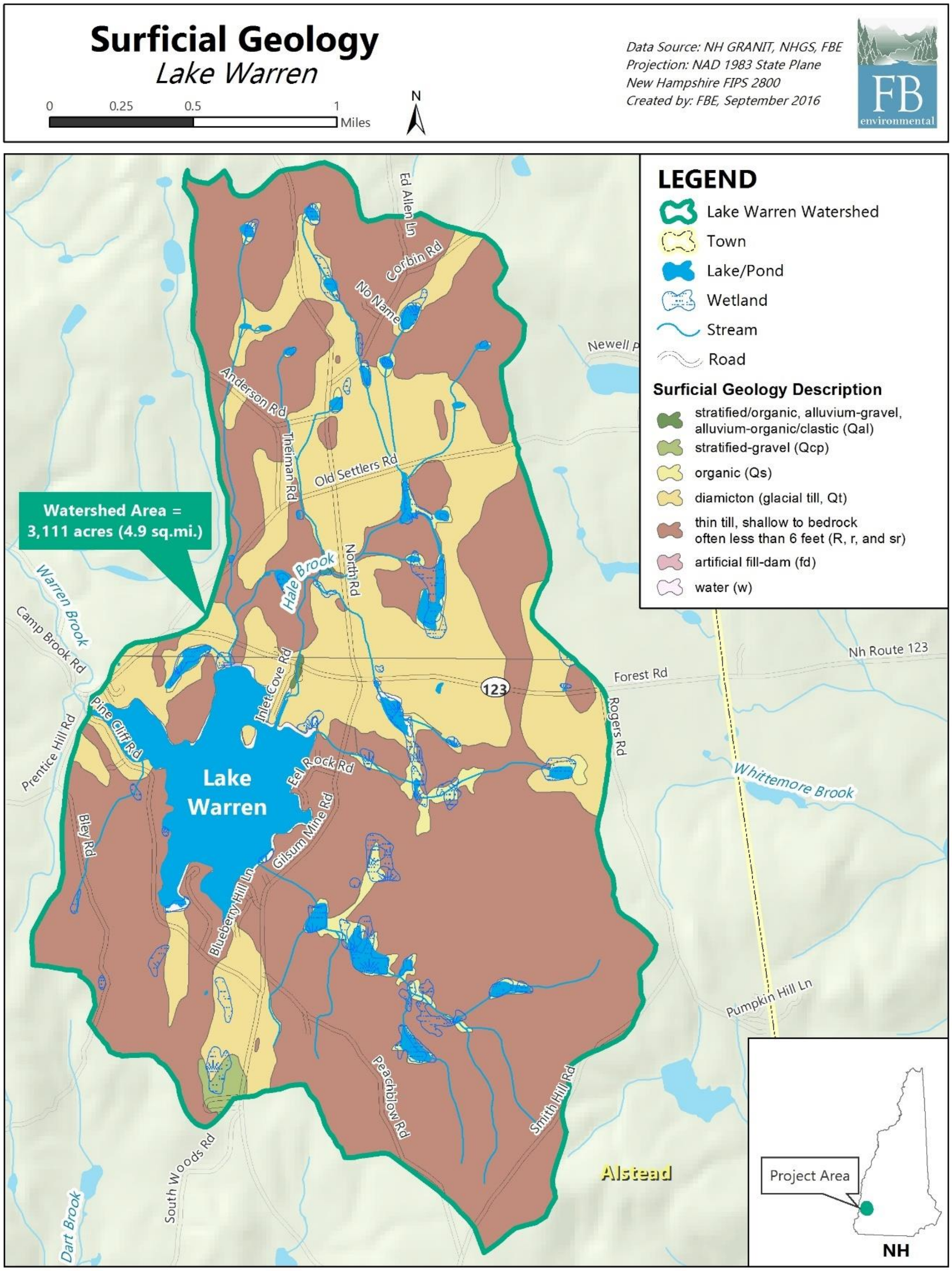
Map 2


Conservation Land and Priority Habitats
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, September 2016
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Stream
Road
Conservation Land
Cons. Easement (8% or 234 acres)
2015 NH WAP Habitat Priority
Tier 1 (2% or 72 acres)
Tier 2 (16% or 484 acres)
Tier 3 (29% or 905 acres)
Tier 1 = Highest Ranking Habitat in NH
Tier 2 = Highest Ranked Habitat in Bio Region
Tier 3 = Supporting Landscape
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
Marlow
Alstead
Project Area
NH
Ed Allen Ln
Corbin Rd
No Name
Newell
Anderson Rd
Theiman Rd
Old Settlers Rd
North Rd
Hale Brook
Warren Brook
Camp Brook Rd
Inlet Cove Rd
123
Forest Rd
Nh Route 123
Rogers Rd
Prentice Hill Rd
Pine Cliff Rd
Eel Rock Rd
Gilsum Mine Rd
Whittemore Brook
Bley Rd
Blueberry Hill Ln
Pumpkin Hill Ln
Peachblow Rd
Smith Hill Rd
South Woods Rd
Dart Brook

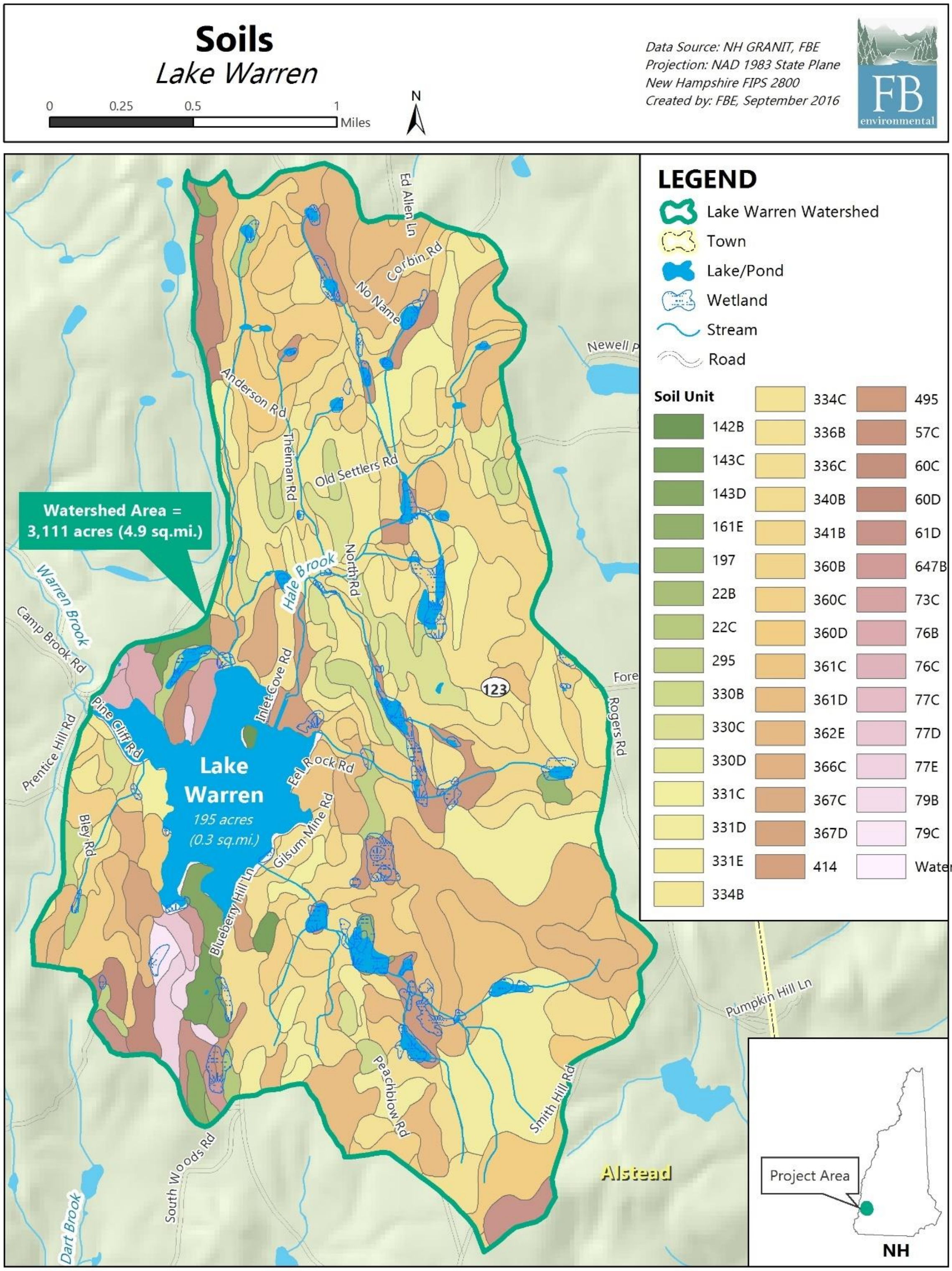
Map 3


Topography
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, NHGS, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, September 2016
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Road
Contour lines are in meters (6m apart)
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
Alstead
Project Area
NH
Anderson Rd
Old Settlers Rd
Theiman Rd
North Rd
Ed Allen Ln
Corbin Rd
No Name
Forest Rd
Nh Route 123
123
Boat Landing Rd
Camp Brook Rd
Prentice Hill Rd
Arbor Way
Pine Cliff Rd
Inlet Cove Rd
White Ln
Eel Rock Rd
Castellano Ln
Blueberry Hill Ln
Gilsum Mine Rd
Woodcraft Ln
Bley Rd
Peachblow Rd
Smith Hill Rd
Rogers Rd
Terrapin Ln
Beebe Rd
South Woods Rd

Map 4

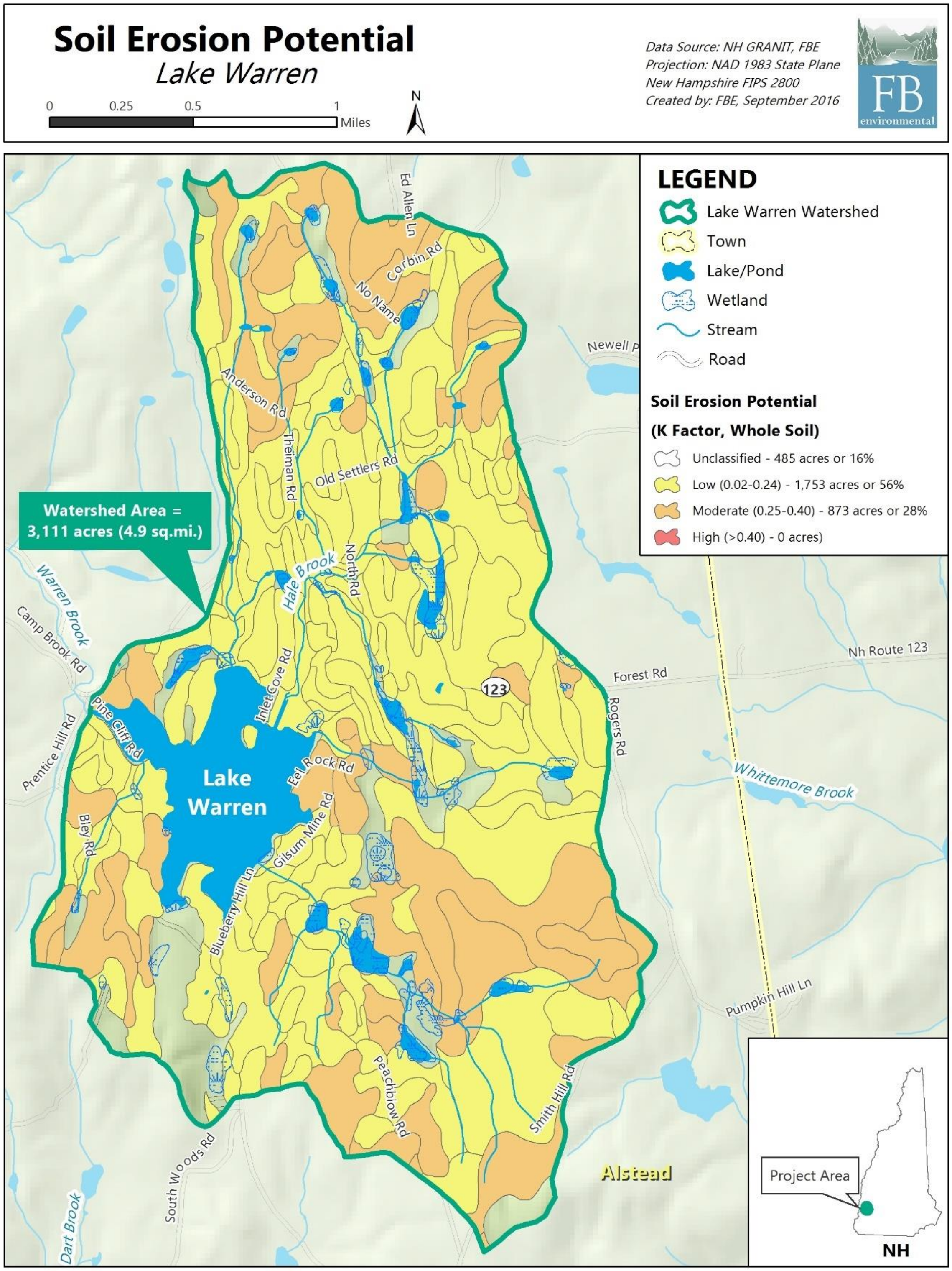

Surficial Geology
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, NHGS, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, September 2016
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Road
Surficial Geology Description
stratified/organic, alluvium-gravel, alluvium-organic/clastic (Qal)
stratified-gravel (Qcp)
organic (Qs)
diamicton (glacial till, Qt)
thin till, shallow to bedrock often less than 6 feet (R, r, and sr)
artificial fill-dam (fd)
water (w)
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
Ed Allen Ln
Corbin Rd
No Name
Anderson Rd
Theiman Rd
Old Settlers Rd
Hale Brook
North Rd
Warren Brook
Camp Brook Rd
Inlet Cove Rd
Forest Rd
123
Nh Route 123
Rogers Rd
Pine Cliff Rd
Prentice Hill Rd
Eel Rock Rd
Whittemore Brook
Bley Rd
Gilsum Mine Rd
Blueberry Hill Ln
Peachblow Rd
Smith Hill Rd
Pumpkin Hill Ln
South Woods Rd
Dart Brook
Alstead
Project Area
NH

Map 5

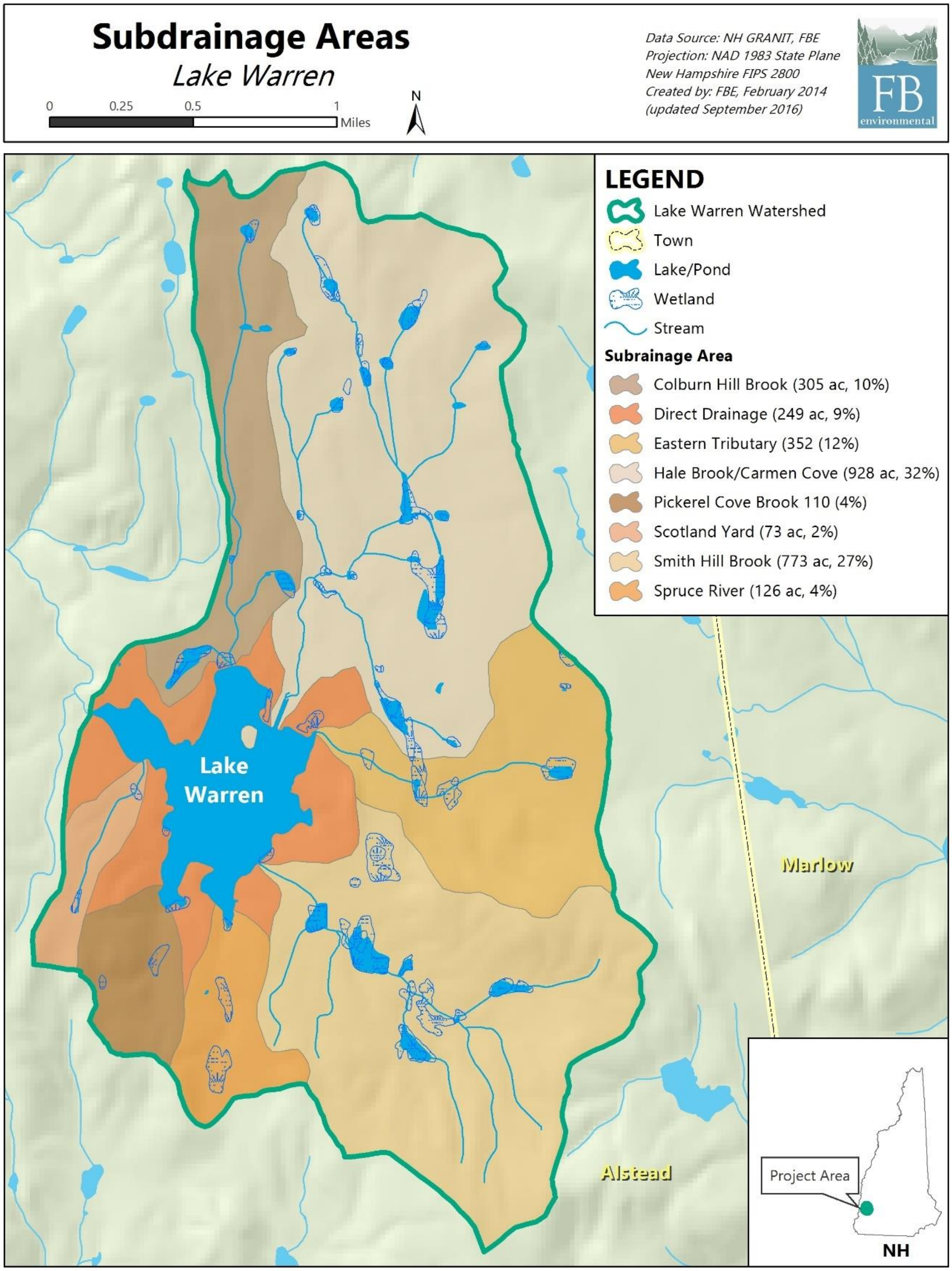


Soils
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, September 2016
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Road
Soil Unit
142B
143C
143D
161E
197
22B
22C
295
330B
330C
330D
331C
331D
331E
334B
334C
336B
336C
340B
341B
360B
360C
360D
361C
361D
362E
366C
367C
367D
414
495
57C
60C
60D
61D
647B
73C
76B
76C
77C
77D
77E
79B
79C
Water
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
195 acres
(0.3 sq.mi.)
Ed Allen Ln
Corbin Rd
No Name
Newell P
Anderson Rd
Theiman Rd
Old Settlers Rd
North Rd
Hale Brook
Warren Brook
Camp Brook Rd
Inlet Cove Rd
123
Fore
Rogers Rd
Pine Cliff Rd
Prentice Hill Rd
Eel Rock Rd
Gilsum Mine Rd
Bley Rd
Blueberry Hill Ln
Pumpkin Hill Ln
Peachblow Rd
Smith Hill Rd
South Woods Rd
Dart Brook
Alstead
Project Area
NH

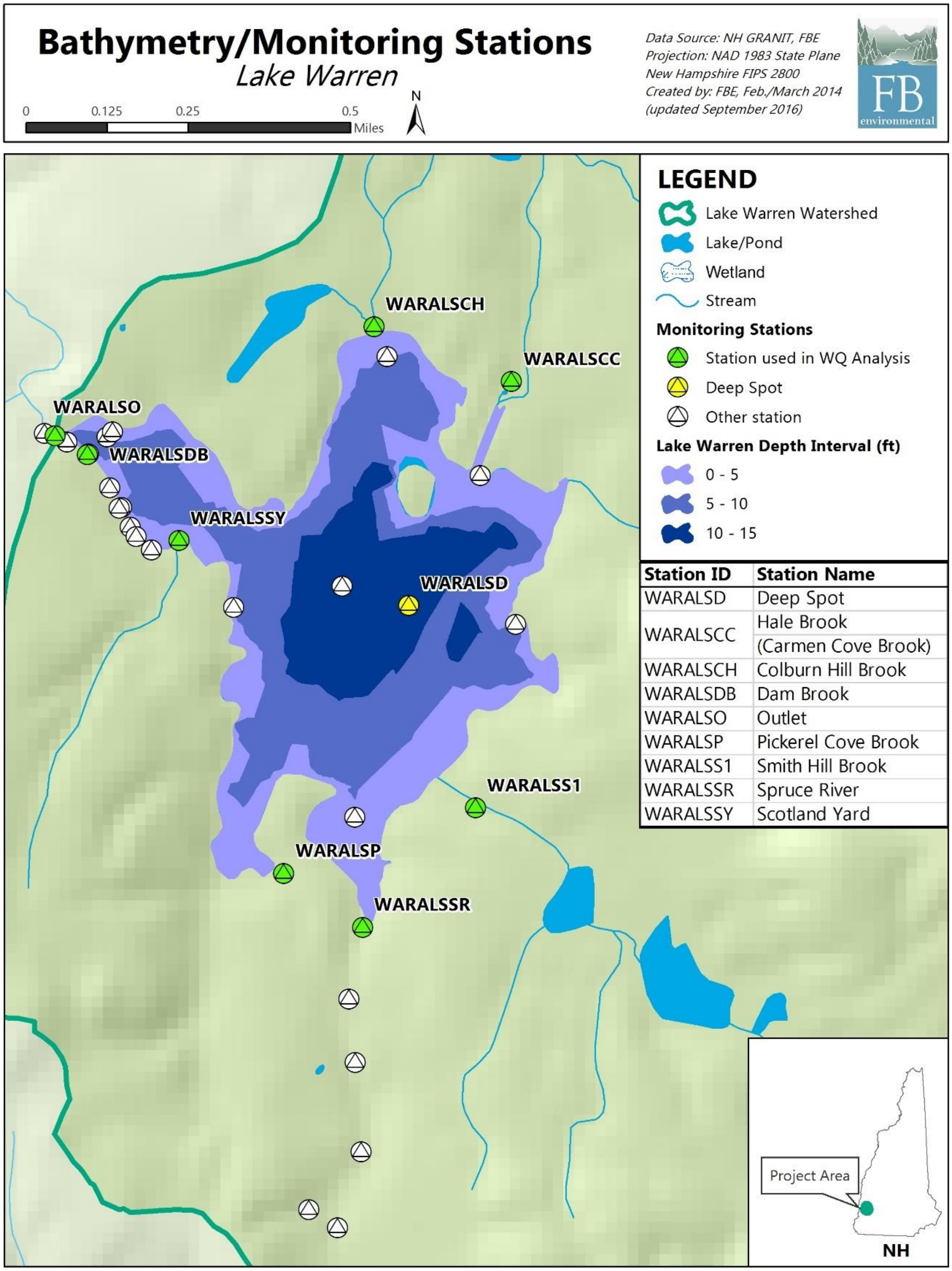
Map 6


Soil Erosion Potential
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, September 2016
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Road
Soil Erosion Potential
(K Factor, Whole Soil)
Unclassified - 485 acres or 16%
Low (0.02-0.24) - 1,753 acres or 56%
Moderate (0.25-0.40) - 873 acres or 28%
High (>0.40) - 0 acres)
Watershed Area = 3,111 acres (4.9 sq.mi.)
Lake Warren
Alstead
Project Area
NH
Ed Allen Ln
Corbin Rd
No Name
Anderson Rd
Theiman Rd
Old Settlers Rd
Hale Brook
North Rd
Warren Brook
Camp Brook Rd
Inlet Cove Rd
Forest Rd
Nh Route 123
123
Rogers Rd
Pine Cliff Rd
Prentice Hill Rd
Eel Rock Rd
Whittemore Brook
Gilsum Mine Rd
Bley Rd
Blueberry Hill Ln
Pumpkin Hill Ln
Peachblow Rd
Smith Hill Rd
South Woods Rd
Dart Brook

Map 7

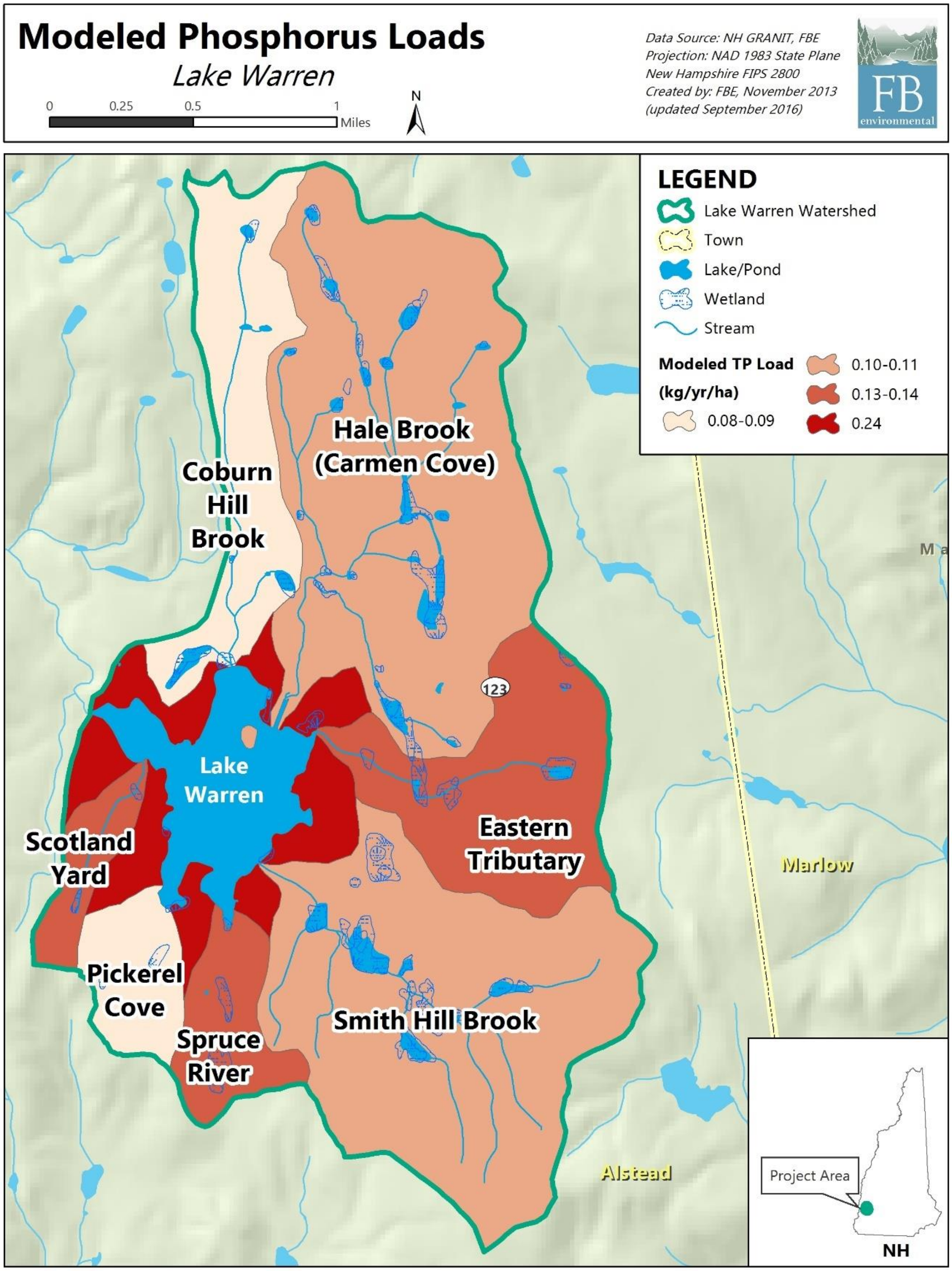

Subdrainage Areas
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, February 2014
(updated September 2016)
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Subrainage Area
Colburn Hill Brook (305 ac, 10%)
Direct Drainage (249 ac, 9%)
Eastern Tributary (352 (12%)
Hale Brook/Carmen Cove (928 ac, 32%)
Pickerel Cove Brook 110 (4%)
Scotland Yard (73 ac, 2%)
Smith Hill Brook (773 ac, 27%)
Spruce River (126 ac, 4%)
Lake Warren
Marlow
Alstead
Project Area
NH

Map 8



Station ID	Station Name
WARALSD	Deep Spot
WARALSCC	Hale Brook (Carmen Cove Brook)
WARALSCH	Colburn Hill Brook
WARALSDB	Dam Brook
WARALSO	Outlet
WARALSP	Pickerel Cove Brook
WARALSS1	Smith Hill Brook
WARALSSR	Spruce River
WARALSSY	Scotland Yard

Map 9


Modeled Phosphorus Loads
Lake Warren
0 0.25 0.5 1 Miles
N
Data Source: NH GRANIT, FBE
Projection: NAD 1983 State Plane
New Hampshire FIPS 2800
Created by: FBE, November 2013
(updated September 2016)
FB environmental
LEGEND
Lake Warren Watershed
Town
Lake/Pond
Wetland
Stream
Modeled TP Load (kg/yr/ha)
0.08-0.09
0.10-0.11
0.13-0.14
0.24
Hale Brook (Carmen Cove)
Coburn Hill Brook
123
Lake Warren
Eastern Tributary
Scotland Yard
Pickerel Cove
Spruce River
Smith Hill Brook
Marlow
Alstead
Project Area
NH

Map 10

APPENDIX B: SOIL SERIES IN THE LAKE WARREN WATERSHED

Table B-1. Acreage and description of soil series in the Lake Warren watershed.

Code (MUSYM)	Soil Series Description	Acres	Percentage
197	Borohemists, ponded	17	1%
295	Greenwood mucky peat	40	1%
495	Ossipee mucky peat	125	4%
142B	Monadnock fine sandy loam, 3 to 8 percent slopes	4	0%
143C	Monadnock fine sandy loam, 8 to 15 percent slopes, very stony	29	1%
143D	Monadnock fine sandy loam, 15 to 25 percent slopes, very stony	22	1%
161E	Lyman-Tunbridge-Rock outcrop complex, 25 to 50 percent slopes	12	0%
22B	Colton loamy fine sand, 3 to 8 percent slopes	2	0%
22C	Colton loamy fine sand, 8 to 15 percent slopes	5	0%
330B	Bernardston silt loam, 3 to 8 percent slopes	44	1%
330C	Bernardston silt loam, 8 to 15 percent slopes	114	4%
330D	Bernardston silt loam, 15 to 25 percent slopes	10	0%
331C	Bernardston silt loam, 8 to 15 percent slopes, very stony	83	3%
331D	Bernardston silt loam, 15 to 25 percent slopes, very stony	262	8%
331E	Bernardston silt loam, 25 to 50 percent slopes, very stony	<1	0%
334B	Pittstown silt loam, 3 to 8 percent slopes	234	8%
334C	Pittstown silt loam, 8 to 15 percent slopes	34	1%
336B	Pittstown silt loam, 3 to 8 percent slopes, very stony	122	4%
336C	Pittstown silt loam, 8 to 15 percent slopes, very stony	264	8%
340B	Stissing silt loam, 0 to 5 percent slopes	42	1%
341B	Stissing silt loam, 0 to 5 percent slopes, very stony	330	11%
360B	Cardigan-Kearsarge complex, 3 to 8 percent slopes	18	1%
360C	Cardigan-Kearsarge complex, 8 to 15 percent slopes	151	5%
360D	Cardigan-Kearsarge complex, 15 to 25 percent slopes	132	4%
361C	Cardigan-Kearsarge-Rock outcrop complex, 8 to 15 percent slopes	124	4%
361D	Cardigan-Kearsarge-Rock outcrop complex, 15 to 25 percent slopes	333	11%
362E	Kearsarge-Cardigan-Rock outcrop complex, 25 to 50 percent slopes	93	3%
366C	Dutchess silt loam, 8 to 15 percent slopes	10	0%
367C	Dutchess silt loam, 8 to 15 percent slopes, very stony	24	1%
367D	Dutchess silt loam, 15 to 25 percent slopes, very stony	20	1%
57C	Becket fine sandy loam, 8 to 15 percent slopes, very stony	10	0%
60C	Tunbridge-Berkshire complex, 8 to 15 percent slopes, very stony	22	1%
60D	Tunbridge-Berkshire complex, 15 to 25 percent slopes, very stony	28	1%
61D	Tunbridge-Lyman-Rock outcrop complex, 15 to 25 percent slopes	39	1%
647B	Pillsbury fine sandy loam, 0 to 5 percent slopes, very stony	9	0%
73C	Berkshire fine sandy loam, 8 to 15 percent slopes, very stony	14	0%
76B	Marlow fine sandy loam, 3 to 8 percent slopes	13	0%
76C	Marlow fine sandy loam, 8 to 15 percent slopes	8	0%
77C	Marlow fine sandy loam, 8 to 15 percent slopes, very stony	2	0%
77D	Marlow fine sandy loam, 15 to 25 percent slopes, very stony	8	0%
77E	Marlow fine sandy loam, 25 to 50 percent slopes, very stony	18	1%
79B	Peru fine sandy loam, 3 to 8 percent slopes, very stony	10	0%
79C	Peru fine sandy loam, 8 to 15 percent slopes, very stony	9	0%
W	Water	196	6%
	TOTAL	**3,111**	

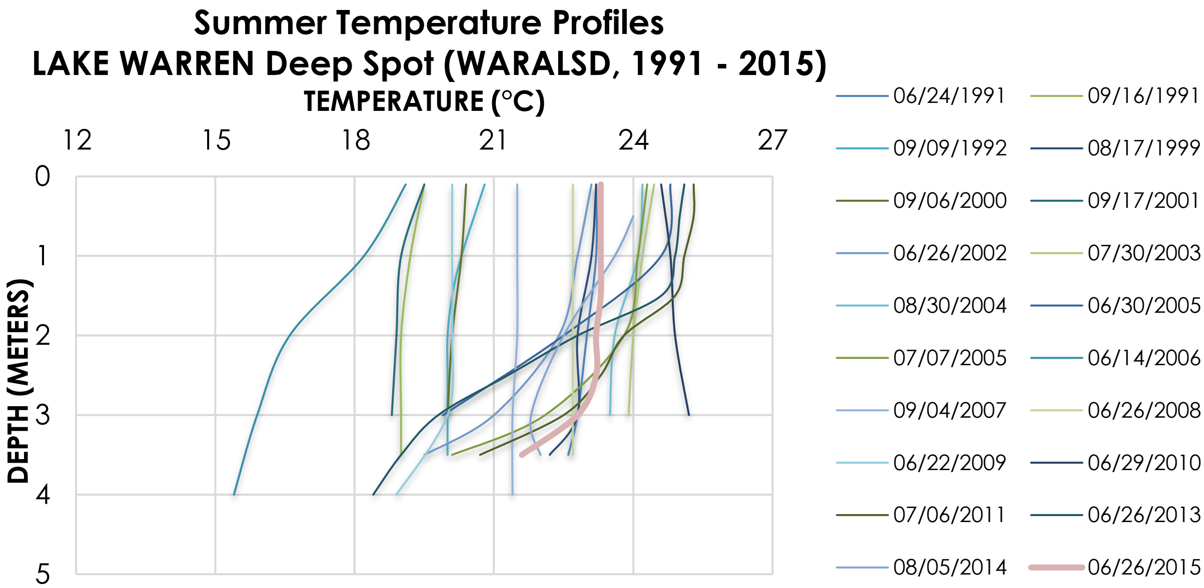
APPENDIX C: SUMMARY OF AVAILABLE WATER QUALITY DATA FOR LAKE WARREN

Summary of Available Water Quality Data for Lake Warren, NH			
Trophic Survey Data and Chemistry from Scott Ashley, NHDES			
Lake Warren Deep Spot	***(WARALSD)***		
Depth, DO, Temperature			*1980, 1991, 2005, 2006*
SDT, Magnesium, Sodium, Potassium, Chl-A, Calcium, Vascular Plant Abundance			*1980, 1991, 2005*
DO (% Saturation)			*1991, 2005, 2006*
pH, Sp. Cond., TP, TN, Alkalinity, Color, Chloride			*1980, 1991, 1992, 2005, 2006*
Turbidity			*1980*
TKN			*1980, 2005, 2006*
Sulfate			*1991, 1992, 2005, 2006*
Bacteria Sample Sites	***(WARALSEC01, WARALSEC02)***		
E. Coli			*2005*
Lake Warren Generic	***(WARALS-GEN)***		
Coliform			*1991*
VLAP Data from Sara Steiner, NHDES			
Lake Warren Deep Spot	***(WARALSD)***		
DO (mg/L), DO (% saturation), Temperature			*1991, 1992, 1999-2011, 2013-2015*
SDT, pH, TP, Chl-A			*1991, 1992, 1999-2013-2015*
Magnesium, Potassium, Vascular Plant Abundance, TN, TKN, Sulfate			*2005*
Depth (bottom)			*2010, 2011, 2013, 2014*
Turbidity			*1999-2015*
Alkalinity			*1991,1992, 1999, 2000-2007*
Acid Neutralizing Capacity			*2008-2015*
Color			*1991, 1992, 2005*
Chloride			*2005, 2010-2015*
Lake Warren Bacteria Sites*			
Lake Warren Boat Landing	***(WARALSBL)***	*E. Coli*	*1991-92, 1999, 2002-03, 2005, 2007, 2010-11, 2013-2015*
Bacteria Sample Sites	***(WARALSEC01, WARALSEC02)***	*E.Coli*	*2005*
Edith's Beach	***(WARALSEB)***	*E.Coli*	*2002-03, 2007-2011, 2013-2015*
Spencer Beach	***(WARALSSB)***	*E.Coli*	*1999, 2002-03, 2006-08, 2010*
Curl Cove	***(WARALSCUCOVE)***		
pH, TP, Turbidity, Color			*2010, 2011*
Warren Lake Generic	***(WARALS-GEN)***		
pH, TP, Color, Sp. Cond.			*1991-1992*
E. Coli			*1999-2000*
Lawlor Shore	***(WARALSLS)***		
pH, Sp. Cond., TP, Turbidity			*2007*
E. Coli			*2007, 2009, 2010*
Rawson Cove	***(WARALSRC)***		
pH, Sp. Cond., TP, Turbidity, E. Coli, Chloride			*2011*
Scotland Yard	***(WARALSSY)***		
pH, Sp. Cond., TP, Turbidity			*2003-05, 2008-2011*
E. Coli			*2004, 2005*
Chloride			*2010, 2011*

Shadowlands	***(WARALSSL)***	
pH, Sp. Cond., TP, Turbidity		*2011, 2013*
E. Coli		*2011*
Hale Brook/Carmen Cove Brook	***(WARALSCC)***	
pH, TP, Turbidity		*1999, 2000, 2002-2015*
Temperature, DO (% saturation)		*2011*
Chloride		*2010-2015*
Coburn Hill Brook	***(WARALSCH)***	
pH, Sp.Cond., TP, Turbidity		*1999, 2000, 2002-2015*
Chloride		*2010-2015*
Smith Hill Brook	***(WARALSS1)***	
pH, Sp. Cond., TP Turbidity		*1999-2015*
Temperature		*2011*
Chloride		*2010-2015*
Spruce River	***(WARALSSR)***	
pH, Sp. Cond., TP Turbidity		*1999-2015*
E. Coli		*1999, 2000, 2002, 2007*
Chloride		*2010-2015*
Pickerel Cove	***(WARALSP)***	
pH, Sp. Cond., TP Turbidity		*1999-2015*
Chloride		*2010-2015*
Dam Brook	***(WARALDB)***	
pH, Sp. Cond., TP Turbidity		*1999, 2002-2011, 2015*
Chloride		*2010, 2011, 2015*
VRAP Data from Ted Walsh, NHDES		
Hale Brook/Carmen Cove Brook	***(WARALSCC)***	
pH, Sp. Cond., Temperature, turbidity		*2011-2012, 2014*
Smith Hill Brook	***(WARALSS1)***	
pH, Sp.Cond.,Turbidity		*2011-2014*
Temperature		*2011-2014*
TP, Chloride		*2013*
NHDES Complaint Investigation Data from Walt Henderson, NHDES		
Culverts 2371-001 - 2371-011		
Turbidity Data		*2011*
NH Fish Study Data from Walt Henderson, NHDES		
Warren Lake Generic	***(WARALS-GEN)***	
Mercury Data		*1995-1997, 2008-2009*

Prepared by FB Environmental Associates for the South West Regional Planning Commission, February 2014 (Update January 2016)

APPENDIX D: SELECT WATER QUALITY ANALYSIS RESULTS



APPENDIX E: SITE SPECIFIC PROJECT PLAN

SITE SPECIFIC PROJECT PLAN FOR:

LAKE WARREN WATERSHED MANAGEMENT PLAN, DEVELOPMENT AND IMPLEMENTATION PROJECT PHASE I

(NHDES Project #RP-15-CT-11)

Under the New Hampshire Section 319 Nonpoint Source Grant Program QAPP
RFA# 08262
August 23, 2013

FINAL
August 25, 2015

PREPARED BY:

FB Environmental Associates
97A Exchange Street, Suite 305, Portland, ME 04101
(207) 221-6699; info@fbenvironmental.com

For Review:

Project Manager: ______________________
Signature/Date
Lisa Murphy, SWRPC

Technical Project Manager/QA Officer: ______________________
Signature/Date
Forrest Bell, FBE

NHDES Project Manager: ______________________
Signature/Date
Jeff Marcoux, NHDES

Program Quality Assurance Coordinator: ______________________
Signature/Date
Jillian McCarthy, NHDES

NHDES Quality Assurance Manager: ______________________
Signature/Date
Vincent Perelli, NHDES

For Receipt:

EPA Nonpoint Source Program Coordinator:

____
Signature/Date
Erik Beck, EPA Region 1

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3-Distribution List

Table 1 lists people who will receive copies of the approved Site Specific Project Plan (SSPP) for "Lake Warren Watershed Management Plan Development and Implementation, Phase 1" under the *New Hampshire Section 319 Nonpoint Source Grant Program Quality Assurance Project Plan* dated August 23, 2013.

Table 1. SSPP Distribution List.

Name	Project Role	Organization	Phone/E-mail
Lisa Murphy	Project Manager	Southwest Regional Planning Commission	lmurphy@swrpc.org
Forrest Bell	Technical Project Manager/QA Officer	FB Environmental	207-221-6699 info@fbenvironmental.com
Laura Diemer	Task Manager, Water Quality Specialist, Modeling	FB Environmental	207-221-6699 laurad@fbenvironmental.com
Jeff Marcoux	NHDES Project Manager	NHDES, Watershed Management Bureau	jeffrey.marcoux@des.nh.gov
Jillian McCarthy	Program QA Coordinator	NHDES	603-271-8475 jillian.mccarthy@des.nh.gov
Vincent Perelli	NHDES QA Manager	NHDES	603-271-8989 vincent.perelli@des.nh.gov
Erik Beck	EPA NPS Program Coordinator	EPA Region 1	617-918-1606 beck.erik@epa.gov

4-Project Organization

Figure 1 outlines the organizational structure of project personnel. Table 2 identifies their specific roles and responsibilities. The Southwest Region Planning Commission (SWRPC) received Federal funding under Section 319(d) of the Clean Water Act obtained through an agreement with the NH Department of Environmental Services (NHDES) in order to develop a Watershed Management Plan and Implementation Project, Phase I, for Lake Warren in Alstead, NH.

FB Environmental Associates (FBE) was selected as the technical consultant to help complete the scope of services for the SWRPC. FBE Technical Project Manager, Forrest Bell, will provide project oversight, technical expertise, and serve as the main point of contact for the SWRPC and project partners.

Laura Diemer will also provide technical expertise and oversight for key modeling tasks including the land use modeling, in-lake phosphorus and assimilative capacity analysis, and pollutant load reduction estimates. As the QA officer, Forrest will ensure that survey results and modeling results have been reviewed and double-checked for potential inconsistencies.

Figure 1. Project Organizational Chart

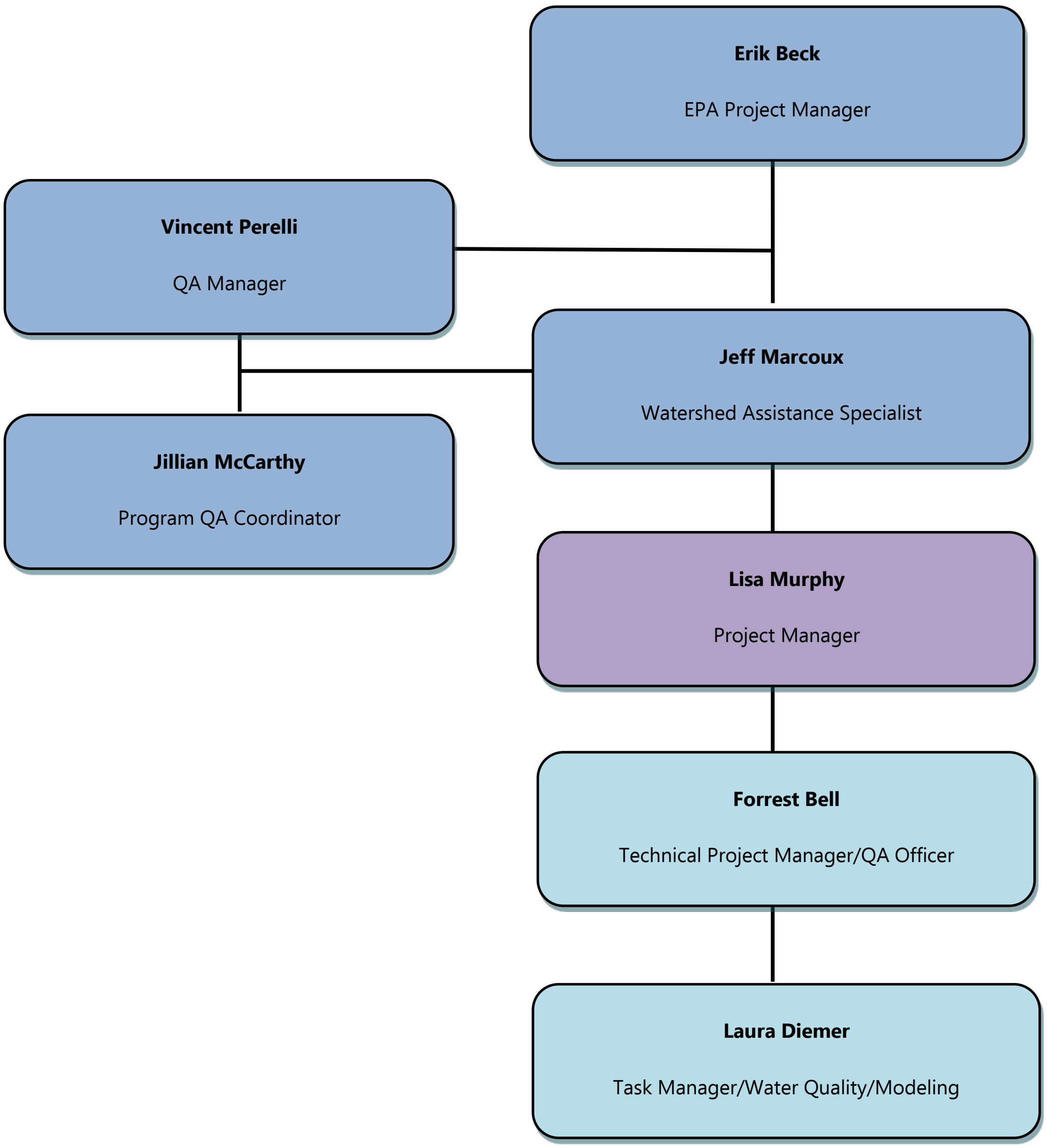


Table 2. Key Project Personnel Responsibilities and Qualifications

Name and Affiliation	Responsibilities	Qualifications
Lisa Murphy Southwest Regional Planning Commission	Project Manager	On file at SWRPC
Forrest Bell FB Environmental	Technical Project Manager; QA Officer	On file at FB Environmental
Laura Diemer FB Environmental	Task Manager, Water Quality, Pollutant Load Modeling	On file at FB Environmental
Jeff Marcoux, NHDES Watershed Management Bureau	Reviews and oversees projects funded by NHDES 319 Restoration Grants in Merrimack Basin	On file at NHDES
Jillian McCarthy, NHDES Watershed Management Bureau	Reviews QAPP preparation and other QA/QC activities	On file at NHDES
Vincent Perelli, NHDES Planning, Prevention & Assistance Unit	Reviews and approves QAPPs	On file at NHDES
Erik Beck US EPA Region I	EPA Project Manager	On file at US EPA

5-Site Information

The Lake Warren watershed is located in the southwestern portion of New Hampshire in the Town of Alstead. Lake Warren is approximately 185.5 acres and is a relatively shallow lake with a maximum depth of 13.8 feet and a mean depth of 7.2 feet. The entire watershed for Lake Warren lies within the Town of Alstead. The Lake Warren watershed is part of the larger Cold River watershed (see Appendix A for map).

6-Project Rationale

Phosphorus is a limiting nutrient in freshwater ecosystems. Excess phosphorus in these systems can lead to nuisance algal blooms and low water clarity. High levels of phosphorus in freshwater lakes and streams are often associated with human activities resulting from stormwater runoff, excessive use of fertilizer, and poorly maintained/malfunctioning septic systems

Lake Warren is listed on New Hampshire's draft 2012 Section 303(d) Surface Water Quality List (NHDES 2012) of impaired waters by the New Hampshire Department of Environmental Services (NHDES) as impaired for Aquatic Life Use due to chlorophyll-a, total phosphorus levels, and pH. However, Lake Warren also serves as an important resource for recreational activities in the Town of Alstead. The Southwest Region Planning Commission and the Lake Warren Association have been active participants in multiple watershed planning efforts to improve the water quality of Lake Warren, including a recent NHDES 604b grant. These efforts include a watershed survey, an assessment of data, a model to identify sources of pollution to the Lake, and an action plan including specific actions for reduction of phosphorus in the lake. The 2014 Lake Warren Modeling Report completed as part of the 604b grant identified stormwater runoff (103.7 kg/year) and septic systems (23.5 kg/year) as the largest contributors of phosphorus to Lake Warren. The 2014 Lake Warren

Monitoring Report also determined that a 28% reduction in phosphorus loading to Lake Warren was needed to restore water quality.

The project team hopes to continue the work supported in past efforts through the Lake Warren Watershed Management Plan Development and Implementation Project, Phase I. The desired outcome of this project is to complete an EPA-approved watershed-based plan to ultimately set a course to improve water quality in Lake Warren to the point it could be removed from the State's List of Impaired Waters. A further goal is to complete demonstration projects by installing Best Management Practices (BMPs) aimed at reducing stormwater runoff at two locations on town-owned property, and to raise public awareness for future phases of this project.

7-Project Description and Schedule

The Southwest Region Planning Commission currently has a 604b grant for the development of pieces of a watershed-based plan for Lake Warren. Although many of the pieces of a complete nine-element watershed-based plan have been accomplished under the existing 604b grant, more work needs to be done to complete this plan. This remaining work is described below, and also includes the assembly of the plan into one cohesive document. Though the plan is not yet complete, beginning to implement the structural BMPs listed in the 2014 Lake Warren Action Plan now would reduce phosphorus loading to Lake Warren and act as demonstration sites to garner public and municipal support for this project. These activities will be complemented by a targeted public outreach and education campaign to facilitate community understanding of septic systems and stormwater management.

The 2014 Lake Warren Action Plan presents specific action items, including both structural and non-structural BMPs that could be employed to reduce phosphorus loading to the lake. A missing piece in the Action Plan is to determine overall pollutant loading that would occur by implementing projects in the plan, particularly at the individual BMP scale. This information would help the Town of Alstead and its partners prioritize sites for implementation. In the Lake Warren Watershed Management Plan Development and Implementation Project, Phase 1, BMPs on Pine Cliff Road and at the Town Boat Launch are expected to reduce the phosphorus loading to the Lake by 22.6 kg/year and 8.3 kg/year of Total Phosphorus, respectively (see Appendix B for map). Load reductions for other proposed BMPs identified in the watershed plan would be estimated through this project. These reductions will be used as part of a prioritization exercise to rank sites for feasibility and effectiveness of implementation.

Completion of the following tasks will occur:

1. **Complete an EPA nine-element watershed-based plan**
    a. <u>BMPs and Phosphorus Reduction</u>
    Determine Total Phosphorous (TP) reduction of proposed BMPs from the 2013 Lake Warren Watershed Survey using the Region 5 Model to determine the overall reduction in phosphorus with the implementation of the proposed BMPs. Cost

estimates will be prepared for each BMP site, with sites ranked for prioritization based on total phosphorus reduction/cost (August - November 2015).

b. Environmental Milestones, Success Indicators, and Monitoring
   i. Develop a series of environmental milestones for Lake Warren based on water quality data and goals (from 2014 Lake Warren Monitoring Report) and input from stakeholders (September - October 2015).
   ii. Develop series of success indicators for Lake Warren based on water quality data and goals and input from stakeholders (September - October 2015).
   iii. Obtain and review current monitoring data for Lake Warren, provide recommendations on future monitoring needs based on existing data (September - October 2015).
c. Assemble all information into a nine-element watershed based plan
   Develop draft watershed plan (January 2016-October 2016), and incorporate edits from NHDES into a final watershed plan (October -December 2016).

2. Outreach and Education

a. Review and Update Lake Warren Action Plan
   i. Review existing action plan previously developed for Lake Warren and organize an Action Plan Prioritization meeting with stakeholders and interested parties to prioritize the list (August-October 2015).
   ii. Review information gathered at the Action Plan Prioritization meeting and update existing action plan based on meeting outcome (October 2015-December 2015).
b. Presentations
   i. Prepare presentation to demonstrate the need for stormwater management and remediation needed to eliminate erosion into Lake Warren from Town-owned locations (December 2016).
   ii. Present watershed plan to municipal staff (December 2016)
   iii. Develop and distribute outreach materials to members of the Lake Warren Association and the Alstead community with information on BMP demonstration sites (July 2016).

3. Implementation of two BMPs on Town-owned properties

a. Work with the Alstead Department of Public Works and the project engineer to assess the two identified BMP sites on Pine Cliff Road and at the Town Boat Launch to determine the level of effort, cost and feasibility of each of the potential sites (August 2015).
b. Select the BMP sites based on input from the town staff and Action Plan Prioritization meeting. Prepare draft design plans of the BMP installations (September – December 2015), and finalize designs (May 2016).
c. Install the two demonstration BMPs on town-owned property (June 2016).

d. Calculate pollutant load reduction estimates attributable to the installed BMPs using the Region 5 model. Submit Pollutant Load Reduction reports to NHDES. Complete photo documentation and installation summaries and submit to NHDES (August 2016).
e. Develop operation and maintenance (O&M) plans to document O&M activities including, but not limited to: description of O&M activities to be performed on management practices; schedule of activities to be performed; responsible parties; record keeping and retention (September 2016)

8-Historical Data Information

The Lake Warren Association (LWA) was awarded a watershed grant by the New Hampshire Department of Environmental Services, with funds from the U.S. Environmental Protection Agency watershed grants program under section 604(b) of the Clean Water Act. Together with the Southwest Region Planning Commission (SWRPC), the LWA developed the Lake Warren Comprehensive Lake Inventory and Management Plan. As part of this plan, a watershed survey was conducted by project consultants (FB Environmental Associates) in 2013 and focused on locating potential sources of phosphorus and sediment throughout the watershed. In addition to non-point source pollution, the 2013 survey also aimed to gather information about septic systems throughout the watershed that may be a threat to water quality in Lake Warren. As a follow-up to this survey, a nutrient loading study of Lake Warren was conducted in 2014 (2014 Lake Warren Modeling Report) as well as a water quality assessment (2014 Lake Warren Monitoring Report). Project consultants developed the 2014 Lake Warren Action Plan to lay out specific action items, including both structural and non-structural BMPs that could be employed to reduce phosphorus loading to the lake. These reports are on file with FB Environmental Associates.

9-Establishing Water Quality Goals

Potential pollution threats to water quality include stormwater runoff, development, recreation, septic systems, erosion, and land-use practices. The goal of this project is to protect surface waters in the watershed from these threats by developing a watershed-based management plan that will establish in-lake and watershed load reduction goals for phosphorus. Establishment of water quality goals in the Lake Warren Watershed Management Plan Development and Implementation Project, Phase 1 project will be guided by the water quality analysis in the 2014 Lake Warren Monitoring Report and watershed load modeling in the 2014 Lake Warren Modeling Report.

The Lake Loading Response Model (LLRM) analyzed in the 2014 Lake Warren Modeling Report found that stormwater runoff (103.7 kg/year) and septic systems (23.5 kg/year) are the largest contributors of phosphorus to the lake. Based on the NHDES assimilative capacity analysis conducted as part of the 2014 Lake Warren Monitoring Report, Lake Warren exceeds the water quality threshold for oligotrophic lakes. This is because there is no remaining reserve assimilative capacity (classified as a Tier 1 waterbody). The assimilative capacity of a waterbody describes the amount of pollutant that can be added to that waterbody without causing a violation of the water quality criteria. A reduction of at least 2.8 ppb (~28% reduction from current TP) of phosphorus is needed in Lake Warren to meet the Oligotrophic water quality threshold for total phosphorus. In addition, the response indicator Chl-a ultimately determines if the lake will be listed as impaired for Aquatic Life Use. As Chl-a is also not supporting in Lake Warren, the lake is considered "impaired" for Aquatic Life Use under the oligotrophic classification.

10-Loading Models

Region 5 Model

The load reduction model used for this project is the Region 5 Load Estimation Model, developed by the State of Michigan Department of Environmental Protection and Illinois EPA. The original version of the model was created in 1999 and was revised in 2002 to include a new worksheet, containing state and county names, correction factors, and the USLE parameter values summarized from the 1997 National Resources Inventory database. Two of the original worksheets for Gully and Bank Stabilization have been modified to allow users the option to input site-specific data instead of using default values. The user manual was revised in 2002 by EPA to correspond to changes made to the model.

The Region 5 Load Estimation Model is recommended by EPA and by NHDES for use on Section 319 grant projects. This model measures pollutants that are associated with stormwater runoff (sediment and nutrients) and is appropriate for this project. The Region 5 Model will adequately assess the load reductions as appropriate for the scale and required accuracy of the project. In addition, the Region 5 Model is used for similar projects in NH, which will make the model analysis comparable with other sites. No modifications will be made to the model for this project.

If problems occur with the model, the NHDES Project Manager will be contacted. If NHDES staff are unable to correct the problem, EPA and Tetra Tech, Inc., the contractor assigned to the STEPL and Region 5 Models will be contacted for assistance in correcting the problem.

11-Quality Objectives and Criteria

The utility of model outputs, and the confidence in decisions made based on those outputs, are only as strong as the data used to build and calculate the model. FBE will make certain that all data used to inform model outputs have gone through careful QA/QC analyses.

The data collected for this project includes data required by the Region 5 Load Estimation Model – Urban Runoff Worksheet. The Region 5 Load Estimation Model is an EPA-approved model for Section 319 projects. The model documentation includes the R5 Load Estimation Model Field Data Entry Sheet – Urban Runoff form that defines the necessary input data (http://tinyurl.com/R5ModelDataSheet). This information is on file at the SWRPC and with the

Contractor (FBE). The Region 5 model gives default values for many inputs in the User's Manual, but requires that the following site-specific information be collected in the field: BMP type and contributing drainage area by land use type (in acres). The approval and endorsement of this model by EPA ensures that the right type, quantity, and quality of data are collected for this project as presented in the Field Data entry form.

Data collected will meet specifications outlined in the Region 5 Load Estimation Model manual "Pollutants Controlled Calculation and Documentation for Section 319 Watershed Training Manual" which was prepared by the State of Michigan Department of Environmental Quality. To collect the data required for the model and the equations, a field data sheet will be filled out during the pre- and post-construction site visits for each installed BMP. The information on the field data sheets will be used to populate the pollutant load reduction model. The model output will estimate the pollutant load reductions likely to be achieved once the BMPs are installed. The Contractor (FB Environmental), the Town of Alstead, and NHDES will use the model and equation output data to measure progress toward attaining water quality standards.

12-Quality Control

Installation of two demonstration BMPs on Town-owned properties: Installation locations for the two demonstration BMPs will be selected based on prioritization recommendations in the 2014 Lake Warren Action Plan and feasibility of installation. The Contractor will create a draft design for each BMP and submit the designs to NHDES for review. If necessary, the Contractor will obtain all applicable State and/or local permits for the work. After revision, final design plans will be submitted to NHDES for review. BMP installations will be photo documented using the NHDES Photo Documentation Procedure for Measuring the Success for Restoration Projects and Best Management Practices (on file at NHDES). The Contractor will also develop Operation and Maintenance (O&M) plans to document O&M activities related to the installed BMPs including, but not limited to, description of O&M activities to be performed on BMPs, schedule of activities to be performed, responsible parties, record keeping, and retention.

Pollutant Reduction Modeling: The Region 5 Load Estimation Model and Bacteria Load Reduction Equations will be used for this project. The data collected for input to the model and equation will be collected in accordance with the Field Data Entry Sheet provided with the model (http://tinyurl.com/R5ModelDataSheet). The data sheet will be checked for completion prior to leaving the site. When running the model and equation, a second person will verify the input values to prevent transcription errors. In addition, a duplicate run, conducted by a second trained modeler will be done each time the model is used. This will further reduce transcription errors and ensure proper estimates. The Contractor will perform these tasks. If transcription or model errors are identified, the Contractor shall correct the error or, if unable to correct the error, the Contractor will consult with the NHDES Project Manager or Tetra Tech staff for assistance. Prior to each model run, project staff will check the EPA Tetra Tech Region 5 model web site for updates to the model or field sheets prior to conducting the field work and/or running the model (http://it.tetratech-ffx.com/steplweb/models$docs.htm). The most up-to-date model and field sheets will be used.

13–Data Evaluation of Load Reduction Estimates

All observations, trends, conclusions, and limitations in the data will be documented and reported. Field sheets will be used and checked for completeness in the office before being entered into digital spreadsheets for final analyses. The Contractor will be responsible for evaluating any data. For the Region 5 Load Estimation Model, pre-implementation loading estimates will be compared to the post-implementation measurements to determine the load reductions achieved for the installed BMPs.

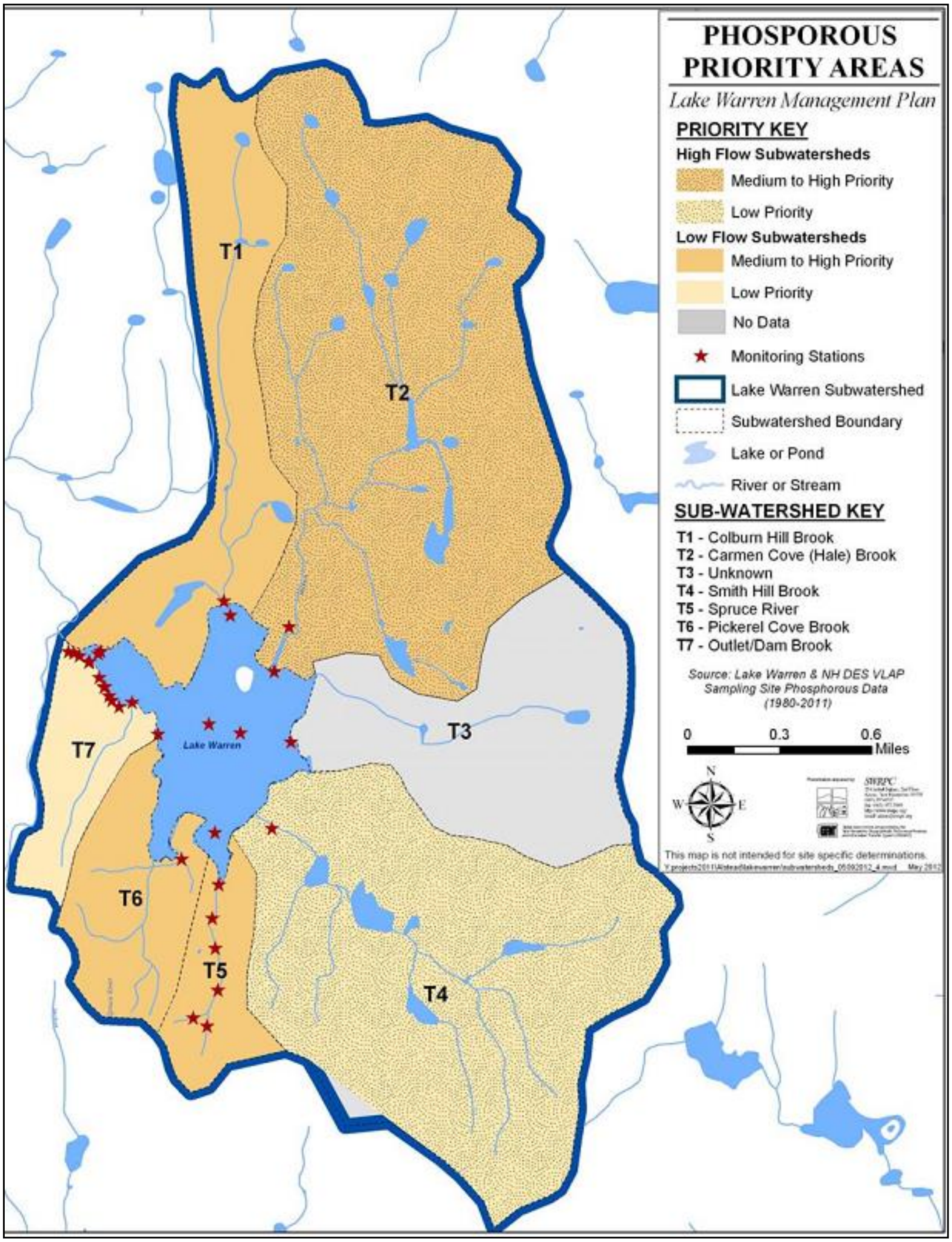
14-Final Products and Reporting

Final products for this project will be submitted by FBE and SWRPC and include the following:

- Approved Site Specific Project Plan under the New Hampshire Section 319 Nonpoint Source Grant Program QAPP for the Pollutant Reduction Modeling (RFA# 08262, 08/2313) – August 2015.
- A nine-element watershed based plan that meets the EPA's requirements – December, 2016.
- Final pollutant load reduction estimates, Pollutants Controlled Reports (PCR), NPS site reports, and Operation & Maintenance plans for installed BMPs – October, 2016.

Semi-annual reports documenting all work performed on the project at the appropriate intervals throughout the duration of the project will be submitted to NHDES by the Project Manager, Lisa Murphy, as required in the contract. The semi-annual reports shall comply with the NHDES and EPA requirements found in the semi-annual report guidance document provided to grant recipients by NHDES. A comprehensive final report in both electronic and hard-copy will be submitted to NHDES on or before the project completion date by the Project Manager, Lisa Murphy. The final report shall include a description of all tasks completed and shall comply with the NHDES and EPA requirements found in the final report guidance document provided to grant recipients by NHDES.

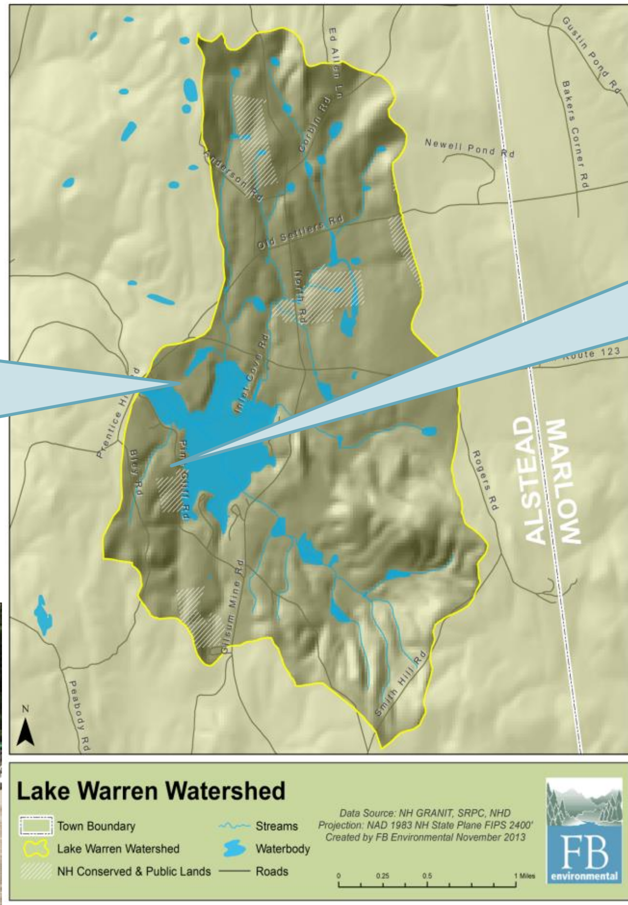
Appendix A: Lake Warren Watershed Map (from SWRPC, 2012)



Appendix B: Lake Warren Watershed and Proposed BMP Locations

Lake Warren Watershed – Potential Project Sites

Location: Town Boat Launch
Problem: Severe erosion on road to Town Boat Launch
Potential Solution: Reshape road; stabilize road shoulders and include turnouts.
Outreach: This site would serve as a demonstration site for water quality, surface runoff, and the need for Best Management Practices on Lake Warren. Informational materials would be posted at an existing kiosk at this site (in photo below).



Location: Pine Cliff Road (town owned)
Problem: Erosion on road; lack of buffer between road and lake; incorrect road pitch; road width; excessive "road dust."
Potential Solution: Reshape road; decrease width of road; install turnouts; stabilize shoulder.
Outreach: Hold a workshop for municipal staff and road agents about proper road shaping techniques and road BMPs.

APPENDIX F: SELECT NUTRIENT MODELING RESULTS

Table F-1. Summary of land area, water flow, and TP loading by sub-basin.

Subwatershed Area	Land Area (ha)	Water Flow (m^3/yr)	Model Result (TP mg/L)	Model Result (TP kg/year)	Model Result (TP kg/ha/yr)	Phosphorus Attenuation Factor*
Coburn Hill Brook	123	753,211	0.013	9.5	0.08	0.50
Hale Brook/Carmen Cove	376	2,226,674	0.016	36.5	0.10	0.50
Direct Drainage	101	639,446	0.037	24.0	0.24	0.95
Eastern Tributary	142	906,651	0.020	18.4	0.13	0.85
Smith Hill Brook	313	2,072,169	0.016	33.5	0.11	0.95
Spruce River	51	336,062	0.020	6.6	0.13	0.65
Pickerel Cove	45	281,204	0.014	4.0	0.09	0.65
Scotland Yard (formerly Outlet/Dam Brook)	29	194,457	0.021	4.1	0.14	0.95

**Phosphorus attenuation factor. 1=no attenuation, 0=full attenuation.*

APPENDIX G: WATERSHED AND SHORELINE SURVEY RESULTS

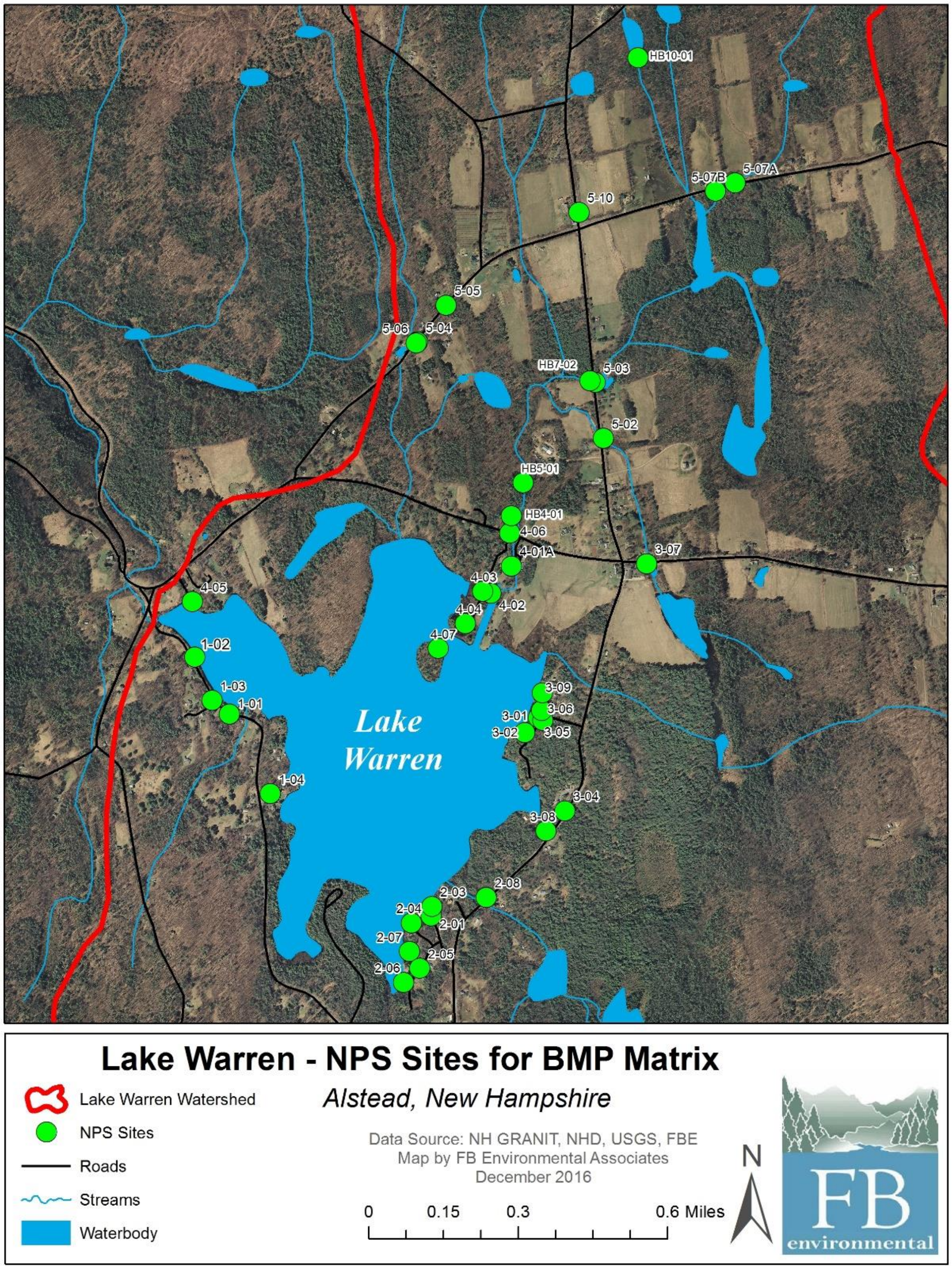


Figure G-1. Map of watershed survey NPS pollution site locations.

Table G-1. Descriptions of watershed survey NPS pollution locations.

Prioritized BMP Matrix. Some sites required multiple entries in the model and have more than one pollutant load. The sum of pollutant loads for each site is used to calculate the cost per kg of P removed. Sites with "0.0" for pollutant reductions have reductions less than 0.1 lbs or tons per year. TP = total phosphorus. TBD = estimate to be determined based on design finalization.

Priority Ranking	Site	Land Use	Impact Rating	Category	TP (kg/yr)*	Cost/ kg P removed	BMP Cost Estimate	BMP Annual Maintenance Cost Estimate	10-yr Cost	10-yr Cost per TP removed ($/kg)	Cost	Technical Level	Recommendation
1	4-06	town road	medium	Public Road	0.7	$310	$225	$25	$475	$654	low	medium	Riprap ditch.
2	HB7-02	stream corridor	medium	Stream Corridor	2.2	$830	$1,800	$50	$2,300	$1,061	low	low	Vegetate with trees/shrubs to stabilize bank.
3	4-02	residential	medium	Shoreland	3.5	$759	$2,650	$133	$3,975	$1,138	medium	low	Divert runoff into wooded areas; vegetate with live willow stakes in banks and vegetated buffer adjacent to field.
4	5-07B	town road	medium	Public Road	0.9	$1,282	$1,163	$25	$1,413	$1,558	low	medium	Riprap and reshape ditch; remove grader/plow berms.
5	3-04	residential /town road	medium	Shoreland	1.2	$1,388	$1,700	$70	$2,400	$1,960	low	medium	Install runoff diverter (water bar); armor around culvert
6	5-05	town road	high	Public Road	2.3	$2,352	$5,440	$544	$10,880	$4,703	high	high	Riprap and reshape ditch; install check dams and sediment pools; remove grader/plow berms; add new surface material (gravel)

Priority Ranking	Site	Land Use	Impact Rating	Category	TP (kg/yr)*	Cost/ kg P removed	BMP Cost Estimate	BMP Annual Maintenance Cost Estimate	10-yr Cost	10-yr Cost per TP removed ($/kg)	Cost	Technical Level	Recommendation
7	3-06	private driveway, residential	medium	Shoreland	0.7	$1,798	$1,305	$41	$1,710	$2,356	low	medium	Install vegetated buffer; armor with stone; install turnouts; building foundation threatened (may require engineering).
8	HB5-01	stream corridor	medium	Stream Corridor	0.6	$2,490	$1,440	$50	$1,940	$3,354	low	medium	Install 2 rootwads/log jams.
9	4-07	private land	low	Shoreland	0.5	$1,587	$720	$36	$1,080	$2,381	low	low	Install vegetated buffer near the high erosion areas.
10	5-10	town road	medium	Public Road	1.5	$3,117	$4,525	$110	$5,625	$3,875	high	high	Riprap ditch; remove culvert clog; install check dams.
11	3-05	private driveway	medium	Shoreland	0.7	$3,100	$2,250	$60	$2,850	$3,927	low	medium	Install turnouts and runoff diverters; riprap and reshape ditch.
12	1-03	private road	medium	Shoreland	1.2	$3,007	$3,546	$187	$5,418	$4,594	high	medium	Regrade and add new surface material; riprap ditch.
13	HB4-01	stream corridor	medium	Stream Corridor	0.6	$3,735	$2,160	$50	$2,660	$4,599	medium	medium	Install 3 rootwads/log jams.
14	2-04	residential /beach access (shared/private)	low	Shoreland	0.3	$1,947	$530	$38	$910	$3,344	low	low	Stabilize foot path with erosion control mulch; install runoff diverter.

Priority Ranking	Site	Land Use	Impact Rating	Category	TP (kg/yr)*	Cost/ kg P removed	BMP Cost Estimate	BMP Annual Maintenance Cost Estimate	10-yr Cost	10-yr Cost per TP removed ($/kg)	Cost	Technical Level	Recommendation
15	2-05	residential	medium	Shoreland	0.2	$4,823	$875	$25	$1,125	$6,201	low	high	Armor culvert inlet/outlet; riprap ditch; unclog culvert pipe.
16	3-02	driveway	low	Shoreland	0.2	$3,307	$750	$25	$1,000	$4,409	low	medium	Regrade driveway; install runoff diverter.
17	4-04	private road	low	Shoreland	0.2	$3,549	$644	$32	$966	$5,324	low	low	Install turnout; reshape ditch; reseed grassed and bare areas.
18	3-09	residential	medium	Shoreland	0.4	$5,556	$2,268	$113	$3,402	$8,333	medium	low	Install vegetated buffer; install runoff diverters and turnouts.
19	5-03	town road	high	Public Road	0.2	$18,188	$3,300	$36	$3,660	$20,172	medium	high	Enlarge culvert; riprap ditch.
20	5-06	town road	medium	Public Road	0.1	$8,267	$750	$25	$1,000	$11,023	low	high	Riprap and reshape ditch; remove grader/plow berms and add gravel to roadway.
21	5-07A	Town road (with Ag across the road)	medium	Public Road	0.0	$5,512	$250	$25	$500	$11,023	low	medium	Armor culvert.
22	5-04	town road	medium	Public Road	0.1	$10,288	$1,400	$48	$1,875	$13,779	low	high	Riprap and reshape ditch; install check dams and sediment pools; remove grader/plow berms and add new surface material (gravel).

Priority Ranking	Site	Land Use	Impact Rating	Category	TP (kg/yr)*	Cost/ kg P removed	BMP Cost Estimate	BMP Annual Maintenance Cost Estimate	10-yr Cost	10-yr Cost per TP removed ($/kg)	Cost	Technical Level	Recommendation
23	5-09	town road	low	Public Road	0.0	$4,409	$200	$25	$450	$9,921	low	medium	Armor culvert inlet/outlet.
24	3-08	driveway	medium	Shoreland	0.1	$14,354	$1,255	$44	$1,690	$19,329	low	medium	Install plunge pool for culvert drainage; Install runoff diverter; vegetate turnout areas.
25	2-08	town road	low	Public Road	0.1	$11,023	$1,000	$25	$1,250	$13,779	low	high	Armor culvert inlet/outlet; stabilize roadside around culvert; stabilize gully near the ditch draining to culvert.
26	5-02	town road	high	Public Road	0.1	$40,786	$3,700	$44	$4,140	$45,636	medium	high	Enlarge and stabilize culvert; riprap ditch.
27	HB10-01	stream corridor	low	Stream Corridor	0.1	$16,702	$1,800	$50	$2,300	$21,341	medium	medium	Install bridge for ATV crossing.
28	1-02	town road	high	Public Road	0.4	$46,960	$16,800	$840	$25,200	$70,440	high	low-high	Reshape road crown and narrow the road; vegetate shoulder/add to buffer along the lake.
29	2-01	private road	medium	Shoreland	0.1	$29,898	$1,635	$47	$2,101	$38,411	low	medium	Reshape road crown; install runoff diverters; install detention basin.
30	4-01A	residential /private road	medium	Shoreland	0.2	$27,099	$4,800	$240	$7,200	$40,649	high	low	Vegetate shoulder of driveway; fix gully.
31	1-04	driveway	low	Shoreland	0.0	$25,376	$750	$25	$1,000	$33,834	low	low	Install runoff diverters (broadbased dip).

Priority Ranking	Site	Land Use	Impact Rating	Category	TP (kg/yr)*	Cost/ kg P removed	BMP Cost Estimate	BMP Annual Maintenance Cost Estimate	10-yr Cost	10-yr Cost per TP removed ($/kg)	Cost	Technical Level	Recommendation
32	1-01	residential	medium	Shoreland	0.1	$49,163	$7,200	$120	$8,400	$57,357	high	medium	Install vegetated buffer; stabilize seawall.
33	2-03	residential	medium	Shoreland	0.1	$46,281	$2,560	$64	$3,200	$57,852	medium	low	Install vegetated buffer; stabilize seawall.
34	3-07	state road	medium	Public Road	0.1	$90,275	$8,300	$290	$11,200	$121,817	high	high	Enlarge culvert; vegetate road shoulder; riprap ditches; discontinue plowing snow into wetland area.
35	2-07	residential / beach access	medium	Shoreland	0.0	$87,698	$1,800	$90	$2,700	$131,547	low	low	Install vegetated buffer.
36	2-06	residential	medium	Shoreland	0.0	$139,203	$4,800	$240	$7,200	$208,804	high	low	Enhance vegetated buffer.
37	4-03	private road with ROW	medium	Shoreland	0.0	$171,473	$5,420	$472	$10,140	$320,799	high	medium	Regrade road; install runoff diverters.
38	3-01	residential /boat access	medium	Shoreland	0.0	$477,669	$520	$36	$884	$812,037	low	low	Install infiltration trench at dripline; add rain barrel.
39	5-08	town road	low	Public Road	NA	NA	$1,500	$25	$1,750	NA	low	high	Enlarge culvert.
40	4-05	town road, boat access	low	Public Road	0.1	NA	TBD	TBD	TBD	NA	high	high	Install runoff diverters; riprap road sides.
				TOTAL	**19.8**		**$103,731**	**$4,424**	**$147,969**				