Lake Sunapee Watershed Management Plan

March 2020

LSPA

Devoted to the Environmental Quality of the Lake Sunapee Watershed

FOUNDED 1898

Lake Sunapee Watershed Management Plan

Prepared by Lake Sunapee Protective Association, DK Water Resource Consulting and Stone Environmental

Contact:

Lake Sunapee Protective Association (LSPA)
63 Main Street
Sunapee, NH 03782
(603) 763-2210
www.lakesunapee.org

This project was partially funded by a Watershed Assistance Grant administered by the NH Department of Environmental Services with funds from Section 319 of the Federal Clean Water Act.

DK Water Resource Consulting LLC

STONE ENVIRONMENTAL
100% EMPLOYEE OWNED

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

LSPA, founded in 1898, is a member supported nonprofit organization dedicated to preserving and enhancing the special environment of the Lake Sunapee Region through education, research and collaborative action.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF DOCUMENTS INCLUDED IN APPENDICES

Executive Summary

Multiple signs indicate that the historically high-quality waters of Lake Sunapee and other waterbodies in the Lake Sunapee Watershed are threatened. Recent trends in water quality data, especially near-shore and in some of the tributaries, lakes, and ponds flowing into Lake Sunapee, show a slow decline. Increasing levels of phosphorus, increasing amounts of algae growth and periodic localized cyanobacteria blooms are occurring. Continuing development in the watershed and more frequent severe storm events, due to climate change, threaten to further this decline in water quality. On the surface these lakes and ponds appear to be healthy, but they remain in a very delicate balance.

This watershed management plan (WMP) addresses ways to improve current water quality in the face of the challenges mentioned above. This effort included the construction of a nutrient budget and setting a target value for phosphorus loading for the Sunapee Watershed. Limiting phosphorus loading to Lake Sunapee and associated algal growth in the lake is the overarching goal of this plan. In order to accomplish this, a goal was set to reduce phosphorus loading into Lake Sunapee by 100 kg/yr, a 7.5% decrease from current levels.

ON THE SURFACE THESE LAKES AND PONDS APPEAR TO BE HEALTHY, BUT THEY REMAIN IN A VERY DELICATE BALANCE

The in-lake summer epilimnetic phosphorus concentration in Lake Sunapee (5 µg/l) is currently below the New Hampshire state threshold for oligotrophic lakes (8 µg/l), however, dissolved oxygen depletion observed in the deep waters of Lake Sunapee suggest that Lake Sunapee does not support all of its designated uses all of the time. Using total phosphorus as a surrogate for the increased productivity that causes reduced dissolved oxygen concentrations, annual average phosphorus concentration of 5.9 µg/L should be reduced to 5.4 µg/L to reduce dissolved oxygen deficits and periodic cyanobacteria blooms.

Specific targeted measures (i.e. better managing stormwater runoff) to control phosphorus inputs into the lake from the watershed are presented and discussed in the plan and will be phased in over a period of ten years. These include both constructed and non-structural (i.e. zoning, ordinances, education and land conservation) solutions. Guidance for obtaining additional funding for phosphorus source control is presented along with an implementation schedule and milestones. Successful implementation of this watershed management plan will be based on the maintenance of in-lake total phosphorus concentrations at or below the phosphorus target (5.4 µg/l annual average). Enhancements to the current monitoring program are proposed to help evaluate the progress and effectiveness of control measures.

While the Lake Sunapee Watershed encompasses the watersheds of several waterbodies, the development of this plan for Lake Sunapee is expected to serve as a model for other lakes and ponds within the greater watershed.

Acknowledgements

Funding for this project was provided in part by a Watershed Assistance Grant from the NH Department of Environmental Services (NHDES) with Clean Water Act, Section 319 funds from the U.S. Environmental Protection Agency (USEPA).

Lake Sunapee Protective Association (LSPA) wishes to thank the following individuals and committee members who provided valuable input and helped put this plan together.

LSPA Staff

Geoff Lizotte, *Watershed Steward and GIS Specialist*
Susie Burbidge, *Water Steward and Program Coordinator*
Kathleen Stowell, *Education Director*
Nancy Brook-Heckel, *Environmental Education*
Teriko MacConnell, *Water Quality Lab Manager*
June Fichter, *Executive Director*
Sue Godin, *Office Manager*

Consultants & NHDES

Don Kretchmer, *DK Water Resource Consulting LLC*
Gabe Bolin, *Stone Environmental*
Jeff Marcoux, *NH Department of Environmental Services (Watershed Plan Assistance)*

Watershed Committee

Lisa Andrews, *LSPA Board Member; ASLPT Board Member*
Dave Beardsley, LSPA *Sunapee Town Rep*
Marla Binzel, Ph.D., *Springfield Conservation Commission*
Barbara Calhoun, *LSPA Board Member*
Regina Cockerill, *Newbury Planning Board*
Jerry Cooper, LSPA *Springfield Town Rep*
Tom Cottrill, LSPA *New London Town Rep*
Marjorie Dorr, *LSPA Former Board Member*
Karen Ebel, *Deputy Speaker of the New Hampshire House of Representatives (Newbury & New London)*
Rick Fingeroth, *LSPA Board Member*
Carol Foss, *Little Sunapee Protective Association (New London)*

<u>Watershed Committee</u> (continued)

Sue Gottling, *Sunapee Select Board, LSPA Board Member*
Charlie Hirshberg, P.E., *Environmental Engineer*
Katheryn Holmes, LSPA *Newbury Town Rep, Newbury Conservation Commission Chair*
Mike Jesanis, Sunapee
Jolyon Johnson, Sunapee
Jack Kutner, Sunapee
Betsy Lyons, *LSPA Board Member*
Nancy Marashio, *Newbury Town Moderator, LSPA Former Board Member*
Bill Robbins, *Sunapee*
Diane Robbins, *LSPA Board Member*
Steven C. Root, *President*, *Little Sunapee Protective Association (New London); ASLPT Board Member*
Becky Rylander, LSPA *Sunapee Town Rep*.
John Trachy, *Springfield*
Roger Wells, *Sutton Planning Board Chair*

<u>Water Advisory Group</u>

Nick Bear, *New London Health Officer, LSPA Board Member*
Marla Binzel, Ph.D., *Springfield Conservation Commission*
Tom Cottrill, LSPA *New London Town Rep.*
Charlie Hirshberg, P.E., *Environmental Engineer*
Betsy Lyons, *LSPA Board Member*
Kak Weathers, *LSPA Scientific Advisory Committee Chair*

1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The Lake Sunapee Watershed covers approximately 46.6 square miles or 29,832 acres, spans Merrimack and Sullivan Counties, and covers portions of the towns of Newbury, Springfield, Sunapee, New London, Sutton and Goshen (Appendix A, Watershed Towns Map 1). The Lake Sunapee Watershed is defined as the area of land and complex of wetlands, ponds, and tributaries which drain to Lake Sunapee (Appendix A, Watershed Relief Map 2). This area includes 13 named lakes and ponds throughout the watershed and 19 major tributary streams that drain directly into Lake Sunapee. There are also numerous smaller streams and brooks further upstream in the watershed. Most of the lakes, ponds and tributaries are explicitly covered in the modeling and recommendations associated with this plan.

Water quality in the open waters of Lake Sunapee is generally good and is representative of a low nutrient, low productivity (oligotrophic) system. However, water quality in lakes and ponds in the watershed and increasingly in embayments of Lake Sunapee show evidence of increased nutrient concentrations and associated increases in productivity. Specifically, the cyanobacteria, *Gloeotrichia echinulata* has been observed more frequently and in greater density in recent years. While the mechanism for increased prevalence of this species even in very low nutrient systems is currently being evaluated regionally, it is likely that increased phosphorus concentrations in the water column or in the sediments are at least a contributing factor (Cottingham et al. 2015). Changes in land use throughout the watershed are likely contributors to increased phosphorus loading to Lake Sunapee and upstream waterbodies. These include but are not limited to logging activity, development of residential housing, road maintenance, residential building and expansion, commercial development and development or redevelopment of lakefront properties. Water quality, particularly phosphorus concentrations and related cyanobacterial, algal and plant growth are elevated, at times, in many locations throughout streams, lakes and ponds in the Lake Sunapee Watershed and in Lake Sunapee itself. These factors support the need for a watershed assessment and management plan for the Lake Sunapee watershed to preserve water quality for the future.

The purpose of this plan is to support the preservation of Lake Sunapee water quality by identifying potential restoration measures to address identified watershed problems, encourage land use guidance to minimize or avoid future problems and educate stakeholders and landowners on ways to minimize the phosphorus footprint of individual parcels throughout the watershed. This document develops, assesses and prioritizes options to protect and improve water quality. It assembles new and existing watershed information, presents restoration plan options, and provides a “roadmap” for the Lake Sunapee Watershed. This plan is designed to be *dynamic* and *adaptive*. As new information is gained, the plan will be updated as needed.

This plan also provides a framework to leverage existing information and data sources. These resources include, but are not limited to, the following:

- LSPA water quality data and reports
- Volunteer Lake Assessment Program (VLAP) water quality data
- 2008 Lake Sunapee Watershed Plan
- NHDES guidance and fact sheets
- Town planning and zoning documents
- New Hampshire Department of Transportation (NHDOT) planning documents
- Regional planning documents
- Non-governmental organization (NGO) plans for conservation activities
- Lake and watershed associations throughout the watershed

All of this information is incorporated into this plan either explicitly or by reference. As related programs evolve or new programs with a shared mission to this watershed plan emerge, this plan should be modified to incorporate this information.

Specifically, this plan:

- quantifies primary sources of phosphorus loading using existing data and a watershed and lake response model;
- uses a buildout analysis approach to predict future phosphorus sources and loading rates;
- documents the development of a stakeholder derived water quality goal;
- prioritizes sources and makes recommendations for actions to reduce phosphorus loading to Lake Sunapee;
- includes an outreach program for residents and lake users about the sources and consequences of non-point source pollution and;
- includes Best Management Practice (BMP) designs to address sources.

This Plan is an update of the 2008 Management Plan for the Lake Sunapee Watershed (Sunapee Area Watershed Coalition and Granite State Rural Water Association 2008).

1.2 STATEMENT OF GOAL

This plan's goal of reducing non-point source pollutants that reach Lake Sunapee is in line with LSPA's mission of preserving and enhancing the special environment of the Lake Sunapee Region through education, research and collaborative action. The stakeholders have set an ambitious goal of reducing the amount of phosphorus loading over a ten-year period by 100 kg which is a 7.5% reduction in the current estimated amount entering the lake. If successful, this will improve the water quality of Lake Sunapee in the face of certain change due to developmental pressures and climate change.

1.3 INCORPORATING EPA'S NINE ELEMENTS

This section provides a roadmap to the nine elements required for watershed plans developed under USEPA guidance. The nine elements and section references are provided below.

A) Identify causes and sources of pollution

This element is satisfied in this report through work that spans several sections. The sources of phosphorus are identified in Section 3.4: Watershed Septic System Survey Assessment, Section 3.5: Water Quality Model and Section 3.6 Watershed Stormwater Survey Assessment.

B) Estimate load reductions needed

The loading model (Section 3.5) was used to evaluate the in-lake implications of the load reduction goal of 100 kg. This plan lays out proposed watershed actions (Section 5.3) that are needed to meet the goal.

C) Describe management measures and targeted critical areas

Plan Implementation (Section 5) provides guidance on education and outreach, research, further evaluation, monitoring and assessment, land conservation, land use regulation, zoning and ordinances, as well as, specific BMPs to address identified sources of phosphorus. These all will help LSPA meet the goal set out in Section 1.2.

A comprehensive list of structural BMPs was developed to address specific stormwater problem areas identified during the watershed surveys. These structural BMPs have been coupled with institutional controls and nonstructural BMPs to develop a suite of measures designed to mitigate phosphorus loadings to Lake Sunapee, over the life of this plan. The identification of stormwater problem areas and development of structural BMPs is explained further in Sections 4.2 and 5.3.7, while institutional and nonstructural controls are discussed in Section 4.2.2.

D) Estimate technical and financial assistance needed

LSPA will serve as lead in implementation of the action plan (Section 5.3) and seek technical assistance as needed such as engineering services and permitting guidance from local, state and federal authorities. Section 5.6 provides cost estimates for implementation of the plan including proposed BMP projects. These cost estimates will facilitate planning over the lifespan of this plan.

E) Develop an information and education program

LSPA currently has a comprehensive education and outreach program. For more details on the Education and Outreach Plan see Section 5.3.1.

F) Develop a project schedule

A schedule developed with input from stakeholders and LSPA is described in Section 5.5.

G) Describe interim measurable milestones

Milestones tied back to the water quality goal for plan implementation are discussed in Section 5.4, Indicators to Measure Progress

H) Identify indicators to measure progress

The monitoring plan described in Section 5.7 builds on the current LSPA monitoring program and provides data to describe the total phosphorus (TP), chlorophyll-*a* and transparency improvement in-lake as well as specific measures to evaluate effectiveness of BMPs and non-structural programs.

I) Develop a monitoring component

The existing monitoring program described in Section 5.7 is sufficient to establish baseline water quality and predict future trends for planning purposes on Lake Sunapee. To improve this program, project specific monitoring of plan elements was proposed to evaluate some BMP projects or critical subwatersheds with limited data in the current program. Areas where reallocation of monitoring resources would be beneficial was also suggested.

1.4 PLAN DEVELOPMENT AND COMMUNITY PARTICIPATION PROCESS

Water quality has been a keystone issue for the Lake Sunapee community since the 1950's. Beginning in the 1980's, LSPA has taken a lead role in education, water quality monitoring, watershed management and advocacy for Lake Sunapee. A historical timeline of the organization can be found in Appendix B. This watershed plan update represents an important step forward in the preservation of Lake Sunapee for the future.

LSPA was awarded a $50,000 grant under Section 319 of the federal Clean Water Act administered by NHDES. The grant partially funds the effort to update the 2008 existing watershed management plan so it satisfies all nine elements required by the EPA for watershed plans. A Request for Qualifications (RFQ) was developed and DK Water Resource Consulting, LLC was selected as the Principal Consultant/Technical Project Manager and Stone Environmental as the Engineering Task Manager. Throughout this document, the consultants in conjunction with the LSPA are referred to as the project team. Below is a timeline of events following the initiation of the grant:

April 12, 2018	First public meeting to inform stakeholders about the grant
June 2018	Grant Watershed Committee created to review recommended actions, water quality goal, and the overall plan
August 2018	Site Specific Project Plan (SSPP) completed First Watershed Committee meeting held at LSPA
October 2018	Watershed survey began
November 2018	FAQ document created about 2020 plan and posted on LSPA website
March 2019	Created brochure with an update on the WMP to be sent to everyone in the watershed
April 2019	Article published in local newspapers about the 2020 WMP (this led to an in-person interview with New Hampshire Public Radio)
May 2019	"Lake Sunapee Watershed Management Plan Update" brochure mailed to all residents in the watershed
Summer/Fall 2019	Water quality goal determined by Water Advisory Group Buildout analysis completed Articles in LSPA's newsletter, *the Beacon,* and e-newsletter the "*Flash of the Beacon*" with updates on the plan
September 2019	Septic system survey completed for all properties within 250 feet of a waterbody in the watershed
January 2020	Plan sent to Grant Watershed Committee to review Public meeting with presentation on final summary of plan
February 2020	Plan sent to NHDES for review

2. WATERSHED CHARACTERIZATION

2.1 LOCATION AND CLIMATE

The Lake Sunapee Watershed experiences seasonal temperature variations consistent with the temperate climate zone of the northeastern U.S. The warmest month of the year is July, with an average maximum temperature of 79 degrees Fahrenheit (°F), while the coldest month of the year is January, with an average minimum temperature of 8 °F (Figure 1) (US Climate Data, 2019).

The average annual precipitation is 47.6 inches (in), which includes an average snowfall amount of 61 inches in the Sunapee area. Precipitation is generally evenly distributed throughout the year, with a large part of the total annual runoff generated from spring snowmelt (Figure 1). Lake Sunapee is a dimictic lake meaning that the lake thermally stratifies in both the summer and winter (under ice cover) and mixes vertically twice per year in the spring and fall.

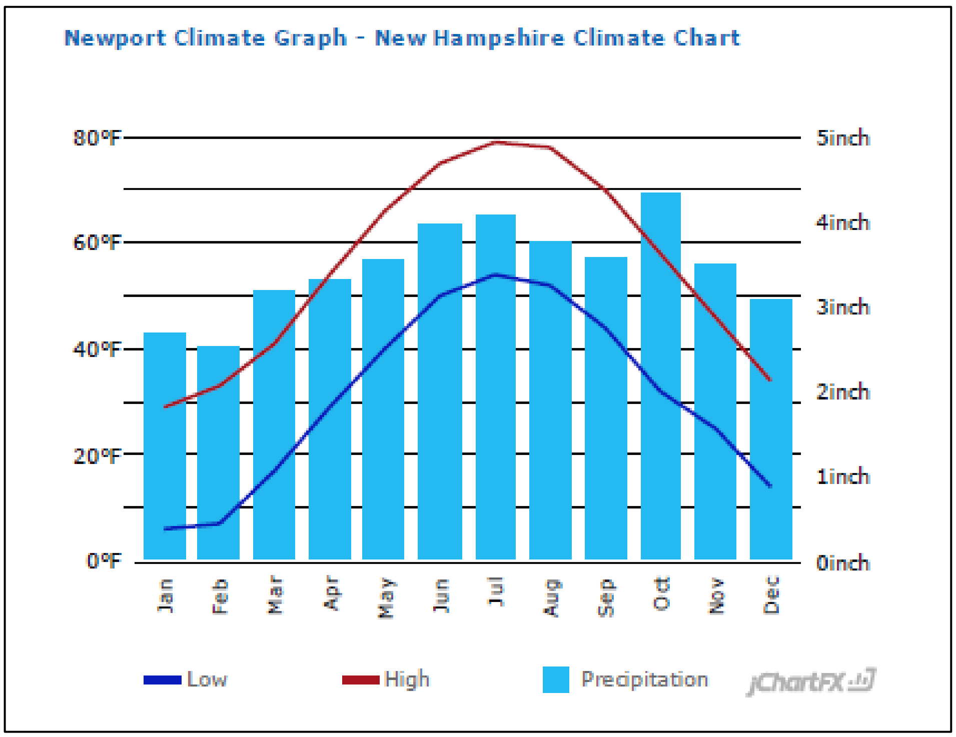

Figure 1. Temperature and Precipitation for Newport, NH (1981-2010) (US Climate Data, 2019).

Hydrologic changes are occurring throughout the northeastern United States and within the Sunapee Watershed [Dupigny-Giroux et al. 2018; Hayhoe et al. 2018]. These changes are most evident in the winter and spring seasons, where temperatures increases have led to advances in the timing of snowmelt and spring runoff by more than 10 days. Seasonal differences in temperatures have decreased as winter months have warmed three times faster than summer months, and the growing season has lengthened. Warmer winter temperatures have increased the fraction of precipitation that falls as rain instead of snow. Over the period 1958 to 2012, the amount of precipitation falling in the heaviest (highest 1%) precipitation events has increased 55% in the Northeastern U.S., including New Hampshire.

Historic weather data show that the climate of the Sunapee Lake Watershed is changing consistent with regional change. Temperature is increasing by 0.2 °F per decade (Figure 2). Precipitation is increasing by 1.19 inches per decade (Figure 3) and the duration of ice cover is decreasing (Figure 4) leading to a longer open water growing season.

Future conditions with warmer temperatures, more rainfall, more intense storms and a longer growing season are expected to increase phosphorus loading and be more favorable to cyanobacteria. Climate change, while a global issue should be accommodated in Lake Sunapee Watershed planning by reducing phosphorus loading further and accommodating increased runoff in any engineered solutions.

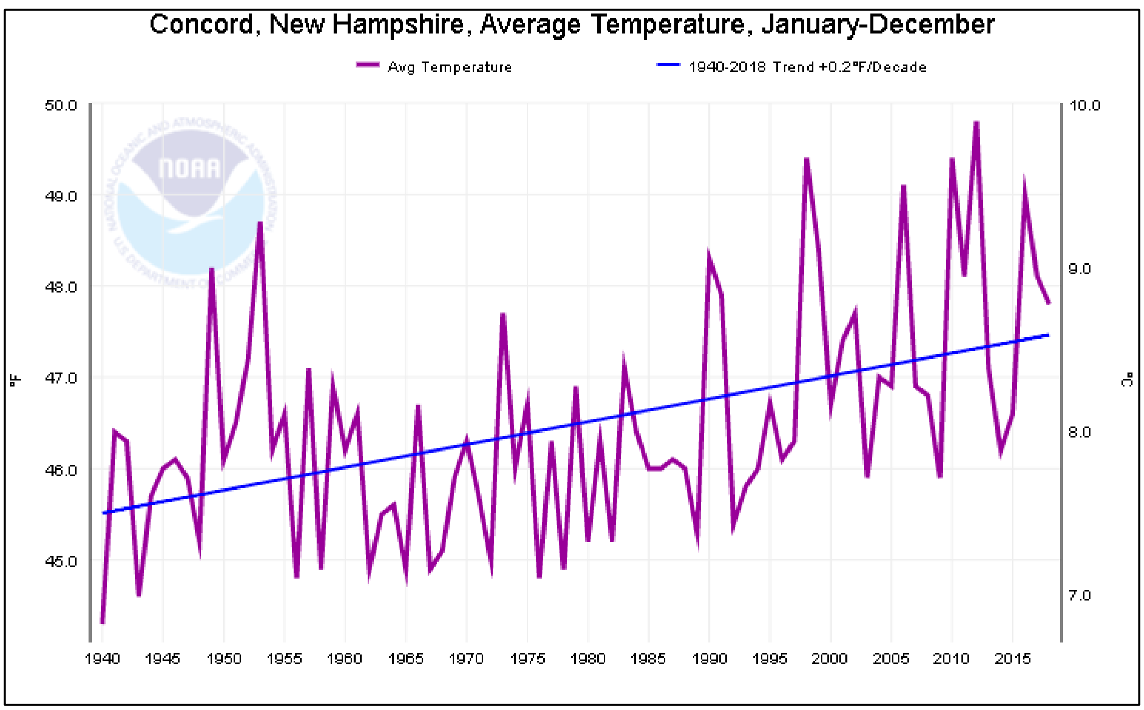

Figure 2. Average Annual Temperature at Concord, NH (National Oceanographic and Atmospheric Administration (NOAA) 2019)

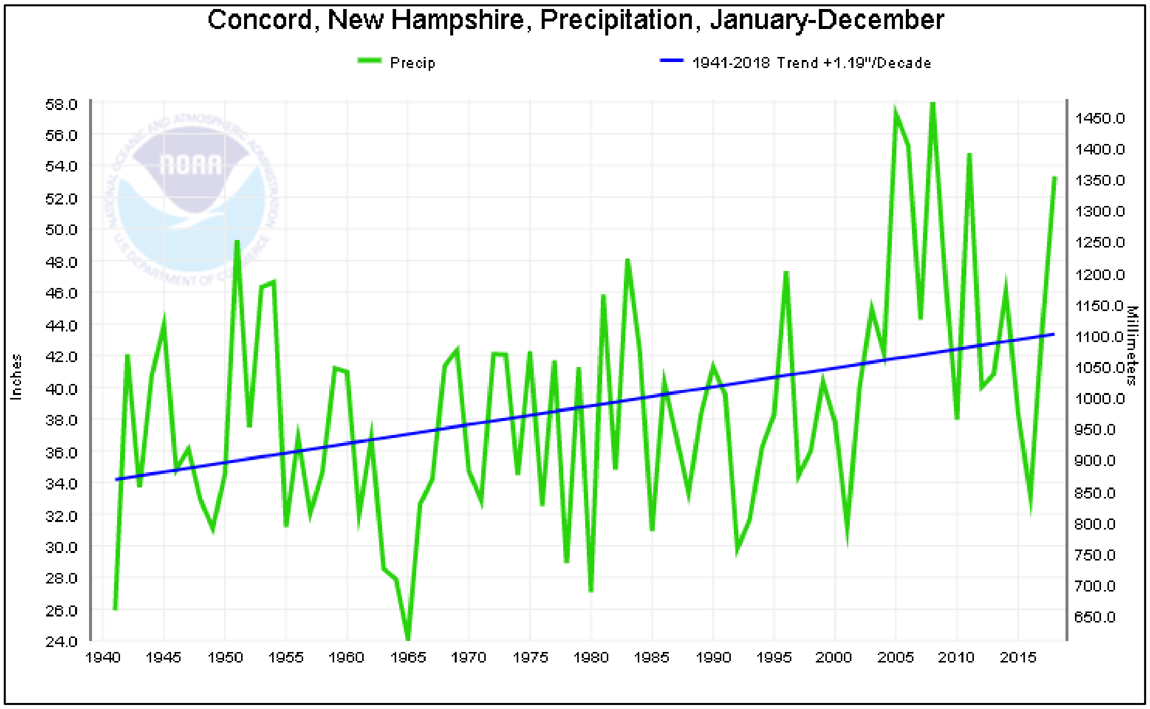

Figure 3. Monthly Average Precipitation at Concord, NH (National Oceanographic and Atmospheric Administration (NOAA) 2019)

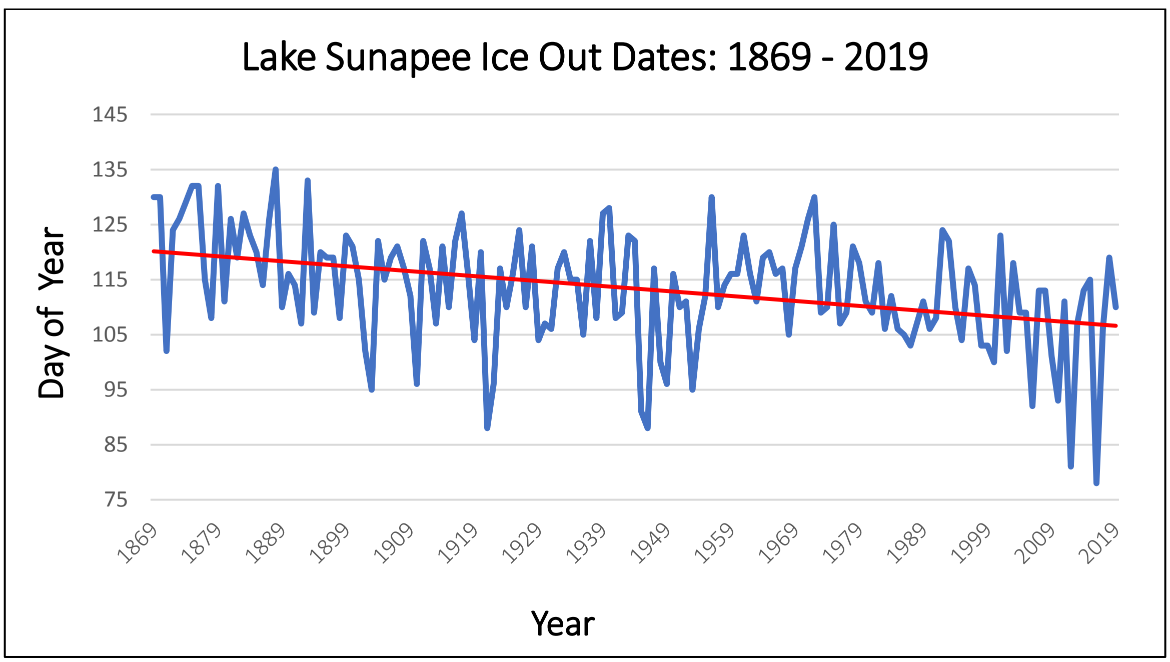

Figure 4. Ice Out Dates on Lake Sunapee from 1869-2019 (Ice out on Lake Sunapee is determined by the ability to navigate from one end of the lake to the other. The red line is a linear trendline. Source: LSPA unpublished data).

2.2 POPULATION, GROWTH TRENDS AND LAND USE

2.2.1 Population and Growth Trends

According to the New Hampshire Economic & Labor Market Information Bureau, the population in the six towns that lie within the Lake Sunapee Watershed totaled 14,057 in 2017 (NHES, 2020). The population for those same towns in 1960 was 4,365, indicating an increase of 9,692, or a percent increase of 222% from 1960 to 2017. The largest decennial percent change for all towns was the increase in population between 1970 and 1980, and the percent increases in towns during those years ranged from 31% in New London, to 89% in Newbury.

Typically, population trends are correlated with building and development. Section 3.3.2 provides information on historical building permits and their trends over time in the three largest towns within the watershed (note that building permit data was not obtained for Goshen, Springfield and Sutton). For the period between 1970 and 1980, the percent of building permits registered relative to the entire record of building permits for each town was 17.5%, 16.4 and 24.4% for New London, Newbury and Sunapee, respectively.

2.2.2 Land Cover

Watershed land cover is critical to watershed planning as both the amount and quality of the water flowing off the land to downstream waterbodies is directly affected by the activities on the land. In general, natural land covers such as forest and wetlands export less water and nutrients (phosphorus) than developed land cover such as roads, lawns, houses and commercial development. NH GRANIT land cover data, LiDAR and aerial photographs were used to determine certain land cover classifications, such as wetlands and forest. Selected land uses were confirmed on the ground during a watershed survey.

In total, 13 major land class categories were used to define all land cover within the watershed. In addition, two minor categories, medium residential (see Table 1) and pastures with animals, were added to further discriminate potentially important phosphorus loading areas within the watershed. This provided more realistic data for the modeling described in Section 3.5. Additionally, paved and unpaved road areas were defined using available length and width information sourced from NH GRANIT.

The dominant land cover for every subwatershed except Rodgers Brook was forest and disturbed forest. The location of most residential and commercial development is near roads and along lake/pond shorelines as can be seen in Appendix A, Land Cover Map 3. The densest areas of development (where impervious cover is highest) within the watershed are the commercial district of New London off Route 11, the western end of Georges Mills Cove, Sunapee Harbor, Newbury Harbor and Blodgett's Landing. There are also three active golf courses within the watershed; Twin Lake Villa on the shoreline of Little Lake Sunapee, Granliden within the Rodgers Brook subwatershed and Baker Hill within the Blodgett and Pike Brook subwatersheds. More information on land cover for each subwatershed is found in Section 3.5.3, Land Cover Update. More detailed land cover methodology can be found in Appendix C.

For the sake of consistency, the project team based land classes used for the land cover assessment on the NH Land Cover Mapping Standard. For more information about how the land cover assessment was done, refer to Section 3.5.3 (Land Cover Update) found in this plan. For class definitions refer to the 2020 WMP Classification Schema in Appendix C.

Table 1 - Medium Density Residential Areas in the Lake Sunapee Watershed

Subwatershed	Subdivision Name	Main Road Name	Area in Hectares[1]
Little Lake Sunapee	Fenwood	Fenwood Drive	3.5
Little Lake Sunapee	Great Pines	Spruce Lane	4.5
Little Lake Sunapee	Hilltop	Hilltop Place	8
Shoreland West	Indian Cave	Indian Cave Landing	6.5
Shoreland South	Edgemont	Edgemont Road	0.75
Shoreland South	North Peak Village	North Peak Village	1
Chandler Brook	North Peak Village	North Peak Village	1.25
Shoreland East	Blodgett's Landing	Blodgett's Landing Road	5

[1]Areas measured by LSPA using ArcGIS Pro software, May 2019

2.2.3 Protected and Public Lands

Conservation of land represents a unique opportunity in watershed planning to permanently protect land in a less developed state. In the northeast, undeveloped conserved land is often forest. Because of this, conserved lands often exhibit the lowest phosphorus export in a watershed. Approximately 8,414 acres, or 34% of the land in the Lake Sunapee watershed has some level of protection as either public or private conservation land (the total acreage excludes pond & lake area greater than 10 acres in size; see Appendix A, Conservation Land Map 4). It is important to note that easement agreements on conservation land often allows some use of the land to occur such as recreation, timber harvesting and agriculture. LSPA will pinpoint key parcels in these subwatersheds and work with local land conservation organizations (i.e. Ausbon Sargent Land Preservation Trust) to preserve them. See the Action Plan (Section 5.3) for more details.

2.3 PHYSICAL FEATURES

General Description

The Lake Sunapee Watershed is a medium-sized drainage basin in the Sugar River Watershed of the upper Connecticut Basin and is defined by the USGS as Hydrological Unit (HUC) 12 number 010801060402. The watershed spans approximately 12,072.5 hectares (29,832 acres) or 46.6 square miles and lies within Merrimack and Sullivan Counties and portions of six towns – Goshen, Newbury, New London, Springfield, Sunapee and Sutton (see Figure 5 and Table 2).

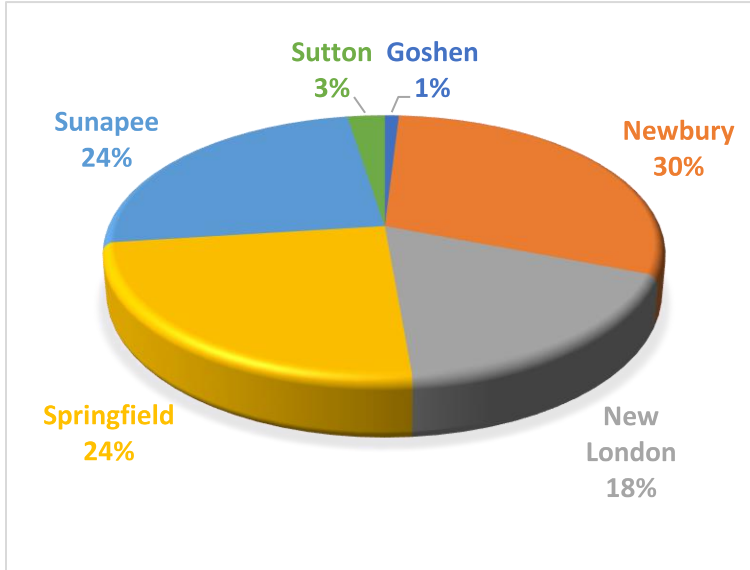

Figure 5. - Watershed Area in Each Town in the Lake Sunapee Watershed

The Lake Sunapee Watershed boundary was delineated using a digital elevation model (DEM) created from NH GRANIT 2016 LiDAR data. This provided a more accurate representation of the watershed due to the higher resolution created by the LiDAR data. Consequently, watershed, subwatershed, and waterbody boundary lines and surface areas did slightly change from the 2008 management plan. Before LiDAR, USGS 7.5-minute DEMs (30-meter resolution) were used to define the watershed and subwatershed boundaries and waterbody sizes were derived from the National Hydrography Dataset (NHD). It should be noted that watershed boundaries are not static and can change due to factors such as road and other development that can alter drainage patterns.

Table 2 - Municipality Surface Area Within the Lake Sunapee Watershed

Municipality	Area in Hectares	Area in Acres	% of Watershed Area
Goshen	115.0	284.2	1
Newbury	3,615.6	8,934.2	30
New London	2,141.4	5,291.6	17.7
Springfield	2,939.6	7,263.9	24.3
Sunapee	2,956.6	7,305.9	24.5
Sutton	304.3	751.9	2.5

2.3.1 Waterbodies, Subwatersheds and Streams

There are 13 named lakes and ponds in the watershed of varying size, shape and depth as listed in Table 3 and viewed in Appendix A, Subwatersheds Map 5. Lake Sunapee, whose shores are largely developed with both year-round and seasonal residential development, is the largest waterbody with Murray Pond being the smallest.

Table 3 - Waterbody Statistics

Waterbody Name	Surface Area[1]		Maximum Depth		Mean Depth[2]		Volume		Perimeter[1]	
	Hectares	Acres	Meters	Feet	Meters	Feet	Cubic Meters	Acre-feet	Kilometers	Miles
Baptist Pond	34.9	86.2	7.5	24.6	2.4	7.9	837,622	679	4.2	2.6
Chalk Pond	9.7	23.9	3.6	11.8	2	6.6	193,382	157	2.1	1.3
Dutchman Pond	12.4	30.8	3	9.8	1.9	6.2	236,546	192	1.9	1.2
Goose Hole Pond[4]	6.9	17.2							1.6	1
Lake Sunapee[3]	1,681.3	4,155	34.1	112	11.4	37.4	191,672,442	155,391	58.7	36.4
Little Lake Sunapee	198.8	491.3	13.3	43.6	4.4	14.4	8,747,386	7,092	11.9	7.4
McAlvin Pond[4]	4.2	10.4							0.9	0.6
Morgan Pond	21.6	53.3	2.6	8.5	1	3.4	224,401	182	3.5	2.2
Mountainview Lake	47.4	117.3	6.7	22	4.1	13.5	1,945,442	1,577	5.1	3.2
Murray Pond[4]	1.4	3.3							0.7	0.4
Mud Pond[4]	3.8	9.5							1	0.6
Otter Pond	76.4	188.7	7.6	24.9	4	13.1	3,054,947	2,477	6	3.7
Star Lake	27.8	68.7	5.4	17.7	2.2	7.1	600,227	487	3.7	2.3

NOTES:

[1]Surface areas and perimeter lengths calculated using 2016 GRANIT LiDAR data.

[2]Mean depth source from NHDES VLAP reports except for Morgan Pond and Star Lake where maximum depth, acquired from the Boating USA App, was used to calculate mean depth (mean depth was estimated as 0.4 times the maximum depth).

[3]Lake Sunapee max depth is calculated from the 2008 Bathymetric Survey made possible by the Breidablik Fund.

[4]Maximum depth of Goose Hole, McAlvin, Murray and Mud ponds not known.

There are 29 defined subwatersheds for perennial streams or waterbodies within the watershed as listed in Table 4. Goose Hole Pond, McAlvin Pond, Murray Pond and Mud Pond are all relatively small with few data to describe them. They were not explicitly split out in the data analysis or modeling effort (Section 3.5) but are incorporated in the analysis as a part of the watershed of the next downstream lake or pond. Additionally, shoreland drainage of Lake Sunapee was divided into four distinct areas, identified as Shoreland North, South, East and West (see Appendix A, Subwatersheds Map 5).

Table 4 - Lake Sunapee Subwatersheds				
		Surface Area[1]		% of
Name	#	Hectares	Acres	Watershed
Baptist Pond	1	630	1,557	6.3
Bartlett Brook	2	163	404	1.6
Bell Cove Brook	3	144	357	1.4
Birch Grove Brook	4	29	72	0.3
Blodgett Brook	5	572	1,413	5.7
Chalk Pond	6	112	276	1.1
Chandler Brook	7	743	1,837	7.5
Cunningham Brook	8	105	259	1.1
Dutchman Pond	9	33	81	0.3
Eagle Rock Brook	10	26	65	0.3
Hastings Creek	11	44	108	0.4
Herrick Cove North Brook	12	123	304	1.2
Herrick Cove South Brook	13	181	448	1.8
Jobs Creek	14	125	310	1.3
King Hill Brook	15	510	1,260	5.1
Little Lake Sunapee	16	1,178	2,911	11.8
Morgan Pond	17	194	480	1.9
Mountainview Lake	18	390	964	3.9
Muzzey Brook	19	247	609	2.5
Newbury Inlet Brook	20	158	390	1.6
Otter Pond	21	1,218	3,011	12.2
Pike Brook	22	466	1,151	4.7
Red Water Creek	23	388	958	3.9
Rodgers Brook	24	140	345	1.4
Shoreland East	25	328	810	3.3
Shoreland North	26	320	791	3.2
Shoreland South	27	426	1,053	4.3
Shoreland West	28	582	1,438	5.8
Star Lake	29	386	953	3.9

NOTES:
[1]Totals do not include upstream ponds or lakes except for Goose Hole, McAlvin, Mud and Murray Ponds which were not explicitly modeled in Section 3.5.

There are 27 named streams and brooks in the watershed (see Appendix A, Major Brooks Map 6), Major Brooks in the Lake Sunapee Watershed). Nineteen of them drain directly into Lake Sunapee.

2.3.2 Topography

Terrain within the watershed ranges from steep slopes (greater than 25%), to rolling terrain. Elevations range from 2,743 feet at the summit of Mount Sunapee to just under 1,093 feet at the Lake Sunapee outflow at the Sugar River in Sunapee. The land surface in the Sunapee drainage basin (watershed) slopes moderately to relatively steeply to the lake from all sides. These slopes are steepest along the southern and western sides of the lake. The slope of the land surface is controlled largely by the underlying bedrock in the region.

2.3.3 Wetlands, Soils and Geology

Wetlands, as identified in the 1991 National Wetland Inventory, represent a relatively small portion of the watershed. Excluding the 13 named lakes and ponds, about 1,030 acres or 3.5% of the watershed is comprised of palustrine (freshwater) wetlands dispersed throughout the watershed. Wetland locations are shown in Appendix A, Land Cover Map 3. A total of 290 wetland units, excluding the 13 named waterbodies have been identified in the watershed.

A total of 2,738 acres are considered steep soils averaging 15% or greater in slope as determined through soils surveys prepared by the Natural Resource and Conservation Service and the 2019 Buildout Analysis for this plan. This represents 9.2% of the watershed.

According to Thompson et al. (1990), the bedrock that underlies Lake Sunapee's drainage basin is composed primarily of Devonian & Cretaceous igneous rocks (granite, granodiorite, quartz monzonite and related rocks). Thompson's map also indicates that a portion of the northeastern and southwestern part of the drainage basin is underlain by Silurian and Devonian metasedimentary rocks (metapelites, metaturbites, quartzites and conglomerates). The bedrock slopes in Lake Sunapee's drainage basin are covered by a thin layer of relatively sandy glacial till (Soil Conservation Service, 1965 & 1988 as cited in Schloss, 1989). The soils formed in the glacial till on the hillsides and mountain slopes in the lake's drainage basin are classified by the Soil Conservation Service (1988) as "deep, gently sloping to very steep, well drained and somewhat excessively drained, loamy and sandy soils of the Monadnock-Marlow-Hermon series". These soils are very strongly acidic and are described by the Soil Conservation Service, 1965 (as cited in Schloss, 1989) as having "good drainage for septic tank systems."

2.3.4 Lake Morphology

Lake Sunapee is relatively long and narrow with a length to width ratio of about 4 to 1 and a watershed to lake area ratio of 6 to 1. The lake is approximately 8 miles long and from 0.5 to 2.5 miles wide (east to west), covering 6.5 square miles. The maximum depth, as determined from the 2008 Bathymetric Study funded by the Breidablik Fund, is 112 feet. It is the sixth largest lake in New Hampshire with a surface area of 4,155 acres and has about 36 miles of shoreline. Being relatively deep, the lake thermally stratifies during the warmer months. There are 11 islands on the lake, the largest one known as Great Island.

2.4 AQUATIC BIOLOGY

Aquatic biology has the potential to significantly influence water quality in lakes, particularly in low-nutrient lakes such as Sunapee. Currently, Lake Sunapee is actively monitored for invasive aquatic plants and animals which can displace native species and impair recreational and aquatic life uses. Variable milfoil (*Myriophyllum heterophyllum),* a problem in many northeast lakes was discovered in at least two locations years ago and eliminated by LSPA and NHDES. Continued vigilance and rapid action have kept invasive aquatic plants and animals from establishing a presence in the lake.

The fish community of Lake Sunapee, like many New Hampshire lakes, is not static. It includes a stocked apex predator (landlocked salmon) in addition to the introduced species largemouth bass, smallmouth bass and recently, rock bass. Native bullhead, chain pickerel, lake trout, smelt, yellow perch and others are also present. Rainbow trout, although not stocked directly, were stocked in upstream lakes (Little Lake Sunapee in 2016) and are likely present in Lake Sunapee. The Sunapee trout is thought to be extinct in Lake Sunapee.

Through predation, the fish community can cause cascading effects through the food web that result in changes in algal growth and nutrient cycling (Carpenter et al. 1986). For example, in Lake Sunapee, trophic effects might explain a partial disconnect between concentrations of chlorophyll-*a* observed relative to phosphorus concentrations in some years. Current research on the Lake Sunapee food web may yield additional insights that may allow some of the trophic interactions to be quantified and may help explain some of the variability in water quality from season-to-season and year-to-year.

THERE ARE NO REASONABLE SCENARIOS WHERE ADDITIONAL PHOSPHORUS INPUT TO LAKE SUNAPEE WILL IMPROVE LONG-TERM WATER QUALITY.

Other potential indirect trophic effects on water quality in Lake Sunapee could be related to the loss of deep oxygen causing salmonid fish (landlocked salmon) to concentrate in the shallower layers of the lake than they prefer, resulting in food chain effects on planktivorous fish (smelt and young of other species), zooplankton and algae. The recent introduction of new species like rock bass may also have effects on the food chain. Further understanding of these potential biological interactions in Lake Sunapee may help guide management in the future. Research on the influence biological interactions may have on water quality is presented in Section 5.3.2.

Regardless of the influence of the aquatic community on water quality, the influence of phosphorus on water quality remains critical to designated use support. There are no reasonable scenarios where additional phosphorus input to Lake Sunapee will improve long-term water quality and future support of designated uses.

3. ASSESSMENT OF WATER QUALITY

3.1 APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

3.1.1 Designated Uses & Water Quality Classification

Designated Uses

The State of New Hampshire has numerous statutes and rules that are designed to protect lakes. Over the past three decades NHDES has made a major effort to ensure that lakes support all designated uses. Designated uses for freshwater are presented in Table 5. All the designated uses for fresh surface waters are present in Lake Sunapee.

Classification

In the 1950s, Lake Sunapee met the standards to be named a Class A (drinking water quality) lake in New Hampshire. All other lakes and ponds in the watershed are classified as Class B. While there is no functional difference in terms of designated use support for Class A and Class B waters (Table 5), they are defined differently (Table 6, following page). Specific water quality standards are somewhat different for Class A vs Class B waters (Table 7, following page).

Table 5 - Designated Uses for Fresh New Hampshire Surface Waters
(adapted from NHDES, 2018a)

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
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

Table 6 - New Hampshire Surface Water Classifications	
Classification	**Description (RSA 485-A:8)**
Class A	Class A waters shall be of the highest quality. There shall be no discharge of any sewage or wastes into waters of this classification. The waters of this classification shall be considered as being potentially acceptable for water supply uses after adequate treatment.
Class B	Class B waters shall be of the second highest quality. The waters of this classification shall be considered as being acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies.

3.1.2 Water Quality Standards and Criteria

Criteria for parameters relevant to this plan are presented in Table 7.

Table 7 - Selected NH Water Quality Standards and Criteria Relevant to the Lake Sunapee Watershed Plan			
Parameter	**Class A**	**Class B**	**Citation**
Dissolved Oxygen	75% saturation, min 6.0 mg/l	75% saturation, min 5.0 mg/l	Env-Wq 1703.07
Dissolved Oxygen - lakes	Top 25% of depth – 75% saturation. >5.0 mg/l below. Must support designated uses	Top 25% of depth – 75% saturation. >5.0 mg/l below. Must support designated uses	Env-Wq 1703.07
Phosphorus	None unless naturally occurring	Concentrations low enough to support designated uses unless naturally occurring	Env-Wq 1703.14 (a), (b)
Phosphorus	No new or increased discharge	No new or increased discharge	Env-Wq 1703.14 (d)
Chloride (acute)	860 mg/l	860 mg/l	Env-Wq 1703.21
Chloride (chronic)	230 mg/l	230 mg/l	Env-Wq 1703.21

Several waterbodies in the Sunapee Watershed have been determined by NHDES to be impaired relative to designated uses. Lake Sunapee, Little Lake Sunapee and Baptist Pond are listed (NHDES 2018b) as impaired (severe, non-supporting) for aquatic life due to inadequate dissolved oxygen levels. Baptist Pond is also listed for exceedance of criteria for total phosphorus and chlorophyll-*a.* A number of tributary streams and ponds in the Sunapee Watershed are listed as impaired for aquatic life use due to low pH.

There is a statewide fish consumption advisory or ban in effect for the general population for one or more fish species due to the atmospheric deposition of mercury. For this reason, all state waterbodies have been classified as "Not Supporting" the fish consumption designated use.

3.1.3 Antidegradation

The purpose of the antidegradation provisions in the water quality standards is to preserve and protect the existing beneficial uses of the State's surface waters and to limit the degradation allowed in receiving waters. Antidegradation regulations are included in Env-Ws 1708 of the New Hampshire Surface Water Quality Regulations. Relevant provisions relative to this plan include; ENV-WQ 1708.03 which states "a proposed discharge or activity shall not eliminate any existing uses or the water quality needed to maintain and protect those uses" and Env-Wq 1708.05 which states "discharges containing "sewage" or "wastes" are not allowed in Class A waters."

3.2 ASSIMILATIVE CAPACITY ANALYSIS

3.2.1 Data Review

Historic Lake Sunapee Data Assessment

Lakes typically go through a natural aging process as the result of sedimentation processes and nutrient additions. Trophic level or lake "age" is determined by many factors including water transparency, nutrient enrichment, planktonic growth, presence of aquatic plants, types of fishery (cold or warm), and dissolved oxygen content. Lake characteristics change as lakes age. For example, oligotrophic waterbodies are considered young or in an early stage of development. Waterbodies in this trophic stage are typically characterized by clear water, low nutrient concentrations, low productivity, few aquatic plants, presence of a cold-water fishery and high dissolved oxygen content. Eutrophic waterbodies are considered old or transitioning towards wetlands. Eutrophic lakes typically have high nutrient concentrations which fuel high planktonic and benthic algal growth, extensive aquatic plant beds, sediment accumulation on the lake bottom and frequent algal blooms. Mesotrophic characteristics fall between eutrophic and oligotrophic.

In New Hampshire, designated uses and the water quality to protect those uses are regulated through the Water Quality Standards, which include RSA 485-A:8 - the Classification of Water, and Env-Wq 1700 - the Surface Water Quality Regulations (Section 3.1). To protect the aquatic life designated use, criteria for total phosphorus and chlorophyll-*a* have been set. (Table 8).

Table 8 - TP and Chl-*a* Criteria for Aquatic Life Designated Use		
Trophic State	TP (µg L-1)	Chl-*a* (µg L-1)
Oligotrophic	< 8.0	< 3.3
Mesotrophic	< or = 12.0	< or = 5.0
Eutrophic	< or = 28	< or = 11

Lake Sunapee and many of the lakes and ponds in the Lake Sunapee Watershed are considered oligotrophic although several of the watershed lakes are mesotrophic and have become so at a faster than natural rate due to development and changes in the watershed.

Surface Water Quality in the Lake Sunapee Watershed

Water quality in Lake Sunapee and lakes and ponds in the watershed has been monitored periodically by a number of state agencies and local associations since 1939 (NH Fish and Game 1977) and consistently since 1986 as a part of the Volunteer Lakes Assessment Program (VLAP). In Lake Sunapee, VLAP volunteers and LSPA staff collect data from four deep spot stations, nine near shore stations and numerous tributary stations (Appendix A, VLAP Monitoring Stations Map 7). VLAP monitors are active in six other lakes and ponds; Baptist Pond, Chalk Pond, Dutchman Pond, Little Lake Sunapee, Mountainview Lake and Otter Pond. Recent water quality data throughout the Sunapee Watershed are readily available on the LSPA website through an interactive mapping program (http://www.lakesunapee.org/trends-concerns). The most recent VLAP water quality reports can also be found there. This monitoring program is critical to the understanding of long-term trends in Lake Sunapee, upstream lakes and ponds and the tributaries. This section contains a summary of those results that are directly relevant to this plan. The reader is directed to the LSPA website above for all parameters and current interpretation. Figure 6 on the following page is from one of the VLAP reports for a deep station in Lake Sunapee. This figure illustrates the low phosphorus and chlorophyll-*a* concentration over time and high transparency depths.

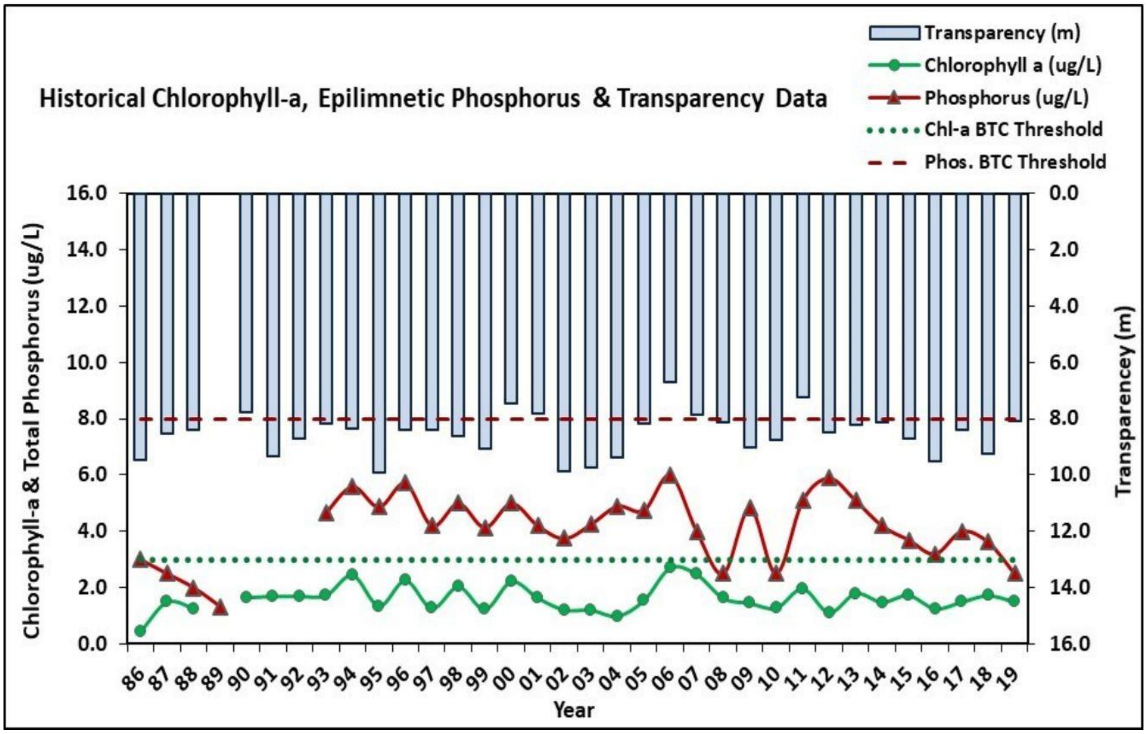

Figure 6. Historic VLAP Monitoring Results for a Deep Station in Lake Sunapee.

The following section of the Plan summarizes water quality information from the Volunteer Lake Assessment Program (NHDES 2017) for each of the lakes and ponds as summarized in Table 9 on the following pages. These results are discussed because they represent a useful long-term dataset as well as a good representation of current conditions.

Table 9 - Summary of Water Sample Results for Selected Biological and Chemical Parameters for Waterbodies in the Lake Sunapee Watershed (Source: NHDES 2017).						
Waterbody	Phosphorus	Chlorophyll-*a*	Transparency	Conductivity	pH and Alkalinity	Dissolved Oxygen - Hypolimnion
Lake Sunapee Deep Spots	Oligotrophic conditions - not significantly changed, much less than state median for P.	Not significantly changed, historical data show the average is less than the state median.	High transparency, stable over time.	Greater than the state median, significantly increasing.	Satisfactory, note higher acidity in the hypolimnion, moderately vulnerable to acidification.	High in the epilimnion but depleted in the hypolimnion – possible risk for future internal loading.
Lake Sunapee Near Shore	Mesotrophic conditions - generally increasing levels of P but highly variable among stations, greater than state median.	Not significantly changed, stations demonstrating some year to year variability.	Stable at all stations except 110 where transparency is significantly decreasing.	Greater than the state median, significantly increasing.	Slightly acidic, moderately vulnerable.	Not applicable
Lake Sunapee Tributaries	Low to moderate levels - somewhat higher in summer.	Not applicable	Not applicable	Wide range of values, some stations are consistently high.	Slightly acidic at most stations and below desirable at some stations.	Not applicable
Baptist Pond	Mesotrophic conditions - phosphorus exceeds threshold for mesotrophic lakes at times, particularly in hypolimnion.	Greater than the state median but stable with some year-to-year variability	Transparency below average and decreasing over time	Slightly greater than state median, stable.	Slightly more Acidic than desirable range.	Insufficient data to assess.
Chalk Pond	Oligotrophic conditions - not significantly changing.	Slightly greater than threshold for oligotrophic lakes. Highly variable.	Transparency decreasing over time.	Close to the state median, but significantly increasing.	Stable, in desirable range with moderate variability among years.	Insufficient data to assess.

Table 9 - Summary of Water Sample Results for Selected Biological and Chemical Parameters for Waterbodies in the Lake Sunapee Watershed (Source: NHDES 2017).

Waterbody	Phosphorus	Chlorophyll-*a*	Transparency	Conductivity	pH and Alkalinity	Dissolved Oxygen - Hypolimnion
Dutchman Pond	Mesotrophic conditions - but trending towards oligotrophic.	Not significantly changed, below threshold for oligotrophic lakes. Historical data show the average is less than the state median and variable.	Very good but decreasing over time.	Stable and low.	Slightly acidic, lower than desired range.	Insufficient data to assess.
Little Lake Sunapee	Oligotrophic conditions in the epilimnion and mesotrophic conditions in the hypolimnion, variable P.	Low but variable. Stable over time.	Transparency decreasing over time.	Greater than the state median, stable but variable.	Slightly acidic, note higher acidity in the hypolimnion.	Lower in metalimnion and hypolimnion than the epilimnion – potential for future internal phosphorus loading.
Mountainview Lake	Mesotrophic conditions - not significantly changed, P concentrations slightly less than state median.	Not significantly changing, historical data show the average is approximately equal to state median.	Transparency decreasing over time.	Greater than the state median, highly variable.	Slightly acidic note pH decreasing over time.	Much lower in hypoliminion – potential for future internal phosphorus loading.
Otter Pond	Mesotrophic range and stable over time.	Lower than state median but increasing over time.	Transparency decreasing over time.	Above state median and increasing.	Generally within desired range but epilimnetic values occasionally low. Decreasing over time.	Much lower in hypoliminion – potential for future internal phosphorus loading.

3.2.2 Water Quality Parameters

Total Phosphorus

Total phosphorus is a measure of all the forms of phosphorus (organic and inorganic) present. Phosphorus, along with nitrogen is a plant limiting nutrient, meaning that the amount of available phosphorus influences the amount of algae growth that can occur. In most lakes, phosphorus is the critical nutrient to algal growth meaning that the more phosphorus in a lake, the greener the lake appears. Conversely, restricting the input of phosphorus to a lake typically leads to clearer water. Phosphorus concentration directly relates to trophic state as described above. For example, values less than 8 µg/L are considered "ideal" and generally indicate oligotrophic conditions. Values greater than 28 µg/L are considered "more P than desirable" and indicate eutrophic conditions. Mesotrophic conditions exist between these two values and are considered "average."

Phosphorus is an important indicator of pollution because this nutrient occurs naturally at very low levels in lakes and ponds in New Hampshire. The median summer total phosphorus concentration in the epilimnion of New Hampshire lakes and ponds is 12 µg/L. The median summer total phosphorus concentration in the hypolimnion of New Hampshire lakes and ponds is 14 µg/L.

Based on data from the past 10 years, phosphorus concentrations across the watershed vary greatly. The Sunapee deep spots, Chalk Pond and Little Lake Sunapee have low enough phosphorus concentrations to support an oligotrophic classification. However, the near shore stations on Lake Sunapee, many tributaries and several lakes and ponds in the watershed show higher concentrations of phosphorus more representative of mesotrophic conditions. In general, these higher concentrations are associated with the more developed portions of the watershed. This suggests that there are existing controllable sources of phosphorus. It is also clear that increasing these sources further will result in a decline of water quality in Lake Sunapee. The data support development of this plan to reduce phosphorus input to Lake Sunapee. This will maintain the current oligotrophic state of the lake into the future.

Chlorophyll-a

Algae are photosynthetic plants that contain chlorophyll but do not have true roots, stems, or leaves. They do, however, grow in many forms such as aggregates of cells (colonies), in strands (filaments), or as microscopic single cells. They may also be found growing on objects, such as rocks or vascular plants, on the lake bottom (benthic algae) or free-floating in the water column (phytoplankton). Cyanobacteria, while not technically plants, share characteristics with both algae and bacteria.

Both algae and cyanobacteria contain chlorophyll-*a* (a green pigment). VLAP uses the measure of chlorophyll-*a* as an indicator of algal and cyanobacterial abundance. The concentration of chlorophyll-*a* measured in the water gives an estimation of the amount of algae and cyanobacteria present. If the chlorophyll-*a* concentration increases, this indicates an increase in the algal and/or cyanobacteria population. A chlorophyll-*a* concentration of less than 3 µg/l typically indicates water quality conditions that are representative of oligotrophic lakes (Table 9, page 24) while a chlorophyll-*a* concentration greater than 11 µg/l indicates eutrophic conditions. A chlorophyll-*a* concentration greater than 10 µg/l generally indicates an algae bloom that is visible.

Chlorophyll-*a* concentrations throughout the watershed tend to be low, which indicates good water quality and implies a low abundance of algae however, Baptist, Chalk and Otter ponds have shown chlorophyll-*a* concentrations that are greater than the threshold for oligotrophic lakes. The concentration in Otter Pond is increasing. This is particularly important to Lake Sunapee as water from the Otter Pond drainage is the largest single source of water to Lake Sunapee.

Transparency

Secchi transparency is a measure of the clarity of water measured by lowering a standard black and white disk into the water column until it disappears from view. Transparency is valued by stakeholders and is one of the easiest parameters to understand. Transparency is affected by growth of algae and cyanobacteria, the presence of organic and inorganic particles in the water column and the color of the water.

Transparency at deep water sites in Lake Sunapee is good however, a decline in transparency over time has been noted in Sunapee nearshore sites and throughout the lakes and ponds in the Sunapee Watershed. Reduction of algal growth related to phosphorus enrichment (a part of this plan) is expected to help slow or reverse the declining transparency trend.

Cyanobacteria

Cyanobacteria (formerly known as blue-green algae) are microorganisms that photosynthesize and share characteristics of both algae and bacteria. Cyanobacteria are some of the oldest and widespread organisms on earth and many produce and release toxins into the water, at times. These toxins can be a concern for drinking water supplies and for recreational contact and are considered "unregulated contaminants". Most cyanobacteria toxins are not released until the cell dies and the cell wall ruptures. There are several types of toxins including hepato (liver), dermo (skin), and neurotoxins (nervous system). There have been a number of blooms and scums in local waters but, toxin concentrations at a level of concern have not been reported to date. LSPA currently assesses toxicity for advisory purposes.

The likelihood of cyanobacteria blooms at nuisance levels rises with increased phosphorus concentrations. Most cyanobacteria tend to rapidly reproduce or "bloom" in high-nutrient (eutrophic) waters. However, some species, such as *Gloeotrichia echinulate* (a species that has been blooming in Lake Sunapee), can bloom and form a surface scum in low-nutrient (oligotrophic) waters. The proliferation of this organism throughout the northeast despite relatively low water column phosphorus concentrations is currently the focus of ongoing research by LSPA's Scientific Advisory Committee (SAC). One likely mechanism is the transport of previously deposited sediment phosphorus up into the water column as cells leave their resting stage on the bottom. This nutrient transport may be an important mechanism for moving phosphorus that was previously unavailable for phytoplankton growth up into the water column for use by *Gloeotrichia* or other algae and cyanobacteria. Transported phosphorus either leaks out of live *Gloeotrichia* cells or is released as *Gloeotrichia* cells die and decompose.

Other species of cyanobacteria are present at times in small numbers. These include *Anabaena*, *Microcystis, Oscillitoria* and others. These species are more likely to be problematic in the formation of floating scums or toxin production if they were found in bloom concentrations. As with all cyanobacteria species, the presence of low concentrations of phosphorus greatly diminishes the likelihood that these species will occur in problematic concentrations

Conductivity

Conductivity is a measure of the ability of water to carry an electrical current. The soft (low ion) waters of New Hampshire have traditionally had low conductivity values, generally less than 50 µS/cm. Elevated values in New Hampshire lakes typically suggest non-natural sources. Foremost among these non-natural sources is road salt applied in the winter which enters surface water throughout the year either directly through highway runoff during snowmelt or more slowly through storage in soils and groundwater. At very high levels, chloride (an ion in road salt) can be toxic to aquatic organisms. High input of saline water can also restrict mixing in lakes and ponds, reducing the re-oxygenation of bottom waters (Novatny and Stefan 2012).

Conductivity values are above the state median and/or increasing throughout the Lake Sunapee Watershed (Table 9, page 24). This is very likely to be attributable to the use of road salt in the watershed of these lakes and ponds. Only Morgan and Dutchman Ponds are currently showing no increase in conductivity. These ponds have little to no road area and associated salt use in their watersheds.

Beginning in 2019, the LSPA began measuring chloride levels at water quality stations throughout the watershed to corroborate rising conductivity levels.

pH

pH is a measure of the acidity of water. pH ranges from 0 to 14 with 7 being neutral. pH below 7 is acidic while pH above 7 is basic. Lake pH is important for the survival and reproduction of fish and other aquatic species as well as governing many chemical reactions. pH is affected by both external and internal factors in lakes. Acid rainfall and release of tannic and humic acids from watershed wetlands both cause a decrease in pH in lakes. Photosynthesis by plants and algae in lakes can increase pH by using carbon dioxide in the water. Respiration and decomposition decrease lake pH by generating carbon dioxide. Because there is typically more decomposition and respiration at depth in lakes than at the surface due to light availability, pH is often lower in bottom waters.

New Hampshire lakes historically have had pH values between 6.5 and 7. A pH of between 6.5 and 8.0 is desired (NHDES 2017). As the pH decreases to between 5 and 6, many fish and aquatic organisms become stressed, and some species disappear because they are unable to tolerate acidic conditions. Fish typically are unable to tolerate acidic conditions below a pH of 5. Most lakes and ponds in the Lake Sunapee Watershed are slightly acidic. Baptist and Dutchman Ponds exhibit pH values slightly below the desired range. Similarly, a number of the tributaries to Lake Sunapee exhibit pH values below the desired range.

Alkalinity (Acid neutralizing capacity)

Alkalinity is the measure of a lake's capacity to neutralize acid inputs. This value is often referred as "Acid neutralizing capacity (ANC)". New Hampshire has had historically low alkalinity waters because of the State's granitic bedrock and there is some evidence that overall alkalinity has decreased in recent years. If the buffering capacity of a lake is lost, pH typically drops and conditions for aquatic life are adversely affected. The mean alkalinity for New Hampshire lakes and ponds is 4.9 mg/L (NHDES per. comm).

Most waterbodies in the Sunapee Watershed have been relatively stable with respect to alkalinity, and data indicate a "moderate vulnerability" to acid.

Dissolved Oxygen

The presence of dissolved oxygen is vital to bottom-dwelling organisms as well as fish and amphibians. Dissolved oxygen concentrations lower than 5 mg/L are not tolerated well by most aquatic organisms. The lowest dissolved oxygen concentrations are often found in the deepest sections of lakes where there is insufficient light for generation of oxygen by plants and algae through photosynthesis. In thermally stratified lakes like Lake Sunapee, deeper waters are isolated from the water surface and atmospheric reaeration throughout much of the summer and winter exacerbate the problem. Low oxygen concentrations at depth often results in organisms moving up in the water column where they are vulnerable to predation or forced to live in warmer water than preferred.

Dissolved oxygen concentrations in the hypolimnion (deeper layers) of Lake Sunapee and several of the watershed lakes and ponds are depressed in the summer at deep stations (Table 9, page 24). This causes stress or in extreme cases mortality for aquatic life, particularly cold-water fish species, and can result in remobilization of phosphorus from the sediments that then fuel further algal growth. Nutrients (primarily phosphorus) can be used as a surrogate for dissolved oxygen if it is determined that the oxygen demand is primarily related to excessive plant and algal growth and not to sediment oxygen demand. The shape of the oxygen profiles in Lake Sunapee suggest that sediment oxygen demand is not the primary driver of low hypolimnetic dissolved oxygen (Figure 7). In Lake Sunapee, depressed dissolved oxygen is seen throughout the hypolimnion not just near the sediment-water interface. A sharp decline in dissolved oxygen only near the sediment water interface suggests sediment oxygen demand. A decline throughout the hypolimnion suggests in-lake productivity and associated decay of algal cells as the cause of the oxygen demand. Because in-lake productivity (algal growth fueled by phosphorus) is likely driving the observed dissolved oxygen depletion, reduction in phosphorus concentrations should result in higher dissolved oxygen concentrations and fewer violations of dissolved oxygen standards in the future. For this plan, phosphorus will be used as a surrogate for dissolved oxygen.

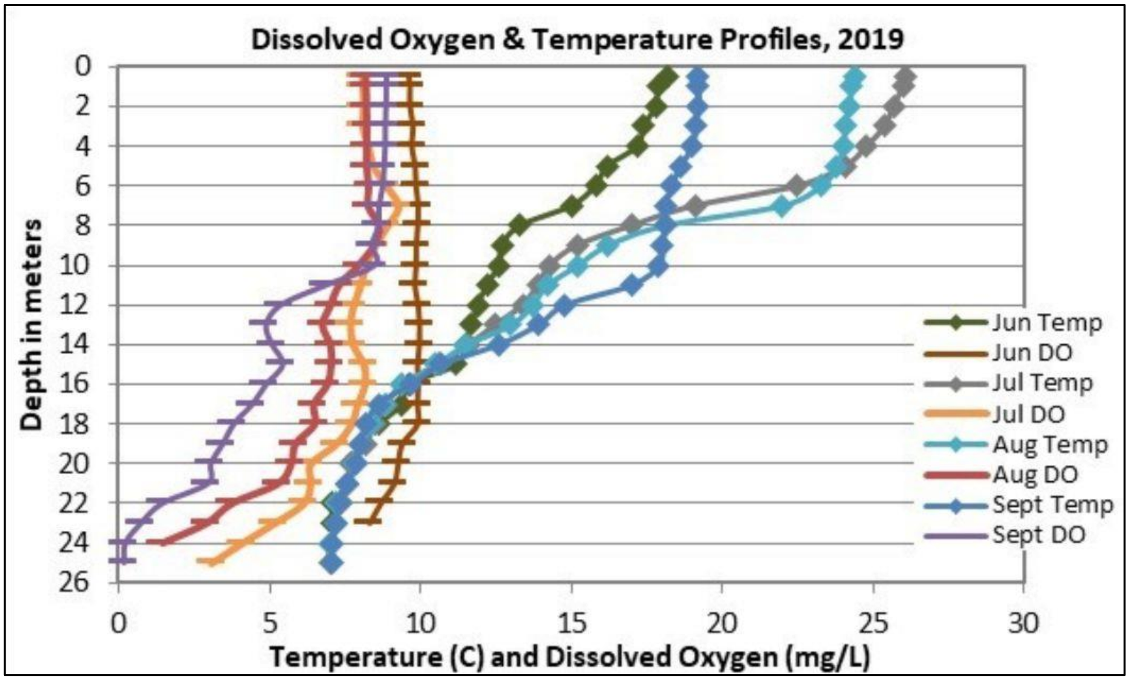

Figure 7. Lake Sunapee Deep Station Oxygen Profiles from Summer of 2019 Showing Oxygen Depletion Throughout the Lower Part of the Water Column in Late Summer.

3.2.3 Long Term Water Quality Summary

Sediment, nutrients and other stormwater contaminants such as chlorides (measured, in part, through conductivity) are major water quality concerns in the Lake Sunapee Watershed. Based on long-term data, Lake Sunapee and other waterbodies have seen increases in total phosphorus concentrations (TP) and specific conductivity. Sediment loading primarily from stormwater runoff impacts, has added to increases in turbidity and decreases in clarity. Current and future potential water quality degradation due to climate change with accompanying increases in precipitation/storm severity and occurrence increase the need to address stormwater runoff issues.

There are multiple signs that Lake Sunapee and the other watershed lakes and ponds are threatened. While on the surface, these lakes and ponds appear to be high quality and healthy, they remain in a very delicate balance. Each of the water quality indicators summarized above demonstrate that the systems are either stable or may be vulnerable.

This trend is shown in the decreasing dissolved oxygen concentrations in the hypolimnion coupled with increasing phosphorus concentrations from the near shore and tributary stations as well as in-lake. Increasing conductivity and the potential for algal blooms and cyanobacterial growth are all indicators of land use activities resulting in non-point source pollution. In addition to the concerns raised by these results, there is a demonstrated need for more information about these waterbodies. For example, there are few available data for Star Lake or Morgan Pond, as well as, a number of tributaries. Recommendations to improve data collection in these areas are discussed further in Section 5.7.

Recent (2009-2018) Lake Sunapee Data Assessment for Model Calibration

An analysis of the existing water quality data available for the last ten years (2009-2018) for Lake Sunapee was performed to determine if the median total phosphorus (TP) and mean chlorophyll-*a* values meet the Tier 2 High Quality Water criteria set by NHDES and to provide benchmarks for calibration of the LLRM water quality model (Section 3.5). Secchi disk transparency data were also compiled as Secchi disk transparency is a response variable in the LLRM modeling effort being undertaken to support the watershed plan. The major source of the water quality data comes from measurements and samples collected by LSPA and volunteers under the VLAP program.

Lake Sunapee has four deep water sites with approximately five monthly samples collected each year from May through September. Phosphorus and chlorophyll-*a* data collected from the epilimnion (upper surface layer) between May and September were used to determine the summer median TP and mean chlorophyll-*a* values for each waterbody. This time period approximately coincides with the period of time that the lake is stratified. The median and mean values for each water quality parameter (TP, chlorophyll-*a*, Secchi depth) for Lake Sunapee (Table 10) were arrived at by first determining the median or mean value of each water quality parameter for each site sampled during 2009 to 2018. For Lake Sunapee, these stations are called 200, 210, 220 and 230. The distribution of values from each site were compared to other sites using a Z-test (Appendix D). This series of tests indicated that there are no statistically significant differences in the mean between any of the four sites for the 2009 through 2018 time period for phosphorus, chlorophyll-*a* or Secchi disk transparency. This allowed the data from all four sites to be pooled to represent the overall lake value for phosphorus, chlorophyll-*a* and Secchi disk transparency.

Table 10 - Summary of Pooled Epilimnetic Water Quality Data for 10-year Period (2009-2018) for Lake Sunapee (Stations 200, 210, 220 and 230)

Parameter	Sunapee 2009-2018
Total Phosphorus (µg/l)	
Mean	5
Median	5
N (Samples)	176
Chlorophyll-*a* (µg/l)	
Mean	1.6
Median	1.6
N (Samples)	175
Secchi disk transparency (m)	
Mean	8.4
Median	8.4
N (Readings)	155

Data from this trophic state assessment support the classification of oligotrophic for Lake Sunapee based on both total phosphorus and chlorophyll-*a* concentration. The phosphorus, chlorophyll-*a* and Secchi disk transparency values from this analysis were used as the primary calibration for the water quality model (Section 3.5).

3.2.4 Assimilative Capacity Analysis

The assimilative capacity of a water body describes the amount of pollutant that can be added to that water body without causing a violation of the water quality criteria. The water quality nutrient criterion for phosphorus has been set at 8 µg L^{-1} for an oligotrophic waterbody (high quality water) and <=12 µg L^{-1} for a mesotrophic waterbody. The NHDES requires 10% of the state standard to be kept in reserve, therefore phosphorus levels must remain below 7.2 µg L^{-1} for oligotrophic and < 10.8 µg L^{-1} for mesotrophic waterbodies to be in the Tier 2 High Quality Water category. An example of the calculations for an oligotrophic classed waterbody is shown below.

Assimilative Capacity (AC) for Total Phosphorus (TP)

- Total AC = Water Quality Standard (8 µg L^{-1} TP) – Best Possible WQ (0 µg L^{-1} TP) = 8.0 µg L^{-1} TP
- Reserve assimilative capacity = 0.10 x Total AC = 0.8 µg L^{-1} TP
- Remaining assimilative capacity = 7.2 µg L^{-1} – Existing WQ

An analysis of a waterbody's assimilative capacity is used to determine the total assimilative capacity, the reserve assimilative capacity, and the remaining assimilative capacity of each water quality parameter being considered in a waterbody (see Figure 8). This information is then used to determine water quality goals and actions necessary to achieve those goals. The assimilative capacity analysis is conducted in accordance with NHDES (2008a).

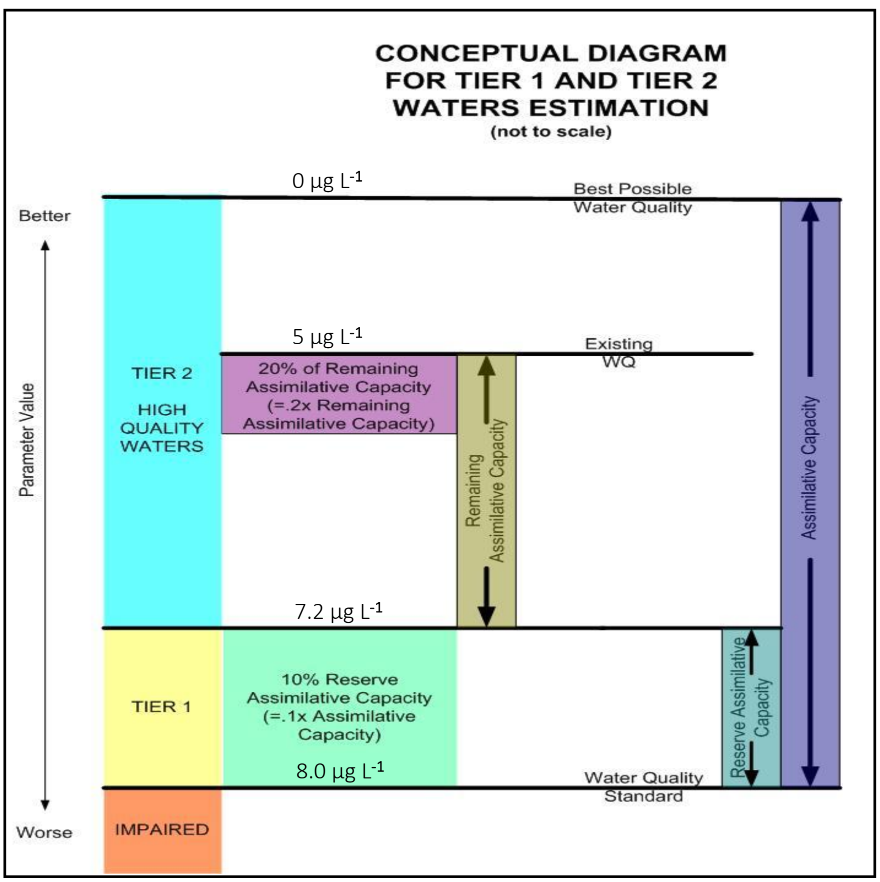

Figure 8. Conceptual Diagram for the Determination of Assimilative Capacity for an Oligotrophic Waterbody.

Results of Assimilative Capacity Analysis

The existing median TP value for Lake Sunapee of 5.0 µg L^{-1} results in a remaining assimilative capacity of 2.2 µg L^{-1}, which qualifies Lake Sunapee in Tier 2 for an oligotrophic waterbody (see Figure 9). The existing chlorophyll-*a* mean value of 1.6 µg L^{-1} is also below the NH State Nutrient Criterion of <3.0 µg L^{-1} for the aquatic life designated use set for an oligotrophic water body.

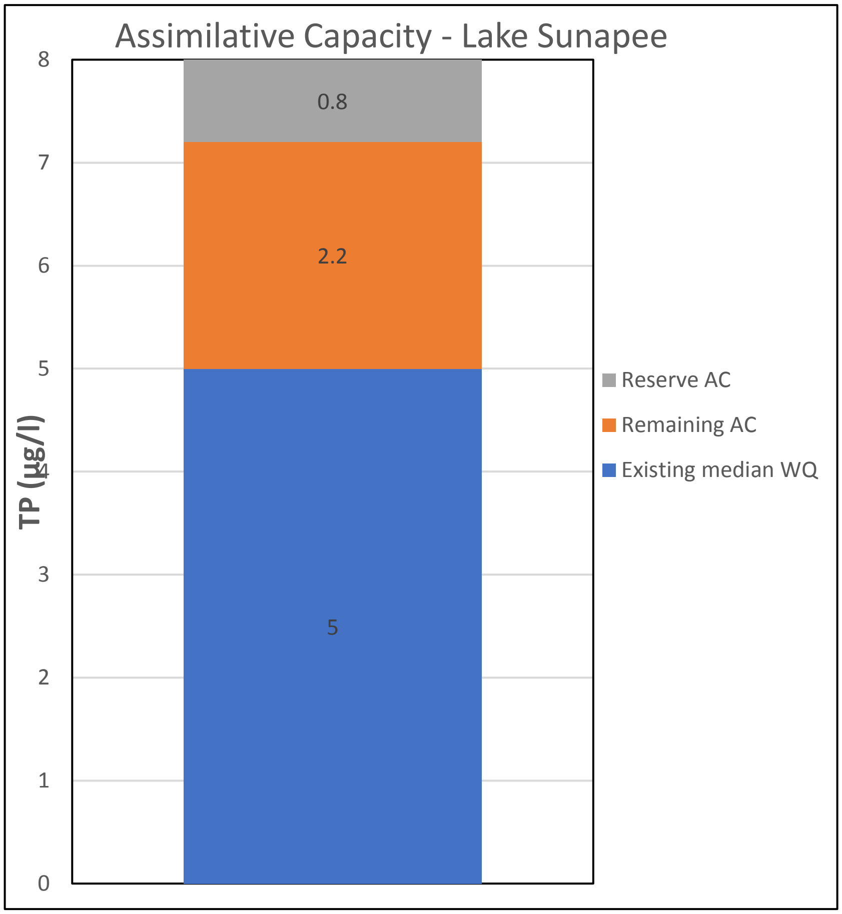

Figure 9. Graph Depicting the Results of the Assimilative Capacity Analysis for Total Phosphorus for Lake Sunapee.

3.2.5 Establishment of a Water Quality Goal

On June 11, 2019, a Water Advisory Group meeting was held at the LSPA Learning Center with 11 in attendance. Group members consisted of LSPA staff, WMP consultants, a NHDES representative and community representatives that were willing and able to participate in this process. The purpose of this meeting was to establish a water quality goal based on preliminary results of the modeling and realistic expectations for phosphorus reduction through remediation of known sources through best management practices (BMPs) and other non-structural strategies for reducing phosphorus loading such as education, zoning and ordinance improvement. Current phosphorus loading to Lake Sunapee is summarized in Figure 10.

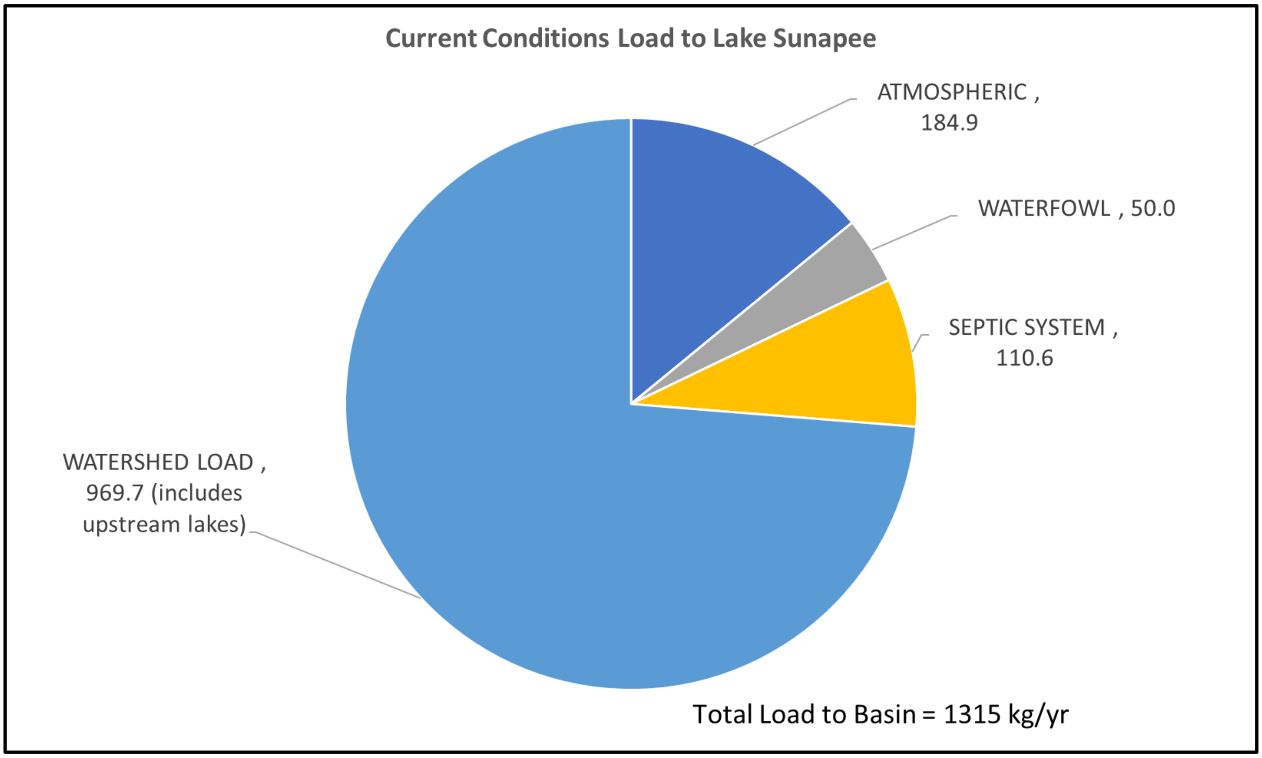

Figure 10. Current Phosphorus Loading to Lake Sunapee.

The project team presented current and future scenarios in relation to in-lake phosphorus loading to the group based on land cover analysis and buildout scenarios (see Figure 11 on following page). Three possible directions were presented for the group to discuss (see insert). In taking the proactive approach, scenarios were presented based on annual increase, no change or several levels of reduction/offset in kg of phosphorus entering Lake Sunapee. Realistic removal rates were discussed based on the proposed water quality improvement sites identified in the watershed survey and from potential reductions coming from septic system upgrades, zoning and ordinances, land conservation and public education campaigns as part of this plan.

Based on the information presented, a consensus was established by the group that an in-lake total phosphorus reduction/offset of 7.5% or 100 kg/yr by 2030 was achievable. This number was also chosen based on the confidence that LSPA as a long-standing organization has the ability and support to meet this goal.

Potential directions

- Use up some of the remaining assimilative capacity by allowing some increase in lake total phosphorus
- Maintain water quality in Sunapee as it is. No change in total phosphorus.
- Recognize that growth and change will occur in the watershed in the future. Reduce total phosphorus now to improve water quality and as a buffer later.

Figure 22 in Section 3.5.7 shows phosphorus export by sub-watershed. These data will be used to prioritize areas for future management of phosphorus loads.

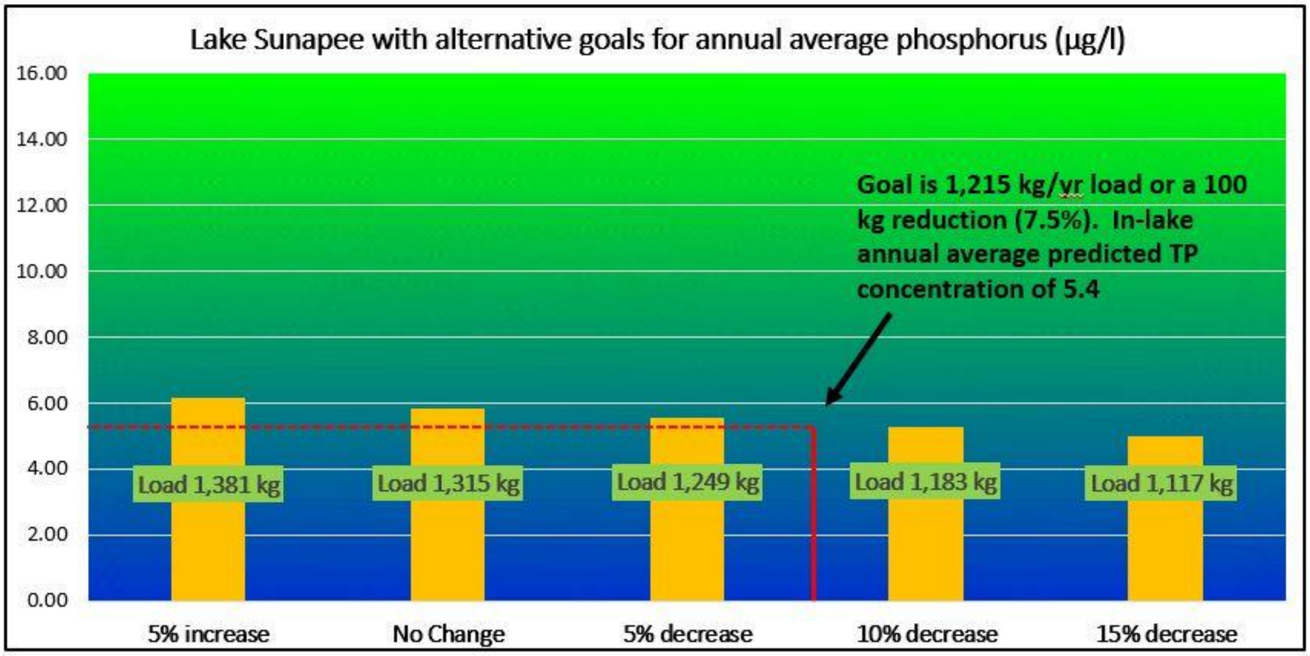

Figure 11. Loads to Lake Sunapee Under Various Future Management Scenarios.

3.3 FUTURE LAND USE PROJECTIONS: BUILDOUT ANALYSIS

The primary goal of the buildout analysis was to reasonably predict building growth throughout the watershed, so that the associated land use adjustments can be utilized to predict water quality impacts to Lake Sunapee, at specific points in the future. Typically, buildout predictions can be based on 1) a specific time interval into the future (i.e. 10 or 20 years from the present) or 2) at a point in the future a certain degree of buildout will potentially occur (i.e. full or half buildout). For this project, both a full and half buildout scenario was developed. A 10-year buildout analysis was also performed, with the thought that this Plan would be revisited and potentially updated 10 years following completion.

The results of the 10-year and the full buildout scenarios were used as input to the watershed model discussed in Section 3.5, facilitating a comparison of existing watershed conditions to the potential buildout scenarios, and an evaluation of impacts to lake water quality based on those specific changes in land use. It is important to note that the buildout analysis was completed using current growth rates, buildable land, zoning and ordinances. Future growth may be different than projections if any of these factors change. Implementation of this watershed plan is an important step towards ensuring that future growth in the Sunapee Watershed can be accommodated without sacrificing water quality.

3.3.1 Collection of Municipal Zoning Information

The project team coordinated with LSPA, the towns of Sunapee, New London and Newbury and staff at NHGRANIT to obtain GIS, zoning and relevant data used to support development of the buildout scenarios. The Town of Newbury was particularly helpful in attaining relevant data, having provided building and zoning data for several towns in the region. In addition to zoning data, environmental resource data were obtained from some towns, NHGRANIT and the USDA NRCS. Communication and data requests were typically submitted via phone calls and emails. Data was transferred by each respective party via cloud-based servers, via email or data download from websites. All data received was GIS-based and incorporated into a GIS database and map project. These data are available to the stakeholders through LSPA as a planning tool going forward.

Similar to the use of a GIS-based system for the project as a whole, a GIS-based platform was chosen as the best system to store and manipulate the buildout data due to the inherent geographic nature of the buildout data, the ease of use and tools available to process data provided by GIS, and the fact that GIS is considered the industry standard for buildout and similar analyses.

3.3.2 Modeled Growth Rate Scenarios

As discussed in Section 2.2.1, historical building permit data from the towns of Sunapee, New London and Newbury were obtained to facilitate development of building growth rate estimates. Annual building permits, dating back to the 1700s and up to 2019, were plotted in Excel and best fit trend lines were fitted to each set of data. Exponential growth curves provided the best fit for each town. The exponential growth curves were then used to predict building growth into the future, for each respective town. An example plot with a best fit trend line is provided in Figure 12.

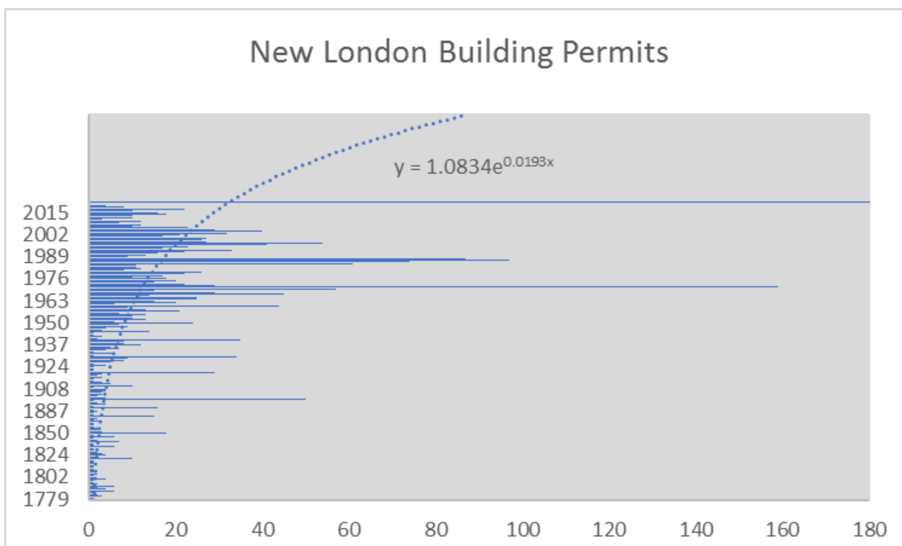

Figure 12. Number of Building Permits Registered in New London, Years 1779 – 2019.

While historical building permit data were not available for Goshen, Springfield and Sutton, the exponential growth curve with the lowest rate of growth (New London) was used to predict growth for those three towns in the buildout analysis, since recent building growth in these towns is significantly lower than growth in Sunapee and Newbury over a similar time period.

3.3.3 Buildout Methodology

The following provides the general steps executed as part of the buildout analysis. All steps were performed in the GIS project, unless otherwise noted:

- The Lake Sunapee Watershed boundary was used to define the portions of each town within the watershed to be analyzed.
- Parcels, property boundaries and zoning information for each town were added to the project.
- The following shapefiles were added to the project, to define areas where building could not occur:
  - Existing buildings and developed land
  - Existing roads, railroads and pipelines
  - Surface water (i.e. lakes, ponds, streams, wetlands)
  - River corridors and flood zones
  - Steep slopes (> 15%)
  - Conservation land
- For the full and half buildout scenarios, future buildable area was simulated per a building density consistent with each town's current zoning standards and minimum lot size requirements. According to the analysis, the full and half buildout scenarios are estimated to occur in years 2050 and 2034, respectively, considering the growth rates discussed above.
- For the 10-year buildout scenario, future buildable area was simulated using the growth rates discussed above and per a building density consistent with each town's current zoning standards and minimum lot size requirements.

Note that while Sunapee, New London and Newbury have specific zoning regulations with multiple zoning districts (i.e. residential, commercial, village, agriculture, etc.) and varied minimum lot size requirements, Goshen, Springfield and Sutton do not have specific zoning regulations in place. The entirety of each town is currently specified as Rural Residential, with the minimum lot size set to 2 acres for Goshen and Sutton, and 1.5 acres for Springfield.

3.3.4 Buildout Results and Use in Water Quality Models

Results for all three buildout scenarios are provided in tables located in Appendix E. The data in each table provide land use adjustments relative to the base 2018 land use data. A comparison of the buildout results compared to the base 2018 land use data indicates the following:

- The percent of developed land (i.e. residential, commercial, roads, outdoor recreation land uses) in 2018 was 12.8%, and that increased to 22.8%, 29.0% and 45.2% for the 10-year, half and full buildouts, respectively.
- The percent of undeveloped land (i.e. open areas, pasture, forest) in 2018 was 85.5%, and that decreased to 75.3%, 69.0% and 52.5% for the 10-year, half and full buildouts, respectively.
- The percent increase in the amount of residential land use, relative to 2018 was 216%, 289% and 479% for the 10-year, half and full buildouts, respectively.
- Dutchman Pond, Morgan Pond and Star Lake sub-basins are projected to have the largest percent increases in developed land. The high percent increases are a function of the lack of developed land that currently exists in these sub-basins, and the amount of buildable land and potential for future development, as identified by this buildout analysis.

The changes in land use for each respective buildout scenario with respect to the base 2018 land use data (Appendix E) were incorporated into the water quality model by modifying the distribution of land uses in the water quality model. A new model run was executed for each buildout scenario. In general, phosphorus loadings increased relative to increases in development. A more detailed discussion of the water quality model with respect to incorporation of buildout data, and the relative impact to water quality in Lake Sunapee with respect to each buildout scenario is provided in Section 3.5.

3.4 WATERSHED SEPTIC SYSTEM SURVEY ASSESSMENT

Based on modeling generated for this plan, it is estimated that nearly 10% of the phosphorous loading into Lake Sunapee comes from septic systems (Section 3.5). In an effort to learn more about the status of septic systems in the watershed, a septic system survey was sent out in September 2019 to 498 properties within 250 feet of waterbodies in the Lake Sunapee Watershed, not on town sewer (see Appendix F for methodology and survey form). The survey was timed to arrive in mailboxes just before EPA's annual "SepticSmart" week to help raise awareness and educate homeowners about the importance of septic system maintenance. We provided two incentives to increase survey responses, including a gift certificate to a local restaurant for including name and address on the survey form, and a septic tank pumping discount from a local septic service company.

A total of 110 property owners responded (22%) by mail or online. The survey included questions about the type of wastewater system on the property, the age of the system, how often the tank is pumped, the occupancy of the property including length of time each year and average number of occupants, appliances used regularly, etc.

Results from the survey showed that 96% of respondents have a septic system comprised of a tank and a leach field. One homeowner has a cesspool and three of the respondents were not sure what type of wastewater system they have on their property Thirty-nine percent (39%) of the systems are more than 25 years old, followed by 29% in the 1-10 year old age category and 25% in the 10-20 year old age category. Only 5% of respondents were not sure of the age of their system and one person left that question blank (Figure 13).

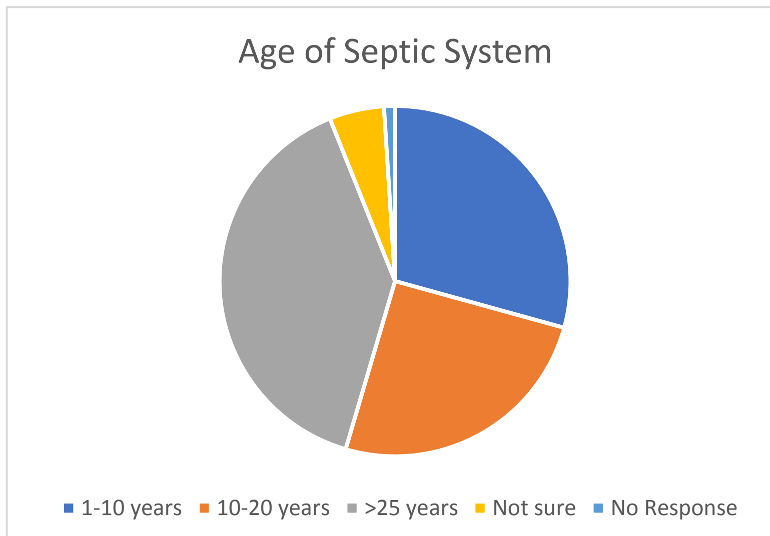

Figure 13. Age of Septic Systems in Lake Sunapee Watershed.

The usage breakdown in terms of length of time each year was almost evenly split among three categories: 2-3 months (31%), 4-6 months (36%) and more than six months (32%) (Figure 14). More than half of the properties (54%) reported an average occupancy of 1-2 people each year, followed by 3-4 people (32%) (Figure 16 on next page). Just over 50% of respondents have their septic tank pumped every 3-5 years as recommended by the EPA and 34% have their tank pumped even more frequently (every 1-2 years). Thirteen percent of homeowners have their septic systems pumped every 6-10 years, 1% reported never having it pumped and 2% have newer systems so they have not established a regular pumping schedule yet (Figure 15). About 85% of the property owners use a washing machine, dishwasher, or both, and close to a quarter use a water softener. Fourteen percent of respondents reported they use a garbage disposal too. Nearly 80% use phosphate-free cleaning products in the home—a sign that more labels are being read when products are purchased and that residents understand the harmful effects of additional phosphorous going into the watershed and waterbodies.

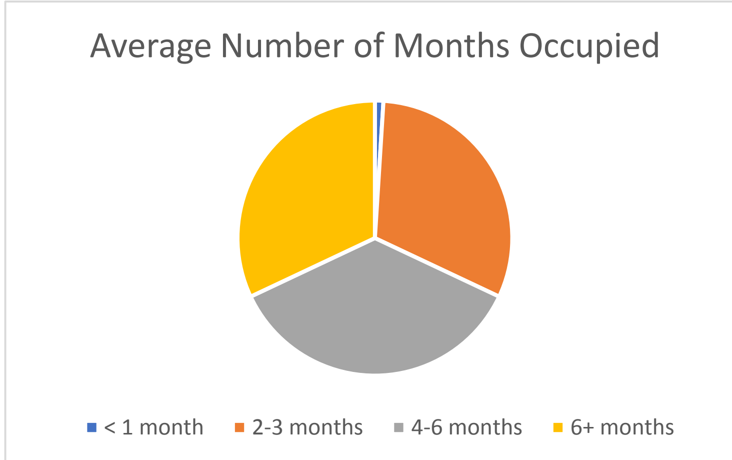

Figure 14. Average Number of Months a Property is Occupied per Year.

Given the amount of phosphorus loading that comes from septic systems and how it can negatively affect water quality, septic system maintenance should be a top priority. LSPA has outlined an ongoing septic system outreach plan (see Section 5.3 for more details) to remind homeowners about the importance of taking care of their septic systems. One thing this survey did not address was the perception of water quality in Lake Sunapee. This might be a good question to ask homeowners in the future to see if they understand how failing septic systems can negatively affect water quality.

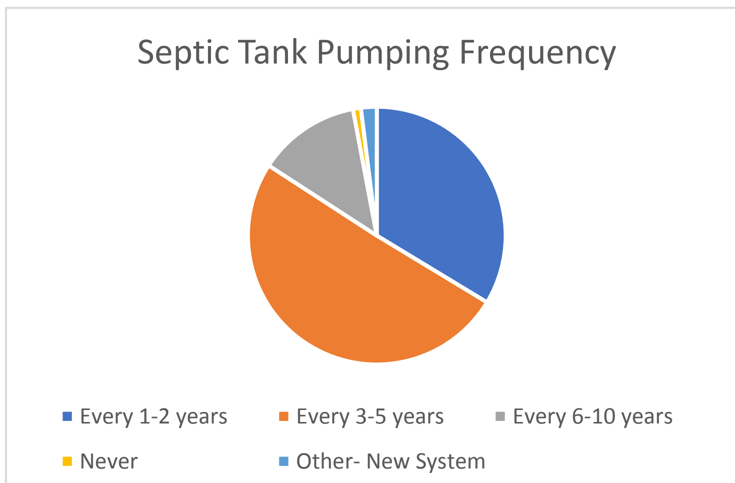

Figure 15. Septic Tank Pumping Frequency.

If we use this as a representative sample of all homeowners on waterbodies in the watershed, this may imply that one in every six households are not maintaining their systems properly and at least one in every three households have systems that are 25 years old or older. Overall, there appeared to be some confusion about the difference between a tank inspection and system inspection. A system inspection includes assessing the condition of components including septic tank, distribution box and the leach field. It is likely that most people are under the impression that the entire system has being inspected at the time of tank pumping while it is not. While the results of this survey were not received in time to incorporate into the water quality model, they will be important to both the education components of this plan and future watershed modeling and planning efforts.

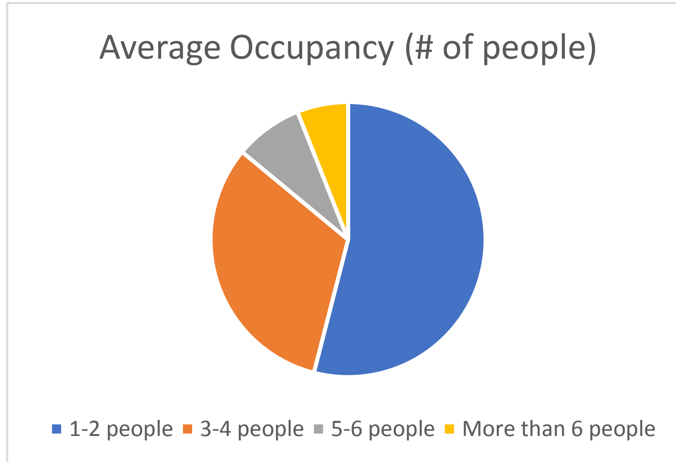

Figure 16. Average Occupancy of Properties in Lake Sunapee Watershed.

3.5 WATER QUALITY MODEL

This section provides results from the Lake Loading Response Model (LLRM) developed for Lake Sunapee. The LLRM is an Excel-based model developed by AECOM for use in New England and modified for New Hampshire lakes by incorporating New Hampshire land use TP export coefficients where available (CTDEP and ENSR, 2004). The model uses environmental data to develop an annual water and phosphorus loading budget for lakes and their tributaries. Surface water, ground water and direct precipitation are the major components of the water budget. Phosphorus loads expressed as both mass and concentration are estimated from all major sources in the watershed. Both water and phosphorus are routed through user set tributary basins to the lake. The tributary basin network can be linear or branched. The model incorporates data about watershed and sub-basin boundaries, land cover, point sources (if applicable), septic systems, waterfowl, rainfall, lake volume and surface area, and internal phosphorus loading. These data are combined with coefficients, attenuation factors, and equations from scientific literature on lakes, rivers, and nutrient cycles.

The following describes the process by which critical model inputs were determined for the Lake Sunapee Watershed using available resources and GIS analysis, and presents annual average predictions of water load, total phosphorus, chlorophyll-*a*, Secchi disk transparency, and algal bloom probability. The model can be used to identify current and future pollution sources, estimate pollution limits and water quality goals, and guide watershed protection and improvement projects.

3.5.1 Watershed and Subwatershed Delineations

Watershed and tributary drainage area (subwatershed) boundaries are needed to estimate water and phosphorus export to the downstream surface waterbody. Land cover types within each subwatershed determine the amount of water and phosphorus that are exported from each subwatershed (See Appendix A, Subwatershed Map 5).

3.5.2 Basin Divisions

Modeling the Lake Sunapee Watershed presents several challenges. The Lake Sunapee Watershed contains eight significant lakes and/or ponds (greater than 20 acres in size) in the watershed. Computationally, the upstream lakes were modeled first and then predicted water and phosphorus from each of these waterbodies was added to the Lake Sunapee model as a point source at the appropriate position in the watershed. A schematic of the watershed is provided in Figure 17. By modeling upstream lakes first, the phosphorus and water balance of each of the watershed lakes and ponds were calibrated to known water quality data. The correct water and phosphorus contribution from each upstream lake and pond to Lake Sunapee was used as input to the watershed model at the appropriate location in the Lake Sunapee Watershed.

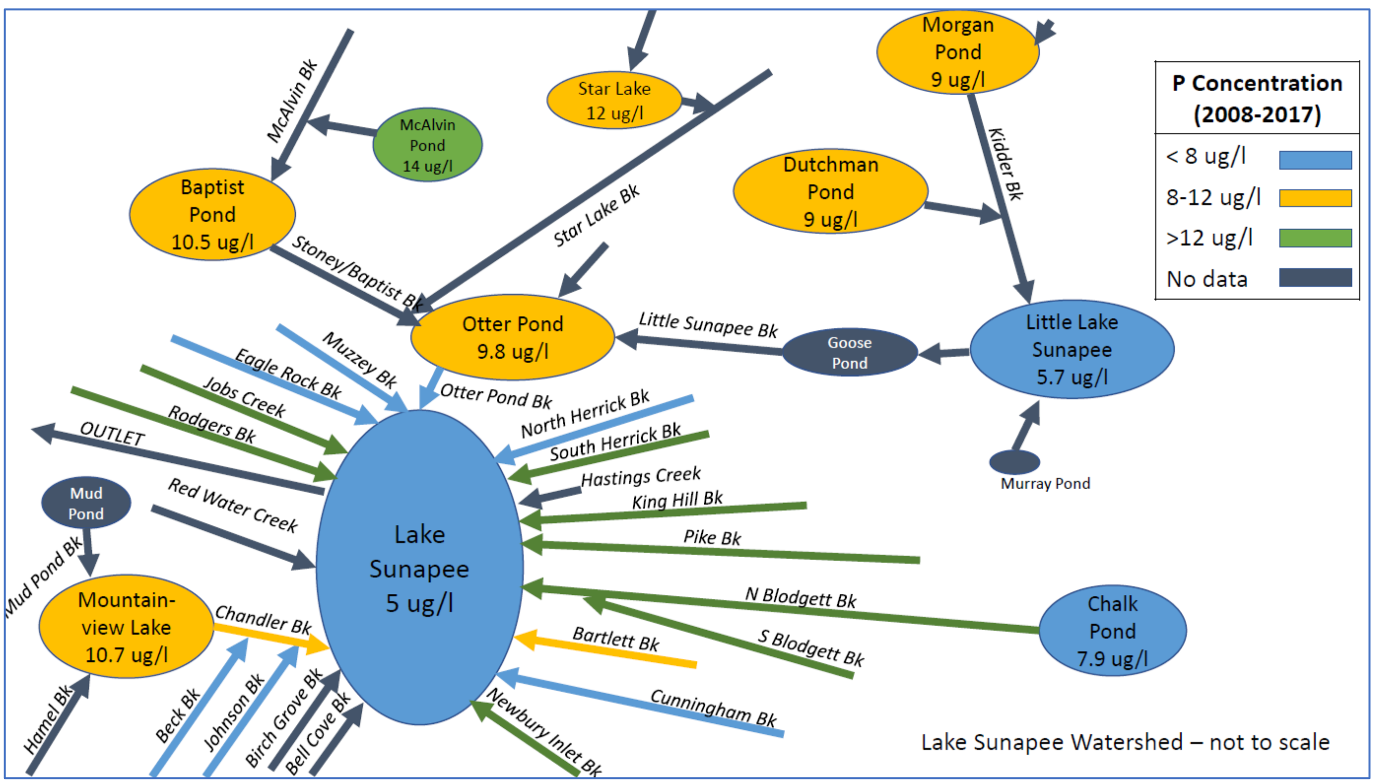

Figure 17. Schematic Representation of the Lake Sunapee Watershed.

Lakes and ponds typically function as phosphorus sinks in that a portion of the phosphorus that enters the lake or pond remains in the lake or pond through sedimentation and biological processes. To accurately simulate the process of phosphorus attenuation in upstream ponds, the Lake Sunapee Watershed was divided into nine models. These included: Baptist Pond, Star Lake, Morgan Pond, Dutchman Pond, Little Lake Sunapee, Otter Pond, Mountainview Lake, Chalk Pond and Lake Sunapee. Output from each upstream model is routed through the Lake Sunapee model (the terminal model) at the appropriate position in the Sunapee Watershed.

3.5.3 Land Cover Update

Land cover for the watershed was classified using a USGS Landsat 8 image from 2018. Based on the Land Cover Mapping Standards created by NH GRANIT, thirteen primary land cover classes were used that best represent dominant land features of the watershed. For more detail on land cover assessment methodology including land cover classes refer to Appendix C, Land Cover Methodology. Most of the subwatersheds are represented by a majority of forest cover that consists of intact or recently disturbed areas by timber harvesting or for other reasons (refer to Figure 18 on following page). Bartlett Brook, Bell Cove Brook, Birch Cove Brook, Dutchman Pond and Morgan Pond subwatersheds are the least disturbed by development. Subwatersheds having the most development (roads, building, maintained fields/open areas) are Hastings Creek, Herrick Cove North Brook, Rodgers Brook and Shoreland West.

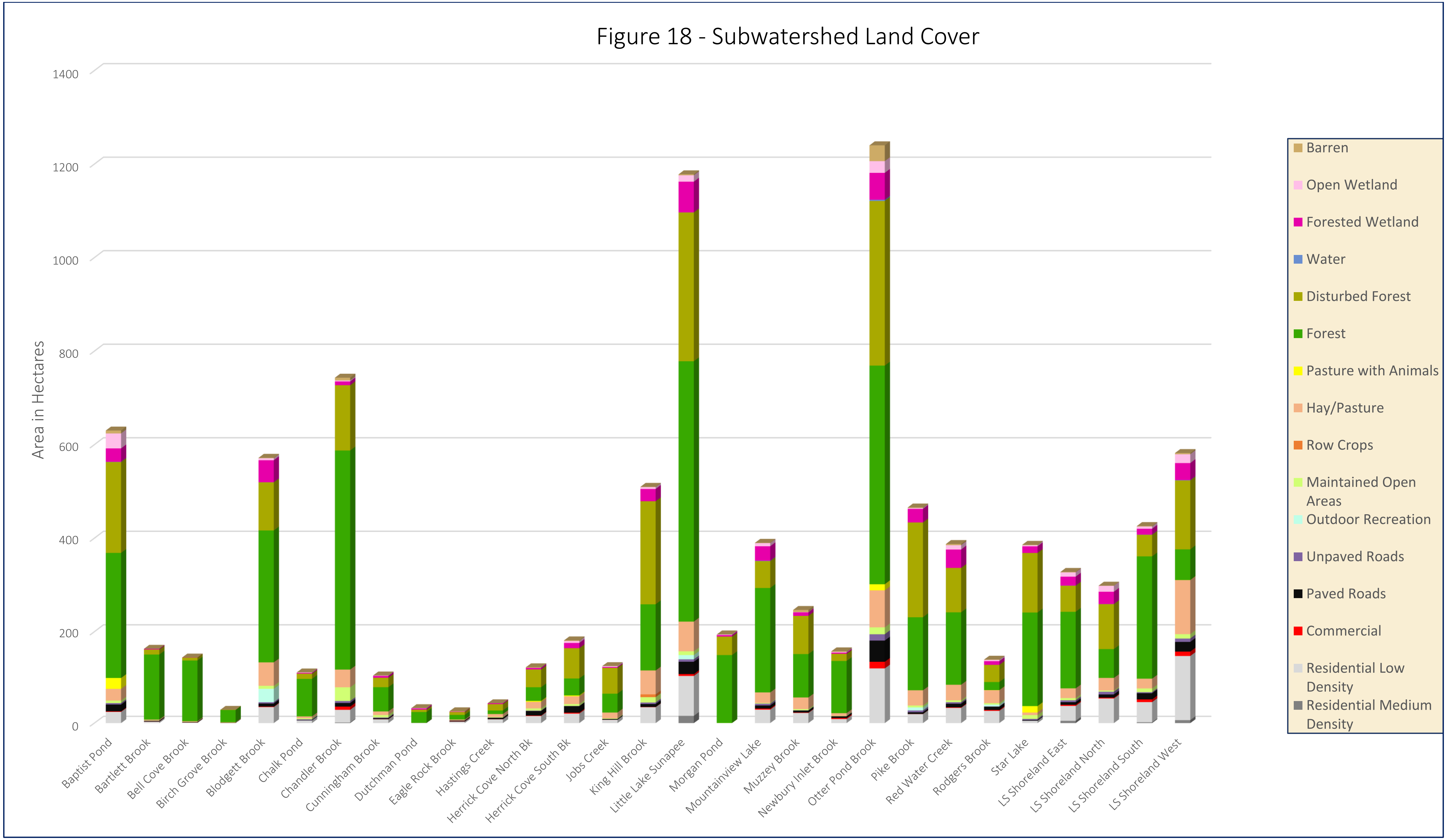
Figure 18 - Subwatershed Land Cover
Area in Hectares
1400
1200
1000
800
600
400
200
0
Baptist Pond
Bartlett Brook
Bell Cove Brook
Birch Grove Brook
Blodgett Brook
Chalk Pond
Chandler Brook
Cunningham Brook
Dutchman Pond
Eagle Rock Brook
Hastings Creek
Herrick Cove North Bk
Herrick Cove South Bk
Jobs Creek
King Hill Brook
Little Lake Sunapee
Morgan Pond
Mountainview Lake
Muzzey Brook
Newbury Inlet Brook
Otter Pond Brook
Pike Brook
Red Water Creek
Rodgers Brook
Star Lake
LS Shoreland East
LS Shoreland North
LS Shoreland South
LS Shoreland West
Barren
Open Wetland
Forested Wetland
Water
Disturbed Forest
Forest
Pasture with Animals
Hay/Pasture
Row Crops
Maintained Open Areas
Outdoor Recreation
Unpaved Roads
Paved Roads
Commercial
Residential Low Density
Residential Medium Density

Based on the land cover assessment, current conditions show that about half the watershed has been impacted by some form of land use activity (Figure 19). Accordingly, nearly 90% of the watershed runoff load to Lake Sunapee is from human impacted land uses (refer to Figure 20) that adds up to 723 kg/yr.

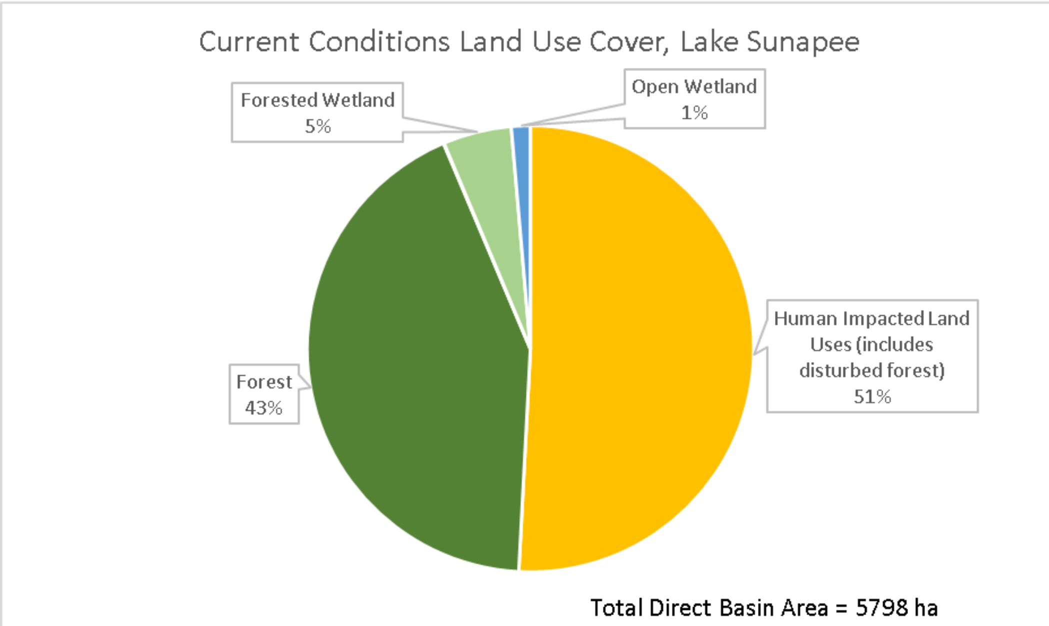

Figure 19. Current Land Cover Distribution for Watershed Drainage to Lake Sunapee (Note: Figure does not include land area above upstream lakes).

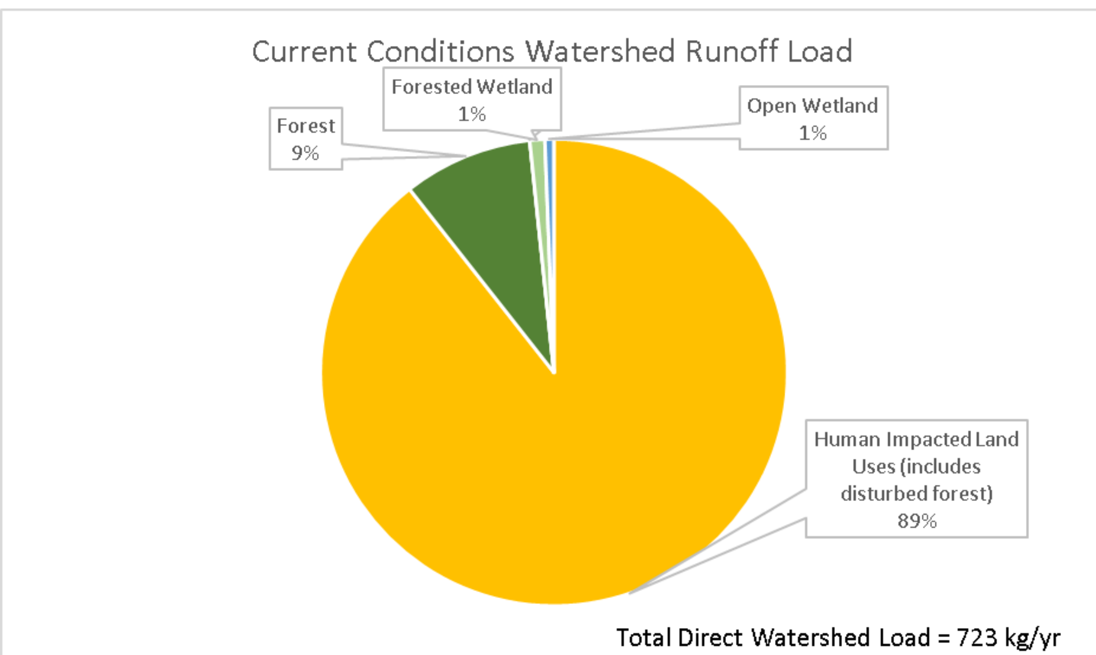

Figure 20. Current Estimated Watershed Load by Aggregated Land Cover Category for Watershed Drainage to Lake Sunapee (Note: Figure does not include loads to upstream lakes).

3.5.4 Other Major LLRM Inputs

The following presents a brief outline of other variable sources and assumptions input to the model. Refer to Limitations to the Model (Section 3.5.6) for further discussion.

- **United States climate data** from Newbury, NH was used to estimate annual precipitation on the watershed (1.21 m/yr) (https://www.usclimatedata.com/climate/newbury/new-hampshire/united-states/usnh0382). Annual discharge data from the USGS gage on the Sugar River (#01152500) for the period 2009-2018 were used to estimate the water yield for the watershed (1.62 cfsm).
- **Lake volume and area estimates** (surface area and perimeter lengths) were calculated using 2016 GRANIT LiDAR data. The mean depth came from NHDES VLAP reports except for Morgan Pond and Star Lake. The maximum depth for those waterbodies was acquired from the Boating USA app and used to calculate the mean depth (mean depth was estimated as 0.4 times the maximum depth). Lake Sunapee maximum depth was calculated from the 2008 Bathymetric Survey made possible by the Breidablik Fund.
- **Lakes in the greater Sunapee Watershed** were modeled independently from Lake Sunapee. Annual water volumes and phosphorus mass leaving these lakes were added to the next downstream model as a point source. In the upper part of the watershed, Morgan and Dutchman Ponds were added to Little Lake Sunapee. Baptist Pond, Star Lake and Little Lake Sunapee were added to Otter Pond. The output from the following lakes were added directly to the Lake Sunapee Model as point sources: Otter Pond, Mountainview Lake and Chalk Pond.
- **Septic system data** were estimated from existing primary dwelling buildings determined during the land cover analysis. These data were used to determine whether septic systems within 250 feet of lakes or adjacent wetlands were modern systems or older non-modern systems. It was assumed that modern systems captured 90% of the phosphorus that entered them while older systems only captured 80%. Each property with a septic system was classified by usage as a full-time residence or a part-time residence (i.e. seasonal). The phosphorus load to each system was calculated based on usage. While no formal septic system survey data were included in the model, a septic survey was conducted in the fall of 2019. For this effort, property records were searched for pertinent information such as date house built, date of most recent septic installation or upgrade, number of bedrooms, seasonal or year-round use, and distance of system to surface water. These results will be compared to assumed values for the model and if warranted, the model will be updated for the next revision.
- **Water quality data** were gathered from the NHDES Environmental Monitoring Database (EMD) and the LSPA. Data were screened for relevant site locations and water quality parameters (Secchi disk transparency, chlorophyll-*a*, total phosphorus, dissolved oxygen, and temperature). The model was calibrated using tributary and lake samples taken between 2009 and 2018 (or recent 10 years). Sites were only included if they were a close match to the outlet of a sub-basin used in the model. Data were summarized to obtain median water quality summaries for total

phosphorus, chlorophyll-*a*, and Secchi disk transparency. Water quality data were discussed in more detail in Section 3.2.1.

- **Waterfowl data** were determined using a standard estimate of 0.3 birds per hectare of lake surface area. Waterfowl can be a direct source of nutrients to lakes; however, if they are ingesting material from the lake and their waste returns to the lake, the net effect may be less than might otherwise be assumed; even so, the phosphorus excreted may be in a form that can be readily used by algae and plants and may be transported from the lake bottom to the surface waters where it is available for algal growth.
- **Internal loading** from anoxic release has not been widely documented in Lake Sunapee or in lakes and ponds in the watershed. It is possible that a degree of internal recycling occurs due to the transport of phosphorus from the sediments to the water column by the cyanobacteria *Gloeotrichia echinulata* however, rates of transfer are not currently available. Ongoing research in Lake Sunapee and elsewhere may allow estimation of this component of the nutrient budget in the future.

3.5.5 Calibration

Calibration is the process by which model estimations are brought into agreement with observed data and is an essential part of environmental modeling. Initial calibration trials focus on the input parameters with the greatest uncertainty. Changes are made within a plausible range of values, with site specific environmental conditions as a guide. In-stream phosphorus concentrations (2009-2018) from most tributaries to Lake Sunapee were available to be used as guideposts however, without streamflow information at the time of sampling, the utility of these data is limited. Flow data allows the calculation of loads which would allow a much more direct calibration of inputs of phosphorus from individual subwatersheds. Observed in-lake phosphorus concentrations (2009-2018) were given primacy during the calibration process, such that the ability of the model to accurately simulate annual average in-lake phosphorus concentrations was used as a leading indicator of acceptable model performance. Upstream models were calibrated first. The mean predicted TP concentration from the empirical models was compared to measured (observed) values. Input factors in the export portion of the model, such as export coefficients and attenuation, were adjusted to yield an acceptable agreement between measured and average predicted TP. Model estimates and monitoring data are presented in Table 11. Where there were sufficient current data, model estimates matched with field data reasonably well. Total phosphorus predictions were typically slightly higher than field data as would be expected given that model predictions are annual averages and field data are summer epilimnetic concentrations. Nurnberg (1996) shows summer epilimnetic concentrations as 14% lower than annual concentrations using a dataset of 82 dimictic lakes while Nurnberg (1998) shows a difference of 40% using a dataset of 127 stratified lakes. The target calibration TP concentration was 10-20% higher than the summer epilimnetic mean. This was achieved in all lakes with sufficient recent data except Dutchman Pond where the model predicted lower than the calibration target and Chalk Pond where the model predicted higher than the calibration target. Neither of these ponds represent major components of the Lake Sunapee nutrient budget (<2% collectively) so small deviations in predicted loads from them have little influence over the Lake Sunapee model estimates.

Table 11 - Predicted vs Measured Water Quality for Major Lakes & Ponds in the Lake Sunapee Watershed

Scenario	Total Phosphorus Load[1] (kg/yr)	Total Phosphorus (µg/l)	Chlorophyll-*a* (µg/l)	Secchi Transparency (µg/l)	Probability of Algal Bloom >10 µg/l (% of time)
Baptist Pond (modeled)	79.3	11.82	3.9	3.5	1.7
Baptist Pond (measured)(N)[2]	na	10.5 (19)	5.7 (19)	5.6 (19)	na
Chalk Pond (modeled)	16.5	11.92	4	3.4	1.8
Chalk Pond (measured)(N)	na	7.9(13)	3.5(13)	3.1 (12)	na
Dutchman Pond (modeled)	4.7	5.91	1.6	5.9	0
Dutchman Pond (measured)(N)	na	9.1(10)	2(10)	na	na
Lake Sunapee (modeled)	1,315	5.9	1.5	5.9	0
Lake Sunapee (measured)(N)	na	5.0(145)	1.6(144)	8.4(128)	0
Little Lake Sunapee (modeled)	164	6.79	1.9	5.3	0
Little Lake Sunapee (measured)(N)	na	5.7(10)	2.7(9)	4.2 (10)	na
Morgan Pond[3] (modeled)	10.2	3.64	0.7	8.5	0
Morgan Pond (measured)(N)	na	9(3)	6.4(2)	3.1 (2)	na
Mountainview Lake (modeled)	60.1	10.03	3.2	3.9	0.5
Mountainview Lake (measured)(N)	na	10.1(15)	3.8(16)	3.1 (14)	na
Otter Pond (modeled)	331.7	10.27	3.3	3.9	0.6
Otter Pond (measured)(N)	na	9.8(37)	3.5(37)	3.0 (37)	na
StarLake[4] (modeled)	35.6	6.98	2	5.2	0
Star Lake (measured)(N)	na	12.1(1)	na	3.7(1)	na

Notes:

[1]TP Load is from all sources including upstream watershed sources

[2]Measured data are from 2009-2018 unless noted (N=number of observations).

[3]Morgan Pond data from 1987-1996

[4]Star Lake data from 1984

Predicted TP in Lake Sunapee was intentionally higher to account for the seasonality of monitoring data as described above. Chlorophyll-*a* predictions were similar to monitoring data. Predicted Secchi transparency was > 2m lower than observed transparency. This discrepancy may be explained, in part, by LSPA's use of a view scope to measure Secchi transparency which typically results in deeper transparency observations. It is unlikely that view scopes were used in the lakes used to develop the TP-Secchi transparency relationship (Oglesby and Shaffner 1978) used in the LLRM. Continued water quality sampling and flow monitoring in the watershed can be designed to increase the confidence in model derived load estimates from individual subwatersheds and reduce some of the simplifying assumptions made during model calibration.

The following key calibration input parameter values and modeling assumptions were made:

- The **standard water yield** coefficient from the USGS gage on the Sugar River is 1.62 cubic ft/sq. mile.
- **Direct atmospheric deposition** phosphorus export coefficient was assumed to be 0.11 kg/ha/yr from Schloss et al. (2013) and represents a largely undeveloped watershed.
- Default **water and phosphorus attenuation factors** were used with exceptions as noted in Table 11. Water can be lost through evapotranspiration, recharge to deep groundwater, and recharge to wetlands, while phosphorus can be removed by infiltration, soil binding, best management practices or uptake processes. Experience from numerous New Hampshire watersheds suggest at least a 5% loss (95% passed through, default) of water in each subwatershed and a 10% loss (90% passed through) of phosphorus for each sub-basin. Larger water losses (<95% passed through) can be expected with lower gradient or wetland-dominated sub-basins. Additional infiltration, filtration, detention, and uptake of phosphorus results in lower phosphorus attenuation values, such as for sub-basins dominated by moderate/small ponds or wetlands (75%-85% passed through) or channel processes that favor uptake (85% passed through), depending on the gradient. Headwater systems were assumed to have a greater attenuation than higher order streams since flows are typically lower, giving more opportunity for infiltration, adsorption, and uptake.
- **In-lake phosphorus concentrations** were estimated by the average in-lake P concentration predicted by empirical model equations from Kirchner and Dillon (1975), Larsen and Mercier (1976), Jones and Bachman (1976), Reckhow (1977) and Nurnberg (1998). Vollenweider (1975) was excluded from the average as it consistently estimated in-lake P that was higher than the rest of the models.

3.5.6 Limitations to the Model

There are several limitations to the model; literature values and best professional judgement are used in place of measured data, where there are few or no data or data are not representative of annual average conditions. Acknowledging and understanding model limitations is critical to interpreting model results and applying any derived conclusions to management decisions. The model should be viewed as one of many tools available for lake and watershed management. Because the LLRM incorporates specific waterbody information and is flexible in applying new data inputs, it is a useful tool that predicts annual average in-lake total phosphorus concentrations with a high degree of confidence; however, model confidence can be further increased with more data (see proposed action item in Section 5.3.4). The following lists specific limitations to the model as it was applied to Lake Sunapee:

- **The model represents a static snapshot in time based on the best information available at the time of model execution.** Factors that influence water quality are dynamic and constantly evolving; thus, the model should be regularly updated when significant changes occur within the watershed and as new water quality and physical data are collected. In this respect, the model should only be considered up to date on the date of its release. Model results represent annual averages and are best used for planning level purposes and should only be used with full recognition of the model limitations and assumptions.
- **Limited phosphorus loading data were available.** Tributaries associated with most sub-watersheds had a great deal of concentration data but few flow data from which to calculate loads for model calibration. Continued data collection at existing sites coupled with flow data would make the dataset stronger and may further increase agreement between tributary observations and model estimates. More data are needed to effectively calibrate the model to known observations for some sub-basins. Until more data are available, we assumed that similar land cover coefficients and attenuation values exist across the entire Sunapee Watershed.
- **Nearly all of the in-lake monitoring data are from the open water season** and most are from the summer, a time when epilimnetic concentrations are typically lower than mean annual concentrations. The empirical models all predict mean annual TP concentrations assuming fully mixed spring overturn conditions.
- **Precipitation varies among years** and hence hydrologic loading will vary. This may greatly influence TP loads in any given year, given the importance of runoff to loading.
- **Upstream lakes** in the watershed were modeled as single subwatersheds primarily due to a lack of supporting tributary data. Many of the upstream lake watersheds could be split further into subwatersheds. This would allow greater insight into the sources of phosphorus to each of the upstream lakes but is not likely to change the Lake Sunapee model much as each upstream lake model was calibrated to data from its respective lake.
- **Septic system loading** was estimated based on literature values and enumeration of systems using GIS and remote sensing data. Literature values for daily water usage, phosphorus concentration output per person, and system phosphorus attenuation factors were used and may not reflect local watershed conditions. Septic data collected during the 2019 LSPA septic survey may allow a more robust estimation of septic influence on total phosphorus concentration in Lake Sunapee in the future.
- **Waterfowl counts were based on regional estimates.** In the future, a large bird (e.g., geese, ducks, etc.) census throughout the year would help improve the model loading estimates.
- **Land cover export coefficients were estimates.** Spatial analysis has innate limitations related to the resolution and timeliness of the underlying data. In places, local knowledge was used to ensure the land use distribution in the LLRM was reasonably accurate, but data layers were not 100%

verified on the ground. In addition, land uses were aggregated into classes which were then assigned export coefficients; variability in export within classes was not evaluated or expressed. While these coefficients may be accurate on a watershed or sub-watershed scale, they often do not represent conditions on individual parcels or parts of parcels within the greater land cover mapping unit. Refer to documentation within the LLRM spreadsheet for specific land cover coefficient citations.

3.5.7 Results

Current Conditions

As described above, the current conditions scenario was developed by calibrating the LLRM to mean observed conditions from 2009-2018 subject to the stated limitations of the model. The model results provide a reasonable accounting of sources and resulting in-lake concentrations on an annual basis. The model can be appropriately used for the planning purposes intended including evaluation of scenarios that might reduce or increase future loads. The model can be appropriately used to inform future decisions in terms of the influence of actions in the watershed on Lake Sunapee water quality.

Table 12 - Total phosphorus (TP) and Water Loading Summary by Source for Lake Sunapee Under Current Conditions

	Current (2019)		
Source	TP (kg/yr)	%	WATER (cubic meter/yr)
Atmospheric	184.9	14%	11,695,963
Internal	0	0%	0
Waterfowl	50	4%	0
Septic System	110.6	8%	102,798
Watershed Load	969.7	74%	61,332,858
Total Load to Lake:	**1,315.20**	**100%**	**73,131,619**

Water and total phosphorus load by source are presented in Table 12. The model predicts that approximately 74% of the total phosphorus load to Lake Sunapee originates in the watershed. This includes the proportion of the load that passes through lakes upstream of Lake Sunapee in the watershed. Atmospheric deposition accounts for 14% of the current load while septic systems and waterfowl account for 8% and 4% respectively of the total phosphorus load.

Table 13 - Predicted Water Quality Parameters Under Different Loading Scenarios for Lake Sunapee

Scenario	Total Phosphorus Load (kg/yr)	Total Phosphorus (µg/l)	Chlorophyll-*a* (µg/l)	Secchi Transparency (m)	Probability of Algal Bloom > 10 µg/l (% of time)
Natural Background	427	1.8	0.1	14.5	0
Current Conditions	1,315	5.9	1.5	5.9	0
10-year Buildout	1,511	6.8	1.9	5.3	0
Full Buildout	1,942	8.7	2.6	4.4	0.2

Current modeled results are presented in Table 13 (previous page). Under current conditions, Lake Sunapee has an estimated annual average total phosphorus concentration of 5.9 µg/l, a chlorophyll-*a* concentration of 1.5 µg/l and a Secchi transparency of 5.9 m. The likelihood of an algal bloom with a chlorophyll-*a* concentration of >10 µg/l is currently 0%.

Total watershed loading by subwatershed (not including contributions from upstream lakes and ponds) is presented in Figure 21. While this table does illustrate where the largest loads originate in the watershed, it is somewhat misleading as the larger watersheds typically have the largest loads. In order to normalize for watershed size, watershed loading by subwatershed is best shown on an areal basis to account for differences in the sizes of subwatersheds. Figure 22 shows areal loading in kg/ha for all the subwatersheds included in the model. These data are displayed spatially in Appendix A, Current Conditions Map 8. The darker green subwatersheds have the highest areal loading rates while the lightest green have the lowest areal loading rate.

Otter Pond is the largest watershed source of phosphorus to Lake Sunapee (Figure 21). This is not surprising as it is the largest subwatershed as well as supporting a substantial development. Many of the small upstream ponds show very small loads as the subwatersheds are small and largely forested. On a per hectare basis (areal) there is much less variability in watershed yield (Figure 22). What is clear is that the more densely developed subwatersheds such as all of the direct shoreline as well as Rogers, Hasting, North Herrick and South Herrick all show relatively high phosphorus yield per hectare while largely undeveloped subwatersheds like Morgan, Dutchman, Bartlett and Bell Cove show relatively low phosphorus yield per hectare.

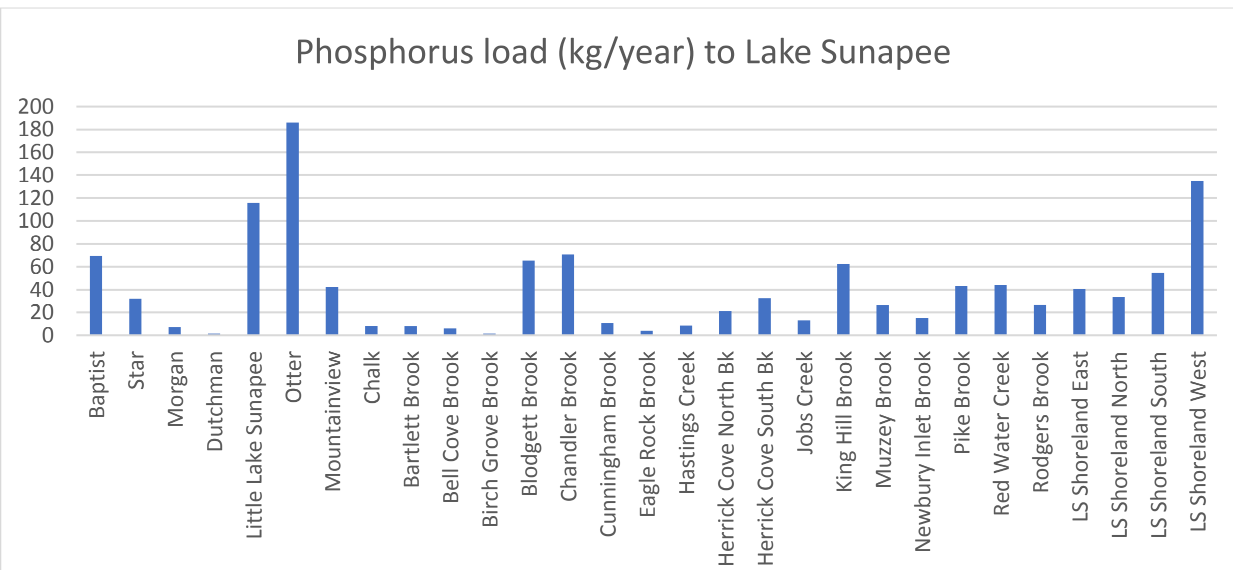

Figure 21. Phosphorus Load (kg/yr) by Subwatershed for the Lake Sunapee Watershed.

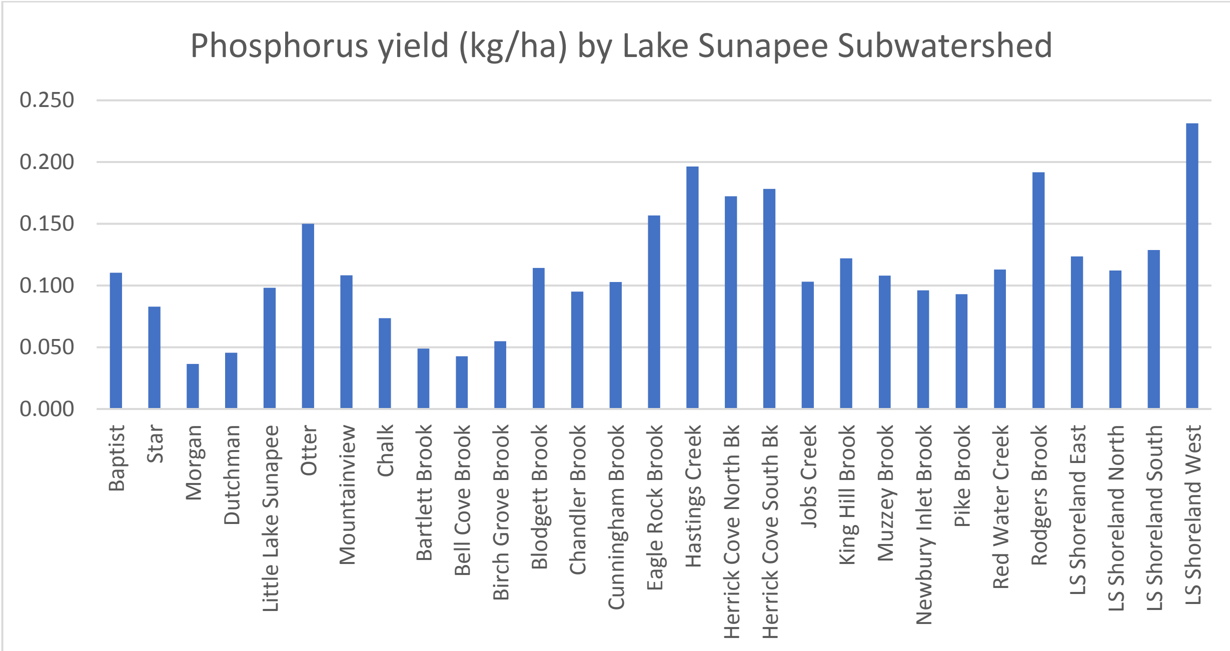

Figure 22. Phosphorus Yield (kg/ha) by Subwatershed for the Lake Sunapee Watershed.

Natural Background

This scenario is a representation of the best possible water quality for Lake Sunapee and was generated by converting all watershed land cover to forest and eliminating septic systems. Each upstream lake was modeled similarly. While it is not realistic to expect the entire watershed to revert to forest, this scenario provides an estimate of the best possible water quality for the lake. Under this scenario, the lake would have been expected to have total phosphorus concentrations approximately 4 µg/l lower than current conditions and continue to support a trophic classification of oligotrophic or very low productivity (Table 13, page 51). Water quality would be excellent under this scenario. Estimated watershed phosphorus yield by subwatershed for the natural background scenario is displayed in Figure 23 (page 55) and in Appendix A, Natural Background Map 9.

Buildout Scenarios

The primary goal of the buildout analysis was to reasonably predict building growth throughout the watershed, so that the associated land use adjustments can be utilized to predict water quality impacts to Lake Sunapee, at specific points in the future. Typically, buildout predictions can be based on 1) a specific time interval into the future (i.e. 10 years from the present) or 2) at a point in the future a certain degree of buildout will potentially occur (i.e. full buildout). Buildout incorporated existing zoning and town specific growth rates and excluded unbuildable areas (See Appendix A, Buildable and Unbuildable Areas Maps 10 & 11). This was described in detail in Section 3.3 above.

For this project, both 10-year and full buildout scenarios were modeled. A half-buildout scenario was also developed but not modeled. The 10-year buildout analysis was developed with the thought that this Plan would be revisited and updated 10 years following completion. The results of the 10-year and full buildout scenarios were used as input to the watershed model discussed below, facilitating a comparison of existing watershed conditions to the potential buildout scenarios, and an evaluation of impacts to lake water quality based on those specific changes in land use.

10-Year Buildout

The 10-year buildout scenario was developed to assess the impact of the potential development of the watershed under current zoning over the 10-year planning window for this plan. This scenario involved converting existing forested and agricultural land not currently in conservation to residential land subject to zoning constraints in each town within the Lake Sunapee Watershed based on historic growth rates and a 10-year time frame. This was designed as a worst-case scenario meaning that all building was conducted under conventional standards and no extraordinary BMPs were included nor was there an attempt to incorporate low impact development principles. Some level of best management practices can be expected for future development so the actual increases in loading might be lower than those projected. It should also be noted that development could also include more intensive uses with changes in zoning which would tend to increase the loading estimates.

Projections of Lake Sunapee water quality under the 10-year buildout scenario are presented in Table 13. Under this scenario, annual phosphorus loading would increase by nearly 200 kg resulting in a total phosphorus concentration increase of approximately 1 µg/L for Lake Sunapee. The chlorophyll-*a* concentration would also increase in the lake while transparency would decline by approximately 0.5 m. Results from this scenario as specified would result in a decline in water quality in Lake Sunapee. However, implementation of the plan described in this document coupled with careful development and redevelopment using best management practices and conservation principles should result in maintenance or improvement in current water quality. Estimated watershed phosphorus yield by subwatershed under the 10-yr buildout scenario is displayed in Figure 23 (page 55) and in Appendix A, 10-Year Buildout Map 12.

Full Watershed Buildout

The full buildout scenario was developed to assess the complete impact of the potential development of the watershed under current zoning. This scenario involved converting all existing forested and agricultural land not currently in conservation to residential land subject to zoning constraints in each town within the Lake Sunapee Watershed. As in the 10-year buildout scenario, it was assumed that all future building would retain similar characteristics as current building in the watershed and similar levels of best management practices. This was also designed as a worst-case scenario meaning that all building was conducted under conventional standards and no extraordinary BMPs were included nor was there an attempt to incorporate low impact development principles. In reality, some level of best management practices could be expected for future development so the actual increases in loading might be lower than those projected. It should also be noted that development could also include more intensive uses which would tend to increase the loading estimates.

Projections of Lake Sunapee water quality under the full buildout scenario are presented in Table 13. Under this scenario, lake phosphorus load would be expected to increase 50% relative to current levels resulting in an in-lake phosphorus concentration of 8.7 µg/L for Lake Sunapee. Chlorophyll-*a* concentrations are projected to increase significantly in the lake to 2.6 µg/L and the probability of algal bloom conditions greater than 10 µg/L would be 0.2 % of the time for Lake Sunapee. Secchi transparency would be reduced to 4.4 m. These projected concentrations would support a trophic classification of mesotrophic or a moderately productive lake. This is a scenario that would likely produce unacceptable water quality in Lake Sunapee for most stakeholders. It also highlights the need for aggressive reduction of existing sources over the lifespan of this plan to offset the phosphorus loading impact of inevitable future development as well as additional measures at the local level to ensure that future development is as low impact as possible. Estimated watershed phosphorus yield by subwatershed under full buildout is displayed in Figure 23 and in Appendix A, Full Buildout Map 13. When compared to current conditions, the rate of phosphorus export from nearly every subwatershed is increased. The only subwatersheds that show only modest increases relative to current conditions are those with little future land development potential as a function of steep slopes, wetlands, conserved land or land that is already developed.

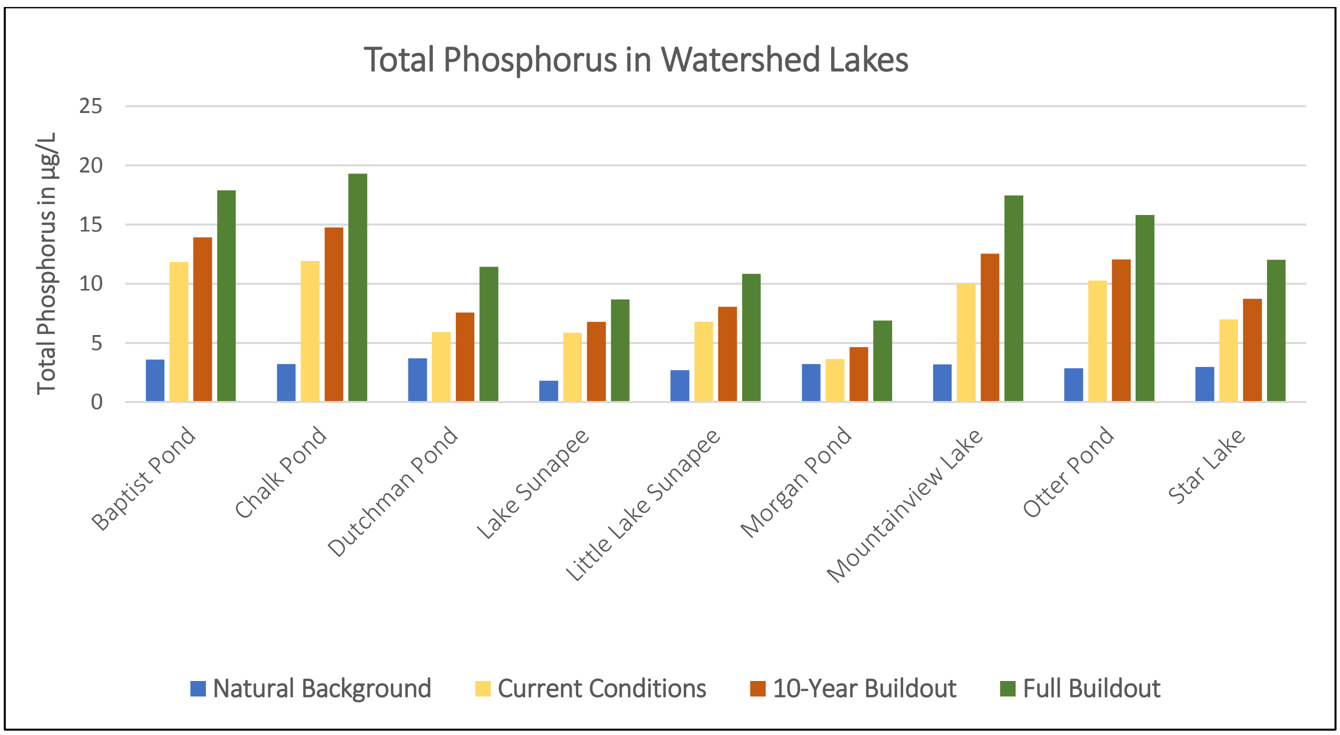

Figure 23. Comparison of In-lake TP Concentrations for Lake Sunapee and Watershed Lakes Under Four Scenarios.

3.6 WATERSHED STORMWATER SURVEY ASSESSMENT

3.6.1 Identification of Potential Stormwater Problem Areas

Prior to surveys performed in the field, the stormwater survey assessment began with 1) an inventory of existing and historical data relevant to known or suspected stormwater problem areas, 2) coordination with local residents and committee members to garner participation in the initial inventory of stormwater concerns, and 3) initial meetings with towns and project stakeholders.

Having been stewards of Lake Sunapee and its watershed since 1898, LSPA had an existing list of known stormwater problem areas, developed from communications with watershed residents and businesses over the last few decades. Additionally, during an initial public meeting presenting this Plan, the project team gave local residents and committee members 'homework', which included the opportunity to reply back to the team via email with known stormwater problem areas that they were aware of. Given the size of the watershed, these initial efforts alone generated a significant number of potential projects to be investigated during field surveys.

The project team then met with the towns that comprised the largest portions of the watershed, including New London, Sunapee, Newbury and Springfield (via phone). A meeting with NHDOT was also conducted, considering the amount of NH Department of Transportation (NHDOT) roadway and facilities within the watershed. These meetings provided an opportunity for LSPA, towns and NHDOT to 1) share maps, information and confirm known stormwater problem areas, 2) discover new problem areas based on each groups existing inventory of issues and gather information on existing capital improvement programs and schedules, and 3) to identify potential synergy between LSPA and future projects. Additional sites were added to the stormwater problem area list based on these meetings.

3.6.2 On the Ground Surveys

With a complete list of potential stormwater problem areas in hand, on the ground surveys began in October 2018. Two separate teams performed surveys over a two-day period on October 23 and 24, 2018. Additional surveys were performed in the spring and summer of 2019 to complete inspections of the initial list of stormwater problem areas, and to perform inspections at sites that were recently added to the list. Each public road in the watershed was driven to locate additional sites not identified during the initial screening meetings.

At each site, the project team collected data to assess existing conditions with respect to stormwater runoff and pollutant loadings, determine suitable BMPs to mitigate loadings, collect measurements to support conceptual BMP development, and collect general site information (photos, GPS coordinates, site ownership, land use type, etc.). A Watershed Survey Datasheet, which summarizes all the information collected was generated for each site. An example of one of these sheets is provided in Appendix G.

3.6.3 Data Processing and Prioritizations

A table describing proposed BMP projects is provided in Appendix H. The table includes a Project ID, project location, site name, drainage characteristics, an estimate of phosphorus generated from the drainage, estimated phosphorus load reductions based on the proposed BMP, and an estimate of design, permitting and construction cost for each project.

The Simple Method (Schueler 1987) was used to estimate annual pollutant loads based on sub-basin area, annual rainfall and pollutant concentration. Pollutant load reductions were calculated based on documented removal efficiencies for specific types of BMPs. Conceptual costs were developed as summarized in Section 5.6. The estimated cost of each project was then divided by the respective P load reduction estimate, to produce a cost per pound of phosphorus removed. A common metric for evaluating the cost effectiveness of a project, the cost per pound of phosphorus removed was used as one of the criteria to prioritize the list of BMP projects, discussed briefly below.

The BMP prioritization was performed by assigning numerical scores to each project relative to six criteria. These criteria were developed by the project team and are specific to the project and characteristics of the lake and watershed. The total scores were used to sort the projects by priority, with the highest score receiving top priority for implementation, and the lowest score having the lowest priority for implementation. The prioritization methodology is discussed in more detail in Appendix H along with a prioritized list of projects.

4. MANAGEMENT STRATEGIES

4.1 GOALS FOR LONG-TERM PROTECTION

Numerical water quality criteria for total phosphorus (TP) in oligotrophic lakes have been established by the State of New Hampshire (Section 3.1). For Lake Sunapee, an oligotrophic lake, the criterion is set at < 8 µg/L. This criterion is 60% higher than the current summer epilimnetic concentration of TP (5.0 µg/L- measured) and 35% higher than the current annual average TP concentration (5.9 µg/L- estimated with LLRM). By this criterion, Lake Sunapee is currently oligotrophic.

Best professional judgment of the project technical team, NHDES, and the steering committee were employed to give a range of options for a goal. The steering committee then selected a quantitative target TP loading that will protect water quality into the future.

Review of existing data and modeling of current conditions suggested that the current phosphorus concentrations in the lake would result in acceptable water quality going forward. This point is bolstered by the fact that water quality as measured by chlorophyll-*a* and TP has not changed appreciably in recent years. At present, the modeling projects a zero percent probability of a lake-wide algal bloom based on current nutrient levels. However, periodic water quality problems like the localized cyanobacteria blooms observed in recent years, evidence that nearshore water quality may be declining and the deficit of dissolved oxygen in the deep sections of the lake is worrying. It is acknowledged that continued development and loading as well as episodic large loading events have the potential to cause an increase in future TP concentrations. It was further recognized there would be future development in the watershed and a goal reducing current loading may allow some of that development impact on nutrient loading to be offset before it occurs. A reduction is related to current loading while an offset is related to future loading that is anticipated but is currently not present. As a result, the Committee selected a 10-year goal of reducing/offsetting phosphorus loading by 100 kg/yr. This represents a 7.5% reduction from current phosphorus loading and would result in a phosphorus load to Lake Sunapee of 1215 kg/yr and an annual average in-lake phosphorus concentration of 5.4 ug/l.

4.2 ADDRESSING NONPOINT SOURCE POLLUTION (NPS)

4.2.1 Structural NPS Restoration

While a variety of stormwater Best Management Practices (BMPs) exist, they can be categorized into four broad categories based on their primary functions and purpose:

1. Volume BMPs –Provide storage of runoff to control flow downstream. They are typically used to reduce peak flows and usually provide a means for settling out suspended sediment from the water column. Examples are wet ponds, dry ponds, and gravel wetlands.

2. Infiltration BMPs – Encourage water to infiltrate into the ground resulting in an overall reduction of runoff volume. Examples include bioretention (i.e. rain gardens), infiltration chambers or trenches, porous pavement, and drywells.

3. Filtering BMPs – Provide a means for filtering or removing suspended sediment and other pollutants out of the water column. BMPs that employ filtering via biological or chemical processes are also included in this category. Examples are grass swales, buffer plantings, sand filter, deep sump catch basins, and manufactured stormwater treatment devices (i.e. 'swirlers').

4. Stabilization BMPs – Includes measures to stabilize or prevent erosion of soils by stormwater runoff or geological instabilities. Examples include stream bank stabilization, replacement of undersized culverts, and stabilization of rills or gullies. Stabilization techniques could include erosion control matting or fabrics, planting of grass, shrubs or trees, bioengineering techniques such as fascines or brush mattresses, or placement of rock.

Roads and Stormwater Management

There are approximately 257 miles of road within the Lake Sunapee Watershed. Of these, 61 miles (24%) are gravel roads and 196 miles (76%) are paved.

Roads, especially gravel roads, are a large source of phosphorus and solids in the watershed, which can be managed with appropriate BMPs. The BMP Prioritization Table located in Appendix H identifies specific road drainage areas in the watershed where runoff from roads is directly conveyed into tributaries and BMPs are recommended. A combination of general road maintenance BMPs and the installation of structural means that promote the infiltration of stormwater from roads can be found in Appendix I.

4.2.2 Non-Structural NPS Restoration

Development regulations pertaining to the Lake Sunapee Watershed are under the jurisdiction of the federal government, the State of New Hampshire and the Towns of Sunapee, Newbury, New London, Springfield, Sutton and Goshen. While this is not intended to be an exhaustive review of those regulations, it highlights important provisions of each of the jurisdictions regulations that have relevance to water quality in the Lake Sunapee Watershed. Any specific development project should do a complete review of requirements prior to any action.

Federal Requirements

- Dredge and fill permit. – Under section 404 of the Clean Water Act dredging and filling of waters of the United States is regulated. A permit is required for dredging or filling water. This included many activities on the waterfront, along streams or in wetlands including construction of beaches, break walls and boat houses.

- Stormwater Permit – A federal stormwater permit (NPDES – Phase II Construction Permit) is required for any land disturbance of greater than 1 acre.

State Requirements

- Site Specific Permit – A Site Specific Permit is required when disturbing more than 100,000 square feet of land or more than 50,000 square feet of land in the Shoreland zone (within 250 feet of a lake or tributary).
- State Septic Permit – A permit for on-site wastewater disposal is required for new construction or expansion of current use of a structure to include additional bedrooms.
- Shoreland Water Quality Protection Act – Requires a permit for many activities in the 250-foot zone from the shoreline of a lake or tributary.

Municipal Requirements

All towns within the watershed maintain varying degrees of stormwater and erosion control requirements, within each respective Zoning Ordinance. A summary of zoning districts per town, and relevant ordinances for each respective district is provided in Appendix J. This table provides information such as minimum lot size, setbacks, maximum lot density for developments, and additional information. A summary of ordinances with respect to stormwater and erosion and sediment control is also provided.

Towns in New Hampshire have the authority to develop and enforce ordinances to protect designated resources of the town such as Lake Sunapee. The statute authority is granted under RSA 674:35 and 674:43 to regulate subdivisions, and nonresidential and multi-family residential site development, respectively. The requirements associated with the development of a town master plan are stated in

RSA 674:1-4. Authority for developing and enforcing zoning ordinances are specified in 674:17-20, and the application of innovative land use controls are described in RSA 674:21.

Considerations for Management of Land Development

Water quality impacts associated with development activities can be mitigated through zoning and planning ordinances and measures including:

- Removing the potential for development: If a landowner is willing, a private owner, conservation organization or the town can either remove the development rights from a property through a conservation easement, or through deeded ownership of the land. Landowners may donate conservation easements in exchange for tax reductions, or easement compensation. Approximately 34% of the land in the Lake Sunapee Watershed is currently under conservation protection. Additional land conservation has the potential to considerably reduce future increases in TP export to Lake Sunapee from the watershed. As presented in the discussion of buildout (Section 3.5), development of all land that could currently be developed in the Lake Sunapee Watershed would result in an increase in phosphorus loading to Lake Sunapee of 50% from the watershed. Additional protection of lands from development would result in a direct decrease in the maximum potential increase in TP loading related to future development.
- General Ordinances
  - Local or regional bans on phosphorus in lawn fertilizer
- New Development / Construction Ordinances
  - Incorporate low impact development (LID) requirements
    - Dry wells
    - Infiltration trenches
    - Bioretention Systems (“rain gardens”)
    - Rain Barrels
  - Minimize disturbed areas
  - Maintain natural buffers
  - Maximize setbacks from lakes and tributaries
  - Minimize impervious cover
  - Minimize construction footprint
  - Pervious pavers / pavement
  - Minimize soil compaction during construction
  - Provide drainage management inclusion for impervious areas (gravel & paved driveways, and roofs) of no net increase in phosphorus export provisions for development.
  - Prohibit stormwater discharges from new driveways and new roads into an existing road or existing road drainage system unless potential impacts (i.e., TP and sediment loading) can be deemed negligible by a qualified professional engineer.

- Enforcement of Ordinances
  - Any of the above provisions could be codified in the watershed town's Planning or Zoning regulations.

5. PLAN IMPLEMENTATION

5.1 PLAN OVERSIGHT

In order to effectively implement this watershed plan, an implementation committee should be formed. Many of the members of the plan development subcommittees could provide continuity and background to the implementation committee. This committee should include all relevant stakeholders across the watershed including local governments. State and federal agency personnel with funding, permitting or technical roles may be invited to participate but need not be committee members. This committee will be charged with ensuring that the plan is up-to-date, progress is being made, regulatory requirements are being met and opportunities for action are fully exploited. In general, the committee is responsible for the following broad objectives:

Develop a plan for sustainable funding. Lack of funding or insufficient funding can often slow or stop the implementation of a watershed plan. Funding should rely on multiple revenue streams to maintain momentum if one or more source of revenue declines or is eliminated.

Continue public outreach. Public outreach throughout implementation is critical to maintaining support for restoration efforts. Publicizing successes may lead directly to opportunities for expansion of existing efforts or new projects elsewhere in the watershed.

Develop a long-term monitoring program. Documenting improvements over time is essential to maintaining momentum in implementation. This may include direct measures, such as documenting water quality improvements through the existing monitoring program or indirect measures such as hectares of land conserved over time. The water quality and GIS data assembled to support this project should be viewed as base data to be continually updated as additional monitoring, assessment or geospatial data become available and projects are completed which result in changes in the watershed. This documentation forms the foundation of outreach efforts and directly impacts the ability to attract additional funding to support phosphorus reduction projects.

Establish measurable milestones. A schedule for implementation is critical to maintaining the forward momentum of the restoration project. A list of action items and target dates for completion is an essential part of the restoration plan. This schedule should include both short-term and long-term restoration schedules. Progress should be measured against milestone targets using metrics directly related to water quality such as in-lake phosphorus concentrations, frequency of cyanobacteria blooms or frequency of dissolved oxygen depletion occurrence.

The ultimate outcome of the watershed plan is to preserve water quality in Lake Sunapee for all human users and the biota that depend on the lake.

Projects implemented to preserve Lake Sunapee water quality would exhibit the characteristics listed in Table 14.

Table 14 - Existing and Desired Conditions Relevant to Preserving Lake Sunapee Water Quality

Parameter	Existing Condition	Desired Future Condition
Water Quality	Phosphorus load supports oligotrophic conditions in the lake. Localized blooms of cyanobacteria do occur. Dissolved oxygen concentrations are depressed in the deeper water of Sunapee.	Lake Sunapee and all waterbodies within the watershed meet water quality standards and support designated uses which include drinking water, contact recreation and aquatic life. This will include phosphorus concentrations supporting an oligotrophic designation, minimal to no cyanobacteria blooms and sufficient dissolved oxygen in the deep water of Lake Sunapee to support aquatic life (>5 mg/l).
Infrastructure	Infrastructure is currently aging or failing in some locations in response to increases in development, intensity of storms and rainfall/runoff.	As infrastructure is replaced, use resilient designs that are stable and sufficient to handle larger volumes of water anticipated in the future.
Land Use Planning	A patchwork of ordinances and zoning among the watershed towns.	Consistent local regulation with preservation of water quality as a priority.
Preservation of Land	Large blocks of land within the watershed are currently protected from development.	Additional blocks of land in critical locations are added to the land currently under conservation.
Education and Outreach	5,634 children and adult attendance/participation at events, workshops and in classrooms for 2019.	Increase attendance/participation at events, workshops and in classrooms to 7,000.
Monitoring	Comprehensive monitoring program currently in place.	Continue existing program with a few changes to facilitate measurement of this plan's success.

5.2 ADAPTIVE MANAGEMENT APPROACH

An adaptive management approach is highly recommended for implementation of this plan. Adaptive management enables stakeholders to develop plans for restoration and protection, determine both what is working and what is not working. Based on a continual evaluation, the plan can be changed to improve the outcome. It also allows the plan to be changed to react to changes in funding availability, specific site conditions, watershed wide conditions, regulatory change and technological advances.

This plan should be considered a living document that will be continually updated as restoration activities are completed, or conditions change. The adaptive management approach recognizes that the entire watershed cannot be restored with a single restoration action or within a short time frame. Instead, adaptive management establishes an ongoing program that provides adequate funding, stakeholder guidance, and efficient coordination of restoration activities. Implementation of this approach ensures that appropriate restoration actions are taken, and that water quality and other environmental conditions are monitored to document restoration over an extended time period.

5.3 ACTION PLAN

The continued education of all stakeholders in the Lake Sunapee Watershed including residents, Town Officials, businesses, visitors and the general public is a critical component of this watershed management plan. LSPA has a long history of education and stewardship of Lake Sunapee and the surrounding watershed making it an important resource in the community. The Action Plan is divided into six categories including Education and Outreach, Research, Further Evaluation, Monitoring and Assessment, Land Conservation and Land Use Regulation, Zoning and Ordinances. Within each category, a brief description of the action item is included along with who will be leading the program, the location and the timeframe for when the action item will begin or be completed.

5.3.1 Education and Outreach

Over the next ten years, LSPA's outreach efforts will focus on helping the public better understand the connection between water quality and using good practices to protect Lake Sunapee and the surrounding watershed. Educational programs will be hosted on-site at LSPA or at other locations where projects have been completed, signs will be installed where permitted to highlight these projects, articles will be included in various publications, and LSPA will pilot new programs that will encourage "lake-friendly" living. All findings from upcoming research projects will also be shared with the public.

Table 15 - Education and Outreach

Action Item	Description	Performed/Led By	Where	Timeframe
Demonstration Sites	Educational tours of project/demonstration sites.	LSPA	Project sites with high educational value and visibility	During project work period and/or at the completion of project – time of greatest educational value
Signage	Educational signage at appropriate project sites where permitted.	LSPA	Projects sites with high public visibility, such as Sunapee Harbor	During project work period and at the completion of project
Progress Reports	Create written reports concerning progress of WMP in each town for annual town reports.	LSPA	Town Reports	Annually
Town Presentation	Make presentations for town administrators and select boards concerning the progress of WMP.	LSPA	In watershed towns	Annually
Publish Articles	Write articles for various local publication (newspapers, The Kearsarge Shopper) as well as LSPA publications with the objective of educating the public about major WMP objectives.	LSPA	Local publications	Three per year
Host Lecture Programs	Plan and carry out lecture/workshop format programs with the objective of educating the public. Possible topics may include runoff and septic issues.	LSPA Education Committee, professional presenters	At LSPA and other appropriate locations	Annually

Table 15 - Education and Outreach				
Action Item	**Description**	**Performed/Led By**	**Where**	**Timeframe**
Host Professional Outreach Programs	Plan and carry out Professional Outreach programs such as UNH Cooperative Extension's Landscaping on the Waters' Edge, UNH T2 Center's Green SnowPro training session and WIT Advisors Sustainable Winter Management Program (SWiM).	LSPA, professional presenters	At LSPA and other appropriate locations	Every 3rd year
Pilot Landscape Program	Pilot a program such as NH LAKES "Lake Smart" and/or develop a Lawn Smart program.	LSPA, homeowners	Homeowner and business venues	Start by 2021 and assess in 2024
Pilot Tour Program	Pilot "lake friendly" garden/lawn tours.	LSPA, identified homeowners	On site or "virtual"	Start by 2022 and assess in 2025
Septic System Reminders	Send septic care/maintenance reminders to residents.	LSPA	Through mail or email	Annually to coincide with EPA's Septic Smart Week in September
Pilot Septic Program	Pilot "Septic Socials" (informal neighborhood gatherings/information sessions).	LSPA, host homeowners	At a host home or appropriate community site	Start by 2023 and assess in 2026
Media Presentations	Create media presentations to add to the LSPA website. Topics may include septic system maintenance, runoff management.	LSPA Education Committee, interns and/or paid professionals	At project sites, private homes, septic company etc.	Start in 2021 and revise as needed annually
Erect Low Road Salt Signs	Identify low salt road areas and look at feasibility of erecting signs to notify public. Review other town roads not listed that would be good candidates for designation.	LSPA Watershed Committee	Watershed	Start in 2022 and complete by 2027
Develop Edgy Outreach Campaign	Develop "edgy" outreach campaign to raise awareness about nonpoint source pollution issues and solutions (similar to EPA's "Watershed Outreach Campaign"). Delivery methods could include print ads, radio ads, LSPA website & newsletters, etc…	LSPA	LSPA	Annually

Table 15 - Education and Outreach				
Action Item	Description	Performed/Led By	Where	Timeframe
Identify Private Unmaintained Stormwater Infrastructure	Work with Towns to determine private stormwater infrastructure not being maintained that is impacting waterways via sediment transport and erosion. Offer suggestions on how to clean and maintain structures such as routinely removing captured sediment from clogged culverts and drains. Assess possibility of drainage easements for sites where homeowners are not willing/able to maintain.	LSPA Watershed Committee	Watershed	Start in 2026 and complete by 2030

5.3.2 Research

Lake Sunapee supports a considerable amount of research in aquatic ecology and water quality. This is essential work that should continue however, there are several other areas of research interest that will greatly help convey a conservation message to the stakeholders and provide valuable insight into the efficacy of efforts to manage phosphorus loading to Lake Sunapee. These are detailed in Table 16 below.

Table 16 - Research				
Action Item	Description	Performed/Led By	Where	Timeframe
Revisit 2012 NOAA Grant Project	Revisit 2012 NOAA Grant project to determine if Towns have "adapted" stormwater infrastructure in critical areas to be more resilient in response to climate change. Properly sized infrastructure will reduce scouring/erosion of soils and outright failure during storm events. Make recommendations to towns based on findings.	LSPA Watershed Committee	LSPA	Start in 2021 and complete by 2025

Table 16 - Research				
Action Item	Description	Performed/Led By	Where	Timeframe
Review Economic Impact Literature	Review existing literature/research on the economic impact of water quality and watershed health to the local economy. Identify information that is applicable for use in the Sunapee Watershed.	LSPA Watershed Committee, student researcher(s)	LSPA	Start in 2020 and complete by 2022
Implement Economic Impact Study	Based on the findings above, research/implement economic impact study for the Sunapee Watershed.	LSPA Watershed Committee, LSPA, student researcher(s)	LSPA	Start in 2022 and complete by 2027
Expand Septic System Database	Expand the septic system status database to include property owners within 250 feet of wetlands and tributaries to determine phosphorous loading	LSPA	LSPA	Start in 2020 and complete in 2022. Revise database in 2030
Identify Septic Repair Funding Sources	Identify potential grant funding sources to fund repair work on failing septic systems.	LSPA	LSPA	Start in 2021 and complete by 2022
Phosphate Free Study	Pursue a study on phosphate-free cleaning products and fertilizers to determine if they are indeed phosphorus free. Preliminary findings from a Colby Sawyer student indicated that some of these products did have phosphorus in them. Depending on future findings LSPA can educate the public about this issue.	LSPA, student researcher(s)	TBD	Start in 2020 and complete by 2022
Airborne Dust Study	Pursue a study on impacts of airborne dust from leaf blowers. Does this activity contribute to phosphorus loading when dust settles onto water surfaces and/or when dust on landscape is washed into waterways from storm events? Depending on findings, LSPA can educate public about any potential harmful impacts aside from noise and air pollution these machines cause.	LSPA, student researcher(s)	TBD	Start in 2024 and complete by 2026.

Table 16 - Research				
Action Item	**Description**	**Performed/Led By**	**Where**	**Timeframe**
Internal Phosphorus Loading Study	Collaborate with LSPA's Scientific Advisory Committee, EPA and NHDES to better understand lake sediment chemistry and the possible release of phosphorus into the lake water column during anoxic conditions.	LSPA, Scientific Advisory Committee	LSPA	Start in 2020 and complete by 2021
Food Web Interactions Study	Collaborate with LSPA's Scientific Advisory Committee on ongoing research on Lake Sunapee to better understand impacts of food web interactions on lake water quality.	LSPA, Scientific Advisory Committee	LSPA	Start in 2022 and complete by 2030
Phosphorus Transfer by Cyanobacteria Study	Collaborate with LSPA's Scientific Advisory Committee on ongoing research on Lake Sunapee to better understand potential transfer of phosphorus from sediment into the lake water column by cyanobacteria. Incorporate relevant research findings into watershed plan.	LSPA, Scientific Advisory Committee	LSPA	Start in 2021 and complete by 2030

5.3.3 Further Evaluation

Due to the scale of the watershed and resource limitations, several areas of the watershed were only evaluated in a cursory fashion in this watershed plan. Additional detailed evaluation of several areas is warranted (Table 17). Data generated through these evaluations will help further the overall Sunapee Watershed goals.

Table 17 - Further Evaluation				
Action Item	**Description**	**Performed/Led By**	**Where**	**Timeframe**
Track Future Use of EWP Renewable Power Plant	Plant located in Springfield is currently closed. Remain engaged in process of sale, reuse or recommissioning of the site to ensure phosphorus export is minimized.	LSPA Watershed Committee	Plant Site	As needed per future use

Table 17 - Further Evaluation				
Action Item	**Description**	**Performed/Led By**	**Where**	**Timeframe**
Evaluate Durgin & Crowell Mill Site	Coordinate with mill owner(s) to evaluate ways to minimize phosphorus export from site.	LSPA, NHDES	Lumber Mill Site	Start in 2022 and complete by 2024
Blodgett's Landing Stormwater Study	Encourage Town of Newbury and Blodgetts's Landing Cottage Association to create a plan addressing excessive stormwater runoff occurring in this development affecting the water quality of the lake. First step includes identifying and mapping above and below ground stormwater infrastructure such as conveyance pipes, dry wells, drop inlets and catch basins and how they connect. Second step includes the assessment and implementation of cost-effective solutions to address excessive runoff such as installing stormwater infiltration/treatment projects on both public and private properties. Grant funding with required match may be helpful to initiate this effort (see Sources of Funding in Section 5.6). Challenges include unknown locations of abandoned wastewater tanks potentially filled with waste, collapsed/plugged conveyance pipes, buried catch basin structures and the existence of asbestos lined pipes.	LSPA, Town of Newbury, Blodgett's Landing Landowners	LSPA, Blodgett's Landing, Town of Newbury	Ongoing effort

5.3.4 Monitoring and Assessment

The monitoring program currently in place at LSPA is very comprehensive in scope and longevity however, preparation of this watershed plan highlighted a number of areas where enhancements to the existing program would greatly increase understanding of the resource and ultimately management of the watershed. These are presented in Table 18 on the following page.

Table 18 - Monitoring and Assessment				
Action Item	**Description**	**Performed/Led By**	**Where**	**Timeframe**
Tributary Flow Gaging	Determine and calculate more accurate flow volumes from tributaries for better idea of phosphorus loading and to record change over time.	LSPA	Tributaries flowing into Lake Sunapee	Start in 2020 and complete in 2021
Shoreline Survey	Perform survey (see example form in Appendix K) of shoreline properties used for long term comparison and identify hotspots. Educate landowners on lake friendly landscaping methods.	LSPA, interns	Lake Sunapee Shoreline	Complete in 2020 and repeat survey every 10 years
Expand Water Quality Program	Bolster data collection in upstream lakes and ponds to refine modeling and consider sub-basin plans for each of them in collaboration with local stakeholders.	Local lake and pond associations with assistance from LSPA	Upstream watershed lakes and ponds	Start in 2020 and continue annually

5.3.5 Land Conservation

Land conservation can play a critical role in the preservation of water quality in Lake Sunapee and the reduction of future phosphorus loads. Table 19 presents elements of a land conservation strategy for the watershed.

Table 19 - Land Conservation				
Action Item	**Description**	**Performed/Led By**	**Where**	**Timeframe**
Identify Key Land Conservation Parcels	Identify undeveloped land parcels within subwatersheds suitable for land conservation based on size and location. Prioritize land parcels in subwatersheds with high TP loading estimates. Establish an in-house land protection committee and work with local land trusts to conserve properties.	LSPA, Local Land Trusts, Local Conservation Commissions	LSPA	Start in 2020 and continue preservation efforts annually

5.3.6 Land Use Regulation, Zoning and Ordinances

The six Lake Sunapee Watershed towns and the State have a patchwork of land use regulations at various levels of detail. As a result, water quality protection is not consistent among the towns and at the State level. Table 20 presents actions to bring the regulations closer together in the shared mission of water quality protection across the watershed.

Table 20 - Land Use Regulation, Zoning and Ordinances

Action Item	Description	Performed/Led By	Where	Timeframe
Water Quality Buffers	Encourage towns to require water quality buffers during construction projects such as 25-foot setbacks from wetlands and streams not under the purview of the Shoreland Protection Act. Healthy riparian buffers reduce nutrient and pollutant loading to waterways and provide important wildlife habitat.	LSPA Watershed Committee, Towns	LSPA	Begin discussion by 2021 and continue as needed
Post Development Stormwater Ordinance	Encourage towns to enact or improve ordinance ensuring stormwater post-development runoff does not exceed pre-development runoff for construction projects. Include provision that requires any stormwater systems installed to comply with this ordinance be functional when a property is sold (model ordinances available). Collecting and infiltrating stormwater runoff onsite helps prevent downstream erosion and scouring of shoreline, streams and properties.	LSPA Watershed Committee, Towns	LSPA	Begin discussion by 2020 and continue as needed
Stormwater System Operation	Encourage advocacy organizations (such as NH LAKES) to introduce a bill requiring proper operation of stormwater systems such as dry wells and pervious driveways that were installed as required by Shoreland Protection Act permits when a property is sold.	LSPA Watershed Committee, NH LAKES	LSPA	Begin discussion in 2022 and continue as needed
Septic System Operation	Encourage advocacy organizations (such as NH LAKES) to introduce a bill requiring proper operation of septic systems including an inspection report from a licensed professional when a property is sold (modeled after other states).	LSPA Watershed Committee, NH LAKES	LSPA	Begin discussion in 2023 and continue as needed

5.3.7 Best Management Practices (BMPs)

Upon completion of the watershed survey, forty-two sites were identified as areas of concern where proposed Best Management Practices (BMPs) projects could be implemented with landowner participation. (See Appendix A, Proposed BMP Sites Map 14 and Appendix H, BMP Tables for site list). LSPA identified three of these projects to pursue in 2020 and applied for 319 Clean Water Act grant money in the fall of 2019 needed to fund engineering services, supplies and materials. These are identified as 1) the Davis Hill Brook Bank Stabilization project located at Davis Hill Road in New London, 2) the Beck Brook Bank Stabilization project located at Lot 1 at the Sunapee Mountain Resort and 3) the Garnet Hill Stormwater Improvement project located at Garnet Hill and Old Norcross Road intersection in Sunapee. These projects are listed as the 3rd, 10th and 20th priority on the BMP Prioritization Table located in Appendix H. LSPA pursued these specific projects due to several factors, including ease of implementation, synergy with upcoming town projects and willingness of landowners to pursue proposed projects.

These projects address erosion, sedimentation and nutrient loading within the Lake Sunapee Watershed. The proposed BMPs at two sites will also capture winter sanding material that is conveyed during spring melt not collected by street sweeping/cleaning machines. The result of having these proposed BMPs implemented will be the reduction of turbidity and available phosphorus and other nutrients within the two streams and lake by helping prevent a further decline in water quality. In addition, stabilizing stream banks at two sites (Beck and Davis Hill Brooks) will likely improve conditions necessary for the survival and reproduction of fish species and benthic macroinvertebrates.

5.3.8 Summary of Estimated Load Reduction Based on the Plan

This plan outlines a number of categories of actions that can reduce or offset phosphorus loads throughout the Lake Sunapee Watershed. Table 21 presents a summary of those actions and the estimated reductions and offsets to phosphorus loading to Lake Sunapee from each category.

Table 21 - Summary of Estimated Phosphorus Loading Reduction/Offsets

Category	Estimated Annual P Load Reduction/Offset (kg)	Estimated 10 year P Reduction/Offset (kg)	Notes
Education and Outreach	1	10	Estimate includes voluntary action, septic upgrades and homeowner projects. Could be substantially higher.
Research	na	na	Critical to understanding watershed and lake processes.

Table 21 - Summary of Estimated Phosphorus Loading Reduction/Offsets				
Category		Estimated Annual P Load Reduction/Offset (kg)	Estimated 10 year P Reduction/Offset (kg)	Notes
Further Evaluation		na	na	Estimated reductions are presented in Best Management Practices Section (to be identified) below.
Monitoring		na	na	Data required to evaluate long term changes.
Land Conservation		2	20	Offset of P loading is 0.26 kg/yr (keeping land in forest rather than residential) for full buildout period. This equates to an offset of 0.08 kg/ha/yr for the next 10 years. Estimate based on 25 ha/yr protected or 250 ha over 10 years.
Land Use Regulation, Zoning and Ordinances		1	10	Estimate
Best Management Practices	Identified	4	40	See Appendix H - BMP Tables
	To be identified	2	20	Sites identified through further evaluation tasks.
Total Reductions/offsets:		**10**	**100**	

5.4 INDICATORS TO MEASURE PROGRESS

There are numerous ways to measure progress. The table below lists indicators and benchmarks that LSPA hopes to reach over the 10-year period.

Table 22 - Environmental Indicators			
Indicators	Benchmarks[1]		
	2020	2025	2030
Reduce the occurrence of cyanobacteria or algal blooms.	No major occurrences at bloom concentrations.	No occurrences at bloom concentrations.	No occurrences at bloom concentrations.
Maintain median summer epilimnetic in-lake total phosphorus of 5 ppb at the deep spot of Lake Sunapee.	Prevent or offset 10 kg/yr in phosphorus loading from new or existing development.	Prevent or offset 50 kg/yr in phosphorus loading from new or existing development.	Prevent or offset 100 kg/yr in phosphorus loading from new or existing development.

Table 22 - Environmental Indicators			
Indicators	Benchmarks[1]		
	2020	2025	2030
Improve dissolved oxygen conditions in bottom waters by reducing the extent and duration of depressed dissolved oxygen in Lake Sunapee.	No further decrease in oxygen to support cold water species throughout the hypolimnion (DO >5mg/l).	Sufficient oxygen to support cold water species throughout the hypolimnion (DO >5mg/l).	Sufficient oxygen to support cold water species throughout the hypolimnion (DO >5mg/l).
Prevent and/or control the introduction of invasive aquatic species to surface waters.	Absence of invasive aquatic species where they currently do not exist.	Absence of invasive aquatic species where they currently do not exist.	Absence of invasive aquatic species where they currently do not exist.
Notes: [1]Benchmarks are cumulative starting at year 1.			

5.5 TARGET SCHEDULE

Program targets are indirect measures of watershed protection and restoration activities (Table 23). Rather than indicating that water quality reductions are being met, these programmatic measurements list actions intended to meet the water quality goal.

Table 23 - Program Targets				
Action Item	Indicator	BenchMarks[1]		
		2020	2025	2030
Education & Outreach	Number of Reports, Articles, Presentations and Programs Published/Hosted/Piloted/Completed	5	25	50
Education & Outreach	Number of Tours Given	1	4	8
Education & Outreach	Number of Signs Erected	1	3	6
Research	Number of Studies/Projects Started and/or Completed	1	5	10
Further Evaluation	Number of Additional Sites Evaluated	1	7	14
Land Conservation	Number of Parcels Identified and Landowners Approached	5	10	15
Model Ordinances	Number of Ordinance Campaigns Started/Enacted	1	2	4
Monitoring & Assessment	Number of Shoreline Surveys Completed	1	1	2
Monitoring & Assessment	Number of Tributaries Evaluated to Attain More Accurate Volume Measurements	1	4	8

Table 23 - Program Targets				
Action Item	Indicator	BenchMarks[1]		
		2020	2025	2030
Monitoring & Assessment	Number of Additional Monitoring Stations from Upstream Lakes/Ponds/Tributaries	2	4	6
BMP Projects	Number of Projects Completed	5	28	56

Notes:
[1]Benchmarks are cumulative starting at year 1.

5.6 ESTIMATED COSTS AND TECHNICAL ASSISTANCE NEEDED

Conceptual level construction cost estimates for each BMP project are provided in the Proposed BMP Projects Table in Appendix H. These costs were developed based on EPA's 2016 document "Methodology for developing cost estimates for Opti-Tool" (EPA 2016) for volume based BMPs and recent construction bid prices for erosion and stabilization related BMPs. Adjustments have been made such that costs are provided in 2019 dollars. Where needed, data from the New Hampshire Department of Transportation's Weighted Average Unit Prices (NHDOT 2019) were also referenced to complete conceptual level construction cost estimates.

Additional cost estimating information is provided in Proposed BMP Projects Table in Appendix H. The *BMP Construction Cost Estimate* column provides conceptual level estimates for design and permitting costs set at 25% of the estimated construction cost. The *BMP Design/Permitting Costs* column includes a cost adjustment factor that can be applied to the total cost to reflect the relative ease or difficulty anticipated in designing, permitting and/or constructing each project. When assigning the adjustment factors, the general assumption made was that it would cost more to install a new BMP in a developed area (with more site constraints) than it would cost to install the same BMP in a previously undeveloped area. A cost adjustment factor of 1.0 was assigned to a new BMP in an undeveloped area; proposed BMPs on private property were given an adjustment factor of 1.5; and BMPs adjacent to or within the NHDOT right-of-way were given a cost adjustment factor of 2.0 to account for the complexity of the NHDOT project development processes.

Regarding technical assistance, it is most likely that LSPA will require technical assistance from several sources when attempting to implement the Plan. Initial discussions regarding potential projects may begin with LSPA staff soliciting input from their internal advisory committees regarding project feasibility, prioritization and funding sources. During the project development and scoping phase, it is likely that LSPA staff will need to coordinate with local town staff and/or private landowners depending on the location of the potential project. These discussions could involve project feasibility, landowner agreements and exploration of potential matching funds and/or assistance from the town. Additional coordination may be required with other various stakeholders such as the Upper Valley Lake Sunapee Regional Planning Commission, local land trusts, other watershed groups, etc.

Close coordination and guidance from potential funders will also be required. When pursing 319 Clean Water Act grant funding (i.e. Watershed Assistance Grants via NHDES), LSPA will require assistance from NHDES staff during both the grant application and implementation phases. And during design and implementation, LSPA will require technical assistance from engineering consultants and construction contractors. LSPA will most likely develop contracts with both and manage those contracts and payments.

The estimated costs presented in Table 24 are expected to be covered by a combination of LSPA in-kind contributions and dedicated program funding, grants, partner funding, private donations and watershed town in-kind and dedicated funding.

Table 24 - Estimated Annual and Total 10-Year Costs for Action Plan Implementation

Category		Estimated Annual Cost	Estimated 10-Year Cost	Basis of Estimate
Education & Outreach		$8,000	$80,000	LSPA Budget
Research		$15,000	$150,000	Costs largely born by participating research institutions and grants.
Further Evaluation		$5,000	$50,000	Cost may be offset, in part, by grant funding.
Monitoring		$5,000	$50,000	LSPA Budget
Land Conservation		$65,000	$650,000	Based on Jan 2020 listing price of parcels >20 ha (50 acres) in watershed towns (see Appendix L). Costs may be substantially less if easements are purchased or if land and/or easements are donated. Costs may include funding from towns and other grants.
Land Use Regulation, Zoning & Ordinances		$2,000	$20,000	Estimate
BMP Projects	Identified	$75,000	$750,000	Costs may be offset, in part, by grant funding. See Appendix H - BMP Tables
	To be identified	$25,000	$250,000	Costs may be offset, in part, by grant funding. Sites identified through further evaluation tasks.
		Total Cost:	**$2,000,000**	

Diverse funding sources and strategies will be needed to implement these recommendations. Below are some possible funding sources. In addition, there are numerous private donors and charitable foundations that may support conservation causes.

Sources of Funding

- **USEPA/NHDES 319 Grants (Watershed Assistance Grants)** – This NPS grant is designed to support local initiatives to restore impaired waters (priorities identified in the NPS Management Program Plan, updated 2014) and protect high-quality waters. 319 grants are available for the implementation of watershed-based management plans and typically fund $50,000 to $150,000 projects over the course of two years.

  https://www.des.nh.gov/organization/divisions/water/wmb/was/categories/grants.htm
- **Water Quality Planning (604B)** - Grants are available to Regional Planning Commissions and/or the Connecticut River Joint Commissions for water quality planning purposes. Funding priority is given to projects developing watershed-based plans.
- **Local Source Water Protection Program -** This grant is available for the protection of public drinking water sources. https://www.des.nh.gov/organization/divisions/water/wmb/was/categories/grants.htm#wqp
- **Water Supply Land Conservation Grant Program –** Cost sharing grants available to assist in the protection of community and non-transient non-community drinking water supplies by providing grant funds for the acquisition of land or conservation easements. https://www.des.nh.gov/organization/divisions/water/dwgb/dwspp/land_acqui/categories/overview.htm
- **NH State Conservation Committee (SCC) Grant Program (Moose Plate Grants)** – County Conservation Districts, municipalities (including commissions engaged in conservation programs), and qualified nonprofit organizations are eligible to apply for the SCC grant program. Projects must qualify in one of the following categories: Water Quality and Quantity; Wildlife Habitat; Soil Conservation and Flooding; Best Management Practices; Conservation Planning; and Land Conservation. The total SCC grant request per application cannot exceed $24,000. https://www.mooseplate.com/grants/
- **Land and Community Heritage Investment Program (LCHIP) –** This grant provides matching funds to help municipalities and nonprofits protect the state's natural, historical, and cultural resources. https://www.lchip.org
- **Aquatic Resource Mitigation Fund (ARM) –** This grant provides funds for projects that protect, restore, or enhance wetlands and streams to compensate for impacted aquatic resources and loss of associates functions and values in a watershed. https://www4.des.state.nh.us/arm-fund/
- **New England Forest and River Grant –** This grant awards $50,000 to $200,000 to projects that restore and sustain healthy forests and rivers through habitat restoration, fish barrier removal, and stream connectivity such as culvert upgrades. https://www.nfwf.org/programs/new-england-forests-and-rivers-fund

- **Milfoil and Other Exotic Plant Prevention Grants (NHDES)** – Funds are available each year for projects that prevent new infestations of exotic plants, including outreach, education, Lake Host Programs, and other activities. https://www.des.nh.gov/organization/divisions/water/wmb/exoticspecies/categories/grants.htm
- **Clean Water State Revolving Loan Fund (NHDES)** – This fund provides low-interest loans to communities, nonprofits, and other local government entities to improve and replace wastewater collection systems with the goal of protecting public health and improving water quality. A portion of the CWSRF program is used to fund nonpoint source, watershed protection and restoration, and estuary management projects that help improve and protect water quality in New Hampshire. https://www.des.nh.gov/organization/divisions/water/wweb/grants.htm
- **Agricultural Nutrient Management Grant Program:** The NH Department of Agriculture, Markets, and Food provides small grants to assist agricultural land and livestock owners with efforts to minimize adverse effects to waters of the state by better management of agricultural nutrients. Applications are accepted annually. More information can be found at: https://www.des.nh.gov/organization/divisions/water/wmb/was/categories/grants.htm

5.7 WATER QUALITY MONITORING PLAN

LSPA has participated in the Volunteer Lake Assessment Program (VLAP) administered by NHDES since 1986. LSPA also participates in the Lake Host program to educate boaters and examine boats and trailers for aquatic invasive plants and animal species entering or leaving lakes.

Sampling is conducted at four deep stations, eight nearshore stations and at most of the major tributaries to Lake Sunapee (Table 25 on following page). In addition, samples are collected from some of the lakes and ponds in the watershed and some tributary streams to those lakes and ponds (Appendix A, VLAP Monitoring Stations Map 7).

Field and Laboratory Protocols for LSPA Water Quality Collection and Analysis 2020

The LSPA follows the NHDES VLAP field sampling protocols, found in the “VLAP Field Manual” on the website: https://www.des.nh.gov/organization/divisions/water/wmb/vlap/categories/publications.htm

The laboratory protocols are found in the Colby-Sawyer/LSPA Satellite Laboratory QA Manual, which is updated yearly and filed with NHDES and EPA and can be obtained by contacting the LSPA Water Quality Lab Manager or NHDES VLAP Coordinator.

Table 25 - VLAP Water Quality Parameters Measured at LSPA Sites			
	Tributary Site (25 locations)	Cove Site (8 locations)	Deep Site (4 locations)
	Data Collected: (each station sampled once per month)		
Water Quality Parameter	May-October	June-September	May-lake turnover (normally October)
Transparency (Secchi Disk)		X	X
Dissolved Oxygen			X
Temperature			X
pH	X	X	E, M, H
Acid Neutralizing Capacity			E
Conductivity	X	X	E, M, H
Turbidity	X	X	E, M, H
Chloride	X	X	E, M, H
Apparent Color	X	X	E
Total Phosphorus	X	X	E, M, H and 1 m off bottom at end of season
Chlorophyll-*a*		Integrated tube one meter from bottom to surface	Integrated tube from metalimnion to surface
Plankton			Haul from metalimnion
Notes: E= epilimnion (surface), M=metalimnion (transition layer), H=hypolimnion (lower layer)			

In general, the existing monitoring program is sufficient to monitor water quality in Lake Sunapee however additional monitoring would assist in quantifying loads from tributaries and understanding the dynamics of watershed lakes and ponds. The following modifications to the existing monitoring program conducted by LSPA are suggested:

1) Tributary stream samples should be collected during both wet and dry periods and multiple samples should be collected during long storm events. Flow measurements associated with the sample collection would allow direct calculation of loads rather than estimation through modeling. This can be accomplished by installing staff gages in each tributary and developing stage/discharge relationships for each gage to relate specific gage readings with specific flows. Furthermore, flow measurements should initially be recorded systematically over a season and after storm events at or near where samples are

taken and preferably where stream profiles can easily be obtained such as at bridge and culvert crossings. If specific locations show consistently high concentrations or loads, visual investigation and/or additional monitoring points upstream should be considered to isolate the cause. Reaches with the highest TP load would be the target of initial efforts to reduce TP.

2) It is recommended that VLAP sampling be continued to document the in-lake response, trends, and compliance with water quality criteria following implementation of TP reduction measures outlined in the plan. Data collected by LSPA which includes TP, DO, conductivity, transparency, planktonic chlorophyll-*a* and the reporting of cyanobacteria scums should continue. LSPA may wish to consider reducing the sampling frequency or eliminating one or more of the four deep stations as analysis of results from 2009-2018 suggest that for TP, chlorophyll-*a* and transparency, there is no difference (statistically) in these parameters among the stations (Section 3.2.1). Resources associated with this monitoring can be directed elsewhere.

3) There exist few data on several of the upstream ponds and lakes in the watershed. Annual deep site profiling and a minimum of monthly sampling on each of the major pond/lake outlets in the watershed would help further inform the modeling and source identification. Recorded data could also form the basis for sub-watershed plans in the future.

4) Visual BMP effectiveness monitoring should commence as soon as practicable from pre-construction through post-construction to document that estimated removal efficiencies are obtained by the "as-built" design. At a minimum, projected TP removal calculations should be compared to calculations for the "as-built" condition. The addition of other parameters such as total suspended solids and flow should be considered in calculation of effectiveness from the "as-built" condition. Geo-referenced photographic evidence should accompany each visual inspection along with field notes. Until the site is stabilized, it should be inspected after every rainfall over 1 inch. Once stabilized, the sites should be visited in the spring and fall of every year. This will allow quick recognition of the need for maintenance or a retrofit to every constructed BMP.

The evaluation of individual BMP's as well as routine data collection will allow progress towards the goal for the Sunapee Watershed to be quantified.

5) In order to evaluate the effectiveness of the public outreach and education efforts to be conducted as a part of this plan, a survey that evaluates the current state of knowledge about fertilizer, shoreland protection, septic system maintenance and stormwater management should be conducted. Use the results of the survey to target specific topics and individuals for educational efforts. After implementation of the public education components of the watershed plan, conduct a follow up survey to test the effectiveness of the program by repeating the initial survey. The increase in awareness will be used as a metric to measure the effectiveness of the program. If deficiencies are still noted in the knowledge of watershed residents, the public outreach and education program can be modified to provide the appropriate information.

5.8 CONCLUSION

Lake Sunapee is an exceptional resource that is well worth preserving. Watershed residents, towns, landowners, business owners, and recreationalists must all be invested in this plan for it to be successful. Every stakeholder has a part to play. The goal of this plan is to improve water quality by reducing phosphorus loading to Lake Sunapee by 100 kg over the next 10 years. This goal can be reached if the actions discussed in this plan are implemented.

Implementation of this plan over the next 10 years is expected to cost $2,000,000 and will require the dedication and hard work of municipalities, conservation groups, and volunteers to ensure that the actions identified in this plan are carried out. As important as adherence to the plan as it is now written is to success, the plan will need to be updated as the plan is implemented, new knowledge is gained and circumstances unknown at this time are realized. As a result, this plan should be viewed as a living document as described in the adaptive management approach section.

REFERENCES

Carlson, R. 1977. *A trophic state index for lakes*. Limnol. and Oceanogr. 22:261-369 Mifflin Co., NY.

Carpenter, S.R., J.F. Kitchell, J.R. Hodgson, P.A. Cochran, J.J. Elser, M.M. Elser, D.M. Lodge, D.W. Kretchmer, X. He and, C.N. von Ende. 1986. *Regulation of lake ecosystem primary productivity by food web structure in whole lake experiments*. Ecology. 1986.

Connecticut Department of Environmental Protection and ENSR. 2004. *A Total Maximum Daily Load Analysis for Kenosia Lake in Danbury, Connecticut*.

Cottingham, K. L., H. A. Ewing, M. L. Greer, C. C. Carey, and K. C. Weathers. 2015. *Cyanobacteria as biological drivers of lake nitrogen and phosphorus cycling*. Ecosphere 6(1):1. http://dx.doi.org/10.1890/ES14-00174.1

Dillon, P.J. and F.H. Rigler. 1974. *The phosphorus-chlorophyll relationship in lakes*. Limnol. Oceanogr. 19:767-773.

Dupigny-Giroux, L.A., E.L. Mecray, M.D. Lemcke-Stampone, G.A. Hodgkins, E.E. Lentz, K.E. Mills, E.D. Lane, R. Miller, D.Y. Hollinger, W.D. Solecki, G.A. Wellenius, P.E. Sheffield, A.B. MacDonald, and C. Caldwell, 2018: Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18

Hayhoe, K., D.J. Wuebbles, D.R. Easterling, D.W. Fahey, S. Doherty, J. Kossin, W. Sweet, R. Vose, and M. Wehner, 2018: Our Changing Climate. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock].

Jones, J. and R. Bachmann. 1976. *Prediction of phosphorus and chlorophyll levels in lakes*. JWPCF 48:2176-2184.

Jones, R.A., W. Rast and G.F. Lee. 1979. *Relationship between summer mean and summer maximum chlorophyll-a concentrations in lakes*. Env. Sci. & Technol. 13:869-870.

Kirchner, W. and P. Dillon. 1975. *An empirical method of estimating the retention of phosphorus in lakes*. Water Resourc. Res. 11:182-183.

Larsen, D. and H. Mercier. 1976. *Phosphorus retention capacity of lakes*. J. Fish. Res. Bd. Can. 33:1742-1750.

MEDEP & Kennebec County Soil and Water Conservation District. April 2010. Gravel Road Maintenance Manual, A Guide for Landowners on Camp and Other Gravel Roads.

New Hampshire Employment Security. Economic & Labor Market Information Bureau. Community Profiles. Available at: https://www.nhes.nh.gov/elmi/products/cp/profiles-htm/sutton.htm. Accessed January 17, 2020.

New Hampshire Department of Environmental Services (NHDES). (2018a). State of New Hampshire 2018 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology (CALM). NHDES-R-WD-19-04. Retrieved from: https://www.des.nh.gov/organization/divisions/water/wmb/swqa/2018/documents/r-wd-19-04.pdf

New Hampshire Department of Environmental Services. 2018b. Section 303(d) Surface Water Quality List.

New Hampshire Department of Environmental Services. 2017. VLAP Reports for 2017. Accessed 11/1/2019.

New Hampshire Department of Environmental Services (NHDES). 2008a. Standard Operating Procedures for Assimilative Capacity Analysis for New Hampshire Waters. August 22, 2008. In NHDES, Guidance for Developing Watershed Management Plans in New Hampshire, Revision #3, April 14, 2010 (pp. 16-21). Concord, NH: NHDES. Retrieved from: https://www.des.nh.gov/organization/divisions/water/wmb/was/documents/wmp_dvlp_guidance.pdf

New Hampshire Department of Environmental Services. 2008b. New Hampshire Stormwater Manual. Revision 1.0. Available at: https://www.des.nh.gov/organization/divisions/water/stormwater/manual.htm

New Hampshire Department of Resources and Economic Development, Division of Forests and Lands. 2016. Best Management Practices for Erosion Control on Timber Harvesting Operations. Available at: https://extension.unh.edu/resources/files/Resource000247_Rep266.pdf

New Hampshire Fish and Game. 1977. Biological Survey of the Lakes and Ponds in Sullivan, Merrimack, Belknap and Strafford Counties. Survey Report No. 8b.

New Hampshire Department of Transportation. 2019. Weighted Average Unit Prices, For Projects Between 7/1/2018 and 6/30/2019. Accessed November 8, 2019. Available at: https://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents/WeightedAveragesImperial.pdf

NOAA (National Oceanographic and Atmospheric Administration). 2018. Local Climatological Data, Daily Summary for Concord, NH. National Weather Service, National Environmental Satellite, Data, and Information Service. Available at: https://www.ncdc.noaa.gov/data-access Accessed 18 December 2019.

Novatny, E. and H.G. Stefan. 2012. *Road salt impact on lake stratification and water quality*. Journal of Hydraulic Engineering 138(12):1069-1080

Nurnberg, G.K. 1996. *Trophic state of clear and colored, soft and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish*. Journal of Lake and Reservoir Management 12(4):432-447.

Nurnberg, G.K. 1998. *Prediction of annual and seasonal phosphorus concentrations in stratified and unstratified polymictic lakes*. Limnology and Oceanography, 43(7), 1544-1552.

Oglesby, R.T. and W.R. Schaffner. 1978. *Phosphorus loadings to lakes and some of their responses. Part 2. Regression models of summer phytoplankton standing crops, winter total P, and transparency of New York lakes with phosphorus loadings*. Limnol. Oceanogr. 23:135-145.

Reckhow, K. 1977. Phosphorus Models for Lake Management. Ph.D. Dissertation, Harvard University, Cambridge, MA.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011, US-EPA, Washington, D.C.

Schloss, J.A. 1989. Lake Sunapee Nutrient Budget Summary. Freshwater Biology Group of the University of New Hampshire.

Schloss, J.A. and J. Connor. 2000. Development of Statewide Nutrient Loading Coefficients through Geographic Information System Aided Analysis. University of New Hampshire, Water Resources Research Center, project summary.

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, DC.

University of New Hampshire Stormwater Center. March 2010. Investigation of Nutrient Removal Mechanisms of a Constructed Gravel Wetland Used for Stormwater Control in a Northern Climate. Prepared in Collaboration with The New England Interstate Water Pollution Control Commission. March 2010. Available at:

http://www.neiwpcc.org/neiwpcc_docs/GravelWetlandNutrientCyclingFinalReport3-31-10.pdf

Sunapee Area Watershed Coalition and Granite State Rural Water Association. 2008. Management Plan for the Lake Sunapee Watershed.

Thompson, J.B., McLelland, J.M., and Rankin D.W., 1990, Simplified Geologic Map of the Glens Falls 1°x2° Quadrangle, New York, Vermont, and New Hampshire: United States Geological Survey, Miscellaneous Field Studies Map MF-2073, scale 1:250,000, one sheet.

University of New Hampshire Stormwater Center. 2010. Protecting Water Resources and Managing Stormwater: A Bird's Eye View for New Hampshire Communities

US Climate Data 2019. Available at https://www.usclimatedata.com/climate/newport/new-hampshire/united-states/usnh0391. Accessed 12/19/2019.

US Environmental Protection Agency. 2016. Memorandum: Methodology for developing cost estimates for Opti-Tool. Karen Mateleska, EPA Regional I. February 20, 2016. Available at: https://www3.epa.gov/region1/npdes/stormwater/ma/green-infrastructure-stormwater-bmp-cost-estimation.pdf

US Environmental Protection Agency. Office of Wetlands, Oceans and Watersheds. Nonpoint Source Management Fact Sheets. Available at https://www.epa.gov/aboutepa/about-office-water#wetlands

Vollenweider, R.A. 1975. *Input-output models with special references to the phosphorus loading concept in limnology*. Schweiz. Z. Hydrol. 37:53-62.

Vollenweider, R. 1982. Eutrophication of Waters: Monitoring, Assessment and Control. OECD, Paris.

Walker, W.W. 1984. Statistical bases for mean chlorophyll-*a* criteria. Pages 57-62 in Lake and Reservoir Management – Practical Applications. Proceedings of the 4th annual NALMS symposium. USEPA, Washington, DC

Walker, W.W. 2000. Quantifying uncertainty in phosphorus TMDLs for lakes. Prepared for NEIWPCC and USEPA Region I. Concord, MA