LAKE KANASATKA

WATERSHED-BASED MANAGEMENT PLAN

PREPARED BY FB ENVIRONMENTAL ASSOCIATES

in cooperation with the Lake Kanasatka Watershed Association

August 2022 | **FINAL**

Lake Kanasatka Watershed Association

P.O. Box 774

Center Harbor, New Hampshire 03226

Dear Reader:

On behalf of the LKWA, we are pleased to share with you the final Lake Kanasatka Watershed-Based Management Plan prepared by FB Environmental Associates. This document details a comprehensive study of the Lake and its watershed to gain a deeper understanding of the dynamics contributing to cyanobacteria blooms. In addition to research into water quality, shoreline conditions, and other factors, the Plan identifies opportunities for us to mitigate areas of concern to help stem future blooms.

This effort would not have been possible without the financial support of the Town of Moultonborough, who unanimously supported this project at the 2021 Town Meeting. Equally important are the many individual financial contributions made in memory of Ted Hilton and by those who love Lake Kanasatka and want to see it protected for generations to come. We also benefitted from the counsel of our Technical Advisory Committee who represented key stakeholders in this process (see Acknowledgements).

We would also like to thank Forrest Bell and Laura Diemer of FB Environmental Associates. Their experience, expertise, and incredible collaboration and communication helped us to gain a deeper understanding of lake ecology and how we can be better lake stewards.

The most important lesson from this process is that we can and must work together to achieve great things, and protecting Lake Kanasatka is one of the greatest things we can do.

Sincerely,

Kirk Meloney

President LKWA

On behalf of the LKWA Advisory Board and the Watershed Management Committee

Established to promote the conservation of the quality of the environment of the area in the watershed of Lake Kanasatka, including the conservation of the natural resources of the land, water, marshland, woodland and open spaces, as well as the plant and animal life therein, and the protection of the water quality of Lake Kanasatka and its tributaries against pollution.

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Funding for this project was provided by the Town of Moultonborough and individual donations to the Lake Kanasatka Watershed Association.

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For questions, comments, or additional information related to the Lake Kanasatka Watershed-Based Management Plan, please contact the Lake Kanasatka Watershed Association at LKWAwatershedplan@gmail.com.

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

ACRONYM	DEFINITION
NHLCD	New Hampshire Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source Pollution
NRCS	Natural Resources Conservation Service
NRI	Natural Resources Inventory
NWI	National Wetlands Inventory
PAS	Potentially Attaining Standards
PCR	Primary Contact Recreation
PCS	Potential Contamination Source
PFAS	Per- and polyfluoroalkyl substances
PNS	Potentially Not Supporting
ppb, ppm	parts per billion, parts per million
RCCP	Regional Conservation Partnership Program
RCRA	Resource Conservation and Recovery Act
ROW	Right-of-Way
SCC	State Conservation Committee
SDT	Secchi Disk Transparency
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
UNH	University of New Hampshire
USLE	Universal Soil Loss Equation
WBMP	Watershed-Based Management Plan
WRBP	Winnipesaukee River Basin Program
YR	Year

DEFINITIONS

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

Anoxia is a condition of low dissolved oxygen.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

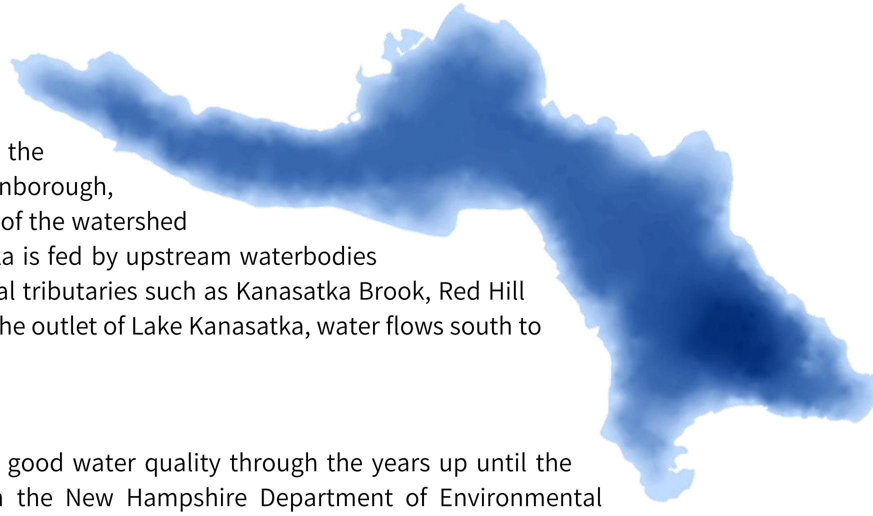
Thermal stratification is the process whereby warming surface temperatures in summer create a temperature and density differential that separates the water column into distinct, non-mixable layers.

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

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

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

EXECUTIVE SUMMARY



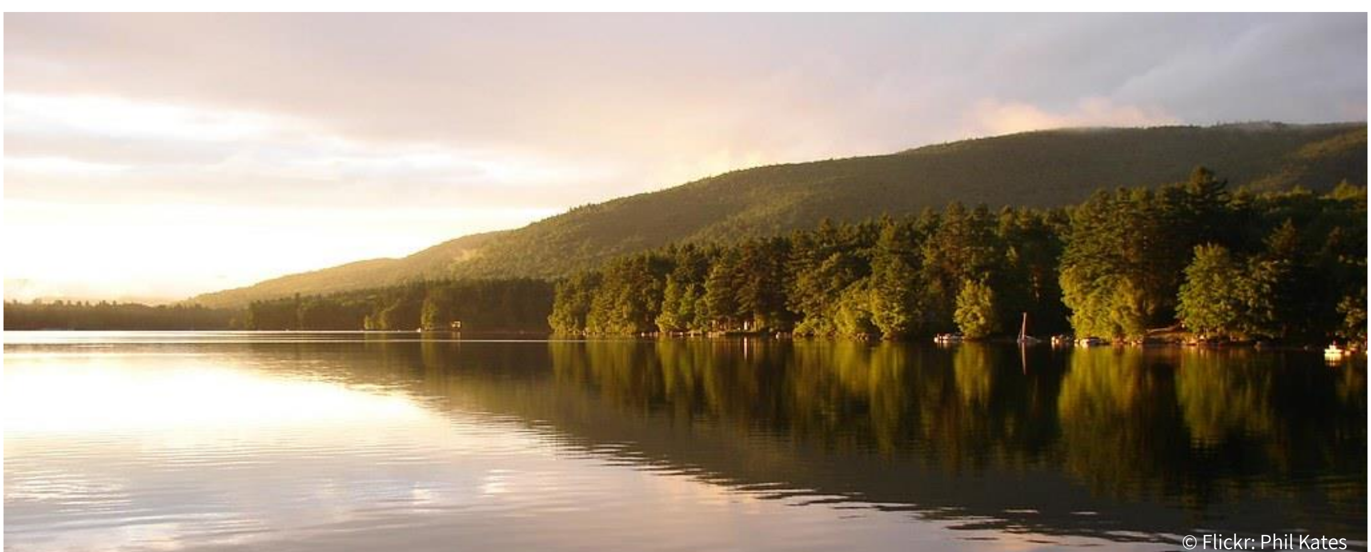
Lake Kanasatka is a 353-acre lake with a 4,528-acre watershed situated within the economically vital Lakes Region of central New Hampshire. Most of the watershed and the entire lake reside within the Town of Moultonborough, though a small area in the western portion of the watershed extends into Center Harbor. Lake Kanasatka is fed by upstream waterbodies including Wakondah Pond as well as several tributaries such as Kanasatka Brook, Red Hill Stream, and Jennifer's Path Stream. From the outlet of Lake Kanasatka, water flows south to Black East Cove in Lake Winnipesaukee.

The Problem

Lake Kanasatka has experienced generally good water quality through the years up until the recent cyanobacteria blooms, resulting in the New Hampshire Department of Environmental Services (NHDES) posting two cyanobacteria advisories in 2020 (for 14 days and 10 days) and two advisories in 2021 (for 15 days and 9 days). These blooms contained a diverse mix of potentially toxic types (taxa), and there was concern that the cyanobacteria could spread upstream to Wakondah Pond and downstream to Lake Winnipesaukee.

Cyanobacteria blooms are typically spurred by a combination of warming waters and excessive nutrients, in particular phosphorus, to surface waters. Sources of phosphorus in the watershed impacting the lake's water quality include stormwater runoff from developed areas, shoreline erosion, erosion from construction activities or other disturbed ground particularly along roads, excessive fertilizer application, failed or improperly functioning septic systems, leaky sewer lines, unmitigated agricultural activities, and pet, livestock, and wildlife waste. Twenty-two (22) problem sites were identified in the watershed during a field survey, and the main issues found were unpaved road and ditch erosion, buffer clearing, and untreated stormwater runoff. Additionally, 121 shorefront properties were identified as having some impact to water quality due to evidence of erosion and lack of vegetated buffer. The model results revealed changes in phosphorus loading and in-lake phosphorus concentrations over time from pre-development through future conditions, showing that the water quality of Lake Kanasatka is threatened by current development activities in the watershed and will degrade further with continued development in the future, especially when compounded by the effects of ongoing climate change.

Finally, a build-up of legacy phosphorus in bottom sediments can be released back into the water column under low oxygen conditions, typically experienced in late summer – a phenomenon known as internal phosphorus loading. The model showed that internal phosphorus loading to Lake Kanasatka is significant at 24% of the total phosphorus load. It is likely that the internal load will need to be addressed to fully restore the excellent water quality of Lake Kanasatka.



The Goal

The goal of the Lake Kanasatka Watershed-Based Management Plan (WBMP) is to improve the water quality of Lake Kanasatka such that it meets state water quality standards for the protection of ALI and substantially reduces the likelihood of harmful cyanobacteria blooms in the lake. This goal will be achieved by accomplishing the following objectives:

OBJECTIVE 1: Reduce phosphorus loading from existing development in the watershed.

OBJECTIVE 2: Mitigate (prevent or offset) anticipated additional phosphorus loading from future development.

The Solution

As a result of the recent cyanobacteria blooms, the Lake Kanasatka Watershed Association (LKWA) initiated a campaign to better understand and protect the water quality of Lake Kanasatka. The monitoring program was significantly expanded to include more frequent sampling of the lake and key tributaries, and funding from the Town of Moultonborough was secured to develop a WBMP for Lake Kanasatka. As part of the development of the WBMP, a build-out analysis, land-use model, water quality and assimilative capacity analysis, septic system database development, shoreline survey, and watershed survey were conducted to identify and quantify the sources of phosphorus and other pollutants to the lake. Results from these analyses were used to determine recommended management strategies for the identified pollutant sources in the watershed. An Action Plan (Section 5) was developed in collaboration with a Watershed Management Plan Committee comprised of key watershed stakeholders (see Acknowledgements). The following actions were recommended to meet the established water quality goal and objectives for Lake Kanasatka:

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

IN-LAKE TREATMENT: Additional data and analyses, as well as consultation with regional lake experts and NHDES staff, are needed to determine whether Lake Kanasatka is a candidate for an in-lake treatment to reduce the internal phosphorus load. If Lake Kanasatka is determined to be a candidate for an in-lake treatment, it is likely that an alum treatment would be recommended. An alum treatment is a management technique where aluminum is added to the bottom of the lake as aluminum sulfate, which permanently binds with phosphorus and hinders the release of phosphorus from bottom sediments (NALMS, 2004). This technique has proved successful in many lakes throughout the country and has been used recently in one New Hampshire lake (Nippo Lake in Barrington) and several Maine lakes (e.g., Long Pond in Parsonsfield, East Pond in Oakland, and Lake Auburn in Auburn). However, it is necessary to address external watershed sources of phosphorus for the alum treatment to be considered and approved at the state level and for the alum treatment to sustain or exceed its expected efficacy or lifespan.

MONITORING: A long-term water quality monitoring plan is critical to evaluate the effectiveness of implementation efforts over time. LKWA, in concert with University of New Hampshire (UNH) Lay Lakes Monitoring Program (LLMP), should continue the annual monitoring program and consider incorporating additional monitoring recommendations laid out in this plan. Additional data are also needed to better evaluate the contribution of internal phosphorus loading in the lake and whether Lake Kanasatka would be a candidate for an in-lake treatment.

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

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

The recommendations of this plan will be carried out largely by LKWA with assistance from a diverse stakeholder group, including representatives from the municipalities (e.g., select boards, planning boards), conservation commissions, state and federal agencies or organizations, nonprofits, land trusts, schools and community groups, local business leaders, and landowners. The cost of successfully implementing the plan is estimated at $0.8-$1.4 million over the next 10 or more years in addition to the dedication and commitment of volunteer time and support to manage plan implementation. However, many costs are still unknown or were roughly estimated and should be updated as information becomes available. This financial investment can be accomplished through a variety of funding mechanisms via both state and federal grants, as well as commitments from municipalities or donations from private residents. Of significant note, this plan meets the nine planning elements required by the EPA, and Lake Kanasatka is now eligible for federal watershed assistance grants.

Important Notes

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

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

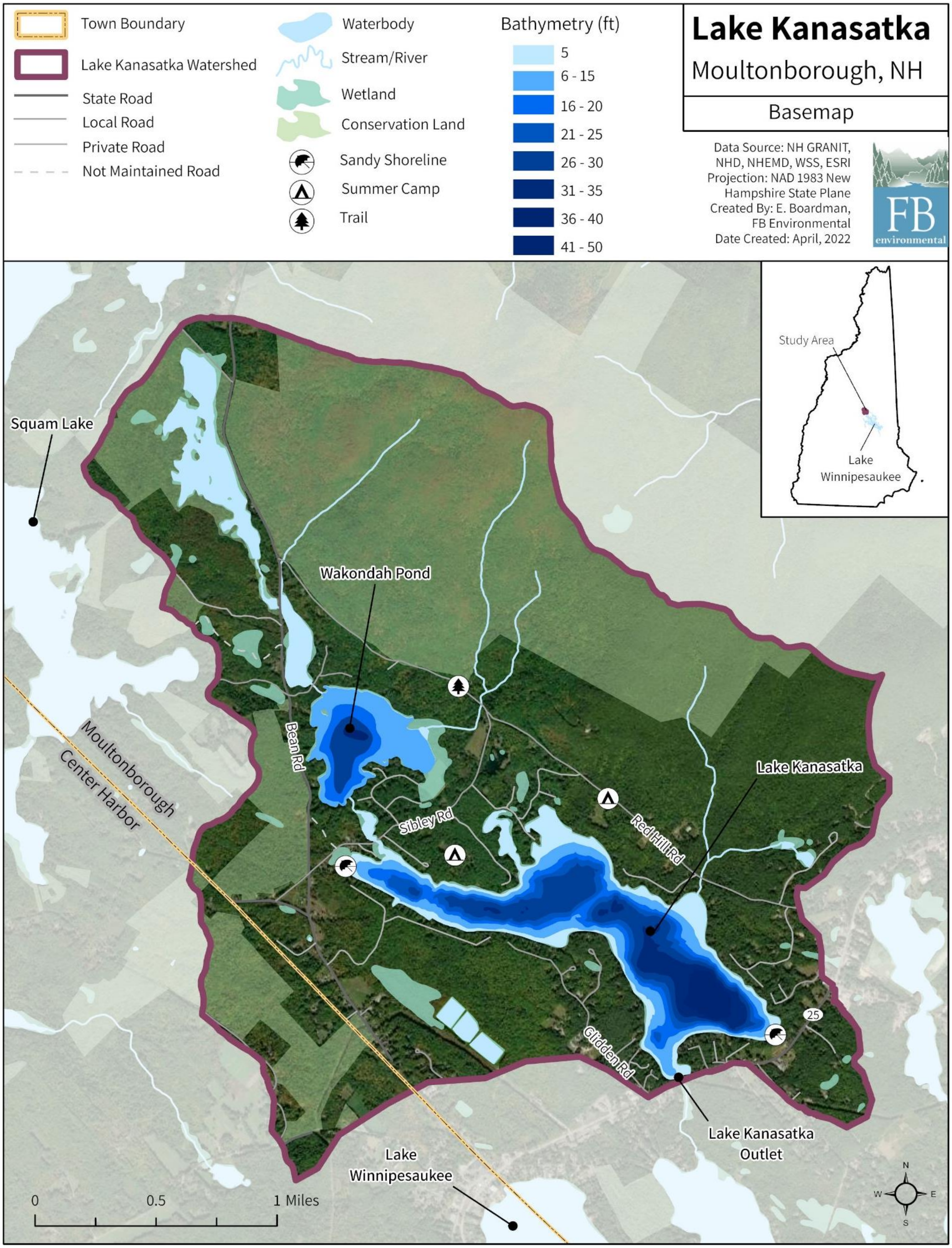


Figure 1. Lake Kanasatka watershed.

1 INTRODUCTION

1.1 WATERBODY DESCRIPTION AND LOCATION

Lake Kanasatka is a 353-acre (143-hectare) lake with a 4,528-acre (1,833-hectare) watershed in the towns of Moultonborough (94%) and Center Harbor (6%). Lake Kanasatka is fed by upstream waterbodies including Wakondah Pond as well as several tributaries such as Kanasatka Brook, Red Hill Stream, and Jennifer's Path Stream. Wakondah Pond is a 94-acre lake connected to Lake Kanasatka by an unnamed tributary, which flows for 879 feet (268 meters) upstream from the Sibley Road crossing at the northwestern end of Lake Kanasatka. From the outlet of Lake Kanasatka at the southern end of the lake, water flows 1,869 feet (579 meters) south via an unnamed tributary[1] near Whittier Highway / NH Route 25 to Black East Cove in Lake Winnipesaukee, just east of Center Harbor village (Figure 1).

The Lake Kanasatka watershed is situated within a temperate zone of converging weather patterns from the hot, wet southern regions and the cold, dry northern regions, which causes various natural phenomena such as heavy snowfalls, severe thunder and lightning storms, and hurricanes. The area experiences moderate to high rainfall and snowfall, averaging 43 inches of precipitation annually. Data were collected for 1950-2021 from the Plymouth weather station (USC00276945), with gaps covered by the following weather stations: Meredith (USC00275350), Plymouth (USC00276944), and Concord (USW00014745) (Figure 2). Annual air temperature (from average monthly data) generally ranges from 20 °F to 70 °F with an average of 44 °F (NOAA NCEI, 2022).

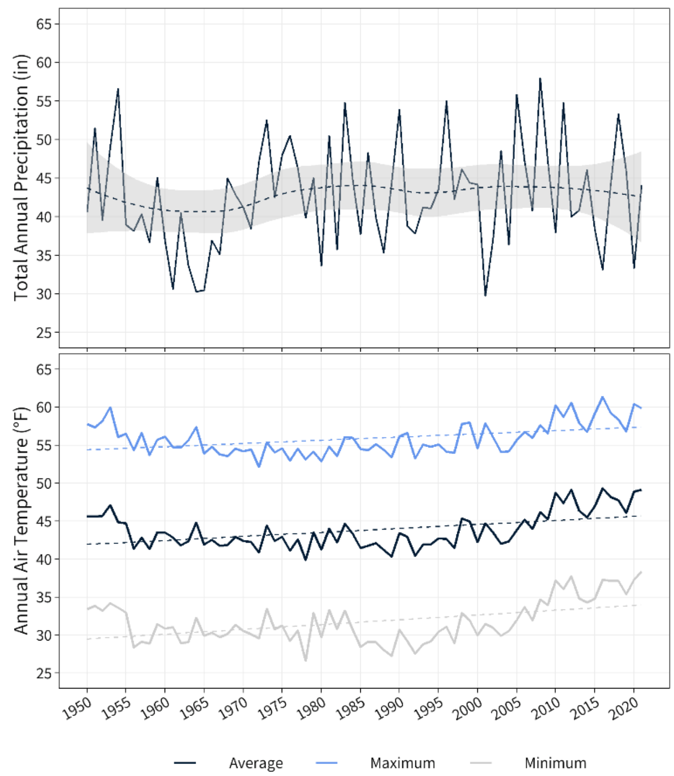


Figure 2. Total annual precipitation and annual max, average, and min of monthly air temperature from 1950 - 2021 for the region. Data collected from NOAA NCEI.

The highest elevation in the watershed (about 2,028 feet above sea level) is located within the Red Hill Conservation area at the northern end of the watershed. Lake Kanasatka and the direct shoreline drainage area are at approximately 520 feet above sea level. These elevation measurements were derived from digital elevation models provided by NH GRANIT.

The watershed is characterized primarily by mixed forest that includes both conifers (e.g., white pine and eastern hemlock) and deciduous (e.g., beech, red oak, and maple) tree species. Fauna that enjoy these forested resources include land mammals (moose, deer, black bear, coyote, bobcats, fisher, fox, raccoon, weasel, porcupine, muskrat, mink, chipmunks, squirrels, snowshoe hares, and bats), water mammals (muskrat, otter, and beaver), land and water reptiles and amphibians (turtles, snakes, frogs, and salamanders), various insects, birds (herons, loons, gulls, geese, multiple species of ducks[2], wild turkeys, ruffed grouse, cormorants, bald eagles, and song birds), and fish. The Town of Moultonborough is home to a variety of threatened and endangered species, including reproducing populations of both bald eagles and common loons, as well as the northern long-eared bat, Blanding's turtle, spotted turtle, and wood turtle, to name a select few (NHFG, 2022).

[1] NHDES Assessment Unit named "Kanasatka Lake Outlet Brook," assessment unit ID NHRIV700020105-05.

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

1.2 WATERSHED PROTECTION GROUPS

The Lake Kanasatka Watershed Association (LKWA) serves as the non-profit lake association for Lake Kanasatka and its surrounding watershed with a mission to "*promote the conservation of the natural resources of the land, water, marshland, woodland and open spaces, as well as the plant and animal life therein, and the protection of the water quality of Lake Kanasatka and its tributaries against pollution.*" LKWA conducts volunteer water quality monitoring with three teams of volunteers in coordination with the University of New Hampshire Lakes Lay Monitoring Program (UNH LLMP). LKWA also helps educate members of the community on proper landscaping, erosion prevention, septic system maintenance, fishing practices, and other activities to protect the lake and watershed, including promotion of the voluntary LakeSmart program. LKWA has led the way on education and advocacy to address recent **cyanobacteria** blooms in the lake.

The Lake Winnipesaukee Association (LWA) is a non-profit organization with the mission of "*protecting the water quality and natural resources of Lake Winnipesaukee and its watershed. Through monitoring, education, stewardship, and utilizing science-guided approaches for lake management, LWA works to ensure that Winnipesaukee's scenic beauty, wildlife habitat, water quality, and recreational potential continues to provide enjoyment today and for the future.*" LWA serves the 14 communities located in Belknap and Carroll counties. LWA is led by several paid staff and a volunteer Board of Directors.

The Carroll County Conservation District (CCCD) and the Belknap County Conservation District (BCCD) are two of 10 county conservation districts in New Hampshire that operate as resource management agencies and a subdivision of local governments. CCCD focuses on "*water quality, erosion & sedimentation, wildlife habitats, health of forests & wetlands, non-point source pollution, and storm water & flooding.*" BCCD's mission is to "*coordinate and implement programs for education and on-the-ground work regarding conservation, use, and development of soil, water, and related resources.*" Both organizations work with farmers, forest owners, landowners, schools, and municipalities to help protect and conserve the area's natural resources through projects such as stream bed restoration, invasive species management, and pollinator plantings. Moultonborough is in the CCCD service area; Center Harbor is in the BCCD service area.

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

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

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

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

1.3 PURPOSE AND SCOPE

The purpose and overarching goal of the Lake Kanasatka Watershed-Based Management Plan (WBMP) is to guide implementation efforts over the next 10 years (2022-2031) to improve the water quality of Lake Kanasatka such that it meets state water quality standards for the protection of Aquatic Life Integrity (ALI) and substantially reduces the likelihood of harmful cyanobacteria blooms in the lake. *Efforts to protect Lake Kanasatka will also help protect downstream Lake Winnipesaukee.*

As part of the development of this plan, a **build-out analysis**, land-use model, water quality and **assimilative capacity** analysis, and shoreline and watershed surveys were conducted to better understand the sources of phosphorus and other pollutants to the lake (Sections 2 and 3). Results from these analyses were used to establish the water quality goal and objectives (Section 2.4), determine recommended management strategies for the identified pollutant sources (Section 4), and estimate pollutant load reductions and costs needed for remediation (Sections 5 and 6). Recommended management strategies involve using a combination of **structural and non-structural Best Management Practices** (BMPs), as well as an **adaptive management approach** that allows for regular updates to the plan (Section 4). An Action Plan (Section 5) with associated timeframes, responsible parties, and estimated costs was developed in collaboration with the Watershed Management Plan Committee and the Technical Advisory Committee (Section 1.4). This plan meets the nine elements required by the United States Environmental Protection Agency (EPA) so that communities become eligible for federal watershed assistance grants (Section 1.5).

1.4 COMMUNITY INVOLVEMENT AND PLANNING

The plan was developed through the collaborative efforts of numerous meetings, public presentations, and conference calls between FB Environmental Associates (FBE), LKWA, UNH, LWA, NHDES, representatives from the towns of Moultonborough and Center Harbor, LRCT, and private landowners (see Acknowledgments).

1.4.1 Plan Development Meetings

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

- **December 7, 2020:** Kickoff meeting with the Watershed Management Plan Committee to discuss project roles, communications, and timeline for tasks and deliverables.
- **February 16, 2021:** Progress check-in meeting with the Watershed Management Plan Committee.
- **April 22, 2021:** Progress check-in meeting with the Watershed Management Plan Committee.
- **June 23, 2021:** The Technical Advisory Committee discussed the water quality data gap analysis, bathymetry mapping by NHDES, and watershed survey.
- **July 10, 2021:** FBE presented an overview of watershed management plan development and restoration at the LKWA Annual Meeting.
- **September 17, 2021:** Progress check-in meeting with the Watershed Management Plan Committee.
- **October 26, 2021:** The Technical Advisory Committee met to review shoreline and watershed survey results and preliminary sediment analysis.
- **December 9, 2021:** Progress check-in meeting with the Watershed Management Plan Committee.
- **December 10, 2021:** NHDES and FBE held a call to discuss the wastewater lagoons in the southwest area of the watershed, including current and future monitoring related to the groundwater discharge permit requirements.
- **December 14, 2021:** The Technical Advisory Committee reviewed preliminary modeling results and water quality indications for goal setting and management strategies.
- **March 11, 2022:** The Watershed Management Plan Committee met to review draft reports and discuss a tentative date for the final public presentation.
- **April 4, 2022:** Progress check-in meeting with the Watershed Management Plan Committee.
- **April 19, 2022:** Progress check-in meeting with the Watershed Management Plan Committee.
- **May 10, 2022:** The Technical Advisory Committee held its final meeting to review and finalize the buildout analysis, water quality model, and water quality goal and objectives.
- **May 17, 2022:** Progress check-in meeting with the Watershed Management Plan Committee.
- **June 21, 2022:** Progress check-in meeting with the Watershed Management Plan Committee.

1.4.2 Final Public Presentation

A final public presentation was held on June 4, 2022 at the Moultonborough Academy auditorium to summarize the analyses and recommendations detailed in the plan. The presentation was attended by over 80 people. An opportunity for public feedback on the plan was offered, including live polling with five questions for the audience to answer.

Most of the audience was seasonal (51%) or year-round (39%) residents on the lake, with a few living in the watershed but not on the lake (5%) or not living in the watershed at all but still interested in helping to protect it (6%). The audience was divided on their opinion of the water quality condition of Lake Kanasatka with most feeling that water quality is slightly below average (35%), slightly above average (26%), or poor (24%); a few were unsure (2%), and some indicated water quality as being "really good" (13%). The top threat to Lake Kanasatka was identified as stormwater runoff (66%), followed by **internal loading** (15%), septic systems (11%), lack of state and local regulations to protect the lake (8%), and increasing development (1%). The top solution to address the top threat to Lake Kanasatka was identified as stormwater controls (71%), followed by an alum treatment (16%), strengthened and enforced state and local regulations to protect the lake (11%), and land conservation (3%). Nearly half (47%) of the audience indicated that they would be willing to make improvements to their shorefront property to stabilize soils and enhance vegetated buffers. The audience was also willing to help with outreach and education efforts (18%), participate in a LKWA committee (18%), and help with local land conservation efforts (16%).

1.5 INCORPORATING EPA'S NINE ELEMENTS

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

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

2 ASSESSMENT OF WATER QUALITY

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

2.1 WATER QUALITY SUMMARY

2.1.1 Water Quality Standards & Impairment Status

2.1.1.1 Designated Uses & Water Quality Criteria

The **Clean Water Act** (CWA) requires states to determine designated uses for all surface waters within the state's jurisdiction. Designated uses are the desirable activities and services that surface waters should be able to support and include uses for ALI, fish consumption, shellfish consumption, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating and fishing), and wildlife. Surface waters can have multiple designated uses. **Primary Contact Recreation (PCR) and ALI are the two major uses for lakes – ALI being the focus of this plan.** In New Hampshire, all surface waters are also legislatively classified as Class A or Class B, most of which are Class B (Env-Wq 1700). **Lake Kanasatka is classified as Class B waters in the State of New Hampshire**. Additionally, from 1974 to 2010, NHDES conducted surveys of lakes to determine **trophic state** (**oligotrophic**, **mesotrophic**, or **eutrophic**). The trophic surveys evaluated physical lake features, as well as chemical and biological indicators. **For Lake Kanasatka, the trophic state was determined to be mesotrophic in 1977 and oligotrophic in 1989 and 2003** (NHDES, 1977, 1989, and 2003). This means that in-lake water quality was consistent with the standards for oligotrophic lakes in 1989 and 2003.

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

2.1.1.2 Antidegradation Provisions

The Antidegradation Provision (Env-Wq 1708) in New Hampshire's water quality regulations serves to protect or improve the quality of the state's waters. The provision outlines limitations or reductions for future pollutant loading. Certain development projects (e.g., projects that require Alteration of Terrain Permit or 401 Water Quality Certification) may be subject to an Antidegradation Review to ensure compliance with the state's water quality regulations. The Antidegradation Provision is often invoked during the permit review process for projects adjacent to waters that are designated impaired, high quality, or outstanding resource waters. While NHDES has not formally designated high-quality waters, unimpaired waters are treated as high quality with respect to issuance of water quality certificates. Antidegradation requires that a permitted activity cannot use more than 20% of the remaining assimilative capacity of a high-quality water. This is on a parameter-by-parameter basis. For impaired waters, antidegradation requires that permitted activities discharge no additional loading of the impaired parameter.

2.1.1.3 Waterbody Impairment Status

Lake Kanasatka is divided into three assessment units; Wakondah Pond is one assessment unit (Table 1). None of the four assessment units are formally listed as impaired for any designated use on the 303(d) New Hampshire List of Impaired Waters for the 2020/2022 cycle (NHDES, 2022a). According to New Hampshire's *Watershed Report Cards* built from the 2020/2022 305(b)/303(d) listing process (NHDES, 2022b), Lake Kanasatka, the largest assessment unit which covers nearly the entire lake, has "*limited data available, however, the data that is available suggests that the parameter is Potentially Attaining Standards (PAS).*" The two beaches, Deer Hill Beach and Camp Quinebarge Beach, have good water quality which "*meets* *water quality standards/thresholds by a relatively large margin*." Wakondah Pond is listed as having no data, and therefore no indication of water quality is provided. Although Lake Kanasatka is not impaired for the designated use of ALI, which overall is rated as PAS, the lake is reported as Potentially Not Supporting (PNS) for ALI for two specific parameters: elevated total phosphorus and low pH (NHDES, 2022b). Additionally, the NH Statewide Mercury Advisory to limit consumption of fish applies to all assessment units (NHDES, 2021). Despite the lack of a formal impairment listing for Lake Kanasatka, cyanobacteria blooms have recently emerged as a serious concern for the lake, as described in Section 2.1.5 on cyanobacteria.

Table 1. NHDES assessment units covering Lake Kanasatka and their associated water quality rating as reported on the NHDES 2020/2022 Watershed Report Cards.

Assessment Unit Name	AUID	Area (acres)	Water Quality
Lake Kanasatka	NHLAK700020105-02	357	Likely Good
Lake Kanasatka – Deer Hill Beach	NHLAK700020105-02-02	1.38	Good
Lake Kanasatka – Camp Quinebarge Beach	NHLAK700020105-02-03	1.38	Good
Wakondah Pond	NHLAK700020105-01	93.9	No Data

2.1.2 Water Quality Data Collection

New Hampshire LLMP has been monitoring Lake Kanasatka almost every year since 1984, producing 31 lake reports through 2018. NHDES, the NH Department of Health and Human Services, and volunteers from LKWA have also monitored and assessed the lake over the years.

Water quality data were obtained for this plan from the NHDES Environmental Monitoring Database (EMD) and directly from Bob Craycraft of UNH LLMP or Lisa Hutchinson of the LKWA Water Quality Committee. More than 30 water quality stations were identified in the watershed (not including the 2020-21 cyanobacteria sample stations). A descriptive overview of available water quality data in the watershed is as follows (ordered from upstream to downstream) for a subset of sites shown in Figure 3:

- **WAKMOUD/WAKMOU-GEN (Wakondah Pond):** variable depth grab samples (from the **epilimnion**, **metalimnion**, and/or **hypolimnion**) were collected from 1982-2002 and in 2021 for numerous parameters but largely for temperature, dissolved oxygen, total phosphorus, nitrogen species, specific conductance, pH, chloride, color, and alkalinity.
- **CAMP QUINEBARGE & CAMP HAWKEYE BEACHES:** surface grab samples were collected from 1987-2013 for *E. coli* to assess public health risk with contact recreation. NHDES has moved away from monitoring private beaches for *E. coli*. Youth camps are still inspected by the NH Department of Health and Human Services prior to the start of each season.
- **KAN02AL/KAN03WL/KANMOUD (Lake Kanasatka deep spots):** variable depth grab or composite samples (from the epilimnion, metalimnion, and/or hypolimnion) were collected from 1983-2021 for numerous parameters but largely for temperature, dissolved oxygen, total phosphorus, chlorophyll-a, **Secchi disk transparency**, specific conductance, pH, color, turbidity, and alkalinity. Ten (10) other sites around the lake were sampled between 1985-1993 and in 2020-21 for total phosphorus and Secchi disk transparency.
- **04-KOB (Route 25 Bridge, Lake Outlet):** surface grab samples were collected from 1993-2005 for dissolved oxygen, *E. coli*, nitrate, pH, total phosphorus, specific conductance, temperature, and turbidity.

Three sites (KAN02AL, KAN03WL, and KANMOUD) are the most recently active sites with the most consistent dataset in the watershed. These three sites were historically monitored comprehensively by LLMP one time per year in July or August. Local volunteers also collect Secchi disk transparency readings around the lake and began in December 2020 to collect surface grab samples for total phosphorus at four tributary sites in the watershed: Red Hill Stream, Wakondah Stream, Kanasatka Stream (a.k.a., Scribner Brook), and Tamarack/Maple Rd. LKWA volunteers in coordination with UNH LLMP expanded monitoring again in 2021 to include sampling at the three deep spots four times per year in June, July, August, and September and at more than eight tributary sites multiple times year-round in 2021. LKWA volunteers also collect biweekly temperature profiles and epilimnetic samples for chlorophyll-a, as well as tube samples for phycocyanin at multiple lake stations throughout the summer season.

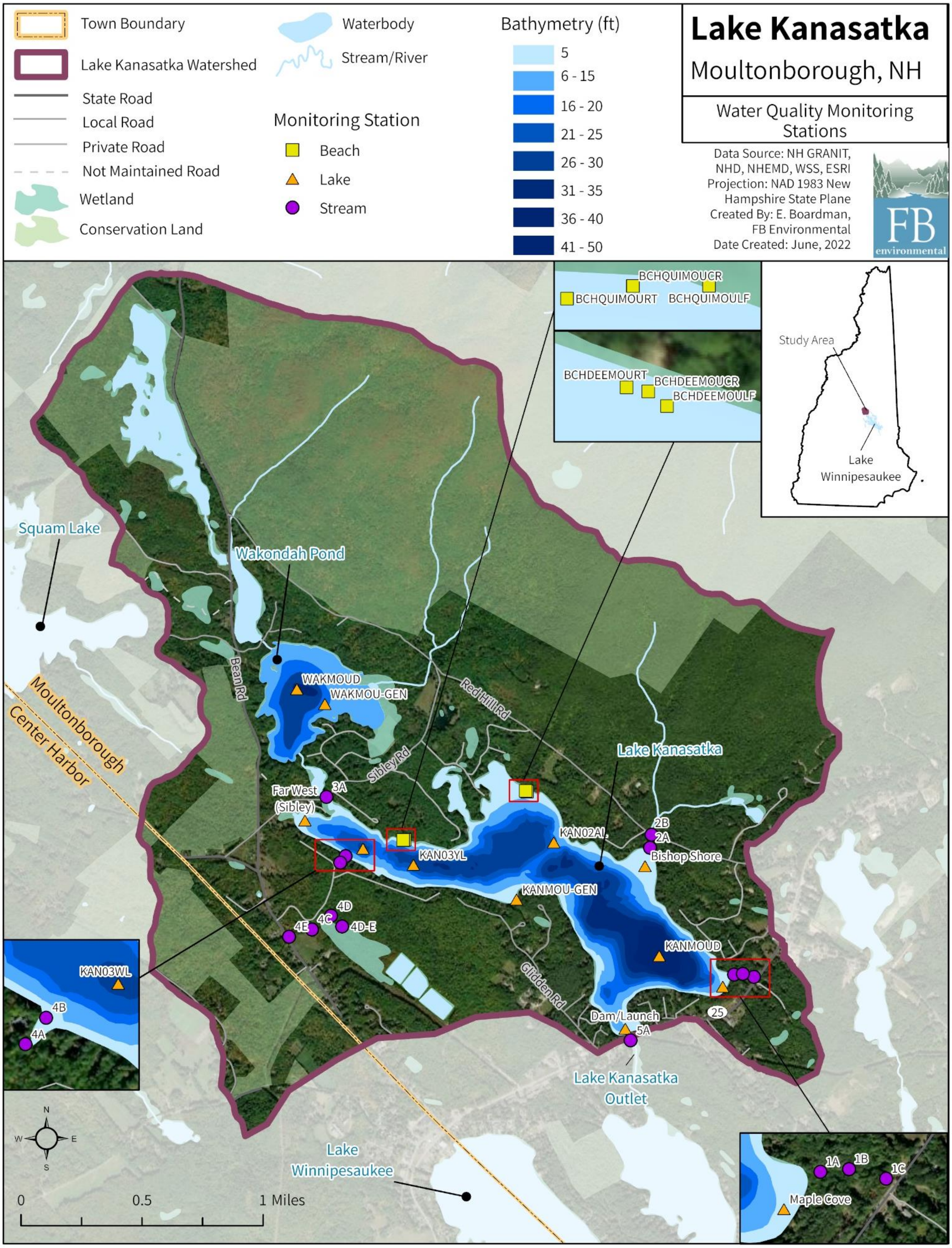


Figure 3. Water quality monitoring sites in the Lake Kanasatka watershed. Not all sites are included in this map. Refer to Table 2 for site descriptions.

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

Site ID	Site Description	Site Type
1A	Jennifer's Path Stream outflow near lake	Stream
1B	Tamarack/Maple Rd	Stream
1C	Jennifer's Path Stream Route 25 culvert outflow	Stream
2A	Red Hill Stream (Near Lake)	Stream
2B	Red Hill Stream (Red Hill Rd crossing)	Stream
3A	Wakondah Stream	Stream
4A	Kanasatka Stream downstream of culvert	Stream
4B	Scribner Brook outflow to lake	Stream
4C	Scribner Brook near stone wall	Stream
4D	Kanasatka Scribner Brook Location 1	Stream
4D-E	Kanasatka Bay District Stream Location 2	Stream
4E	Scribner Brook Bean Rd culvert	Stream
5A	Outlet (04-KOB)	Stream
BCHDEEMOUCR	Deer Hill Beach Center	Beach
BCHDEEMOULF	Deer Hill Beach Left	Beach
BCHDEEMOURT	Deer Hill Beach Right	Beach
BCHQUIMOUCR	Camp Quinebarge Beach Center	Beach
BCHQUIMOULF	Camp Quinebarge Beach Left	Beach
BCHQUIMOURT	Camp Quinebarge Beach Right	Beach
Bishop Shore	Bishop Shore	Lake
Dam/Launch	Dam/Launch	Lake
Far West (Sibley)	Far West (Sibley)	Lake
KAN02AL	Lake Kanasatka 2 Animal	Lake
KAN03WL	Lake Kanasatka 3 West	Lake
KAN03YL	Lake Kanasatka 3 Youngs	Lake
KANMOUD	Lake Kanasatka Deep Spot	Lake
KANMOU-GEN	Lake Kanasatka - Generic	Lake
Maple Cove	Maple Cove	Lake
WAKMOUD	Wakondah Pond Deep Spot	Lake
WAKMOU-GEN	Wakondah Pond - Generic	Lake

2.1.3 Trophic State Indicator Parameters

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

No statistically significant trends were found for total phosphorus, chlorophyll-a, or Secchi disk transparency at the three deep spot sites, except for a statistically significant increasing trend for chlorophyll-a at 3-West ($p=0.0267$) (Figure 4). Summer median total phosphorus in 2020 (when the first major blooms were recorded) was the highest (worst) on record since 2010. Summer mean water clarity in 2020 was also the lowest (worst) on record since 2008. Internal loading is most evident at 1-Deep and shows a statistically significant increasing trend at 1-Deep ($p=0.002$) (Figure 5). Internal loading is minimal at 3-West and 2-Animal. Multiple samples were collected in 2021 to better understand changes in trophic state indicators over time and depth. Internal loading at 1-Deep was significant in 2021, having reached a peak of 185 ppb total phosphorus in the hypolimnion in September (Figure 6). Caution should be used when interpreting these data given the limited availability (e.g., usually only one sample collected in August each year before peak internal loading occurs).

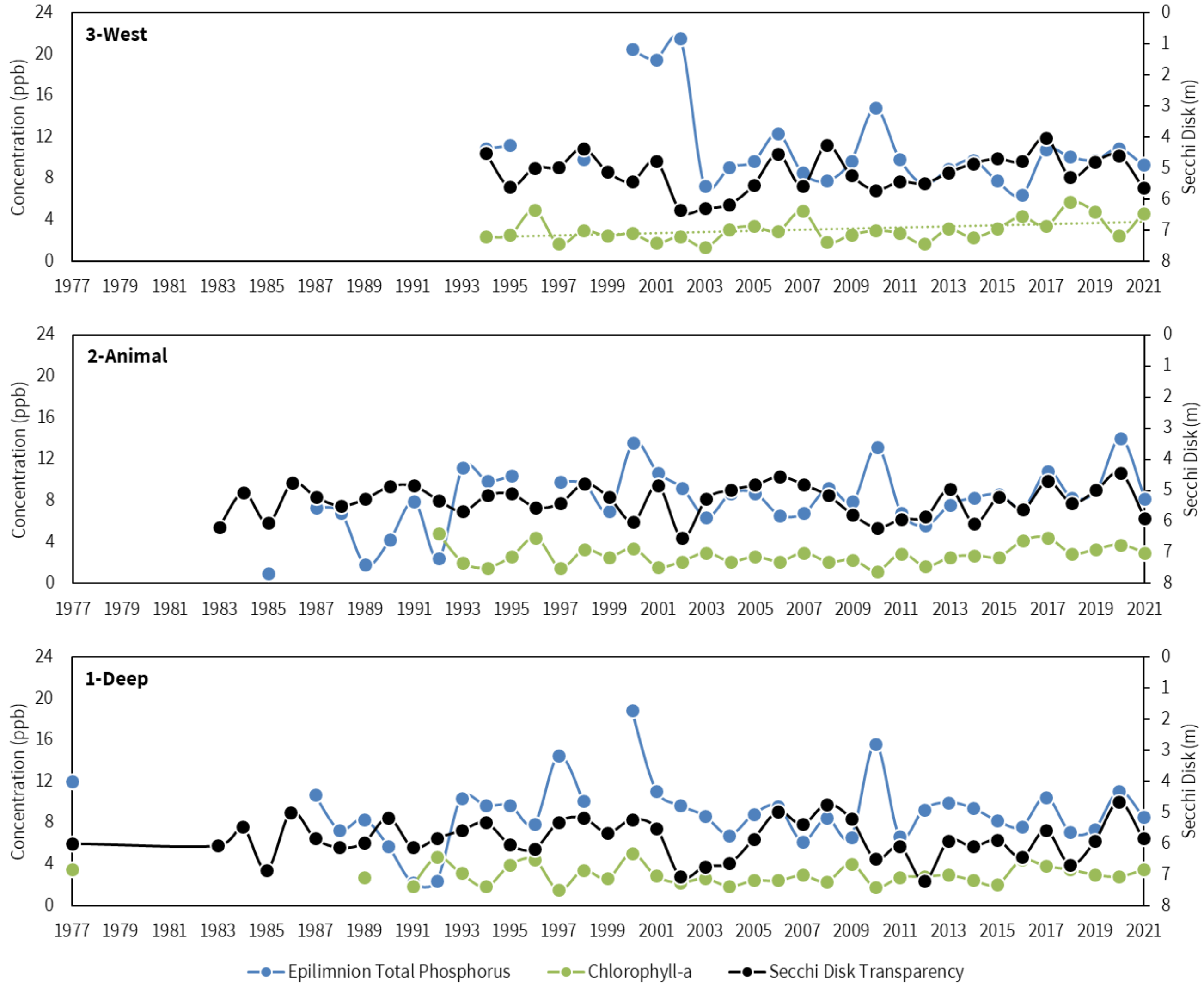


Figure 4. Median epilimnion total phosphorus, median epilimnion chlorophyll-a, and mean water clarity (Secchi Disk depth) measured at Lake Kanasatka in June-September from 1977-2021 for stations 3-West (TOP), 2-Animal (MIDDLE), and 1-Deep (BOTTOM). Blooms were recorded in 2009, 2011, 2014, 2020, and 2021. A statistically significant increasing trend was detected for chlorophyll-a at 3-West (p=0.0267) using *rkt* package in R.

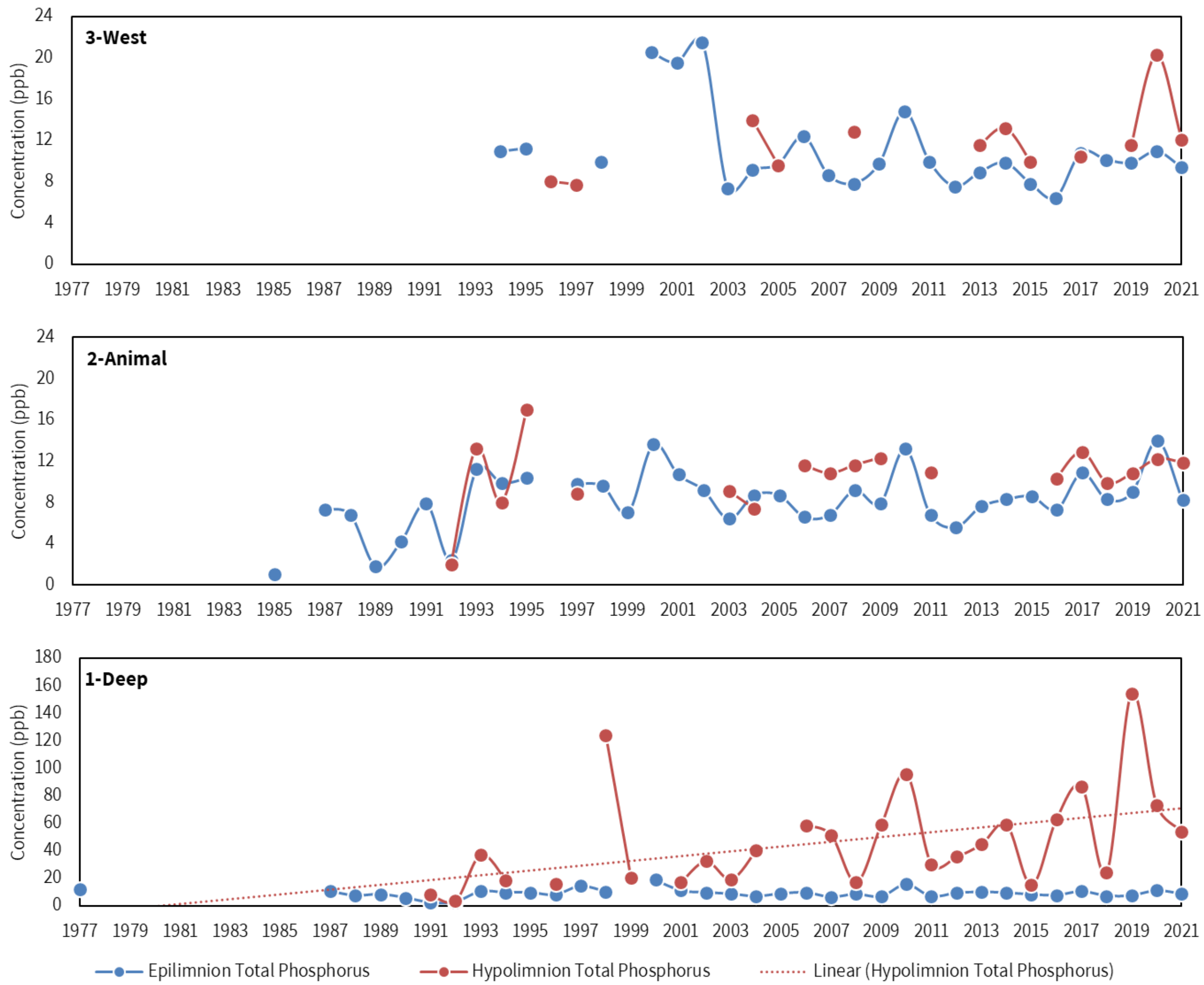


Figure 5. Median epilimnion total phosphorus and median hypolimnion total phosphorus measured at Lake Kanasatka from 1977-2021 for stations 3-West (TOP), 2-Animal (MIDDLE), and 1-Deep (BOTTOM). Blooms were recorded in 2009, 2011, 2014, 2020, and 2021. A statistically significant increasing trend was detected for hypolimnion total phosphorus at 1-Deep (p=0.002) using *rkt* package in R.

2.1.4 Dissolved Oxygen & Water Temperature

A common occurrence in many New England lakes is the depletion of dissolved oxygen in the deepest part of lakes throughout the summer months, a natural phenomenon in some **dimictic** lakes that is made more severe by human disturbance. Chemical and biological processes occurring in bottom waters deplete the available oxygen throughout the summer, and because these waters are colder and denser, the oxygen cannot be replenished through mixing with surface waters. Dissolved oxygen levels below 5 ppm (and water temperature above 24 °C) can stress and reduce habitat for coldwater fish and other sensitive aquatic organisms. In addition, **anoxia** (dissolved oxygen < 2 ppm) at lake bottom can result in the release of sediment-bound phosphorus (otherwise known as **internal phosphorus loading**), which can become a readily available nutrient source for algae and cyanobacteria. It is important to keep tracking these parameters to make sure the extent and duration of low oxygen does not change drastically because of human disturbance in the watershed, resulting in excess phosphorus loading.

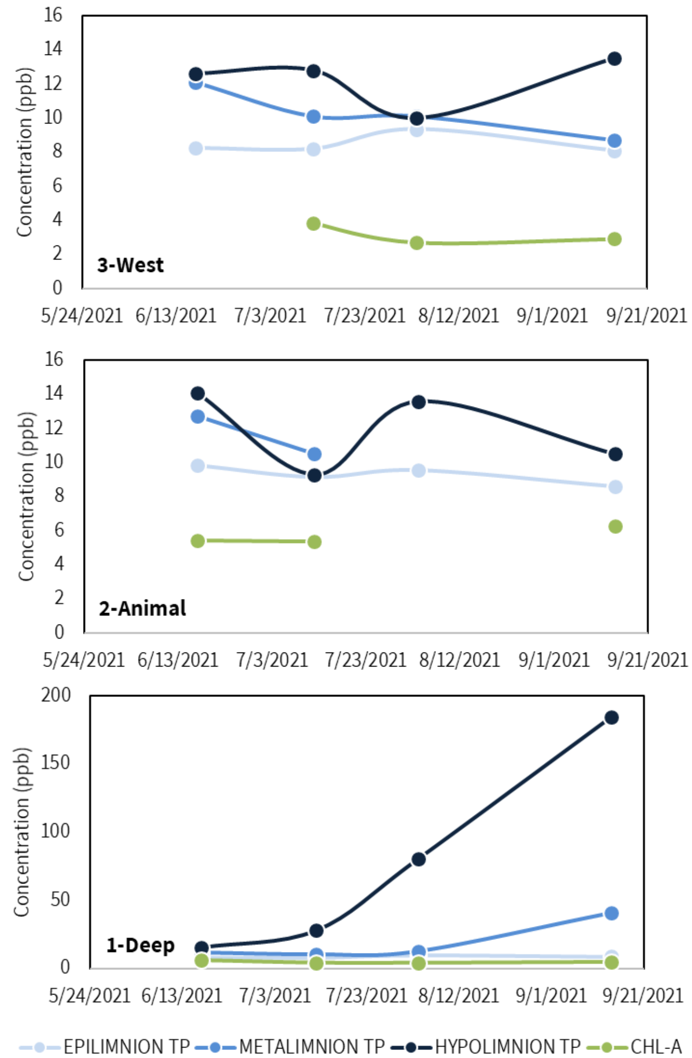


Figure 6. Epilimnion, metalimnion, and hypolimnion total phosphorus and chlorophyll-a measured at Lake Kanasatka in 2021 for stations 3-West (TOP), 2-Animal (MIDDLE), and 1-Deep (BOTTOM). Blooms were recorded in August and September 2021.

Figure 7 shows temperature and dissolved oxygen profiles averaged across sampling dates (1977-2021) during **thermal stratification** in summer (between spring and fall **turnover**) for the three deep spot stations. The change in temperature, seen most dramatically between 5 and 9 meters, indicates thermal stratification in the water column at all three sites. An increase in dissolved oxygen between 5 and 7 meters (near or at the top of the **thermocline** where microorganisms can be neutrally buoyant) indicates photosynthetic activity by phytoplankton. The average dissolved oxygen of <2 ppm at 7.5-13 meters depth indicates the possibility of internal loading under anoxic conditions. Historic recording of temperature and dissolved oxygen profiles included only one water column profile per sampling season. While these data are useful in tracking major trends over time, the more recent monitoring consisting of several profiles per sampling season can provide better insight to seasonal changes in the lake. Historic dissolved oxygen and temperature profiles show that the extent of low oxygen (<2 ppm) in Lake Kanasatka may be worsening, extending historically from 8.5-13 meters from 1977-2015 at 1-Deep to 7.5-13 meters in 2021 at 1-Deep (Figure 8). The possible increased prevalence of low oxygen conditions affecting bottom areas of the lake that are 7.5 meters or deeper represents a significant shift in the potential for phosphorus release from sediment because the surface area change from 8.5+meters to 7.5+meters is large (Figure 9).

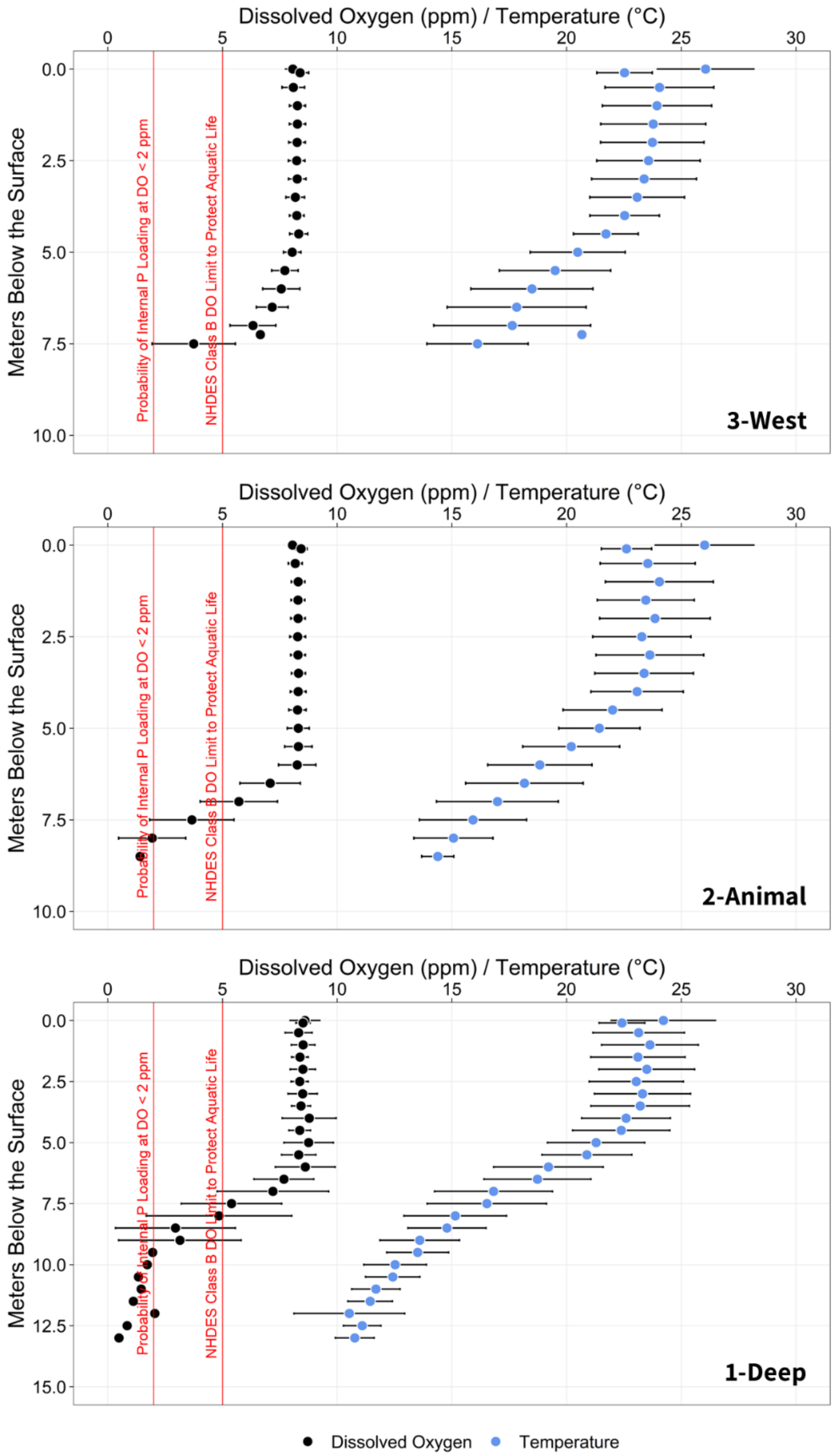


Figure 7. Dissolved oxygen (black) and temperature (blue) depth profiles for the three deep spots of Lake Kanasatka: 3-West (TOP), 2-Animal (MIDDLE), and 1-Deep (BOTTOM). Dots represent average values across sampling dates for each respective depth. Error bars represent standard deviation. Profiles were collected in 2005-06, 2011, 2014, 2015, and 2021 for 3-West (n=9); in 2005-06, 2008, 2011, 2014, 2015, and 2021 for 2-Animal (n=10); and in 1977, 1989, 1990, 2003-06, 2008-09, 2011, 2013-15, and 2021 for 1-Deep (n=20).

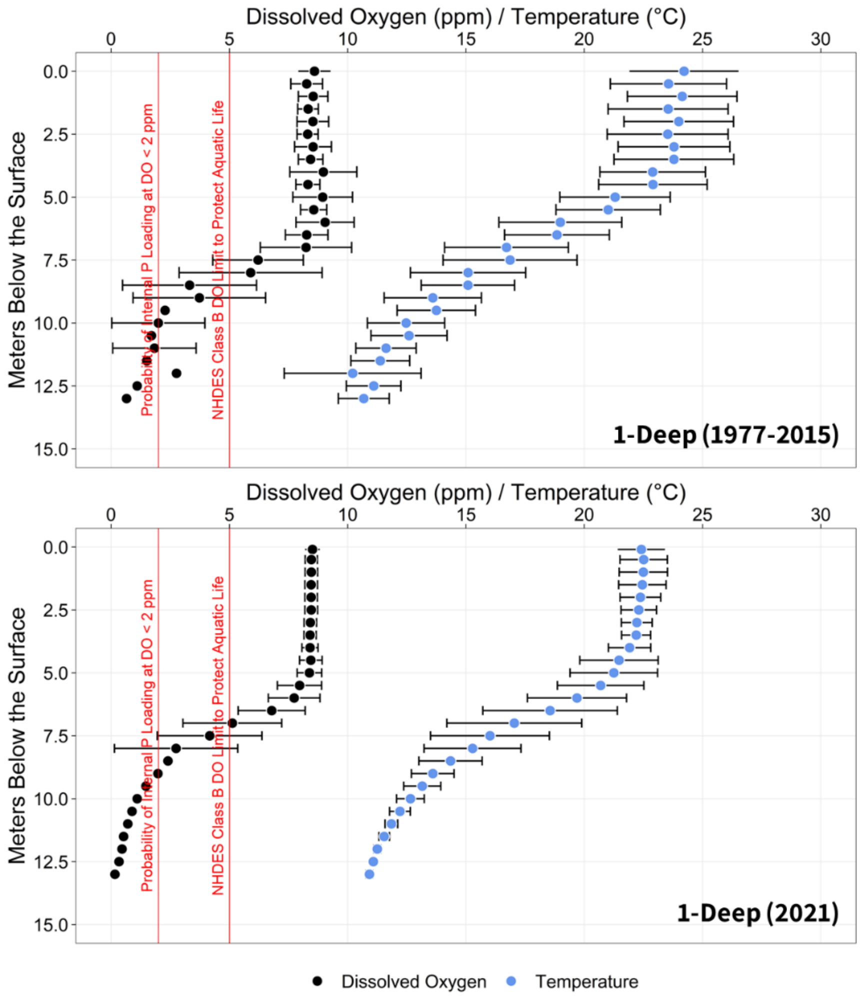


Figure 8. Dissolved oxygen (black) and temperature (blue) depth profiles for 1-Deep in 1977, 1989, 1990, 2003-06, 2008-09, 2011, 2013-15 (n=16) (TOP) and in 2021 (n=4) (BOTTOM). Dots represent average values across sampling dates for each respective depth. Error bars represent standard deviation.

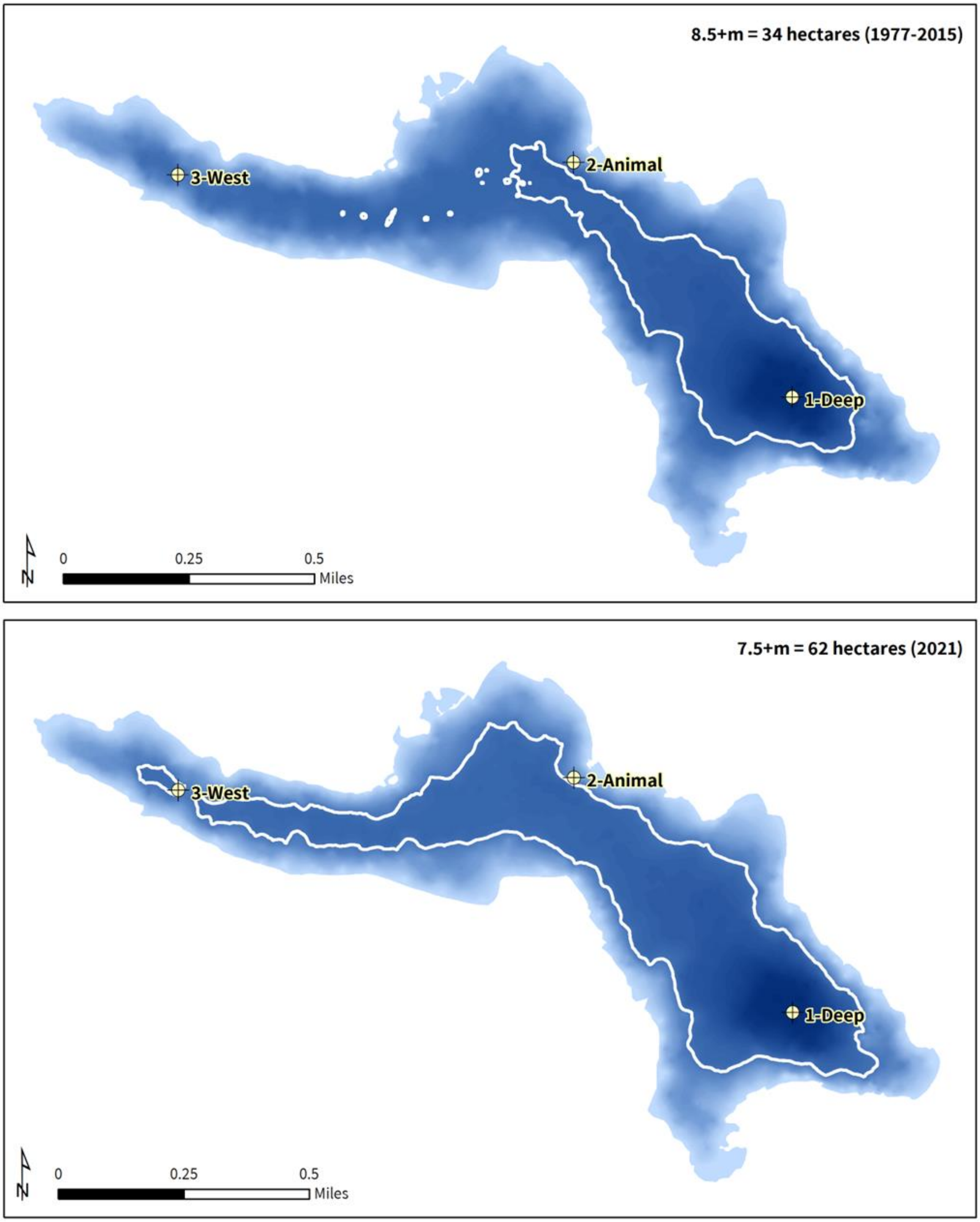


Figure 9. Bathymetric map depicting the increased extent of anoxia in Lake Kanasatka from 34 hectares at 8.5+meters for dissolved oxygen profiles collected from 1977-2015 to 62 hectares at 7.5+meters for dissolved oxygen profiles collected in 2021.

2.1.5 Phytoplankton (Cyanobacteria) and Zooplankton

2.1.5.1 Phytoplankton/Zooplankton Surveys

Phytoplankton and zooplankton samples were collected and analyzed during the 1977, 1989, and 2003 NHDES Trophic Surveys of Lake Kanasatka (Table 3). The dominant phytoplankton species were *Asterionella* (diatom) and *Chrysosphaerella* (golden algae). The 7/3/1989 sample showed a phytoplankton count of 1,275 cells/mL, indicating a possible bloom. The dominant zooplankton species were *Calanoid* and *Cyclopoid copepods*, with total zooplankton counts ranging from 39-437 cells/L (Table 3). Copepods are small crustaceans that eat phytoplankton and provide an important food source to fish. *Daphnia* are among the most efficient grazers of phytoplankton but were present in small amounts in Lake Kanasatka. None of the dominant zooplankton species found in Lake Kanasatka are known for consuming cyanobacteria, indicating that there are likely few predators to control cyanobacteria growth in the lake.

Table 3. Phytoplankton and zooplankton data summary for Lake Kanasatka.

Date	Phytoplankton Species (% Total)	Total Phytoplankton Count (cells/mL)	Zooplankton Species (% Total)	Total Zooplankton Count (cells/L)
2/10/1976	*Asterionella* (95%)		*Calanoid copepod* (45%) *Cyclopoid copepod* (20%)	
8/25/1977	*Asterionella* (50%) *Chrysosphaerella* (15%)		*Vorticella* (65%)	437
1/16/1990	*Tabellaria* (70%) *Asterionella* (20%)		*Cyclopoid copepod* (51%)	39
7/3/1989	*Dinobryon* (55%) *Certium* (20%) *Chrysosphaerella* (15%)	1,275	*Calanoid copepod* (38%) *Daphnia* (29%)	42
1/20/2004	*Synura* (50%) *Asterionella* (25%) *Rhizosolenia* (7%)		*Ciliate* (64%) *Calanoid copepods* (6%)	90
7/2/2003	*Dinobryon* (35%) *Asterionella* (25%) *Mallomonas* (10%)		*Ciliate* (39%) *Calanoid copepods* (17%) *Keratella* (10%)	231

2.1.5.2 Cyanobacteria Bloom History

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

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

- ***Anabaena/Dolichospermum***: typically observed as filaments, associated with microcystins, anatoxins, saxitoxins, and cylindrospermopsin, *documented in Lake Kanasatka in 2020 and 2021*

- ***Microcystis***: typically observed as variations of small-celled colonies, associated with microcystins and anatoxins, *documented in Lake Kanasatka in 2020*
- ***Aphanizomenon***: Typically forms rafts of filaments, associated anatoxin-a, anatoxin-a (S), saxitoxins, and possibly microcystins, *documented in Lake Kanasatka in 2020*
- ***Woronichinia***: Typically forms dense colonies, associated with microcystins, *documented in Lake Kanasatka in 2020*
- ***Planktothrix/Oscillatoria***: typically observed as filaments, associated with microcystins and cylindrospermopsin, can maintain high growth rate at relatively low light intensities when it forms metalimnetic blooms (NHDES, 2020)

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

Cyanobacteria blooms emerged as a major concern for Lake Kanasatka in 2020 when NHDES began posting cyanobacteria bloom advisories for the first time in the lake's history. Although there were no advisories prior to 2020, there were occasional blooms. A green scum of *Anabaena/Dolichospermum* (64,000 cyano cells/mL) was noted in NHDES's EMD accumulating along the shore at 22 Deer Crossing Rd near Camp Quinebarge Beach on 11/24/09. An isolated cyanobacteria bloom (44% *Coelosphaerium*, 20% *Anabaena/ Dolichospermum*, 36% non-cyano, 223,780 cyano cells/mL) was also reported on 10/8/11. A greenish slime along the shoreline was also noted as potentially cyanobacteria on 9/8/14.

NHDES issued four cyanobacteria bloom advisories over 2020 and 2021 in late summer (August and September) for periods ranging from seven to 15 days (Table 4). During their routine sampling of Lake Kanasatka, UNH LLMP first alerted NHDES to a possible cyanobacteria bloom in early August 2020. All four bloom periods were lakewide except for the 9/29/20 bloom that was more localized with scum forming along the shorelines. The dominant taxa identified for each bloom in 2021 (Table 4 and noted above) were determined from 32 samples collected by NHDES from seven areas around the lake, largely along the shoreline or at the Animal Island deep spot.

NHDES and LKWA collected samples for speciation and toxin analysis from August through December 2020. NHDES reported that the blooms that occurred in Lake Kanasatka in 2020 were serious because of the diversity of potentially toxic taxa present. There were concerns about these cyanobacteria blooms extending up to Wakondah Pond and down to Black East Cove in Lake Winnipesaukee, but there were no complaints of blooms, and the single sample sets that NHDES collected were clear for those waters. NHDES also received several anecdotal health complaints in August 2020, but no one filled out a NHDES form to officially document the cases (despite LKWA's door-to-door campaign to encourage residents and vacationers to do so). One report of a puppy getting sick after swimming in the lake was reported by the NHDES to the Centers for Disease Control and Prevention (CDC).

Table 4. Cyanobacteria advisories issued by NHDES for Lake Kanasatka (NHDES, 2022c).

Advisory Date	Duration (days)	Dominant Taxa	Illness Reported	Total Cell Concentration (cells/mL)
August 12, 2020	14	*Anabaena/Dolichospermum*	None	78,750
September 29, 2020	10	*Microcystis, Aphanizomenon, Woron*	None	393,500
August 4, 2021	15	*Dolichospermum*	None	775,000
September 13, 2021	9	*Dolichospermum*	None	500,000

It is unlikely that cyanobacteria will be fully eradicated in the Lake Kanasatka watershed; some species of cyanobacteria can become dormant in sediment and then can jump-start cell reproduction once conditions are favorable (warm water temperatures and plenty of sunlight and nutrients). Given the long-term trend of increasing hypolimnion total phosphorus concentration in the lake, the likelihood of blooms will continue and possibly accelerate, though year-to-year variability in weather may determine the availability of phosphorus and/or the presence of other oxygen compounds such as nitrates and thus determine the timing, extent, and severity of blooms in any given year. Despite this, conditions favorable for blooms can be substantially minimized by reducing nutrient-rich runoff from the landscape during warm, sunny spells. Water level and flow also helps to either flush out blooms or limit upstream nutrient sources to stymie growth.

2.1.6 Preliminary Sediment Analysis

In 2021, NHDES collected five lake bottom sediment cores (top 4 inches) to test for susceptibility of internal phosphorus loading within Lake Kanasatka. Sediment testing included analysis of phosphorus fractions by sequential lab extractions, as well as analysis of total phosphorus, total iron, and total aluminum (Table 5).

Phosphorus fractions analyzed included loosely bound phosphorus, iron bound phosphorus, labile organic phosphorus, and aluminum bound phosphorus. Loosely bound phosphorus is the most readily available fraction for uptake by algae. Iron bound phosphorus is phosphorus bound to iron which can be released under low oxygen conditions. Labile organic phosphorus is phosphorus bound to organic matter that is slowly released during decomposition. Aluminum bound phosphorus is phosphorus bound to aluminum which is permanently retained within bottom sediments. Results showed that loosely bound phosphorus is low at all depths in the lake. Iron and aluminum bound phosphorus are both higher in deeper areas of the lake compared to shallower areas, which is expected given that sediments tend to migrate to deeper parts of the lake over time. Labile organic phosphorus is high across sites, particularly the deepest site, indicating that the biogenic fraction of phosphorus (in addition to the iron bound phosphorus) may be a significant source of phosphorus release to the hypolimnion.

A high ratio of aluminum to iron and aluminum to phosphorus means that there is enough aluminum to permanently bind settled phosphorus, keeping the internal load in the lake low. Typically, a ratio of 3:1 or greater between aluminum and iron (Al:Fe) indicates that aluminum is present in enough abundance relative to iron that phosphorus is more likely to permanently bind to aluminum in the sediments. Additionally, a ratio of 25:1 or greater between aluminum and phosphorus (Al:P) indicates that there is enough aluminum to bind with available phosphorus. Results showed that Lake Kanasatka is vulnerable to internal loading due to Al:Fe ratios less than 3 and Al:P ratios less than 25 for all five sampled sites (shallow and deep areas of the lake).

WHAT IS INTERNAL LOADING?

Over time, as phosphorus enters the lake from the landscape, this phosphorus either stays in the lake (i.e., settles to the bottom or is taken up by plants/algae for growth) or leaves the lake (i.e., get flushed out). The phosphorus that settles on the lake bottom will generally bind with one of two naturally occurring elements that also get flushed into the lake each year from the watershed: aluminum or iron. If phosphorus binds with aluminum, then the bond is permanent, and the phosphorus is sedimented in the lake bottom. If the phosphorus binds with iron, then the bond is non-permanent and in summer when the lake bottom is deprived of oxygen (anoxic), it triggers a chemical reaction that releases phosphorus from iron. This phosphorus is now free to be mixed up into the water column and serve as a nutrient source for plants and algae. Looking at the ratios between aluminum, iron, and phosphorus indicates whether the lake is vulnerable to internal loading or cycling of phosphorus.

Table 5. Sediment testing results. Data were collected by NHDES and analyzed by the University of Wisconsin-Stout Center for Limnological Research and Rehabilitation. Red indicates conditions favorable for release of phosphorus under anaerobic conditions. P=Phosphorus. Al=Aluminum. Fe=Iron.

Site	Loosely-bound P (mg/g)	Iron-bound P (mg/g)	Labile organic P (mg/g)	Aluminum-bound P (mg/g)	Total P (mg/g)	Total Fe (mg/g)	Total Al (mg/g)	Al:Fe	Al:P
West Cove	0.016	0.070	0.179	0.208	0.7	11.6	11.8	2.1	18.5
3	0.018	0.172	0.312	0.369	1.3	18.4	17.4	2.0	15.4
2	0.022	0.139	0.217	0.394	1.2	15.1	15.1	2.1	14.4
1	0.026	0.285	0.355	0.478	1.4	20.0	17.7	1.8	14.6
East Cove	0.012	0.053	0.130	0.149	0.6	11.6	10.6	1.9	19.5

If Al:Fe <3, favorable for release of P under anaerobic conditions.
If Al:P <25, favorable for release of P under anaerobic conditions.

2.1.7 Air Temperature & Precipitation

2.1.7.1 Historic Weather Review

New Hampshire has experienced earlier recorded ice-out (or ice-off) dates in the last decade compared to the last century. Scientists are increasingly recognizing the relationship between winter lake processes and growing season water quality; however, historical winter data are limited. In other lake systems, particularly in temperate and Arctic regions, earlier ice-out has been shown to correspond with increasing biological growth. It has also been shown that climate change is causing a decrease in the temperature gradient between winter and summer, causing lakes to mix poorly. This is thought to keep algae and cyanobacteria cells in the lake for longer periods of time due to cells growing uninterrupted by mixing and persisting longer into fall months. Under ice, blooms often correlate to ice thickness and snowpack cover, with decreased cover allowing more light penetration for growth.

Recent ice out dates for Lake Kanasatka, provided by LKWA is shown below. There are not enough long-term data to determine any statistically significant trends.

- 2022 April 4
- 2021 April 1
- 2020 April 3
- 2019 April 22
- 2018 April 22
- 2017 April 16
- 2016 March 17 (earliest on record)

Figure 10 shows average monthly temperature and cumulative monthly precipitation from 1977 to 2021. In the winter preceding summer 2020, the region experienced a warmer-than-usual winter with average monthly temperature increasing slightly before dropping again (evidenced by the double peaks, circled in red). Additional data are needed to understand if winter air temperatures are correlated to observed cyanobacteria blooms.

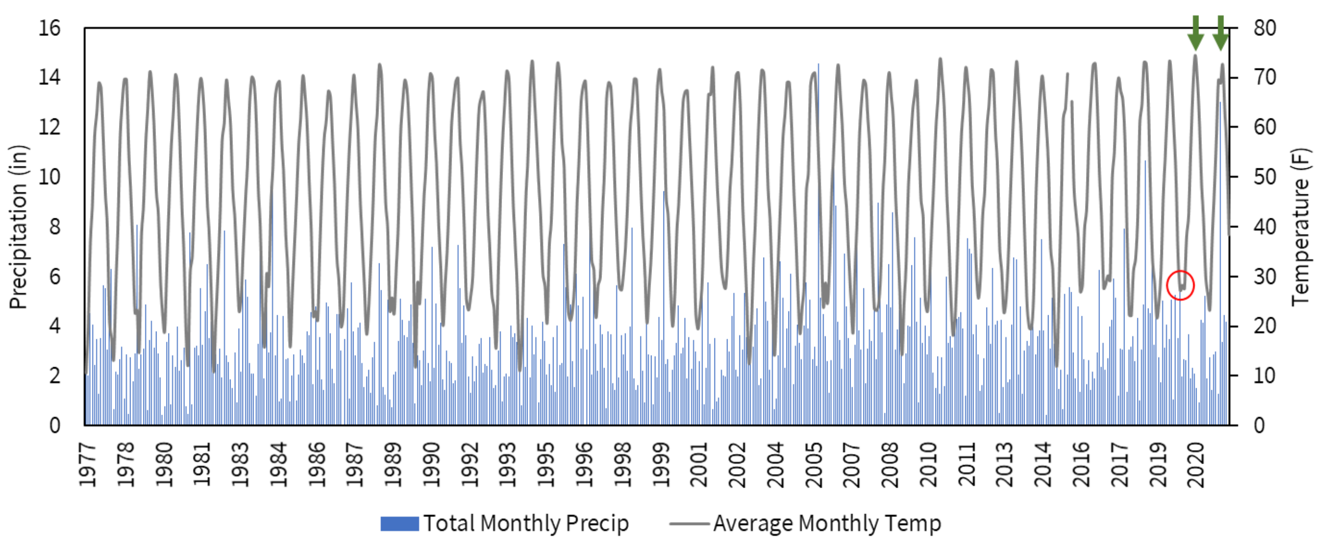


Figure 10. A timeseries graph of cumulative monthly precipitation and average monthly temperature for Concord, NH (USW00014745). Recorded cyanobacteria bloom years (2020, 2021) are noted as green arrows. An unusually warm winter preceding the 2020 bloom is circled in red.

2.1.7.2 Groundwater Depletion Theory

A recent study found that decreasing groundwater supply to groundwater dominated lakes impacted by droughts can increase bottom water temperatures, enhance oxygen depletion and internal phosphorus release, and trigger algae growth

(Safaie et al., 2021). In other words, sudden algae blooms in groundwater-dominated lakes may be associated with droughts decreasing groundwater supply, worsening anoxia, and releasing internal phosphorus rather than an increase in external nutrient loads from the landscape. According to the model results, we estimate that 64% of the total water load to Lake Kanasatka comes from baseflow, which includes both stream and groundwater inputs. In this case, Lake Kanasatka is a stream drainage (and not groundwater) dominated lake. However, the long-term trend in surface and bottom water temperatures for Lake Kanasatka (1-Deep) indicate a possible cooling of surface waters and warming of bottom waters (Figure 11), the latter of which may support the explanation proposed by Safaie et al. (2021). Lake Kanasatka has endured more frequent and more severe droughts in recent years, generally corresponding to the sudden onset of blooms beginning in 2020, suggesting a possible correlation with diminishing groundwater reserves feeding Lake Kanasatka (Figure 12). In addition, the impact of groundwater on bottom water temperatures may be more significant during other times of the year not represented in the long-term dataset, such as during early spring when the lake is impacted by decreased snowpack over winter, earlier ice-out, and earlier onset of stratification.

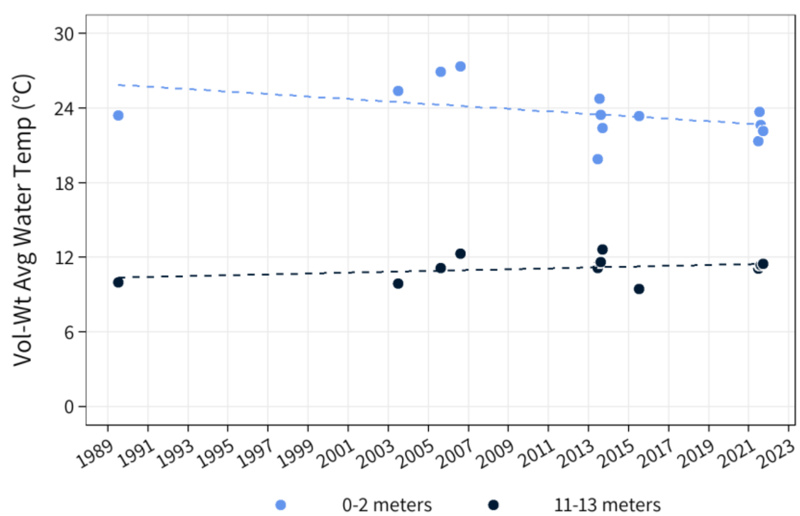


Figure 11. Volume-weighted average water temperatures for 0-2 meters and 11-13 meters in Lake Kanasatka from 1989-2021 for June-September. Calculated using R package *rLakeAnalyzer*.

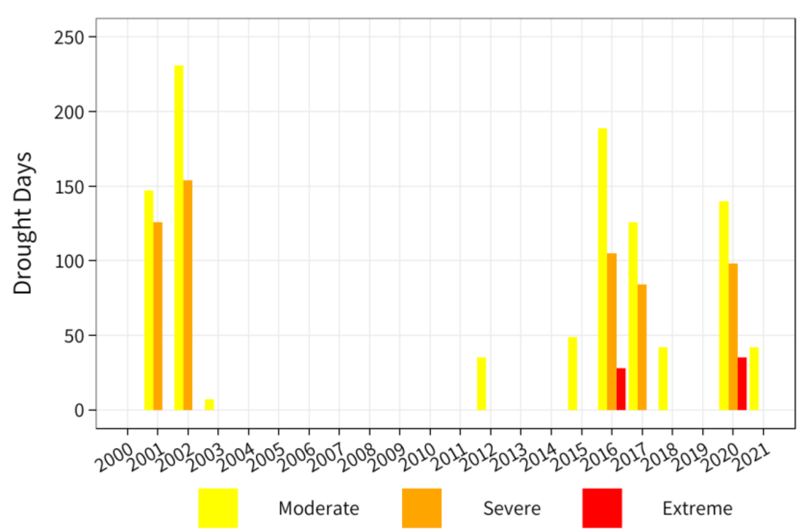


Figure 12. Number of drought days for moderate (D1), severe (D2), and extreme (D3) conditions in Carroll County, New Hampshire from 2000-2021. Data source: US Drought Monitor.

2.1.8 Fish

Fish are an important natural resource for sustainable ecosystem food webs and provide recreational opportunities. Lake Kanasatka supports populations of warm water species including but not limited to smallmouth bass, largemouth bass, chain pickerel (Eastern), black crappie, white and yellow perch, and pumpkinseed (common sunfish). The brindle shiner is a species of concern within the watershed, as identified in the 2015 Wildlife Action Plan (NHFG, 2015).

2.1.9 Invasive Species

The introduction of non-indigenous invasive aquatic plant species to New Hampshire's waterbodies has been on the rise. These invasive aquatic plants are responsible for habitat disruption, loss of native plant and animal communities, reduced property values, impaired fishing and degraded recreational experiences, and high removal costs. Once established, invasive species are difficult and costly to remove. Lake Kanasatka is part of the Lake Host Program, which provides courtesy boat inspections aimed at preventing the transport of invasive aquatic species into or out of the lake, as well as the Weed Watcher Program, which monitors the lake for invasive species. Both programs are overseen and funded by the Moultonborough Milfoil Committee with LKWA participation since 2000. NHDES indicates in its Lake Information Mapper that there are no known invasive species in Lake Kanasatka.

2.2 ASSIMILATIVE CAPACITY

The assimilative capacity of a waterbody describes the amount of pollutant that can be added to a waterbody without causing a violation of the water quality criteria. For oligotrophic waterbodies such as Lake Kanasatka, the water quality criteria are set at 8 ppb for total phosphorus and 3.3 ppb for chlorophyll-a (Table 6). Each trophic state has a certain phytoplankton biomass (chlorophyll-a) that represents a balanced, integrated, and adaptive community. Exceedances of the chlorophyll-a criterion suggests that the algal community is out of balance. Since phosphorus is the primary limiting nutrient for growth of freshwater algae (chlorophyll-a), phosphorus is included in this assessment process. NHDES requires 10% of the difference between the best possible water quality and the water quality standard be kept in reserve; therefore, total phosphorus and chlorophyll-a must be at or below 7.2 ppb and 3.0 ppb, respectively, to achieve Tier 2 High Quality Water status. Chlorophyll-a will dictate the final assessment if both chlorophyll-a and total phosphorus data are available and the assessments differ (Table 7).

Results of the assimilative capacity analysis show that Lake Kanasatka is overall impaired for its trophic class designation (Table 8). All three sites have existing median total phosphorus concentrations significantly higher than the assimilative capacity threshold (1.1-2.5 ppb above 7.2 ppb). One of the three sites has existing median chlorophyll-a concentration higher than the assimilative capacity threshold (0.8 ppb above 3.0 ppb); the other two fall at 3.0 ppb and thus achieve Tier 1 (Within Reserve) designation. The aggregation of the three deep spot sites shows a remaining assimilative capacity of -1.6 ppb for total phosphorus and -0.3 ppb for chlorophyll-a, indicating that Lake Kanasatka is overall impaired as an oligotrophic waterbody.

Table 6. Aquatic life integrity (ALI) nutrient criteria ranges by trophic class in New Hampshire. TP = total phosphorus. Chl-a = chlorophyll-a, a surrogate measure for algae.

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

Table 7. Decision matrix for aquatic life integrity (ALI) assessment in New Hampshire. TP = total phosphorus. Chl-a = chlorophyll-a, a surrogate measure for algae concentration.

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

Table 8. Assimilative capacity (AC) analysis results for Lake Kanasatka. Chlorophyll-a dictates the assessment results.

Parameter	AC Threshold (ppb)	Existing Mean WQ (ppb)*	Remaining AC (ppb)	Assessment Results
Lake Kanasatka – 3 WEST [KAN03WL]				
Total Phosphorus	7.2	9.7	-2.5	Impaired
Chlorophyll-a	3.0	3.8	-0.8	
Lake Kanasatka – 2 ANIMAL [KAN02AL]				
Total Phosphorus	7.2	8.3	-1.1	Tier 1 (Within Reserve)
Chlorophyll-a	3.0	3.0	0.0	
Lake Kanasatka – 1 DEEP SPOT [KANMOUD]				
Total Phosphorus	7.2	8.3	-1.1	Tier 1 (Within Reserve)
Chlorophyll-a	3.0	3.0	0.0	
Lake Kanasatka - Aggregate Deep Spot Sites				
Total Phosphorus	7.2	8.8	-1.6	Impaired
Chlorophyll-a	3.0	3.3	-0.3	

** Existing water quality data truncated to May 24-Sept 15 in the previous 10 years (2012-2021) for composite, epilimnion, or upper samples (in order of priority on a given day). Data were summarized by day, then month, then year using median statistic.*

2.3 WATERSHED MODELING

2.3.1 Lake Loading Response Model (LLRM)

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

The LLRM is an Excel-based model that uses environmental data to develop a water and phosphorus loading budget for lakes and their tributaries (AECOM, 2009). Water and phosphorus loads (in the form of mass and concentration) are traced from various sources in the watershed through tributary basins and into the lake. The model incorporates data about watershed and sub-watershed boundaries, land cover, point sources (if applicable), septic systems, waterfowl, rainfall, volume and surface area, and internal phosphorus loading. These data are combined with coefficients, attenuation factors, and equations from scientific literature on lakes, rivers, and nutrient cycles to generate annual average predictions[3] of total phosphorus, chlorophyll-a, Secchi disk transparency, and algal bloom probability. The model can be used to identify current and future pollutant sources, estimate pollutant limits and water quality goals, and guide watershed improvement projects. A complete detailing of the methodology employed for the Lake Kanasatka LLRM is provided in the *Lake Kanasatka Lake Loading Response Model Report* (FBE, 2022a).

2.3.1.1 Lake Morphology & Flow Characteristics

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

The surface area of Lake Kanasatka is 353 acres (5.2 miles of shoreline) with a maximum depth of 46 feet (14.0 m) and volume of 8,344,010 m^3 (Appendix A, Map A-1). The **areal water load** is 22 ft/yr (6.8 m/yr), and the flushing rate is 1.2 times per year. The flushing rate of 1.2 means that the entire volume of Lake Kanasatka is replaced 1.2 times per year.

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

There are several dams in the watershed historically or currently controlling water flow. There is one breached dam (Koenig Dam), two dams indicated as "ruins" and are otherwise in disrepair (Indian Carry Dam, Wakondah Pond Dam), and one active dam (Lake Kanasatka Dam) (NHDES, 2022d).

2.3.1.2 Land Cover

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

Current land cover in the Lake Kanasatka watershed was determined by FBE using a combination of the 2001 New Hampshire Landcover Database (NHLCD), ESRI World Imagery from October 1, 2020, and Google Earth satellite imagery from June 3, 2018. For more details on methodology, see the *Lake Kanasatka Lake Loading Response Model Report* (FBE, 2022a). Refer also to Appendix A, Map A-2.

As of the 2018/2020 aerial imagery, development accounts for 12% (507 acres) of the watershed, while forested and natural areas account for 80% (3,325 acres). Wetlands and open water represent 7% (314 acres) of the watershed, not including the surface area of Lake Kanasatka. Agriculture represents 1% (30 acres). Figure 13 shows a breakdown of land cover by major category for the entire watershed (not including lake area), as well as total phosphorus load by major land cover category (refer to Section 2.3.1.4 or FBE, 2022a). Developed areas cover 12% of the watershed and contribute 74% of the total phosphorus watershed load to Lake Kanasatka.

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

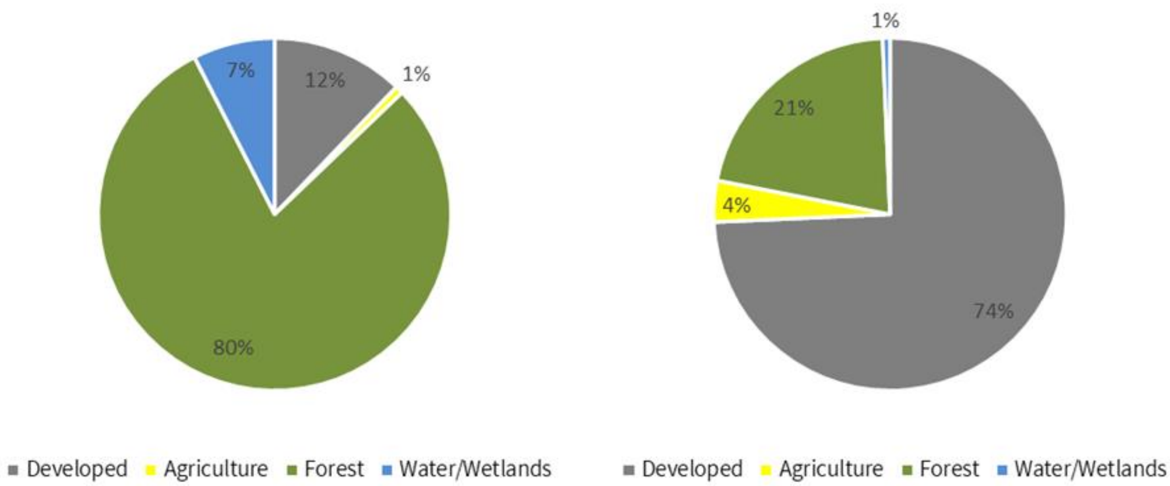


Figure 13. Lake Kanasatka watershed land cover area by general category (agriculture, developed, forest, and water/wetlands) (LEFT) and total phosphorus (TP) watershed load by general land cover type (RIGHT). This shows that developed areas cover 12% of the watershed and contribute 74% of the TP watershed load to Lake Kanasatka. Water/wetlands category does not include the lake area.

2.3.1.3 Internal Phosphorus Loading

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

2.3.1.4 LLRM Results

Overall, model predictions were in good agreement with observed data for total phosphorus (3%), chlorophyll-a, and Secchi disk transparency (Table 9). It is important to note that the LLRM does not explicitly account for all the biogeochemical processes occurring within a waterbody that contribute to overall water quality and is less accurate at predicting chlorophyll-a and Secchi disk transparency. For example, chlorophyll-a is estimated strictly from nutrient loading, but other factors strongly affect algae growth, including transport of phosphorus from the sediment-water interface to the water column by cyanobacteria, low light from suspended sediment, grazing by zooplankton, presence of heterotrophic algae, and flushing effects from high flows. There were insufficient data available to evaluate the influence of these other factors on observed chlorophyll-a concentrations and Secchi disk transparency readings.

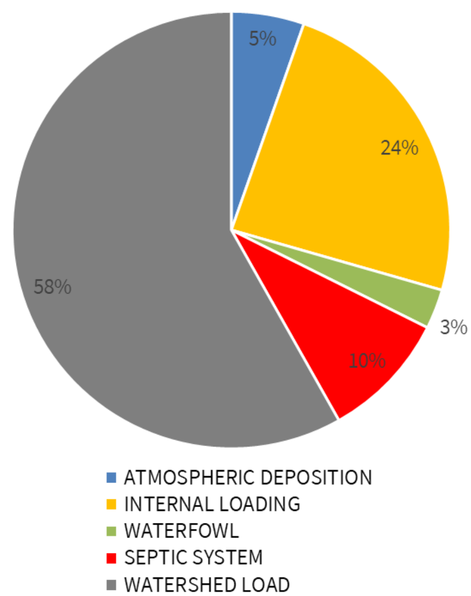


Figure 14. Summary of total phosphorus loading by major source for Lake Kanasatka. Refer to Table 10 for a breakdown.

Watershed runoff combined with baseflow (58%) was the largest phosphorus loading contribution across all sources to Lake Kanasatka, followed by internal loading at 24% and shorefront septic systems at 10% (Table 10; Figure 14). Atmospheric deposition (5%) and waterfowl (3%) were relatively minor sources. Development in the watershed is most concentrated around the shoreline where septic systems or holding tanks are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures, which leach untreated, nutrient-rich wastewater effluent to the lake. Note that 1) the estimate for the septic system load is only for those systems directly along the shoreline and potentially short-circuiting minimally treated effluent to the lake; and 2) the load from septic systems throughout the rest of the watershed is inherent to the coefficients used to generate the watershed load.

Internal loading, whereby low dissolved oxygen in bottom waters is causing a release of phosphorus from sediments, was estimated as a significant source of phosphorus to the lake; however, significantly more data would be needed over at least 1-2 field seasons to determine whether the lake is a candidate for an in-lake treatment of the internal load. In the meantime, watershed protection efforts should focus on reducing the watershed and septic system loads.

Normalizing for the size of a sub-watershed (i.e., accounting for its annual discharge and direct drainage area) better highlights sub-watersheds with elevated pollutant exports relative to their drainage area. Sub-watersheds with moderate-to-high phosphorus mass exported by area (> 0.20 kg/ha/yr) generally had more development (i.e., the direct shoreline areas to Wakondah Pond and Lake Kanasatka; Figure 15). Drainage areas directly adjacent to waterbodies have direct connection to lakes and are usually targeted for development, thus increasing the possibility for phosphorus export.

Once the model is calibrated for current in-lake phosphorus concentration, we can then manipulate land cover and other factor loadings to estimate pre-development loading scenarios (e.g., what in-lake phosphorus concentration was prior to human development or the best possible water quality for the lake). Refer to FBE (2022a) for details on methodology. Pre-development loading estimation showed that total phosphorus loading to Lake Kanasatka increased by 411%, from 57 kg/yr prior to European settlement to 293 kg/yr under current conditions (Table 10). These additional phosphorus sources are coming from development in the watershed (especially from the direct shoreline of Lake Kanasatka and Kanasatka Scribner Brook), internal loading, septic systems, and atmospheric dust (Table 10). Water quality prior to settlement was predicted to be excellent with extremely low phosphorus and chlorophyll-a concentrations and high water clarity (Table 9).

We can also manipulate land cover and other factors to estimate future loading scenarios (e.g., what in-lake phosphorus concentration might be at **full build-out** under current zoning constraints or the worst possible water quality for the lake). Refer to FBE (2022a) and the *Lake Kanasatka Watershed Build-out Analysis* (FBE, 2022b) for details on methodology. Note: the future scenario did not assume a 10% increase in precipitation over the next century (NOAA, 2013), which would have resulted in a lower predicted in-lake phosphorus concentration; this is because the model does not consider the rate and distribution of the projected increase in precipitation. Climate change models predict more intense and less frequent rain events that may exacerbate erosion of phosphorus-laden sediment to surface waters and therefore could increase in-lake phosphorus concentration (despite dilution and flushing impacts that the model assumes).

Future loading estimation showed that total phosphorus loading to Lake Kanasatka may increase by 73%, from 293 kg/yr under current conditions to 506 kg/yr at full build-out (2075) under current zoning for Lake Kanasatka (Table 10). Additional phosphorus will be generated from more development in the watershed (especially from the direct shoreline of Lake Kanasatka and Kanasatka Scribner Brook), enhanced internal loading, greater atmospheric dust, and more septic systems (Table 10). The model predicted higher (worse) phosphorus (19.4 ppb), higher (worse) chlorophyll-a (7.2 ppb), and lower (worse) water clarity (2.4 m) compared to current conditions for Lake Kanasatka (Table 9). The number of bloom days may increase from an average of 12 days currently to an average of 119 days at full build-out (Table 9).

Table 9. In-lake water quality predictions for Lake Kanasatka. TP = total phosphorus. Chl-a = chlorophyll-a. SDT = Secchi disk transparency. Bloom Days represent average annual probability of chlorophyll-a exceeding 8 ppb.

Model Scenario	Median TP (ppb)	Predicted Median TP (ppb)	Mean Chl-a (ppb)	Predicted Mean Chl-a (ppb)	Mean SDT (m)	Predicted Mean SDT (m)	Bloom Days
Pre-Develop.	--	2.2	--	0.2	--	12.6	0
Current (2021)	9.0 (10.8)	11.2	3.1	3.6	5.4	3.6	12
Future (2075)	--	19.4	--	7.2	--	2.4	119

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

Table 10. Total phosphorus (TP) and water loading summary by source for Lake Kanasatka.

SOURCE	PRE-DEVELOPMENT			CURRENT (2021)			FUTURE (2075)		
	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)	TP (KG/YR)	%	WATER (CU.M/YR)
ATMOSPHERIC	10.0	17%	1,041,494	15.7	5%	1,041,494	35.7	7%	1,041,494
INTERNAL	0.0	0%	0	70.4	24%	0	119.7	24%	0
WATERFOWL	8.6	15%	0	8.6	3%	0	8.6	2%	0
SEPTIC SYSTEM	0.0	0%	0	27.7	10%	20,540	34.0	7%	25,242
WATERSHED LOAD	38.7	68%	8,687,890	170.2	58%	8,607,904	308.1	60%	8,521,824
TOTAL LOAD TO LAKE	**57.2**	**100%**	**9,729,384**	**292.5**	**100%**	**9,669,939**	**506.1**	**100%**	**9,588,560**

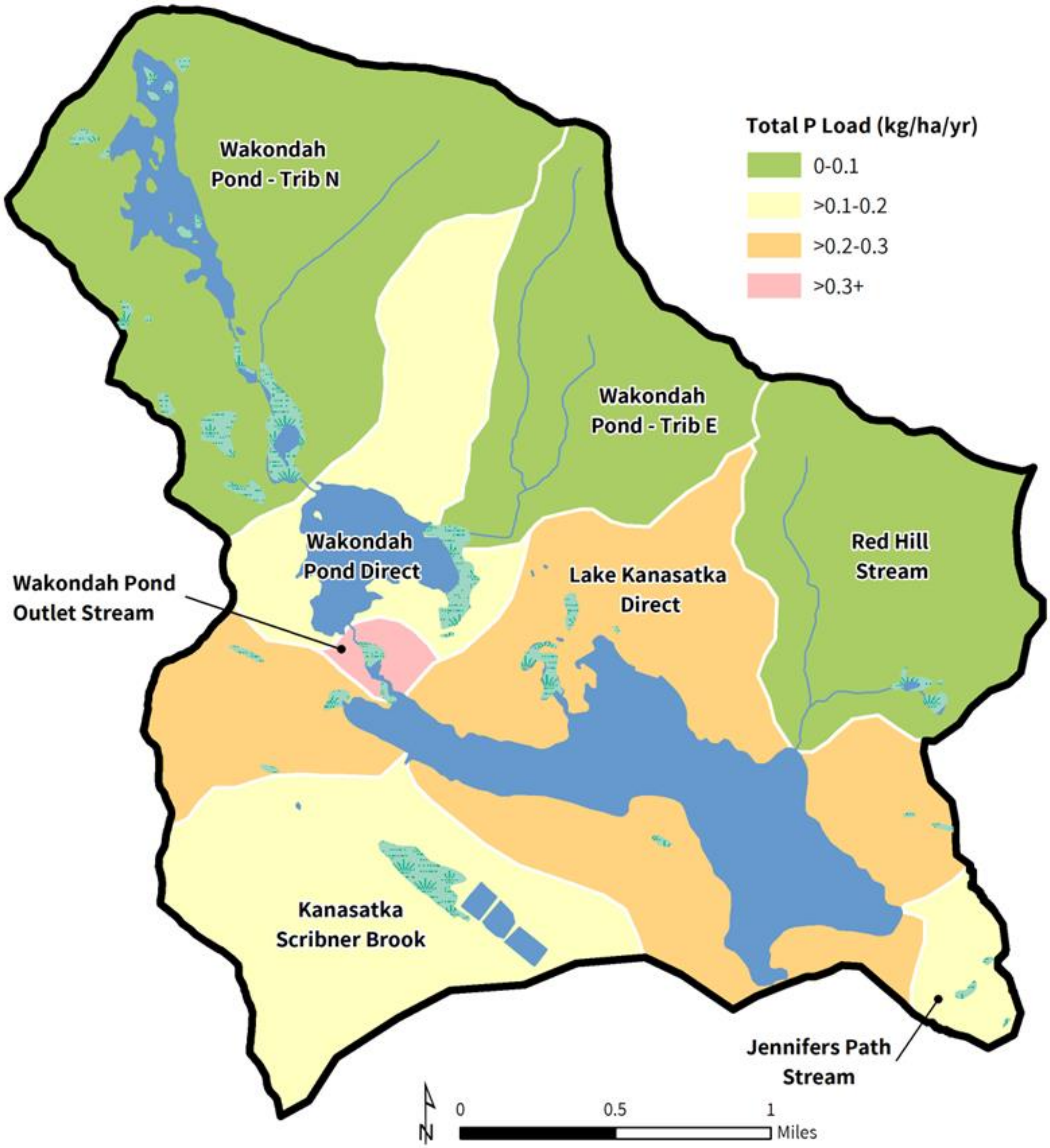


Figure 15. Map of current total phosphorus load per unit area (kg/ha/yr) for each sub-watershed in the Lake Kanasatka watershed. Higher phosphorus loads per unit area are concentrated in the more developed portions of the watershed along the lake shoreline and around the Wakondah Pond outlet stream.

2.3.2 Build-out Analysis

A full build-out analysis was completed for the Lake Kanasatka watershed for the municipalities of Moultonborough and Center Harbor (FBE, 2022b). A build-out analysis identifies areas with development potential and projects future development based on a set of conditions (e.g., zoning regulations, environmental constraints) and assumptions (e.g., population growth rate). A build-out analysis shows what land is available for development, how much development can occur, and at what densities. “Full Build-out” is a theoretical condition representing the moment in time when all available land suitable for residential, commercial, and industrial uses has been developed to the maximum capacity permitted by local ordinances and zoning standards. Local ordinances and zoning standards are subject to change, and the analysis requires simplifying assumptions; therefore, the results of the build-out analysis should be viewed as planning-level estimates only for potential future outcomes from development trends.

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

To determine where development may occur within the study area, the build-out analysis first subtracts land unavailable for development due to physical constraints, including environmental restrictions (e.g., wetlands, conserved lands, hydric soils), zoning restrictions (e.g., shoreland zoning, street Right-of-Ways (ROWs), and building setbacks), and practical design considerations (e.g., lot layout inefficiencies) (Appendix A, Map A-3). Existing buildings also reduce the capacity for new development.

The build-out analysis showed that 25% (974 acres) of the watershed is buildable under current zoning regulations (Appendix A, Map A-4). The Residential/Agricultural zone in Moultonborough has the most acreage of buildable area at 826 acres (Table 11). FBE identified 415 existing buildings within the watershed, and the build-out analysis projected that an additional 473 buildings could be constructed in the future, resulting in a total of 888 buildings in the watershed at full build-out (Appendix A, Map A-5). A town-wide build-out analysis was completed for the Town of Moultonborough in 2015 and was reviewed and updated during the process of completing this build-out analysis for the Lake Kanasatka watershed. Key revisions included updated conserved land areas and updated population estimates for the TimeScope Analysis. Results of this build-out, which showed that 25% of the Lake Kanasatka watershed is buildable, are consistent with the 2015 results, which showed that 28% of the Town of Moultonborough is buildable.

Table 11. Amount of buildable land and projected buildings in the Lake Kanasatka watershed.

Zone	Total Area (Acres)	Buildable Area (Acres)	Percent Buildable Area	No. Existing Buildings	No. Projected Buildings	Total No. Buildings	Percent Increase
Moultonborough							
Residential/Agricultural Zone	3,505	826	24%	369	379	748	103%
Commercial Zone A	85	47	55%	29	31	60	107%
West Village Overlay District	19	16	84%	4	6	10	150%
Center Harbor							
Agricultural Rural Zone	282	85	30%	13	57	70	438%
Total	**3,891**	**974**	**25%**	**415**	**473**	**888**	**114%**

Three iterations of the TimeScope Analysis were run using compound annual growth rates (CAGR) for 30-, 40- and 50-year periods from 1990-2020 (0.99%), 1980-2020 (1.42%) and 1970-2020 (2.13%), respectively (Table 12). Full build-out is projected to occur in 2100 at the 30-year CAGR, 2075 at the 40-year CAGR, and 2056 for the 50-year CAGR. This analysis showed that if the towns within the watershed continue to grow at recent rates identified in the 30- and 40-year period, and current zoning and other development constraints remain the same, full build-out could occur within 35 years (Figure 16).

Note that the growth rates used in the TimeScope Analysis are based on town-wide census statistics but have been applied here to a portion of the municipalities. Also note that the population growth rate in these municipalities is decreasing, so the 30-year estimate is likely more accurate than the 50-year estimate. Using census data to project population increase and/or development has inherent limitations. For instance, the building rate may increase at a different rate than population such as when considering commercial versus residential development. As such, the TimeScope Analysis might over or underestimate the time required for the study area to reach full build-out. Numerous social and economic factors influence population change and development rates, including policies adopted by federal, state, and local governments. The relationships among the various factors may be complex and therefore difficult to model.

Table 12. Compound annual growth rates for the two municipalities in the Lake Kanasatka watershed, used for the TimeScope Analysis. 2020 Census data was not available for towns with populations less than 5,000 (Moultonborough and Center Harbor) at the writing of this plan in Spring 2022, so the analyis used US Census Bureau "Vintage 2020 Population Estimates," 2020 estimates based on the 2010 census. Data from US Census Bureau.

	Compound Annual Growth Rate		
Town	**50 yr. Avg. 1960-2020**	**40 yr. Avg. 1980-2020**	**30 yr. Avg. 1990-2020**
Moultonborough	2.36%	1.63%	1.19%
Center Harbor	1.43%	0.77%	0.32%
Combined	**2.13%**	**1.42%**	**0.99%**

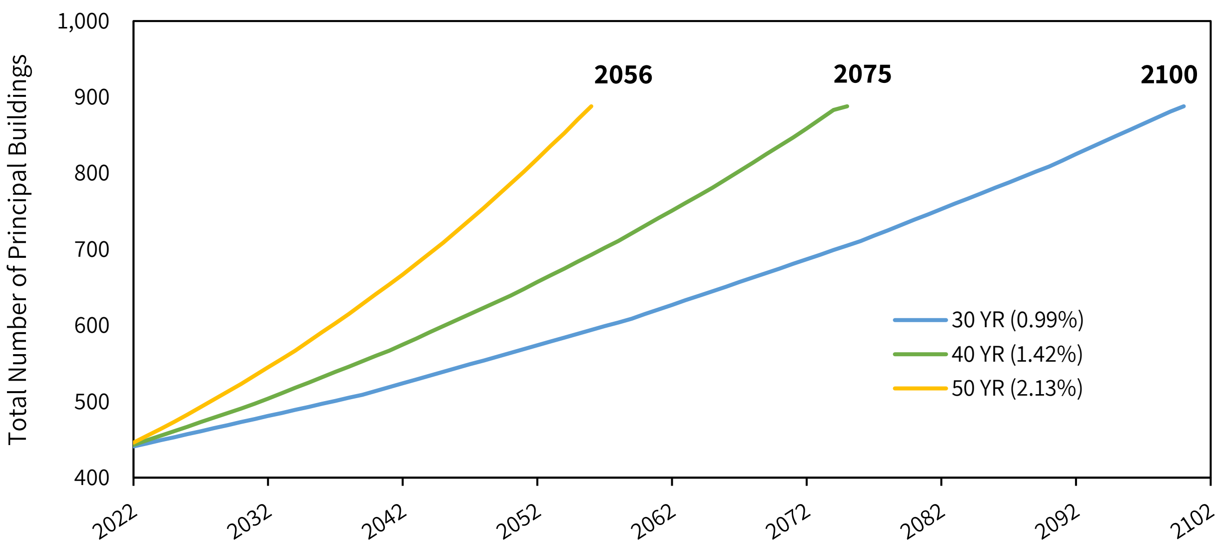


Figure 16. Full build-out projections of the Lake Kanasatka watershed (based on compound annual growth rates).

2.4 WATER QUALITY GOAL & OBJECTIVES

The model results revealed changes in total phosphorus loading and in-lake total phosphorus concentrations over time from pre-development through future conditions, showing that the water quality of Lake Kanasatka is threatened by current development activities in the watershed and will degrade further with continued development in the future. We can use these results to make informed management decisions and set an appropriate water quality goal for Lake Kanasatka. In-lake chlorophyll-a and total phosphorus concentrations indicate that there may not be reserve capacity for the lake to assimilate additional nutrients under a "business as usual" scenario. Thus, it is highly recommended that strong objectives be established to protect the water quality of Lake Kanasatka over the long term, especially given that the lake is not meeting water quality criteria, is experiencing cyanobacteria blooms, and is threatened by new development. The water quality goal and objectives were set by the Technical Advisory Committee with guidance from FBE.

The goal of the Lake Kanasatka WBMP is to improve the water quality of Lake Kanasatka such that it meets state water quality standards for the protection of ALI and substantially reduces the likelihood of harmful cyanobacteria blooms in the lake. This goal will be achieved by accomplishing the following objectives. Specific action items to achieve these objectives are provided in the Action Plan (Section 5).

Objective 1: Reduce phosphorus loading from existing development by 20% (59 kg/yr) to Lake Kanasatka to improve average summer in-lake total phosphorus concentration from 8.8 ppb to 7.2 ppb.

Objective 2: Mitigate (prevent or offset) phosphorus loading from future development by 40 kg/yr to Lake Kanasatka to maintain average summer in-lake total phosphorus concentration in the next 10 years (2031).

The interim goals for each objective allow flexibility in re-assessing water quality objectives following more data collection and expected increases in phosphorus loading from new development in the watershed over the next 10 or more years (Table 13). Understanding where water quality will be following watershed improvements compared to where water quality should have been following no action will help guide adaptive changes to interim goals (e.g., goals are on track or goals are falling short). If the goals are not being met due to lack of funding or other resources for implementation projects versus due to increases in phosphorus loading from new development outpacing reductions in phosphorus loading from improvements to existing development, then this creates much different conditions from which to adjust interim goals. For each interim goal year, LKWA should update the water quality data and model and assess why goals are or are not being met (refer to Section 6.5: Indicators to Measure Progress for environmental indicators). LKWA will then decide on how to adjust the next interim goals to better reflect water quality conditions and practical limitations to implementation.

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

Water Quality Objective	Interim Goals/Benchmarks		
	2024	2026	2031
1. Reduce phosphorus loading from existing development by 20% (59 kg/yr) to Lake Kanasatka to improve average summer in-lake total phosphorus concentration from 8.8 ppb to 7.2 ppb.			
	Achieve **5% (15 kg/yr)** reduction in TP loading	Achieve **10% (29 kg/yr)** reduction in TP loading; re-evaluate water quality and track progress	Achieve **20% (59 kg/yr)** reduction in TP loading; re-evaluate water quality and track progress
2. Mitigate (prevent or offset) phosphorus loading from future development by 40 kg/yr to Lake Kanasatka to maintain average summer in-lake total phosphorus concentration in the next 10 years (2031).			
	Prevent or offset **5 kg/yr** in TP loading from new development to Lake Kanasatka	Prevent or offset **20 kg/yr** in TP loading from new development to Lake Kanasatka; re-evaluate water quality and track progress	Prevent or offset **40 kg/yr** in TP loading from new development to Lake Kanasatka; re-evaluate water quality and track progress

3 POLLUTANT SOURCE IDENTIFICATION

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

3.1 WATERSHED DEVELOPMENT

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

3.1.1 Watershed Survey

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

Road ditch maintenance causing erosion on Avon Shores Rd, May 2022. Photo credit: Kevin Kelly.

FBE conducted the watershed survey in April and September 2021. For each location, field staff recorded site data and photographs on tablets. Information collected included location description and GPS coordinates; NPS problem description and measurements (e.g., gully dimensions); receiving waterbody; discharge type (direct or indirect/limited); and preliminary recommendations to mitigate the NPS problem. Field staff accessed sites from public and private roads and waterfront access points.

FBE identified 22 problem sites in the watershed (Figure 17). The main issues found were unpaved road and ditch erosion, unstable or undersized culverts, buffer clearing, and camp and beach runoff. FBE estimated the potential pollutant removal that could be achieved by implementing recommendations. Appendix B summarizes the recommendations, load reduction estimates, and estimated costs for each site. The top five high priority sites (based on lowest impact-weighted cost per mass of phosphorus removed) are shown below. In addition to these specific sites, managers of both private and public roads should use best practices for road installation and maintenance to for water quality protection.

Site 1-03: Shady Lane construction site
Location (latitude, longitude): 43.7180826, -71.43585
Impact: **High**

Observations: A large construction site (a few acres) with a lot of bare soil was observed at the end of Shady Lane. Mulch socks were distributed throughout the site; however, they were not effectively placed to mitigate all erosion on the site. Surveyors did not walk down the driveway but viewed the site from a distance as to not encroach on private land.

Recommendations: It is recommended that an inspector is sent to review the erosion and sediment controls and that additional erosion controls (e.g., silt fence, erosion control mulch) be explored and/or added in an organized and effective manner.

View of construction site from the top of Shady Lane.

Site 1-20: Common beach off Brook Rd to Wakondah Pond
Location (latitude, longitude): 43.7327844758593, -71.4711676543441
Impact: **High**

Observations: This 50' by 60' beach area appears to be likely refreshed with new sand. There is a very steep grade leading directly into the pond. One wooden retaining wall was observed, but it is overtopped with sand. Signs of significant shoreline erosion and retreat are evident.

Recommendations: Work with the right of way stakeholders to determine the needs and use of this common area. Any sand replenishment should be stopped. A defined access area should be established. We recommend installing infiltration steps from the parking area down to the water. Mulching and planting all other areas would also decrease erosion and runoff.

Steep grade leading from parking area directly to pond, showing overtopped, wooden retaining wall.

Site 1-22: Sandy Cove Rd
Location (latitude, longitude): 43.7172152136905, -71.4485283343078
Impact: **High**

Observations: A steep sloping private road (Sandy Cove Rd) leads down to a common beach area. Landowners have installed water diversions to the left side of the road (if facing the lake). Water travels down the left side of the road, and along grassed lawns, until it ultimately flows directly into the lake. There is minimal treatment of the runoff as it flows down the road, besides the runoff from the top of the road being diverted to a culvert on the left. This diverts water under the road to the right where it flows through the woods and is sent through an underground pipe. This pipe discharges at the edge of one property's lawn just before the common beach area.

(Left) Steep grade leading directly to beach area/lake, (Right) eroded left side of road running off into gully.

Recommendations: Consider halting any beach sand replenishment and leaf raking. The addition of a retaining wall with sediment forebay to define parking the parking/beach boundary would also collect any surface material runoff. Regrade the road to further divert water into the woods on the right side of the road (if facing the lake). Assess the condition of the flow channel through the woods for any further modification or water treatment and stabilize the underground pipe outlet with possible rock-lined plunge pool.

Site 1-16: Right of way off Ames Rd
Location (latitude, longitude): 43.7198124212571, -71.4381511323629
Impact: **Medium**

Observations: Eroding common access right of way off Ames Rd leading down to the lake (approximately 233'). The trail is compacted and sloping down towards the water with minimal water diversion. There is only one turn-out present on the trail. Clear evidence of water flowing down the trail was observed. Additionally, there is a 73' by 23' grassed common sitting area by water. This area is encased by a rock wall.

Recommendations: Add multiple water bars with infiltration trenches. It would also be beneficial to add erosion control mulch to the path and infiltration steps to the end of the trail, where the path steepens before reaching the water. Plant shade and acidic soil loving shrubs along the access way to manage erosion at this site.

(Left) Erosion along path leading down to water, (Middle) steep area at end of path, and (Right) grass sitting/common area.

Site 1-05: Boat ramp
Location (latitude, longitude): 43.7153763, -71.4453189
Impact: **High**

Observations: There was significant evidence of road surface erosion of the dirt parking area that was directly entering the lake. The edge of the paved road (Route 25) at the entrance of the parking area is breaking up. The silt fence around the dam is not functioning as intended.

Recommendations: Regrade and pave the entry to the parking lot and consider either paving or adding permeable pavers on the dirt parking lot surface. Pave or install permeable pavers on the boat launch. Add a vegetated buffer around the dam. This is a great spot to install signage or other educational material about water quality and erosion on the existing kiosk.

(Left) The edge of Route 25 where vehicles enter the parking lot. (Right) The dirt parking surface.

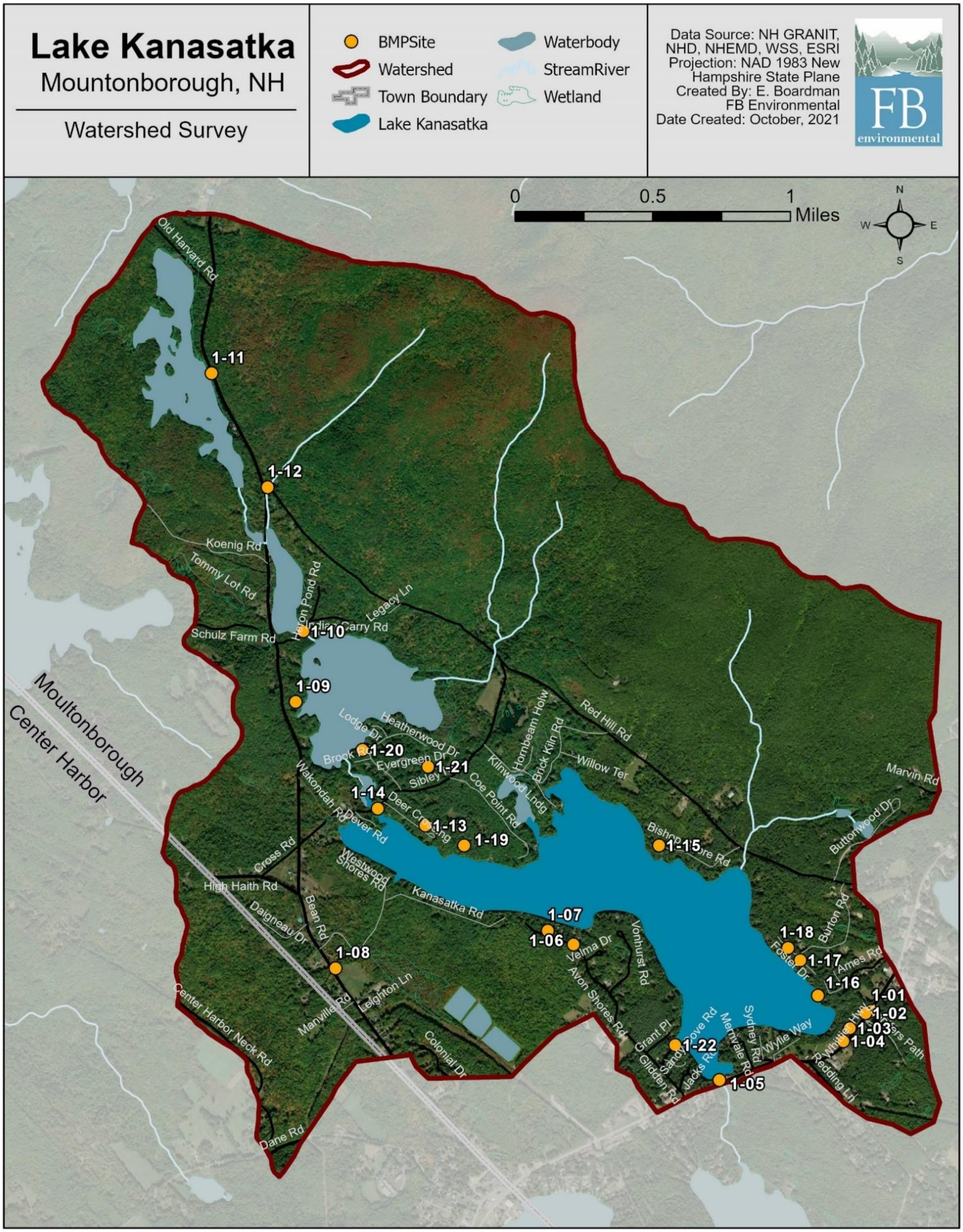


Figure 17. Location of identified nonpoint source sites in the Lake Kanasatka watershed.

3.1.2 Shoreline Survey

FBE technical staff, assisted by LWA staff and LKWA volunteers, conducted a shoreline survey of Lake Kanasatka on June 18, 2021. The shoreline survey uses a simple scoring method to highlight shoreline properties around the lake that exhibit significant erosion. This method of shoreline survey is a rapid technique to assess the overall condition of properties within the shoreland zone and prioritize properties for technical assistance or outreach. Two boats were used for surveying parcels with lake frontage. Technical staff and volunteers documented the condition of the shoreline for each parcel using a scoring system that evaluates vegetated buffer, presence of bare soil, extent of shoreline erosion, distance of structures to the lake, and slope. These scores were summed to generate an overall "Shoreline Disturbance Score" and "Shoreline Vulnerability Score" for each parcel, with high scores indicating poor or vulnerable shoreline conditions. Photos were taken at each parcel and were cataloged by tax map-lot number. These photos will provide LKWA with a valuable tool for assessing shoreline conditions over time. It is recommended that a shoreline survey be conducted in mid-summer every five years to evaluate changing conditions.

A total of 182 parcels were evaluated along the shoreline of Lake Kanasatka in Moultonborough (Appendix A, Map A-6). The average Shoreline Disturbance Score (Buffer, Bare Soil, and Shoreline Erosion) for the entire lake was 7.1 (Table 14). About 66% of the shoreline (or 121 parcels) scored 7 or greater. A disturbance score of 7 or above indicates shoreline conditions that may be detrimental to lake water quality. These shoreline properties tended to have inadequate buffers, evidence of bare soil, and shoreline erosion. The average Shoreline Vulnerability Score (Distance and Slope) was 4.1 (Table 14). About 79% (or 146 parcels) scored 4 or greater. A vulnerability score of 4 or greater indicates that the parcel may have a home less than 150 ft. from the shoreline and a moderate or steep slope to the shoreline. Parcels with a vulnerability score of 4 or greater are more prone to erosion issues whether or not adequate buffers and soil coverage are present.

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

Evaluated Condition	Average Score
Buffer (1-5)	2.9
Bare Soil (1-4)	2.4
Shoreline Erosion (1-3)	1.8
Shoreline Disturbance Score (3-12)	**7.1**
Distance (0-3)	2.3
Slope (1-3)	1.8
Shoreline Vulnerability Score (1-6)	**4.1**

The pollutant loading estimates are based on the Shoreline Disturbance Scores. Three (3) parcels with a score of 11 or greater generate approximately 6 kg of phosphorus load to Lake Kanasatka annually[4]. If shoreline landowners were to create adequate buffers and install other shoreline Best Management Practices (BMPs) on these properties (at a 50% BMP efficiency rate), the annual reduction would be 3 kg of phosphorus. The 118 parcels with scores 7-10, are contributing approximately 34 kg of phosphorus annually[5]. Remediation efforts on all properties using a 50% BMP efficiency rate could result in the annual reduction of 17 kg of phosphorus.

Certain site characteristics, such as slope, can cause shorelines to be naturally more vulnerable to erosion. Other site characteristics such as structure distance to the lake, are often a direct consequence of the historic development on that parcel and cannot be easily changed. Shoreline buffers and amount of exposed soil are more easily changed to strengthen the resiliency of the shoreline to disturbance in the watershed. In summary, the overall average shoreline condition of Lake Kanasatka is fair (average disturbance score slightly above 7) for erosion issues, with 121 properties (66%) needing to address

[4] Based on Region 5 model bank stabilization estimate for silt loams, using 100 ft (length) by 5 ft (height) and moderate lateral recession rate of 0.2 ft/yr.
[5] Based on Region 5 model bank stabilization estimate for silt loams, using 50 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

erosion issues that are impacting the lake. Lake Kanasatka is also generally more prone to erosion issues because many homes are located close to shore and on moderate to steep slopes (average vulnerability score is 4.1).

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

3.1.3 Soil & Shoreline Erosion

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

3.1.3.1 Surficial Geology

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

The current landscape formed 12,000 years ago at the end of the Great Ice Age, as the mile-thick glacier over half of North America melted and retreated, scouring bedrock and depositing glacial till to create the deeply scoured basin of the region's lakes. The retreating action also eroded mountains and left behind remnants of drumlins and eskers from ancient stream deposits. The glacier deposited a layer of glacial till more than three feet deep. Glacial till is composed of unsorted material, with particle sizes ranging from loose and sandy to compact and silty to gravely. This material laid the foundation for vegetation and streams as the depression basins throughout the region began to fill with water (Goldthwait, 1951).

The unique geological formation in this area formed the Winnipesaukee River Basin Stratified Drift Aquifers, comprising seventeen of the cleanest and most productive aquifers in the region. Several of these aquifers border Lake Kanasatka to the east and north, and there are others within the watershed including several surrounding Wakondah Pond, as mapped by Ayotte (1997). These aquifers were not among the selected aquifers described in detail by Ayotte (1997). Saturated thickness was indicated as mostly between 0 to 20 ft; and the aquifers' transmissivities are up to 1,000 ft^2/day, though there is a small area to the west of Lake Kanasatka with 20 to 40 ft depth and 1,000-3,000 ft^2/day transmissivity. The mapped stratified drift aquifers do not underlie the sewage lagoons in the watershed. By receiving groundwater from stratified drift aquifers, Lake Kanasatka is a discharge point for the Winnipesaukee River Basin Stratified Drift Aquifer. Any contamination in these aquifers will move quickly due to the high transmissivity of the material and enter Lake Kanasatka and other surface waters. Therefore, protection of the aquifer is vital to the protection of the lake.

3.1.3.2 Soils and Erosion Hazard

The soils in the Lake Kanasatka watershed (Appendix A, Map A-7) are a direct result of geologic processes. Of the 51 different soil series present within the Lake Kanasatka watershed (excluding soils beneath waterbodies), the most prevalent soil group in the watershed is Lyman-Berkshire-Rock outcrop complex, very stony (1,200 acres, 26%), followed by Gloucester fine sandy loam, extremely stony (363 acres, 8%), Henniker fine sandy loam, very stony (298 acres, 7%), and Metacomet fine sandy loam, very stony (264 acres, 6%). Lyman-Berkshire-Rock, Gloucester, and Henniker soils are well drained, while Metacomet is classified as moderately well drained. The remaining 53% of the watershed (excluding the lake area) is a combination of 47 additional soil series ranging from 4.1% to 0.01% of the watershed.

Soil erosion hazard is dependent on a combination of factors, including land contours, climate conditions, soil texture, soil composition, permeability, and soil structure (O'Geen et al., 2006). Soil erosion hazard should be a primary factor in determining the rate and placement of development within a watershed. Soils with negligible soil erosion hazard are primarily low-lying wetland areas near abutting streams. The soil erosion hazard is determined from the associated slope and soil erosion factor K_w[6] used in the Universal Soil Loss Equation (USLE). The USLE predicts the rate of soil loss by sheet or rill erosion in units of tons per acre per year. A rating of "slight" specifies erosion is unlikely to occur under standard conditions. A rating of "moderate" specifies some erosion is likely and erosion-control measures may be required. A rating of "severe" specifies erosion is very likely and erosion-control measures and revegetation efforts are crucial. A rating of "very severe" specifies significant erosion is likely and control measures may be costly. These ratings are derived as part of the Soil Erosion Hazard Off-Road/Off-Trail for each soil series; however, during development of this plan, the Soil Erosion Hazard Off-Road/Off-Trail data were not available online or directly through the Natural Resources Conservation Service (NRCS) due to a processing error that will be fixed by 10/1/2022 (after publication of this plan). As a simple method to generally replicate the Soil Erosion Hazard ratings, we intersected soils with a soil erosion factor K_w rating and located on slopes greater than 15% and rated those areas as follows: "moderate" for soil erosion factor K_w less than 0.15, "severe" for soil erosion factor K_w between 0.15 and 0.28, and "very severe" for soil erosion factor K_w between 0.28 and 0.37. Excluding the lake area, "severe" and "very severe" erosion hazard areas account for 7% of the Lake Kanasatka watershed and are mostly concentrated along Red Hill Rd at the base of the steep northern and western headwater areas of the watershed (Appendix A, Map A-8). Moderate erosion hazard areas account for <1% of the watershed land area. The remaining watershed area has soils not rated for the soil erosion factor K_w and/or located in low-lying areas with slopes less than 15%. Development should be restricted in areas with severe and very severe erosion hazards due to their inherent tendency to erode at a greater rate than what is considered tolerable soil loss. Since a highly erodible soil can have greater negative impact on water quality, more effort and investment are required to maintain its stability and function within the landscape, particularly from BMPs that protect steep slopes from development and/or prevent stormwater runoff from reaching water resources.

3.1.3.3 Shoreline Erosion

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

3.1.4 Wastewater

3.1.4.1 Septic Systems

Untreated discharges of sewage (domestic wastewater) are prohibited regardless of source. An example of an NPS discharge of untreated wastewater is from insufficient or malfunctioning subsurface sewage treatment and disposal systems, commonly referred to as septic systems, but which also include holding tanks and cesspools. When properly designed, installed, operated, and maintained, septic systems can reduce phosphorus concentrations in sewage within a zone close to the system (depending on the development and maintenance of an effective biomat, the adsorption capacity of the underlying native soils, and proximity to a restrictive layer or groundwater). Age, overloading, or poor maintenance can result in system failure and the release of nutrients and other pollutants into surface waters (EPA, 2016). Nutrients from insufficient

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

septic systems can enter surface waters through surface overflow or breakout, stormwater runoff, or groundwater. Cesspools are buried concrete structures that allow solid sludge to sink to the bottom and surface scum to rise to the top and eventually leak out into surrounding soils through holes at the top of the structure. Holding tanks are completely enclosed structures that must be pumped regularly to prevent effluent back-up into the home.

LKWA completed an initial review of available data on septic systems along the Lake Kanasatka shoreline in October 2021. The objective of this data survey was to determine the number of septic systems along the shoreline of Lake Kanasatka and the proportion of older septic systems. LKWA queried the NHDES OneStop online database for subsurface permits and reviewed Moultonborough tax parcel records. There were 185 shoreline properties identified (within 250 feet of the shoreline), 167 of which had structures built on them. Septic system permits within OneStop were found for 41% of the built properties. Of these, 25% were found to have septic systems newer than 25 years, and 5% had septic system information prior to 1996. There were 17 properties (10%) which had septic system permits that had expired and were not installed.

FBE estimated the pollutant loading from shoreline septic systems using default literature values for daily water usage, phosphorus concentration output per person, and system phosphorus attenuation factors. The number of people using shoreline septic systems was calculated by multiplying the number of "old" (>25 years) and "young" (<25 years) shoreline septic systems used seasonally or year-round by the number of bedrooms (as a surrogate for the average number of persons using the septic systems). As detailed in the *Lake Kanasatka Lake Loading Response Model Report* (FBE, 2022a), shoreline septic systems contribute 27.7 kg/yr of total phosphorus loading to Lake Kanasatka, comprising 10% of the total phosphorus load from all sources to the lake. Septic systems, cesspools, or holding tanks are located within a short distance to the water, leaving little horizontal (and sometimes vertical) space for proper filtration of wastewater effluent. Improper maintenance or siting of these systems can cause failures, which leach untreated, nutrient-rich wastewater effluent directly to the lake.

3.1.4.2 Wastewater Lagoons

Sewage lagoons were constructed around 1966-1968 in the southwest portion of the watershed. They are currently owned and maintained by the Bay District Sewer Commission as part of the Winnipesaukee River Basin Program (WRBP)[7]. FBE, with LKWA and NHDES assistance, conducted a review of the lagoons' history and condition to evaluate their possible effects on Lake Kanasatka water quality.

Aerial image of sewage lagoons in Moultonborough.

The series of three lagoons were built for wastewater storage (31-million-gallon capacity, 6 ft depth maximum) and secondary facultative treatment of wastewater prior to discharge to Lake Winnipesaukee. Solids settle to the bottom of the lagoons as sludge before liquid waste is discharged from the system. In 1990, the sewage lagoons' discharge was diverted from Lake Winnipesaukee to a series of pumps and underground piping running along Route 25 from Moultonborough and Meredith to the centralized treatment plant in Franklin (owned and operated by NHDES). The lagoons currently serve 90 residential homes and 30 commercial properties, which contribute 58,000 gallons per day in winter and 104,000 gallons per day in summer (maximum allowance is 240,000 gallons per day). Four miles of collection lines and two pump stations move sewerage to the lagoons.

[7] In 1959, the Lakes Region Clean Waters Association was formed and through many years of persistent grassroots efforts from community members, a $1 million dollar grant was secured from the EPA under the CWA Construction Grants Program to establish the WRBP, a state-owned sewer system with a wastewater treatment plant in Franklin. The sewer system went online in 1976 and processed sewage from several municipalities in the area. The plant is located outside the watershed, but there is a maintenance facility and several pump-out stations in the watershed along with the connecting sewer lines. The sewer system serves over 14,500 residential connections in 10 communities. WRBP owns and maintains the main sewer line and pump stations that convey the sewage from each community to the plant. The sewer infrastructure that connects homes and businesses to the main sewer line is owned and maintained by each respective municipality or by private owners. WRBP is funded by each municipality through the sewer tax bill collected.

The lagoons operate under NHDES Groundwater Discharge Permit Number GWP-199007028-M-005 (expires 5/16/27) because the lagoons are currently considered unlined[8] and potentially discharging to groundwater via infiltration. The original intent of the construction plans noted the use of a 2-4 ft deep compacted impervious fill around the lagoons, but the Bay District Sewer Commission was unable to provide adequate proof to NHDES who then classified the lagoons as unlined. Four groundwater monitoring test wells were installed around the lagoons in 2001 (Figure 18). The permit requires semi-annual testing of the wells for contaminants of interest, including chloride, total dissolved phosphorus, nitrate, pH, Total Kjeldahl Nitrogen (TKN), *E. coli*, specific conductance, volatile organics, per- and polyfluoroalkyl substances (PFAS), dioxane, arsenic, barium, boron, cadmium, chromium, lead, mercury, selenium, silver, temperature, and static water level. BDS-1 was installed upgradient of the lagoons to the east; three other downgradient wells were installed to the south (BDS-4), west (BDS-3), and north (BDS-2). Wells were installed 15-26 feet below ground. Two surface water sampling locations are being established under the newly issued 2022 permit: SW-1 is located immediately southwest of the northernmost lagoon in a small seep that discharges to the northwest into a large wetland complex; SW-2 is located in the stream where it crosses Kanasatka Rd.

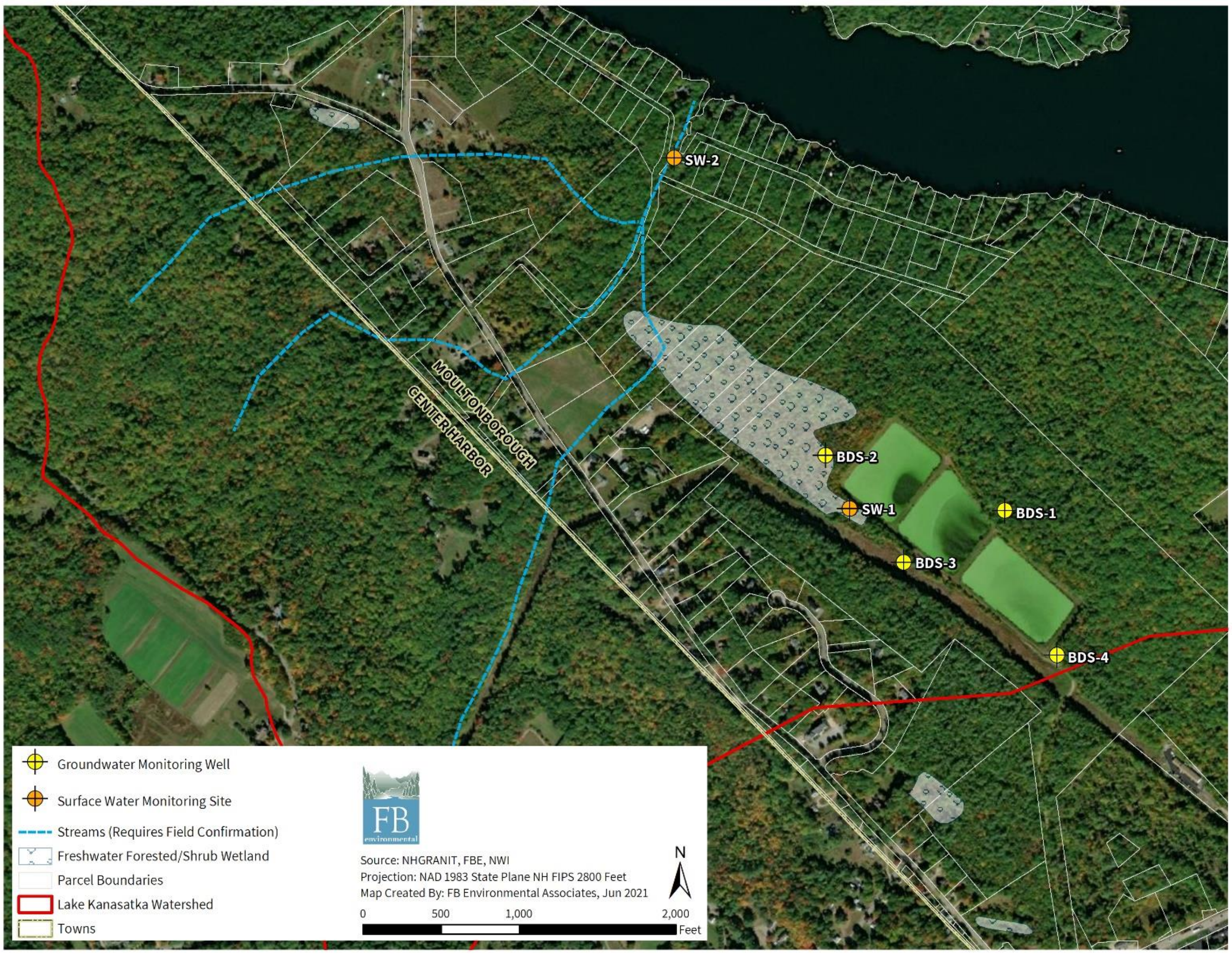


Figure 18. Monitoring well and surface water sample locations around the lagoons in relation to wetlands, draft stream channels, parcel boundaries, and Lake Kanasatka.

[8] Lagoons are lined with 1.5-2' marine clay, 12-25' to bedrock. They switched to being considered unlined in the 1990s because of change in definition. NHDES started calling synthetic liners as lined lagoons, natural materials like marine clay were no longer considered lined.

Maintenance of the lagoons includes routine mowing, periodic inspections of embankments for leaks or breakthroughs (trenches surround the lagoons to contain any leaking wastewater), and intake structure inspection and cleaning. No sludge has ever been removed from the lagoons. The Groundwater Discharge Zone boundary was defined as the 128-acre property boundary (Tax Map ID 140-017). Under the newly issued 2022 permit, the Bay District Sewer Commission is required to develop and submit to NHDES a Sludge Management Plan for the facility.

During the early stages of developing of the WBMP for Lake Kanasatka in 2021, the sewage lagoons were identified as a possible concern and source of contamination to the lake. Upon further investigation by LKWA, a formal complaint was filed with NHDES on June 3, 2021, identifying possible surface water contamination emanating from the watershed of Tax Map ID 140-017 (Bay District Sewerage, owner) and affecting surface waters within the Town of Moultonborough. Local volunteers noted excessive algae growth in the wetland area draining from the lagoons. Noticeable differences in water color were also observed at the confluence of the wetland/stream draining from the lagoons and the locally-named Scribner Brook. The water color difference could also be natural tannins from the wetlands. Total phosphorus and total nitrogen samples were collected by local volunteers in May 2021 from the potentially impacted stream and Scribner Brook. Results showed elevated nutrient levels in the potentially impacted stream (25.6-52.5 ppb TP; 546-721 ppb TN) compared to Scribner Brook (5.3-15.4 ppb TP; 226-233 ppb TN). Again, wetlands can also be sources of nutrients but can also attenuate nutrients depending on site conditions and/or time of year.

Excessive algae growth was documented by local volunteers in the wetland area draining from the lagoons (left, middle). Confluence point of Scribner Brook (flowing in from right) and Bay District stream (flowing in from above) (Location 1) on 5/31/2021, after 1.5 days / 0.9 inches of steady light rainfall (right). Photo Credit: Woody Cartwright.

In addition, samples from the groundwater monitoring wells showed elevated parameters in the impacted downgradient wells compared to the control upgradient well. From 2001-2020, TKN was minimal in the upgradient well (BDS-1) and elevated in the downgradient well (BDS-2), which ranged from 4-35 mg/L. Chloride was also elevated in BDS-2, ranging from 29-36 mg/L, compared to the upgradient well (BDS-1, ranging from <1-4 mg/L). However, discussions with the NHDES Drinking Water Program equated these elevated parameters to the likely natural conditions associated with wetlands soils in which the BDS-2 downgradient well is located. FBE modeled total phosphorus load from the Kanasatka Scribner Brook sub-watershed in which the lagoons are located and possibly discharge. The land use based watershed load alone (assuming no point source discharge to groundwater from the lagoons) generated a predicted annual in-stream total phosphorus concentration matching observed data well. Given the lack of discrepancy between predicted and observed total phosphorus concentration, there is currently no evidence that the sewage lagoons pose a significant threat to the water quality of Lake Kanasatka.

Despite no concrete evidence of potential groundwater contamination from the lagoons, NHDES has encouraged the Bay District Sewer Commission to pursue funding for a planning study to "*assess the feasibility for discontinuing the use of its unlined lagoons and instead discharge all of its wastewater directly to the WRBP wastewater treatment facility, as well as permanent closure of the lagoons*" (NHDES, 2022e).

3.1.5 Fertilizers

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

3.1.6 Pets

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

3.1.7 Agriculture

Agriculture in the Lake Kanasatka watershed includes cropland and grazing areas. Agricultural activities, including dairy farming, raising livestock and poultry, growing crops, and keeping horses and other animals for pleasure or profit, involve managing nutrients.

Agricultural activities and facilities with the potential to contribute to nutrient impairment include:

- Plowing and earth moving;
- Fertilizer and manure storage and application;
- Livestock grazing;
- Animal feeding operations and barnyards;
- Paddock and exercise areas for horses and other animals; and
- Leachate from haylage/silage storage bunkers.

Diffuse runoff of farm animal waste from land surfaces (whether from manure stockpiles or cropland where manure is spread), as well as direct deposition of fecal matter from farm animals standing or swimming in surface waters, are significant sources of agricultural nutrient pollution in surface waters. Farm activities like plowing, livestock grazing, vegetation clearing, and vehicle traffic can also result in soil erosion which can contribute to nutrient pollution.

Excessive or ill-timed application of fertilizer or poor storage which allows nutrients to wash away with precipitation not only endangers lakes and other waters, it also means those nutrients are not reaching the intended crop. The key to nutrient application is to apply the right amount of nutrients at the right time. When appropriately applied to soil, synthetic fertilizers or animal manure can fertilize crops and restore nutrients to the land. When improperly managed, pollutants in manure can enter surface waters through several pathways, including surface runoff and erosion, direct discharges to surface water, spills and other dry-weather discharges, and leaching into soil and groundwater.

3.1.8 Future Development

Understanding population growth, and ultimately development patterns, provide critical insight to watershed management, particularly as it pertains to lake water quality. According to the US Census Bureau, Moultonborough and Center Harbor have experienced moderate population growth over the last 50 years, increasing from a total of 1,850 people in 1970 to 5,308 people in 2020 (see Section 2.3.2). The Lake Kanasatka watershed area has long been treasured as a recreational haven for both summer vacationers and year-round residents. The area is among the oldest summer vacation spots in New Hampshire and offers fishing, hiking, boating, sailing, canoeing, kayaking, and swimming in the summer, and ice fishing, cross-country skiing, snowshoeing, and snowmobiling in the winter. The desirability of Lake Kanasatka and the greater Lake Winnipesaukee area as a recreational destination will likely stimulate continued population growth in the future. Growth figures and estimates suggest that towns should continue to consider the effects of current municipal land-use regulations on local water resources. As the region's watersheds are developed, erosion from disturbed areas increases the potential for water quality decline.

3.2 INTERNAL PHOSPHORUS LOAD

Phosphorus that enters the lake and settles to the bottom can be re-released from sediment under anoxic conditions, providing a nutrient source for algae, cyanobacteria, and plants, otherwise known as internal phosphorus loading. The watershed modeling in Section 2.3 identified internal phosphorus load as the second largest source of phosphorus to Lake Kanasatka. To fully meet the established water quality goal and objectives, it is likely that LKWA will need to pursue further investigation of a possible in-lake treatment option for substantially reducing the internal phosphorus load to Lake Kanasatka. In the meantime, watershed protection efforts should focus on reducing the watershed and septic system loads.

3.3 POTENTIAL CONTAMINATION SOURCES

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

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

On April 29, 2022, FBE downloaded datasets for above ground storage tanks, underground storage tanks, automobile salvage yards, solid waste facilities, hazardous waste sites, local potential contamination sources, NPDES outfalls, and remediation sites in the Lake Kanasatka watershed. Out of the eight possible categories, only two occur in the watershed: remediation sites and underground storage tanks (Appendix A, Map A-9).

3.3.1 Remediation sites

The seven remediation sites present within the Lake Kanasatka watershed consist of illegal dumping, on-premise use facilities containing oil, an untreated wastewater/sewage lagoon, and a leaking underground storage tank. All the remediation sites are located in Moultonborough.

3.3.2 Underground storage tanks

The underground storage tank layer identifies the locations of registered underground storage tanks in New Hampshire. There are two underground storage tanks within the Lake Kanasatka watershed, both in Moultonborough and both owned by petroleum distributors.

3.4 WILDLIFE

Fecal matter from wildlife such as geese, gulls, other birds, and beaver may be a significant source of nutrients in some watersheds. This is particularly true when human activities, including the direct and indirect feeding of wildlife and habitat modification, result in the congregation of wildlife (CWP, 1999). Congregations of geese, gulls, and ducks are of concern because they often deposit their fecal matter next to or directly into surface waters. Examples include large mowed fields adjacent to lakes and streams where geese and other waterfowl gather, as well as the underside of bridges with pipes or joists directly over the water that attract large numbers of pigeons or other birds. Studies show that geese inhabiting **riparian** areas increase soil nitrogen availability (Choi et al., 2020) and gulls along shorelines increase phosphorus concentration in beach sand pore water that then enters surface waters through groundwater transport and wave action (Staley et al. 2018). When submerged in water, the droppings from geese and gulls quickly release nitrogen and phosphorus into the water column, contributing to eutrophication in freshwater ecosystems (Mariash et al., 2019). On a global scale, fluxes of nitrogen and phosphorus from seabird populations have been estimated at 591 Gg N per year and 99 Gg P per year, respectively (with the highest values derived from arctic and southern shorelines) (Otero et al., 2018). Additionally, other studies show greater concentrations of nitrogen, ammonia, and dissolved organic carbon downstream of beaver impoundments when compared to similar streams with no beaver activity in New England (Bledzki et al., 2010). The model estimated that waterfowl are likely contributing 8.6 kg/yr (3%) of the total phosphorus load to Lake Kanasatka.

3.5 CLIMATE CHANGE

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

These trends will likely continue to impact both water quality and quantity. Climate change models predict a 10-40% increase in stormwater runoff by 2050, particularly in winter and spring and an increase in both flood and drought periods as seasonal precipitation patterns shift. Adding to this stress is population growth and corresponding development in New Hampshire. The build-out analysis for the watershed showed that about 974 acres is still developable and up to 473 new buildings could be added to the watershed at full build-out based on current zoning standards. Lake Kanasatka is at serious risk for sustained water quality degradation because of new development in the watershed unless climate change resiliency and **low impact development** (LID) strategies are incorporated to existing zoning standards.

4 MANAGEMENT STRATEGIES

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

4.1 STRUCTURAL NONPOINT SOURCE (NPS) RESTORATION

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

4.1.1 Watershed & Shoreline BMPs

Twenty-two (22) NPS sites identified during the 2021 watershed survey and 121 high/medium impact rated shoreline properties from the 2021 shoreline survey were documented to have some impact to water quality through the delivery of phosphorus-laden sediment (refer to Section 3.1.1-3.1.2). As such, structural BMPs to reduce the external watershed phosphorus load are a necessary and important component for the protection of water quality in the watershed.

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

- Address the top five high priority sites (and the remaining 17 medium and low priority sites as opportunities arise) identified during the 2021 watershed survey. The sites were ranked based on phosphorus load reduction and waterbody proximity. The full prioritization matrix with recommended improvements is provided in Appendix B.
- Provide technical assistance and/or implementation cost sharing to three high impact shoreline properties identified during the 2021 shoreline survey. Encourage landowners to implement stormwater and erosion controls on the 118 medium impact shoreline properties identified during the 2021 shoreline survey. Workshops and tours of demonstration sites can help encourage landowners to utilize BMPs on their own property. Conduct regular shoreline surveys to continue prioritizing properties for technical follow-up.

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

4.2 NON-STRUCTURAL NONPOINT SOURCE (NPS) RESTORATION

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

4.2.1 Pollutant Reduction Best Practices

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

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

Improved road ditch maintenance along Route 25 in Moultonborough. Photo credit: Kevin Kelly.

4.2.2 Zoning and Ordinance Updates

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

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

- **Installing Green Infrastructure and Nature-Based Solutions:** Planning for greener infrastructure requires that we think about creating a network of interconnected natural areas and open spaces needed for groundwater recharge, pollution mitigation, reduced runoff and erosion, and improved air quality. Examples of green infrastructure include forest, wetlands, natural areas, riparian (banks of a water course) buffers, and floodplains; all of which already exist to various extents in the watershed and have minimized the damage created by intense storms. As future development occurs, these natural barriers must be maintained or even increased to reduce runoff of pollutants into freshwaters. See also Section 4.2.3: Land Conservation.
- **Using LID Strategies:** Use of LID strategies requires replacing traditional approaches to stormwater management using curbs, pipes, storm drains, gutters, and retention ponds with innovative approaches such as bioretention, vegetated swales, and permeable paving.
- **Minimizing Impervious Surfaces:** Impervious surfaces such as roads, buildings, and parking lots should be minimized by creating new ordinances and building construction design requirements which reduce the imperviousness of new development. Property owners can increase the permeability for their lots by incorporating permeable driveways and walkways.
- **Encouraging Riparian Buffers and Maintaining Floodplains:** Municipal ordinances should forbid construction in floodplains, and in some instances, floodplains should be expanded to increase the land area to accommodate larger rainfall events. Riparian (vegetated) buffers and filter strips along waterways should be preserved and/or created to slow runoff and filter pollutants.

- **Protecting and Re-establishing Wetlands:** Wetlands are increasingly important for preservation because wetlands hold water, recharge groundwater, and mitigate water pollution.
- **Encouraging Tree Planting:** Trees help manage stormwater by reducing runoff and mitigating erosion along surface waters. Trees also provide critical shading and cooling to streams and land surfaces.
- **Promoting Landscaping Using Native Vegetation:** Landowners should promote the use of native vegetation in landscaping, and landscapers should become familiar with techniques which minimize runoff and the discharge of nutrients into waterbodies (Chase-Rowell et al., 2012).
- **Slowing Down the Flow of Stormwater:** To slow and infiltrate stormwater runoff, roadside ditches can be armored or vegetated and equipped with turnouts, settling basins, check dams, or infiltration catch basins. Rain gardens can retain stormwater, while waterbars can divert water into vegetated areas for infiltration. Water running off roofs can be channeled into infiltration fields and drainage trenches.
- **Coordinating Infrastructure, Housing, and Transportation Planning**: Coordinate planning for infrastructure, housing, and transportation to minimize impacts on natural resources. Critical resources including groundwater must be conserved and remain free of pollutants especially as future droughts may deplete groundwater supplies.

4.2.3 Land Conservation

Land conservation is essential to the health of a region, particularly for the protection of water resources, enhancement of recreation opportunities, vitality of local economies, and preservation of wildlife habitat. Land conservation is one of many tools for protecting water quality for future generations. For Lake Kanasatka, 37% (1,656 acres) of the watershed has been classified as conservation land (refer to Appendix A, Map A-10). Major conserved areas include the Red Hill, Sheridan Woods, Koenig Forest, and Pine Hill conservation areas, as well as the Center Harbor Woods and the Unsworth Preserve. Most of the northeast sector of the watershed is contiguous conservation land, consisting of Red Hill and Sheridan Woods conservation areas and Unsworth Preserve.

Local groups should continue to pursue opportunities for land conservation in the Lake Kanasatka watershed based on the highest valued habitat identified by the New Hampshire Fish & Game (NHFG). NHFG ranks habitat based on value to the State, biological region (areas with similar climate, geology, and other factors that influence biology), and supporting landscape. These habitat rankings are published in the State's 2015 Wildlife Action Plan (with updated statistics and data layers released in January 2020), which serves as a blueprint for prioritizing conservation actions to protect Species of Greatest Conservation Need in New Hampshire. The Lake Kanasatka watershed is part of the Sebago-Ossipee Hills and Plains ecoregional subsection of the biological region (NHFG, 2015). Approximately 120 acres (2.7%) of the Lake Kanasatka watershed are considered Highest Ranked Habitat in New Hampshire. There is considerable overlap of Highest Ranked Habitat in New Hampshire and conservation land within the watershed. A map of priority habitats for conservation based on the NH Wildlife Action Plan can be found in Appendix A, Map A-11.

Table 15. Ordinance review summary of regulatory and non-regulatory tools for natural resource protection in Moultonborough, which comprises 94% of the Lake Kanasatka watershed and the entire lake shoreline.

	STRATEGY	MOULTONBOROUGH
REGULATORY TOOLS	Shoreland zoning.	"Waterfront Property" [Article IV, effective 2008] addresses impervious surfaces and tree cutting/buffers for waterfront properties within 250 feet of all lakes, ponds, rivers, and streams.
	Cluster development and/or open space provisions for subdivisions.	Article VII "Multi-Family and Cluster Development" with the purpose to "…preserve the natural beauty of existing undeveloped land and to encourage less intensive residential development, to allow diversity of housing opportunities with open space areas and increased pedestrian and vehicle safety, and to allow efficient use of land, streets, and utility systems."
	Septic pump-out ordinance or regulation of septic and sewer systems.	New or replacement water and sewer systems in flood hazard areas are regulated through Article VIII "Floodplain Development". Septic systems are not permitted on slopes of 25% or greater.
	Zoning districts address environmental protection.	Zoning districts addressing environmental protection: "Waterfront Property", "Floodplain Development", "Wetland Resources Conservation Overlay District", "Stormwater Management", "Groundwater Protection Ordinance", "Steep Slope Protection Ordinance".
	Zoning overlay districts that address wetland conservation.	"Overlay Districts (A" Wetland Resources Conservation Overlay District" [Article IX] applicable to wetlands that are greater than 20,000 sq. ft. and wetlands of any size contiguous to a river, brook, lake, or pond, except as exempted. Addresses setbacks, permitted uses, and prohibited uses.
	Zoning overlay districts that protect groundwater.	"Groundwater Protection Ordinance" [Article XIII, effective 2010] establishes a groundwater protection overlay district that includes performance standards for pollution prevention, recharge, BMPs for animal manure and fertilizer storage, sanitary sewer design, and storage of regulated substances.
	Protection of steep slopes.	"Steep Slopes Protection Ordinance" [Article XIV, effective 2011] applicable to development with a slope of 15% or greater where the proposed site disturbance is greater than 20,000 sq. ft. Addresses performance standards such as preserving existing natural and topographic features, preventing negative impact to water quality, requiring proper stormwater management design.
	Nutrient loading analysis required for fresh waterbodies.	None identified. Nutrient loading to surface waters identified in Master Plan.
	Low impact development requirements and standards.	None identified.
	Fertilizer and/or pesticide ordinances.	None identified (fertilizer storage regulated in groundwater ordinance).
	Implement and enforce a Stormwater Management Plan.	"Stormwater Management Ordinance" [Article XII, effective 2010] requires a Stormwater Management Plan for developments that disturb 20,000 sq. ft. or more.

	STRATEGY	MOULTONBOROUGH
CONSERVATION FUNDING STRATEGIES	Development transfer overlay district.	None identified.
	Conservation impact fees.	None identified.
	Wetland mitigation funds.	Participate in state wetland mitigation program.
	Fee in lieu of land dedication.	None identified.
	Stormwater utility district.	None identified.
	Open space or non-lapsing conservation fund.	None identified.
	Has a Land Use Change Tax per RSA 79-A:25.	None identified.
	Participate or collaborate with a local watershed association.	Lake Winnipesaukee Association, Lake Kanasatka Watershed Association.
	Participate or collaborate with a local land trust.	Lakes Region Conservation Trust.
NON-REGULATORY TOOLS	Open space plan.	None identified.
	Master plan addresses natural resources and environmental protection.	Yes [2008]. Sub-chapters relevant to environmental protection include (Ch. 1, updated 2019) Natural Resources, (Ch.2) Land Use and Development.
	Conduct a town-wide natural resources inventory.	Yes, completed in 2016.
	Incentive-based programs for voluntary low impact development implementation.	None identified.
	Incentive-based programs for stormwater reduction efforts.	None identified.
	Have established conservation commission.	Yes.
	Incentivize and/or encourage property owners to implement low impact development stormwater practices.	None identified.
	Encourage property owners to put land into farmland/tree growth programs.	None identified.

4.2.4 Septic System Regulation

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

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

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

4.2.5 Sanitary Sewer System Inspections

Because a portion of the watershed also relies on or includes infrastructure for a municipal sewer system, it is important for municipalities with sewer to develop a program (if not already in place) to inspect and evaluate their sanitary sewer system in coordination with the Bay District Sewer System and reduce identified leaks and overflows, especially in areas near waterbodies.

4.2.6 Fertilizer Use Prohibition

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

4.2.7 Pet Waste Management

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

4.2.8 Agricultural Practices

Manure and fertilizer management and planning are the primary tools for controlling nutrient runoff from agricultural areas. Direct outreach and education should be conducted for small hobby farms and any larger-scale operations in the watershed. NRCS is a great resource for such outreach and education to farmers. Larger-scale agricultural operations can work with the NRCS to complete a Comprehensive Nutrient Management Plan (CNMP). These plans address soil erosion and water quality concerns of agricultural operations through setting proper nutrient budgets, identifying the types and amount of nutrients necessary for crop production (by conducting soil tests and determining proper calibration of nutrient application equipment), and ensuring the proper storage and handling of manure. Manure should be stored or applied to fields properly to limit runoff of solids containing high concentrations of nutrients. Manure and fertilizer management involve managing the source, rate, form, timing, and placement of nutrients. Writing a plan is an ongoing process because it is a working document that changes over time.

4.2.9 Nuisance Wildlife Controls

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

4.2.10 In-Lake Treatment

Lake Kanasatka may be a candidate for an in-lake treatment to reduce the internal phosphorus load. If Lake Kanasatka is determined to be a candidate for an in-lake treatment, it is likely that an alum treatment would be recommended. An alum treatment is a management technique where aluminum is added to the bottom of the lake as aluminum sulfate, which permanently binds with phosphorus and hinders the release of phosphorus from bottom sediments (NALMS, 2004). This technique has proved successful in many lakes throughout the country and has been used recently in one New Hampshire lake (Nippo Lake in Barrington) and several Maine Lakes (e.g., Long Pond in Parsonsfield, East Pond in Oakland, and Lake Auburn in Auburn). However, it is necessary to address external watershed sources of phosphorus for the alum treatment to be considered and approved at the state level and for the alum treatment to sustain or exceed its expected efficacy or lifespan.

4.3 OUTREACH & EDUCATION

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

4.4 ADAPTIVE MANAGEMENT APPROACH

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

- **Maintaining an Organizational Structure for Implementation.** Communication and a centralized organizational structure are imperative to successfully implementing the actions outlined in this plan. A diverse group of stakeholders through LKWA should be assembled to coordinate watershed management actions. This group can include representatives from state and federal agencies or organizations, municipalities, local businesses, and other interested groups or private landowners. Refer to Section 6.1: Plan Oversight.
- **Establishing a Funding Mechanism.** A long-term funding mechanism should be established to provide financial resources for management actions. In addition to initial implementation costs, consideration should also be given to the type and extent of technical assistance needed to inspect and maintain structural BMPs. Funding is a key element of sustaining the management process, and, once it is established, the plan can be fully vetted and restoration actions can move forward. A combination of grant funding, private donations, and municipal funding should be used to ensure implementation of the plan. Refer to Section 6.3 for a list of potential funding sources.
- **Determining Management Actions.** This plan provides a unified watershed management strategy with prioritized recommendations for restoration using a variety of methods. The proposed actions in this plan should be used as a starting point for grant proposals. Once a funding mechanism is established, designs for priority restoration actions on a project-area basis can be completed and their implementation scheduled. Refer to Section 5: Action Plan.
- **Continuing and Expanding the Community Participation Process.** Plan development has included active involvement of a diversity of watershed stakeholders. Plan implementation will require continued and ongoing participation of stakeholders, as well as additional outreach efforts to expand the circle of participation. Long-term community support and engagement is vital to successfully implement this plan. Continued public awareness and outreach campaigns will aid in securing this engagement. Refer to Section 4.3: Outreach & Education.
- **Continuing the Long-Term Monitoring Program.** A water quality monitoring program is necessary to track the health of surface waters in the watershed. Information from the monitoring program will provide feedback on the effectiveness of management practices. Refer to Section 6.4: Monitoring Plan.
- **Establishing Measurable Milestones.** A restoration schedule that includes milestones for measuring restoration actions and monitoring activities in the watershed is critical to the success of the plan. In addition to monitoring, several environmental, social, and programmatic indicators have been identified to measure plan progress. Refer to Section 6.5: Indicators to Measure Progress and Section 2.4: Establishment of Water Quality Goal for interim milestones.

5 ACTION PLAN

5.1 ACTION PLAN

The Action Plan (Table 16) outlines responsible parties, approximate costs[9], an implementation schedule, and potential funding sources for each recommendation within the following major categories: (1) Watershed & Shoreline BMPs; (2) Road Management; (3) Municipal Operations; (4) Municipal Land Use Planning & Zoning; (5) Land Conservation; (6) Septic System Management; (7) Agricultural Practices; (8) In-Lake Treatment, and (9) Education and Outreach. The plan is designed to be implemented from 2022-2031 and is flexible to allow for new priorities throughout the 10-year implementation period as additional data are acquired.

Table 16. Action plan for the Lake Kanasatka watershed.

Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
Watershed & Shoreline BMPs			
Complete design and construction of mitigation measures at the top five high priority sites identified in the watershed survey. **Achieves 12% (7 kg/yr P of 59 kg/yr P) of Objective 1.**	LKWA, CCCD, Municipalities, private landowners	$72K-$155K 2022-27	CWSRF, Grants (319, Moose Plate, NFWF 5-Star, ILFP), Municipalities, private landowners
Complete design and construction of mitigation measures at 17 medium and low priority sites identified in the watershed survey as opportunities arise (refer to Appendix B for complete list). **Achieves 7% (4 kg/yr P of 59 kg/yr P) of Objective 1.**	LKWA, CCCD, BCCD, Municipalities, private landowners	$188K-$493K 2022-31	CWSRF, Grants (319, Moose Plate, NFWF 5-Star, ILFP), Municipalities, private landowners
Continue promoting the LakeSmart program evaluations and certifications through NH Lakes to educate property owners about lake-friendly practices such as revegetating shoreline buffers with native plants, avoiding large grassy areas, and increasing mower blade heights to 4 inches. Coordinate with NHDES Soak Up the Rain NH program for workshops and trainings. Direct landowners to UNH Extension's *Landscaping at the Water's Edge*. Cost assumes coordination of and materials for up to five workshops.	LKWA, CCCD, BCCD, NH Lakes, NHDES Soak Up the Rain NH, Municipalities	$5K 2022-31	NH Lakes, NHDES Soak Up the Rain NH, Grants (319, Moose plate), CWSRF, Municipalities
Provide technical assistance and/or implementation cost sharing to watershed/shoreline property owners to install stormwater and/or erosion controls such as rain gardens and buffer plantings. Prioritize high impact properties identified during the shoreline survey. Cost assumes technical assistance and implementation cost sharing provided to the three high impact shoreline properties. **Achieves 5% (3 kg/yr P of 59 kg/yr P) of Objective 1.**	LKWA, CCCD, Municipalities, Landowners	$55K 2022-25	Grants (319, Moose plate), CWSRF, Landowners

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

Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
Implement stormwater and erosion controls on watershed/shoreline properties. Prioritize medium impact properties identified during the shoreline survey. Cost assumes landowner implementation costs (budget: $3K each) for 118 medium impact shoreline properties. **Achieves 29% (17 kg/yr P of 59 kg/yr P) of Objective 1.**	LKWA, CCCD, Municipalities, Landowners	$354K 2022-31	Grants (319, Moose plate), CWSRF, Landowners
Conduct a shoreline survey of Lake Wakondah. Use the results to target education and technical assistance for high impact sites. Cost assumes hired consultant for survey and summation of shoreline survey results.	LKWA, Municipalities	$5K 2025	Municipalities, Grants (Moose plate), CWSRF
Repeat the shoreline surveys in 5-10 years when updating the WBMP. Use the results to target education and technical assistance for high impact sites. Cost assumes hired consultant for survey and summation of shoreline survey results.	LKWA, Municipalities	$15K 2025, 2030	Municipalities, Grants (Moose plate), CWSRF
Road Management			
Review practices for road and drainage maintenance currently used by public and private entities/groups and determine areas for improvement.	Municipalities, LKWA, CCCD, BCCD	$3K 2023	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star)
Develop and/or update a written protocol for road maintenance best practices. Consider coordinated effort with nearby stakeholders (other lake associations) for cost sharing savings.	Municipalities, LKWA, CCCD, BCCD	$4K 2023	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star)
Provide education and training to contractors and municipal staff on protocols for road maintenance best practices. Assumes one workshop. Consider holding joint workshop with other Lake Winnipesaukee region municipalities (or other wider service area) for cost sharing savings.	Municipalities, LKWA, CCCD, BCCD	$15K 2024	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star)
Hold informational workshops on proper road management and winter maintenance and provide educational materials for homeowners about winter maintenance and sand/salt application for driveways and walkways. Cost assumes up to five workshops.	LKWA, CCCD, BCCD, Municipalities, private landowners	$10K 2022-31	CWSRF, Municipalities, Grants (Moose Plate, NFWF 5-Star), private landowners
Municipal Operations			
Review and optimize MS4 compliance for towns (regardless of MS4 designation), including infrastructure mapping, erosion and sediment controls, illicit discharge programs, and good housekeeping practices. Sweep municipal paved roads and parking lots two times per year (spring and fall).	Municipalities (Public Works/Highway)	TBD 2022-31	Municipalities
Participate in Green SnowPro training. Become Green SnowPro Certified once program rules for municipalities have been adopted by the Joint Legislative Committee on Administrative Rules.	Municipalities (Public Works/Highway)	Est. $150-$250/person 2022-31	Municipalities
Review and update winter operations procedures to be consistent with Green SnowPro best management practices for winter road, parking lot, and sidewalk maintenance.	Municipalities (Public Works/Highway)	N/A 2023	Municipalities

Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
In Moultonborough (and Center Harbor, if applicable), adopt policies to either eliminate fertilizer applications on town properties or implement best practices for fertilizer management (to minimize application and transport of phosphorus). Consider extending these regulations to private properties as well.	Municipalities (Public Works/Highway)	N/A 2022-25	Municipalities
Municipal Land Use Planning & Zoning			
Present WBMP recommendations to Select Boards/City Council and Planning Boards in Moultonborough and Center Harbor.	LKWA	$1K 2022	Grants (319), CWSRF
Meet with municipal staff to review recommendations to improve or develop ordinances addressing setbacks, buffers, lot coverage, low impact development, and open space.	LKWA, Municipalities	$3K 2022-25	Municipalities, Grants (319), CWSRF
Incorporate WBMP recommendations into municipal master plans and encourage regular review of the WBMP action plan.	Municipalities	N/A 2022-25	Municipalities
Adopt/strengthen zoning ordinance provisions and enforcement mechanisms: 1) to promote low impact development practices; 2) to require stormwater regulations that align with MS4 Permit requirements; 3) to promote or require vegetative buffers around lake shore and tributary streams; 4) to require shorefront "tear down and replace" home construction to be no more non-conforming than existing structures; 5) to require shorefront seasonal to year-round conversions of homes to demonstrate no additional negative impacts to lake water quality; 6) to establish a lake protection overlay zoning ordinance that prohibits erosion from sites in sensitive areas (e.g., lake shorefront, along lake tributaries, steep slopes); and 7) to enhance performance standards for unpaved roads to prevent erosion and protect lake water quality.	Municipalities	N/A 2022-31	Municipalities
Increase municipal staff capacity for inspections and enforcement of stormwater regulations on public and private lands.	Municipalities	TBD 2022-31	Municipalities
Land Conservation			
Update the Natural Resource Inventories (NRI) for Moultonborough (2016) and Center Harbor (2014) when needed.	Municipalities, Conservation Commissions	$8-16K per municipality 2030	Municipalities, Grants (NFWF NEFRG), CWSRF
Identify additional watershed areas that need protection based on NRIs. Refer to Section 4.2.3 to understand current conservation lands and valuable habitats and wildlife in the watershed that can be used to help identify potential areas to target for conservation.	LKWA, Municipalities, Conservation Commissions, Lakes Region Conservation Trust	$2-4K 2022-25	Grants (NFWF NEFRG, NAWCA), CWSRF, Municipalities

Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
Identify potential conservation buyers and property owners interested in easements within the watershed. Use available funding mechanisms, such as the Regional Conservation Partnership Program (RCPP) and the Land and Community Heritage Investment Program (LCHIP), to provide conservation assistance to landowners.	LKWA, Municipalities, Conservation Commissions, Lakes Region Conservation Trust	N/A 2022-25	Grants (Moose Plate, LCHIP, RCCP, NAWCA, LWCF, ACEP, CSP, EQIP)
Septic System Management			
Distribute educational materials to property owners about septic system function and maintenance.	Municipalities, LKWA	$3K 2022, 2027, 2031	Municipalities, Grant (319), CWSRF
Look into whether any septic pumping companies would give a quantity discount or a discount to members to incentivize septic system pumping.	LKWA	N/A 2022-25	CWSRF
Evaluate locations of older and/or noncompliant septic systems (including cesspools or holding tanks) to identify clusters where conversion to community septic systems might be desirable.	LKWA, Municipalities	TBD 2022-25	CWSRF, Municipalities
Require inspection for all home conversions (from seasonal to permanent residences) and property sales to ensure systems are sized and designed properly. Require upgrades if needed. Consider modeling an ordinance on Meredith's septic system regulations pertaining to the Lake Waukewan watershed.	Municipalities	N/A 2022-31	Municipalities
Develop and maintain a septic system database for the watershed to facilitate code enforcement of any septic system ordinances.	Municipalities	$5-10K 2022-25	Municipalities, CWSRF
Institute a minimum pump-out/inspection interval for shorefront septic systems (e.g., once every 3-5 years). Pump-outs (~$250 per system) are the responsibility of the owner.	Municipalities	N/A 2022-25	Municipalities
If not already in place, develop a program to evaluate the sanitary sewer system and reduce leaks and overflows, especially in the areas near waterbodies. Include periodic inspections of the sewer line.	Municipalities	N/A 2022-31	Municipalities
Agricultural Practices			
Work with NRCS to implement soil conservation practices such as cover crops, no-till methods, and others which reduce erosion and nutrient pollution to surface waters from agricultural fields.	NRCS, farm owners	TBD 2022-31	Grants, NRCS
In-Lake Treatment			
Update internal phosphorus load estimate with 2022 data and perform preliminary assessment of the lake's candidacy for an in-lake treatment. If the lake is a candidate, then proceed with the following actions.	LKWA	$3,000 2022-23	LKWA Membership Dues, Donations
Complete sediment assays of five stations around the lake. Partner with St. Joseph's College in Standish, ME.	*LKWA*	*$8,000 2023*	*Municipalities, CWSRF*

Action Item	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
Complete alternatives analysis to determine the appropriate in-lake treatment option for Lake Kanasatka, along with dosage determination and cost estimation. An alum treatment would be the likely recommended option.	*LKWA*	*$10,000 2023*	*Municipalities, CWSRF, Grants (Moose Plate)*
Jump-start a large fundraising campaign to generate the funds needed for the in-lake treatment.	*LKWA*	*N/A 2023-25*	*Municipalities, Volunteers*
Complete and receive approval for a state permit to complete the in-lake treatment. Coordinate with state officials on the process.	*LKWA*	*$20,000 2024-25*	*Municipalities, Grants (319), CWSRF*
Hire a contractor(s) to complete the in-lake treatment, pre-, during, and post-monitoring requirements, and permitting follow-up.	*LKWA*	*TBD 2025*	*Municipalities, Grants (319), CWSRF*
Education & Outreach			
Share additional/dynamic information on the LKWA website, such as water quality data, weather conditions, and webcam, to generate more traffic to the website.	LKWA	TBD 2022-25	Grants
Offer workshops for landowners with 10 acres or more for NRCS assistance with land conservation. Cost assumes up to two workshops.	LKWA	$5K 2022-25	Grants (RCCP, ACEP, CSP, EQIP)
Encourage private property owners to hire Green SnowPro certified commercial salt applicators.	LKWA, CCCD, BCCD, Municipalities	N/A 2022-31	Grants, Municipalities
Educate contractors and municipal staff about erosion and sediment control (ESC) practices required on plans. Work with municipalities to ensure that there are sufficient resources to enforce permitting conditions.	Municipalities, WWN, CCCD, BCCD	$6K 2022-25	Municipalities, Grants (319), CWSRF
Create flyers/brochures or other educational materials through printed or online mediums, regarding topics such as stormwater controls, road maintenance, buffer improvements, fertilizer and pesticide use, pet waste disposal, boat pollution, invasive aquatic species, waterfowl feeding, and septic system maintenance. Consider creating a "watershed homeowner" packet that covers these topics and is distributed (mailed separately or in tax bills or posted at community gathering locations or events) to existing and new property owners, as well as renters. Hold 1-2 informational workshops per year to update the public on restoration progress and ways that individuals can help. Cost is highly variable.	Municipalities, LKWA, CCCD, BCCD	$20K-$60K 2022-31	Municipalities, Grants (319), CWSRF
Collaborate with NH Lakes on legislative or advocacy issues such as boat speed limits.	LKWA, NH Lakes	N/A 2022-31	Grants

5.2 POLLUTANT LOAD REDUCTIONS

To meet the water quality goal, Objective 1 set a target phosphorus load reduction of 59 kg/yr to achieve an in-lake total phosphorus concentration of 7.2 ppb, which meets state water quality standards for oligotrophic waterbodies and is anticipated to substantially reduce the likelihood of cyanobacteria blooms in Lake Kanasatka. The following opportunities for phosphorus load reductions to achieve Objective 1 were identified in the watershed based on field and desktop analyses:

- Remediating the 22 watershed survey sites could prevent up to **11 kg/yr** of phosphorus load from entering Lake Kanasatka.
- Treating shoreline sites could reduce the phosphorus load to Lake Kanasatka by **3 kg/yr** for the three high impact sites (disturbance score 11+) and by **17 kg/yr** for the 118 medium impact sites (disturbance score between 7-10) identified from the shoreline survey.
- Upgrading the 115 shorefront septic systems older than 25 years is estimated to reduce the phosphorus load to Lake Kanasatka by **12 kg/yr**.
- Completing an in-lake treatment could reduce the internal phosphorus load to Lake Kanasatka by **63 kg/yr**, representing a 90% reduction.

Addressing these field-identified phosphorus load reduction opportunities coming from the external watershed load (i.e., watershed and shoreline sites and shorefront septic systems) could reduce the phosphorus load to Lake Kanasatka by 43 kg/yr, meeting 73% of the needed reductions to achieve Objective 1 (Table 17). Because more reduction in the phosphorus load may be needed for Lake Kanasatka, it is likely that also reducing the internal load will be needed to meet Objective 1. We recommend that an intensive monitoring program be set up for 2022 and 2023 to determine whether the lake may qualify for an in-lake treatment. LWKA is already working to implement an expanded monitoring program for 2022, the results from which will be used to improve the internal phosphorus load estimate in the model and possibly calculate an appropriate dosage if the lake is determined to be a candidate for an alum treatment. Discussions with NHDES and regional in-lake treatment experts will be needed for this phase of next steps with restoration. Note: It will be necessary to address external watershed sources of phosphorus for any in-lake treatment to be considered and approved at the state level.

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

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

Table 17. Breakdown of phosphorus load sources and modeled water quality for current and target conditions that meet the water quality goal (Objective 1) and that reflect all field identified reduction opportunities in the watershed. Reduction percentages are based out of the current condition value for each parameter.

			WQ Goal & Estimated Reduction Needed		Field Identified Reduction Opportunities	
Parameter	**Unit**	**Current Condition**	**Target Condition**	**Reduction (Unit, %)**	**Target Condition**	**Reduction (Unit, %)**
Total P Load (All Sources)[3]	kg/yr	293	234	-59 (20%)	187	-106 (36%)
(A) Background P Load[1]	kg/yr	63	63	0 (0%)	63	0 (0%)
(B) Disturbed (Human) P Load[2]	kg/yr	230	171	-59 (26%)	124	-106 (46%)
(C) Developed Land Use P Load	kg/yr	132	85	-47 (36%)	101	-31 (23%)
(D) Septic System P Load	kg/yr	28	16	-12 (43%)	16	-12 (43%)
(E) Internal P Load	kg/yr	70	70	0 (0%)	7	-63 (90%)
In-Lake TP*	ppb	8.8	7.2	-1.6 (18%)	6.1	-2.7 (31%)
In-Lake Chl-a*	ppb	3.3	3.0	-0.3 (9%)	2.3	-1.0 (30%)
In-Lake SDT*	meters	5.4	6.0+	+0.6 (NA)	6.0+	+0.6 (NA)
In-Lake Bloom Probability*	days	12	0	-12 (100%)	0	-12 (100%)

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

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

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

** Water quality parameters were sourced from the model, but total phosphorus and chlorophyll-a were adjusted to match the Assimilative Capacity analysis (which uses a slightly different time period for averaging data).*

6 PLAN IMPLEMENTATION & EVALUATION

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

6.1 PLAN OVERSIGHT

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

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

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

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

6.2 ESTIMATED COSTS

The strategy for reducing pollutant loading to Lake Kanasatka to meet the water quality goal and objectives set in Section 2.4 will be dependent on available funding and labor resources but will include approaches that address sources of phosphorus loading, as well as water quality monitoring and education and outreach. Additional significant but difficult to quantify strategies for reducing phosphorus loading to the lake are revising local ordinances such as setting LID requirements on new construction, identifying and replacing malfunctioning septic systems, performing proper road maintenance, and improving agricultural practices (refer to Section 5: Action Plan for more details). With a dedicated stakeholder group in place and with the help of grant or local funding, it is possible to achieve the target phosphorus reductions and meet the established water quality goal for Lake Kanasatka in the next 10 years. **The cost of successfully implementing the plan is estimated to be at least $0.8-$1.4 million over the next 10 or more years** (Table 18). However, many costs are still unknown or were roughly estimated and should be updated as information becomes available. In addition, costs to private landowners (e.g., septic system upgrades, private road maintenance, etc.) are not reflected in the estimate.

Table 18. Estimated pollutant reduction (TP) in kg/year and estimated total and annual 10-year costs for implementation of the Action Plan to meet the water quality goal and objectives for Lake Kanasatka. The light gray shaded planning actions are necessary to achieve the water quality goal. Other planning actions are important but difficult to quantify for TP reduction and costs, the latter of which were roughly estimated here as general placeholders.

Planning Action	TP Reduction (kg/yr)	Estimated Total Cost	Estimated Annual Cost
Watershed & Shoreline BMPs	**31**	$694,000 - $1,082,000	$69,400 - $108,200
Road Management	TBD	$32,000	$3,200
Municipal Operations	TBD	TBD	TBD
Municipal Land Use Planning & Zoning	**40***	$4,000	$400
Land Conservation		$10,000 - $20,000	$1,000 - $2,000
Septic System Management	**12**	$8,000 - $13,000	$800 - $1,300
Agricultural Practices	TBD	TBD	TBD
In-Lake Treatment (actual treatment cost TBD)	**63**	$3,000-$41,000	$300-$4,100
Education & Outreach	TBD	$31,000 - $71,000	$3,100-$7,100
Monitoring (includes equipment)	*NA*	$30,000-$100,000	$3,000-$10,000
Total	**146**	**$812,000-$1,363,000**	**$8,120-$136,300**

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

6.3 FUNDING STRATEGY

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

Funding Options:

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

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

6.4 MONITORING PLAN

A long-term water quality monitoring plan is critical to evaluate the effectiveness of implementation efforts over time. LKWA, in concert with UNH LLMP, should continue the following annual monitoring protocol:

- UNH LLMP and/or LKWA monitors three deep spot stations in Lake Kanasatka (1 Deep, 2 Animal, and 3 West) and one deep spot station in Wakondah Pond three to five times each summer (June-September or October) for total phosphorus (epilimnion, metalimnion, and hypolimnion and/or at 2 meter depth increments starting at 1 meter from the lake surface to 1 meter from the lake bottom), chlorophyll-a (composite or epilimnion), Secchi disk transparency, and dissolved oxygen-temperature profiles.
    - Ensure that dissolved oxygen-temperature profiles are being collected concurrently with sampling of lake deep spot stations, and consider collecting profiles at a higher frequency (e.g., every two weeks from May-October).
- UNH LLMP and/or LKWA collect monthly samples for speciation and enumeration of phytoplankton via a grab sampler or core and zooplankton by tows in the water column.
- Volunteers collect additional Secchi disk transparency readings at the four deep spot stations in Lake Kanasatka and Wakondah Pond, as well as four nearshore sites (Bishop Shore, Dam/Launch, Far West (Sibley), and Maple Cove) throughout the summer season (ideally every other week and more frequently during a bloom if safe). These data would be important to tracking the onset, duration, and extent of a bloom throughout the season.
- Continue to monitor the lake for cyanobacteria blooms and alert NHDES immediately. Coordinate with NHDES to collect samples for analysis.
- LKWA monitors total phosphorus and flow (as well as specific conductance, temperature, and/or turbidity, if able) in four tributary or outlet stations in the watershed, two to five times per year each summer.
- Consider measuring specific conductivity or collecting samples for chloride at all tributary stations and throughout the water column at the lake deep spot stations.

6.5 INDICATORS TO MEASURE PROGRESS

The following environmental, programmatic, and social indicators and associated numeric targets (milestones) will help to quantitatively measure the progress of this plan in meeting the established goal and objectives for the Lake Kanasatka watershed (Table 19). These benchmarks represent short-term (2023), mid-term (2023), and long-term (2033) targets derived directly from actions identified in the Action Plan (Section 5). Setting milestones allows for periodic updates to the plan, maintains and sustains the action items, and makes the plan relevant to ongoing activities. LKWA should review the milestones for each indicator on an ongoing basis to determine if progress is being made, and then determine if the plan needs to be revised because the targets are not being met.

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

Table 19. Environmental, programmatic, and social indicators for the Lake Kanasatka Watershed-Based Management Plan.

Indicators	Milestones*		
	2023	**2026**	**2031**
ENVIRONMENTAL INDICATORS			
Achieve an average summer deep spot epilimnion total phosphorus concentration of 7.2 ppb at the deep spot stations in Lake Kanasatka	<8.8 ppb	<8.0 ppb	<7.2 ppb
Achieve an average summer deep spot epilimnion chlorophyll-a concentration of less than 3.0 ppb at the deep spot stations in Lake Kanasatka	<3.3 ppb	<3.0 ppb	<3.0 ppb
Eliminate the occurrence of cyanobacteria or algal blooms in Lake Kanasatka (milestones based on model results)	12 days/yr	6 days/yr	0 days/yr
Achieve an average summer water clarity of 6 m or deeper at the deep spot stations in Lake Kanasatka	5 m+	5 m+	6 m+
Prevent and/or control the introduction and/or proliferation of invasive aquatic species all waterbodies	Absence of invasives	Absence of invasives	Absence of invasives
PROGRAMMATIC INDICATORS			
Amount of funding secured from municipal/private work, fundraisers, donations, and grants	$150,000	$750,000	$1,500,000
Number of NPS sites remediated (22 identified)	6	12	22
Linear feet of buffers improved in the shoreland zone	500	2,000	5,000
Percentage of shorefront properties with LakeSmart certification	25%	50%	75%
Number of watershed/shoreline properties receiving technical assistance for implementation cost sharing	2	10	25
Number of workshops and trainings for stormwater improvements to residential properties (e.g., NHDES Soak Up the Rain NH program)	1	2	5
Number of updated or new ordinances that target water quality protection	1	2	3
Number of new municipal staff for inspections and enforcement of regulations	1	1	2
Number of voluntary or required septic system inspections (seasonal conversion and property transfer)	2	10	25
Number of septic system upgrades	2	10	25
Number of informational workshops and/or trainings for landowners, municipal staff, and/or developers/landscapers on local ordinances, watershed goals, and/or best practices for road management and winter maintenance	1	5	10
Number of parcels with new conservation easements or number of parcels put into permanent conservation	1	2	5
Number of copies of watershed-based educational materials distributed or articles published	200	500	1,000
Number of new best practices for road management and winter maintenance implemented on public and private roads by the municipalities	2	5	10
Number of municipalities fully implementing key aspects of the MS4 program	1	1	1
Number of meetings and/or presentations to municipal staff and/or boards related to the WBMP	4	12	30
Number of CNMPs completed or NRCS technical assistance provided for farms in the watershed	1	2	3
SOCIAL INDICATORS			
Number of new association members	5	10	25
Number of volunteers participating in educational campaigns	6	12	25
Number of people participating in informational meetings, workshops, trainings, BMP demonstrations, or group septic system pumping	25	50	100

Indicators	Milestones*		
	2023	2026	2031
Number of watershed residents installing conservation practices on their property and/or participating in LakeSmart	5	25	50
Number of municipal DPW staff receiving Green SnowPro training	1	3	5
Number of groups or individuals contributing funds for plan implementation	25	50	100
Number of newly trained water quality and invasive species monitors	2	4	6
Percentage of residents making voluntary upgrades or maintenance to their septic systems (with or without free technical assistance), particularly those identified as needing upgrades or maintenance	10%	25%	50%
Number of farmers working with NRCS, CCCD, or BCCD	1	2	3
Number of daily visitors to the LKWA website	10	25	50

**Milestones are cumulative starting at year 1.*

ADDITIONAL RESOURCES

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

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

Environmental Fact Sheet: Erosion Control for Construction within the Protected Shoreland. New Hampshire Department of Environmental Services, SP-1, 2020. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/sp-1.pdf

Gravel road maintenance manual: a guide for landowners on camp and other gravel roads. Maine Department of Environmental Protection, Bureau of Land and Water Quality. April 2010. Online: http://www.maine.gov/dep/land/watershed/camp/road/gravel_road_manual.pdf

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

Innovative land use techniques handbook. New Hampshire Department of Environmental Services. 2008. Online: https://www.nh.gov/osi/planning/resources/innovative-land-use-guide.htm

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

New Hampshire Homeowner's Guide to Stormwater Management: Do-It-Yourself Stormwater Solutions for Your Home. New Hampshire Department of Environmental Services, Soak Up the Rain NH. Revised November 2019. Online: https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/homeowner-guide-stormwater.pdf

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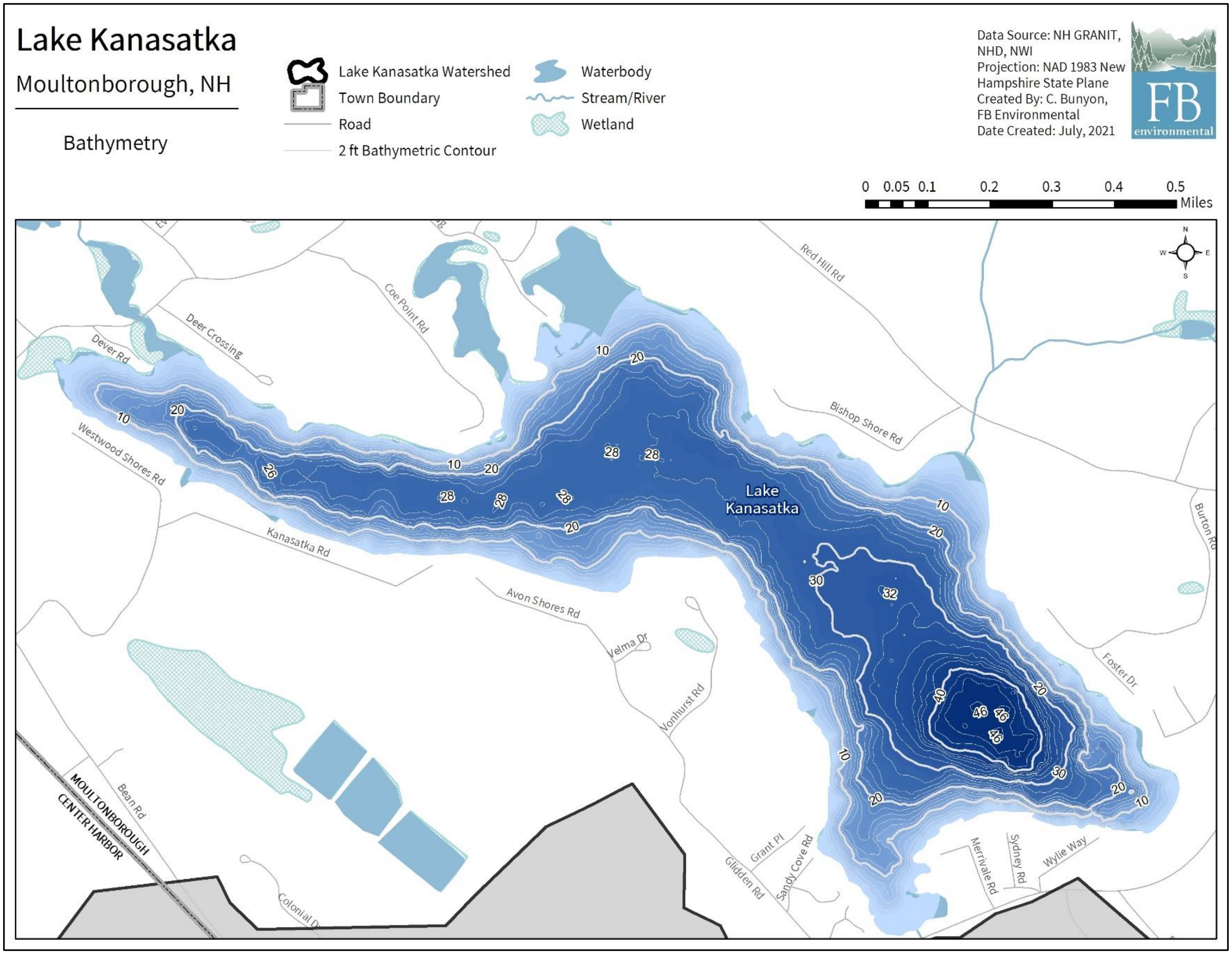
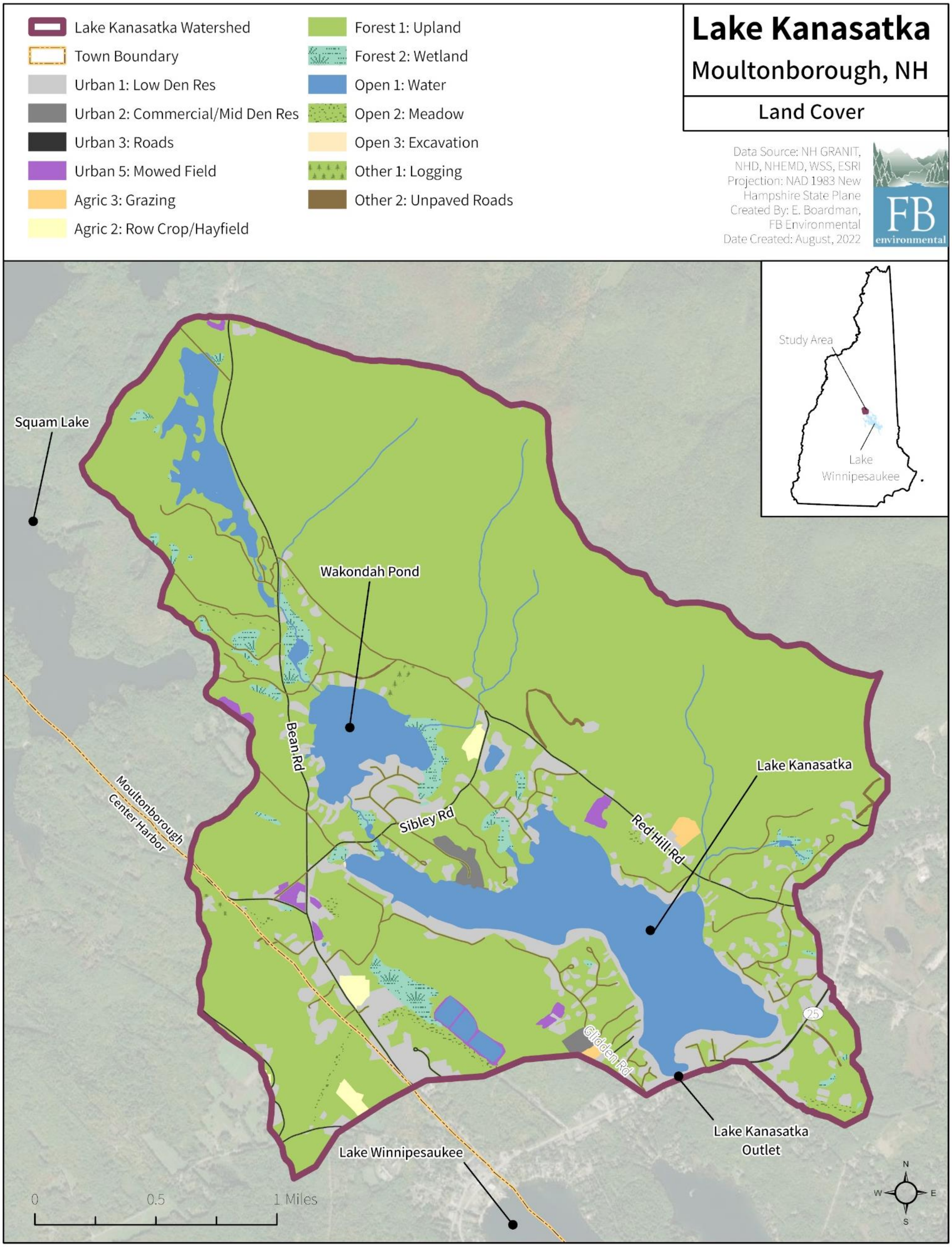
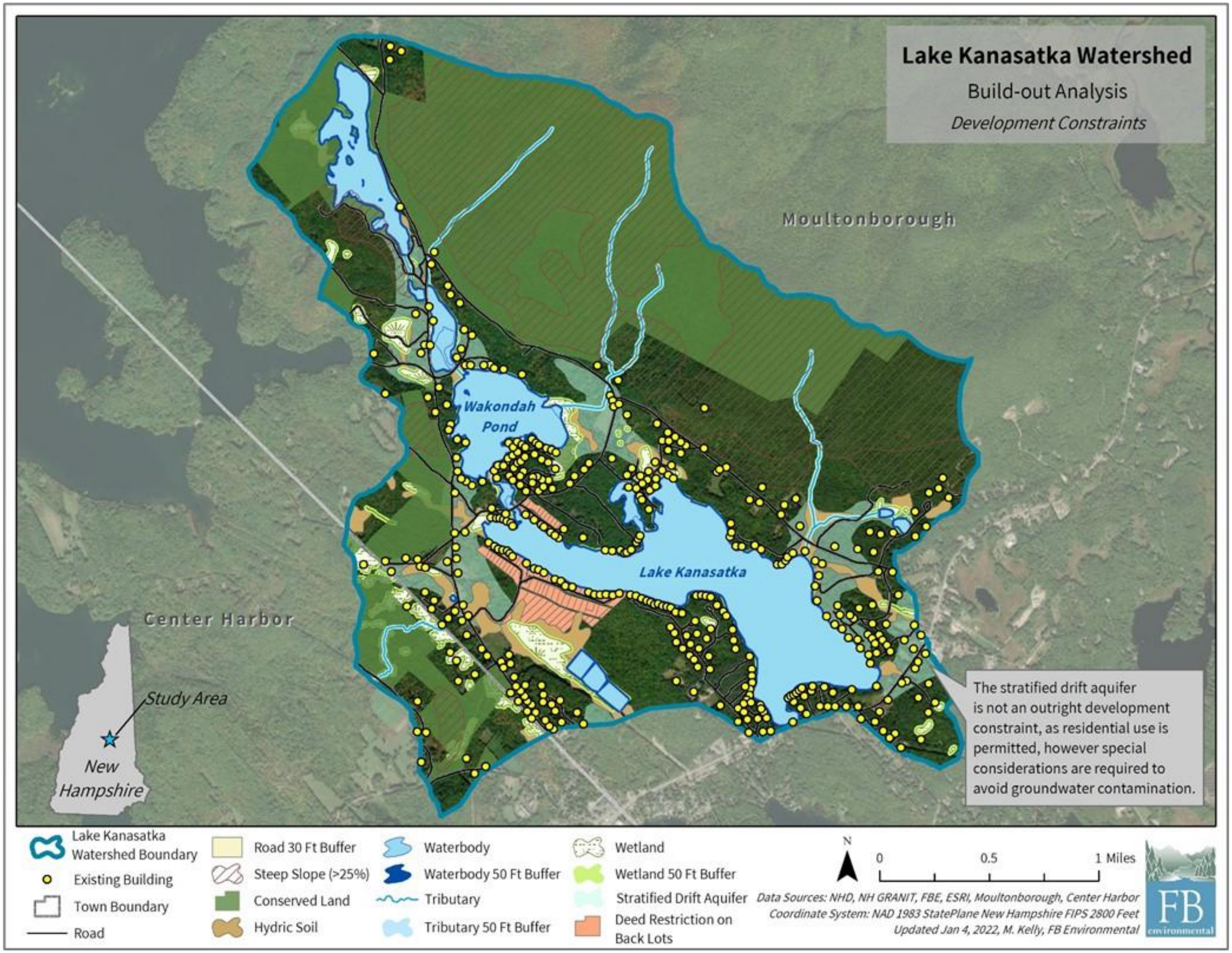
APPENDIX A: SUPPORTING MAPS



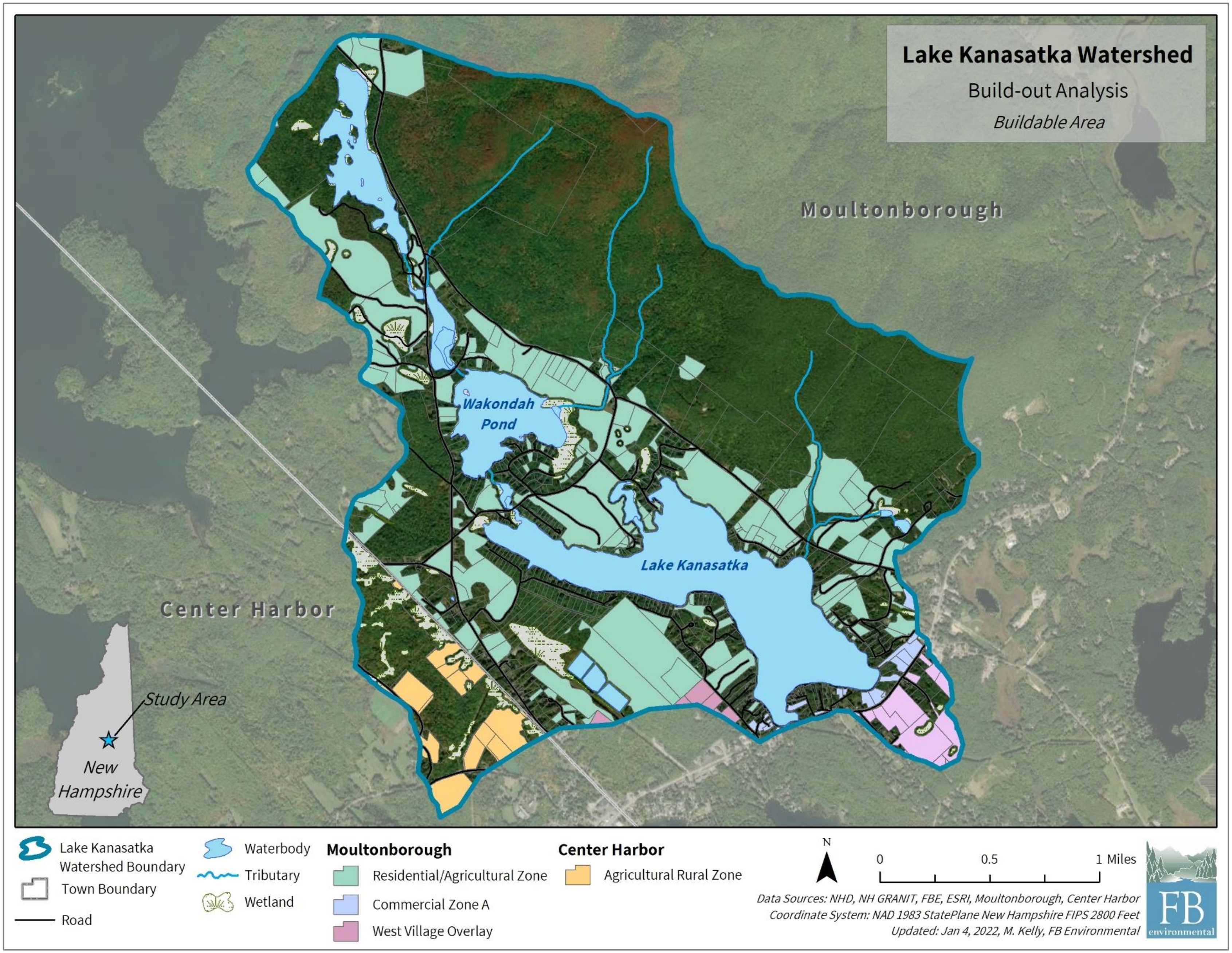
Map A-1. Bathymetry as 2-foot depth contours for Lake Kanasatka. Surveyed by NHDES in 2021.



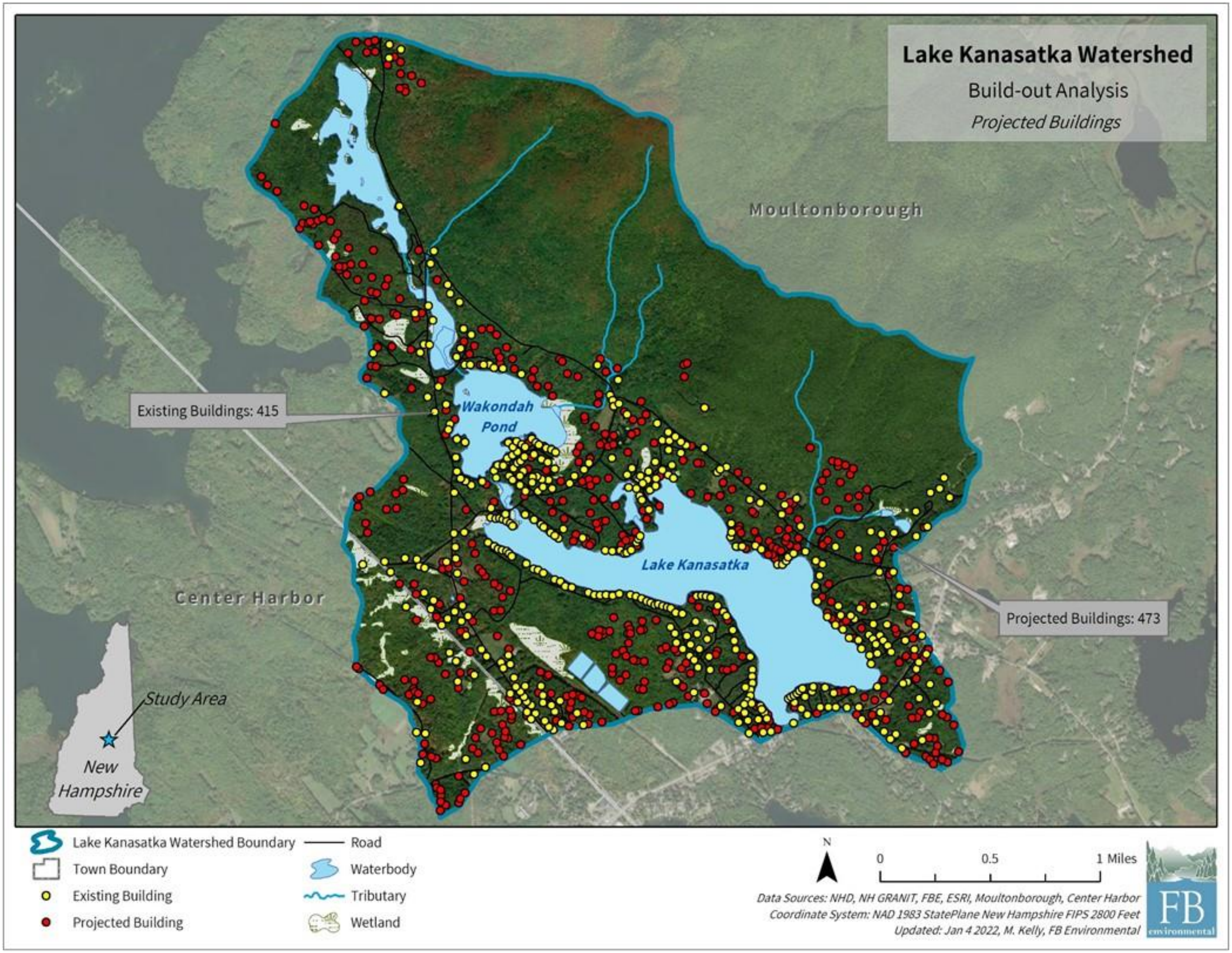
Map A-2. Land cover for the Lake Kanasatka watershed.



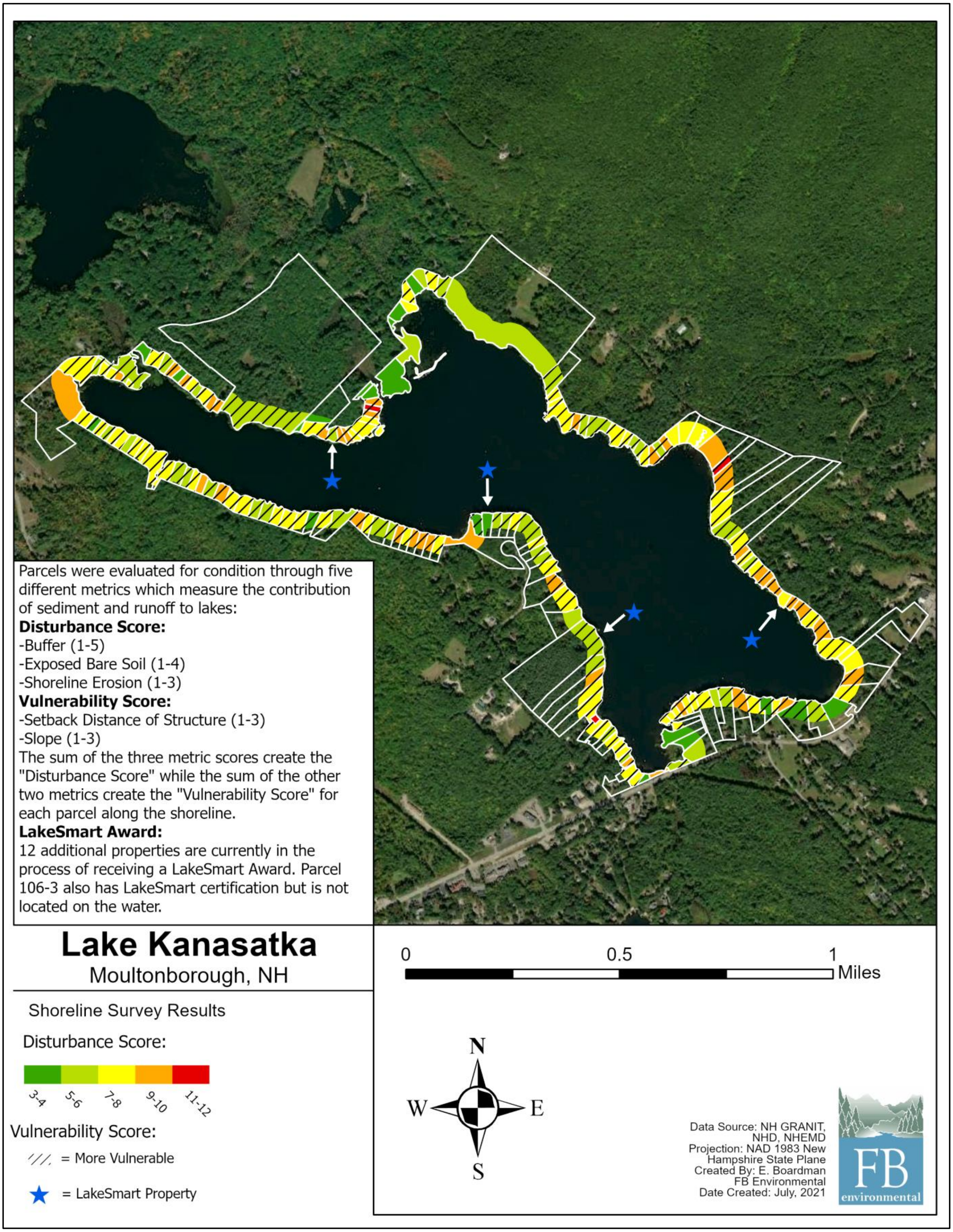
Map A-3. Development constraints (including existing buildings) in the Lake Kanasatka watershed in Moultonborough and Center Harbor, New Hampshire.



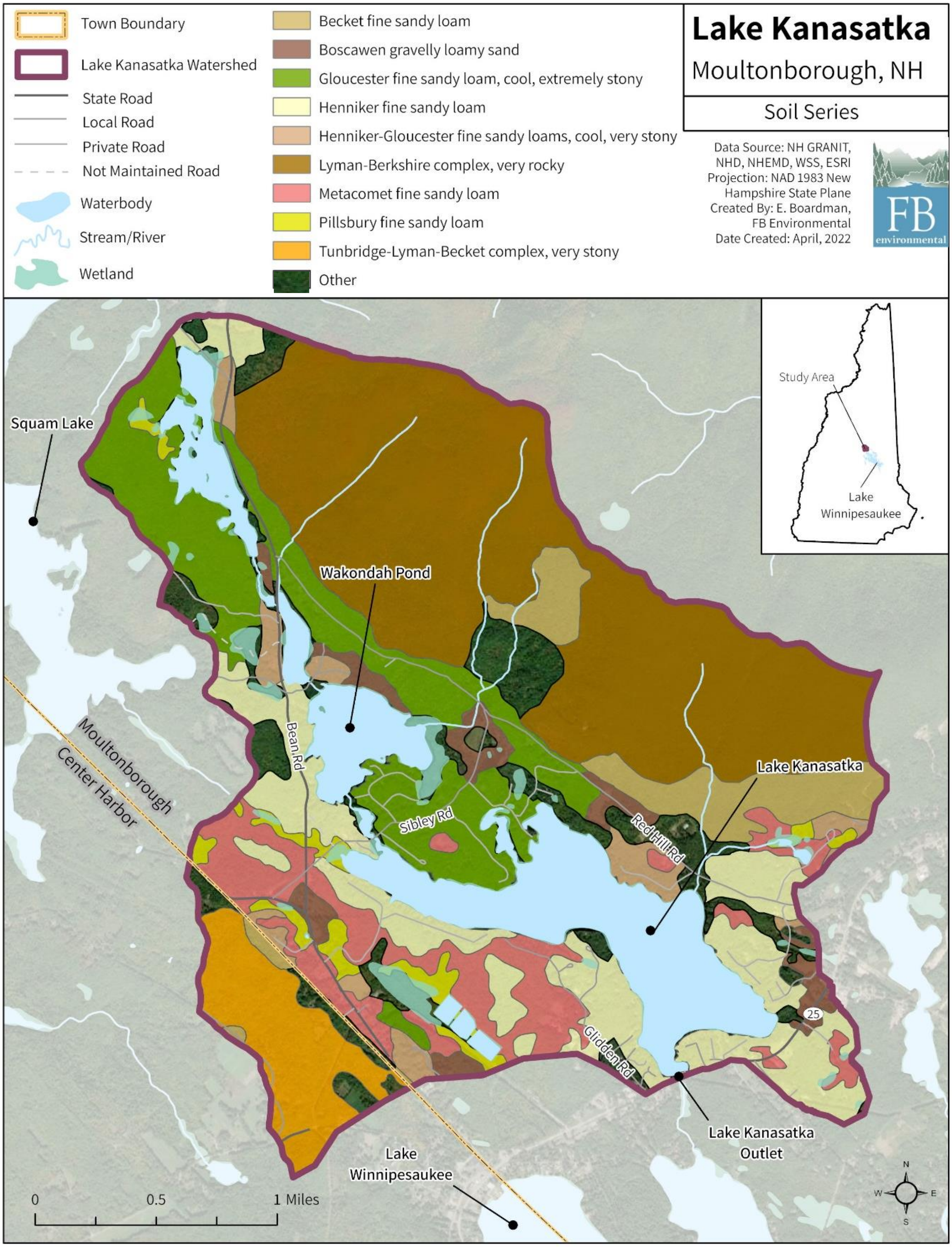
Map A-4. Buildable area by municipal zone in the Lake Kanasatka watershed in Moultonborough and Center Harbor, New Hampshire.



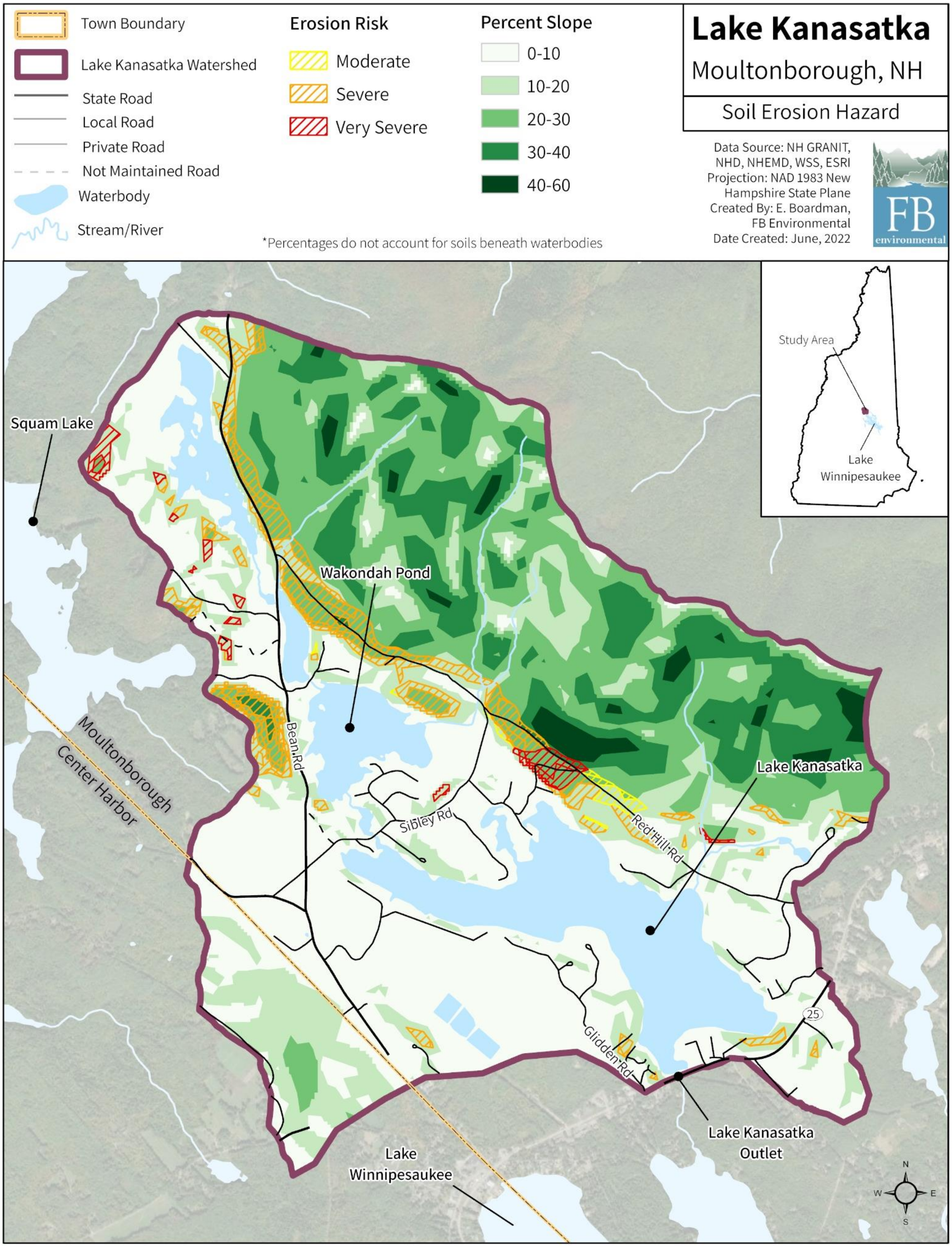
Map A-5. Projected buildings in the Lake Kanasatka watershed in Moultonborough and Center Harbor, New Hampshire.



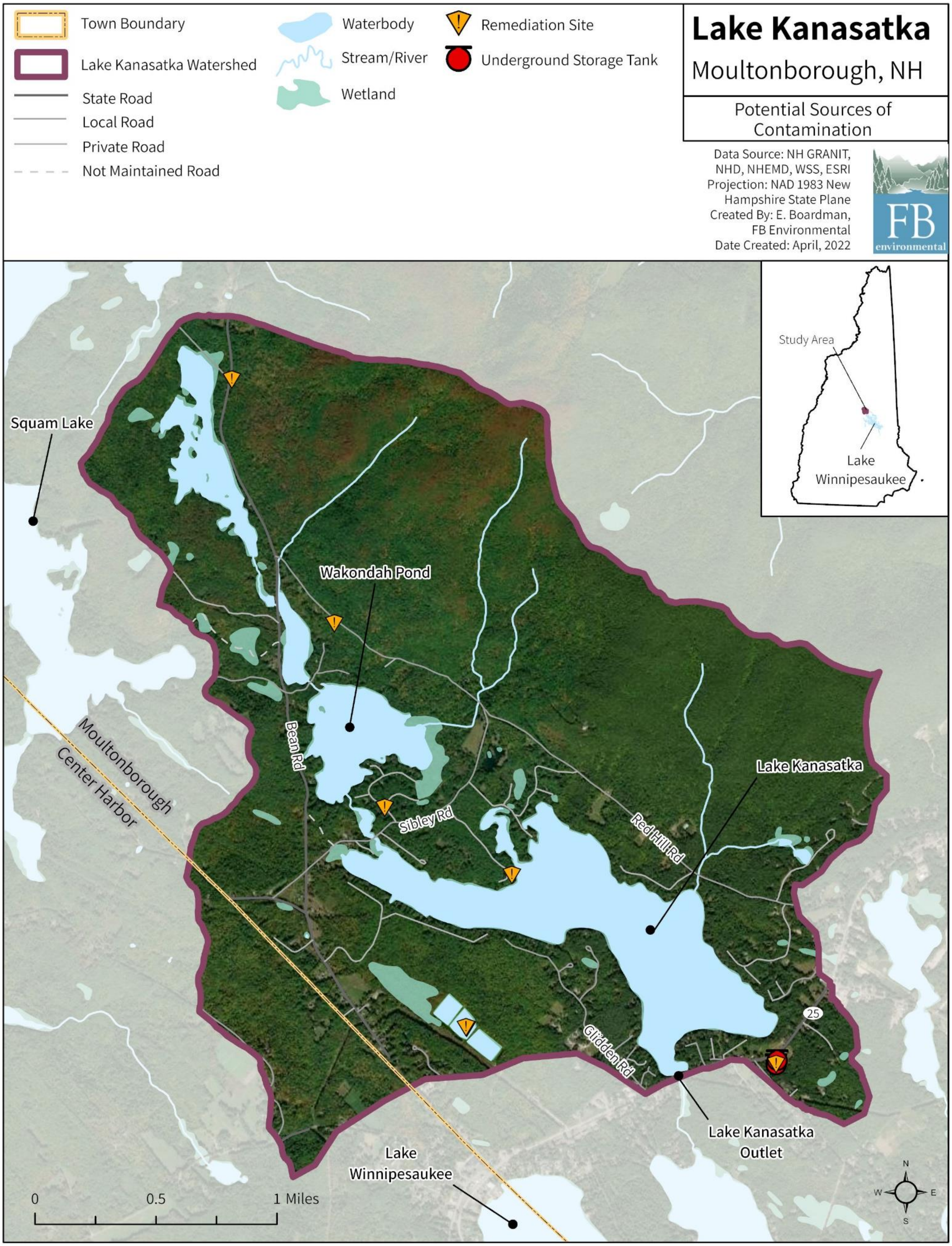
Map A-6. Shoreline Disturbance Score for parcels with frontage on Lake Kanasatka, as rated during the 2021 shoreline survey by FBE and LWA technical staff.



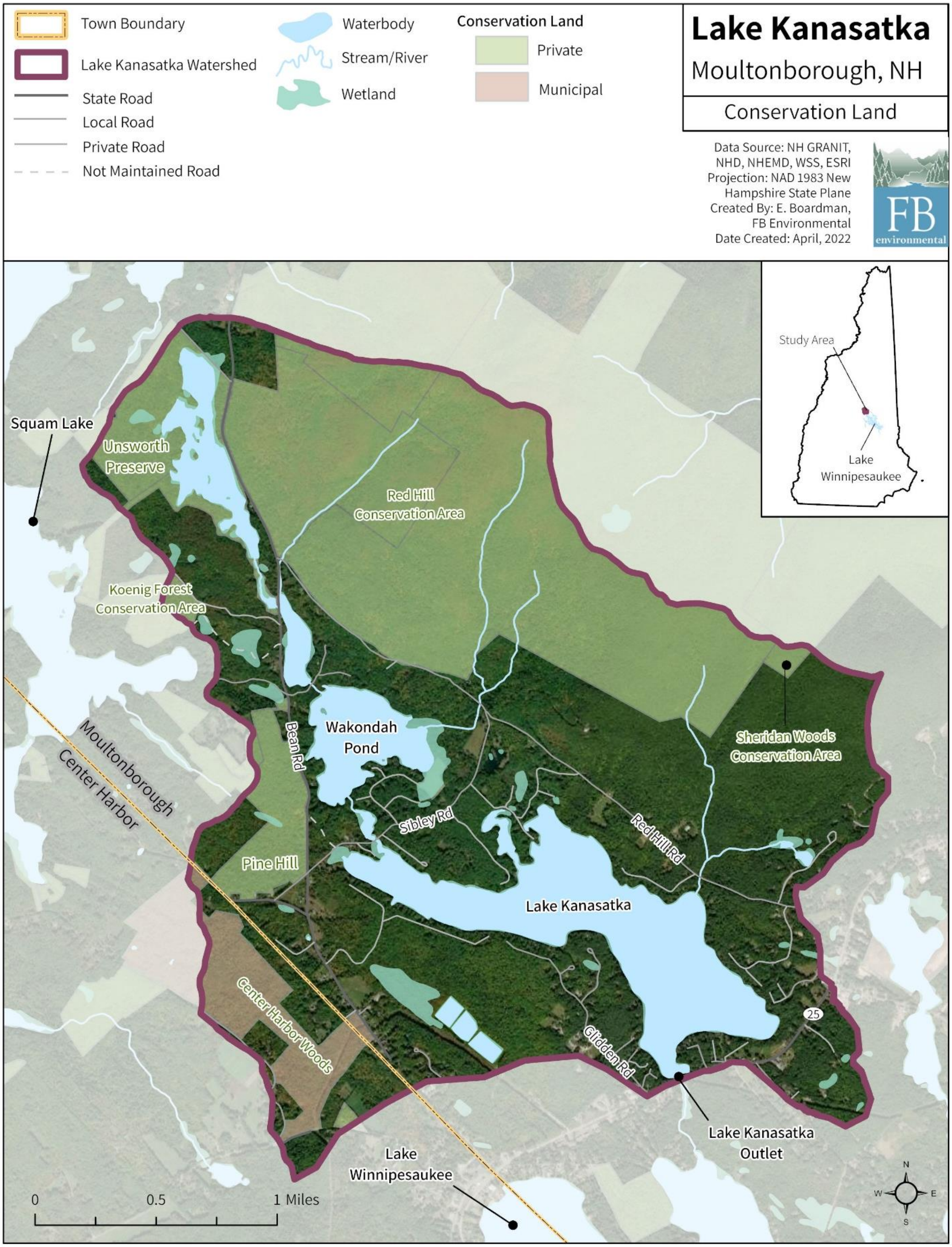
Map A-7. Soil series in the Lake Kanasatka watershed.



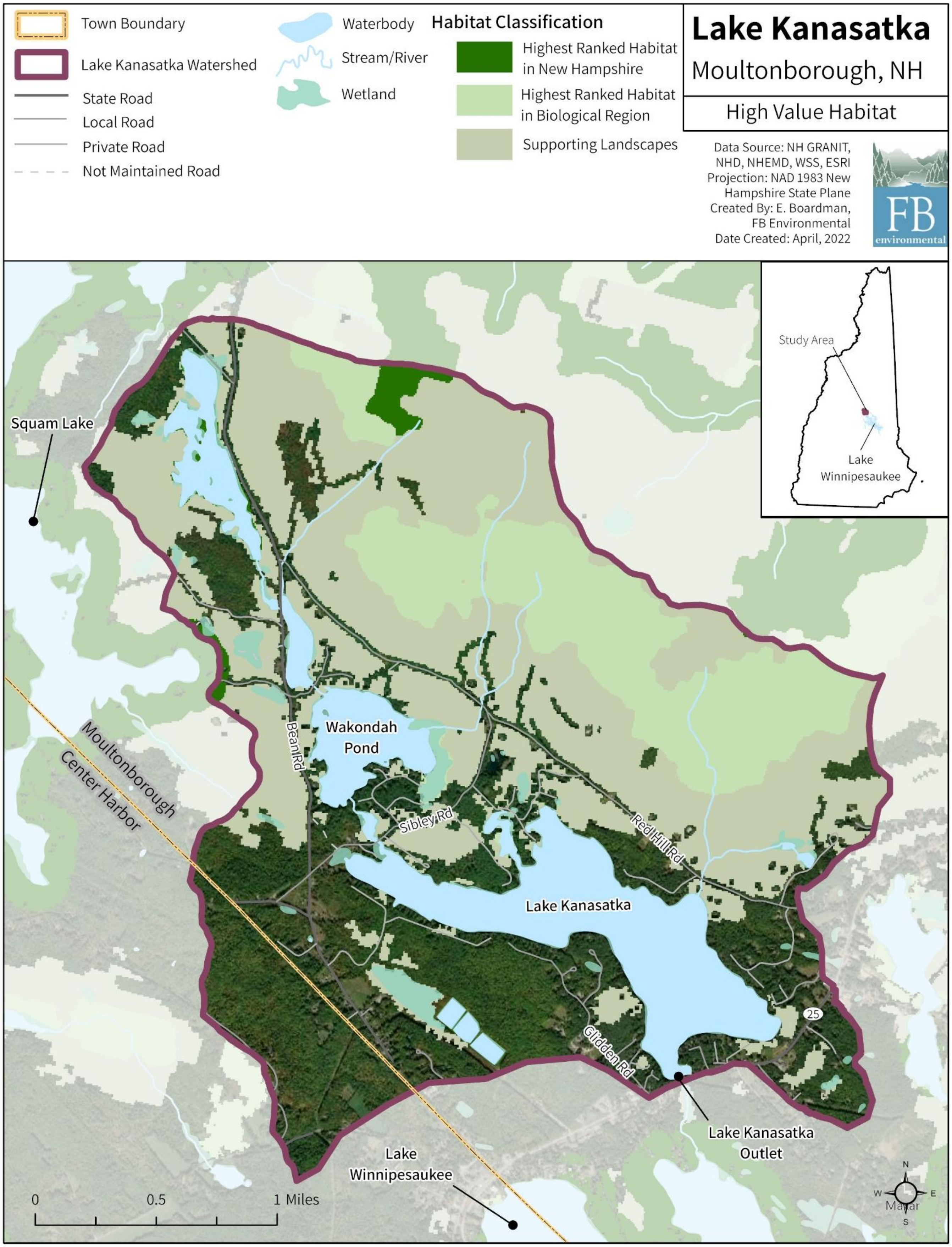
Map A-8. Soil Erosion Hazard in the Lake Kanasatka watershed.



Map A-9. Potential sources of contamination in the Lake Kanasatka watershed.



Map A-10. Conservation land within the Lake Kanasatka watershed.



Map A-11. High value habitat in the Lake Kanasatka watershed according to the 2015 New Hampshire Wildlife Action Plan.

APPENDIX B: BMP MATRIX

Table B-1. Site ID, location description, problem description, BMP recommendation, water quality impact, estimated load reduction and implementation costs, and ranking for the 22 nonpoint source sites identified in the Lake Kanasatka watershed. Pollutant load reduction and cost estimates are preliminary and are for planning purposes only. Cost estimates are based on pre-COVID19 ranges (adjusted for 2021 inflation), and thus actual construction costs could be highly variable at this time. The top five priority sites for remediation are highlighted in gray.

					LOAD REDUCTION			ESTIMATED COST		RANKING
SITE ID	**LOCATION**	**PROBLEM**	**RECOMMENDATION**	**IMPACT**	TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	Est. Low Cost	Est. High Cost	Low-High Impact-Weighted Cost Per TP Load Reduction
1-03	End of Shady Lane	Big construction site with a lot of bare soil. Mulch socks distributed throughout but don't look effective. Didn't walk down driveway but recommend sending an inspector.	Install erosion controls (e.g., silt fence)	High	0.88	1.36	5.98	$5,000	$10,000	1
1-20	Common beach off Brook Rd to Wakondah Pond	50'x60' beach area likely refreshed regularly with new sand; very steep grade to lake; one wooden retaining wall present but sand overtopping it; shoreline erosion and retreat evident.	Work with the right of way stakeholders to determine needs and use of common area; stop any sand replenishment; define access infiltration steps from parking area down to the water; mulch and plant all other areas.	High	4.54	1.91	3.81	$15,000	$30,000	2
1-22	Sandy Cove Rd	Steep private road leads down to common beach area; landowners installed water diversions to left side of road if facing lake; water travels down left side of the road along grassed lawns until it ultimately flows directly into the lake; minimal treatment of water along the way; top of road runoff is diverted to a culvert on the left that diverts water under the road to the right, flows through the woods, and is sent through an underground pipe that discharges at the edge of one property's lawn just before the beach.	Consider halting any beach sand replenishment and leaf raking; add retaining wall with pervious sediment forebay to define parking/beach boundary and collect any surface material runoff; regrade road to divert water into woods (right side of road if facing lake); assess condition of flow channel in the woods for any further modification or water treatment; stabilize underground pipe outlet with possible rock lined plunge pool.	High	0.67	1.63	0.73	$20,000	$50,000	3
1-16	Common right of way to water off Ames Rd	Eroding common access right of way off Ames Rd down to the lake (233' in length); sloped trail compacted and covered by pine needles with minimal water diversion (one turn out present); evidence of water flowing down the trail; 73' by 23' grassed common sitting area by water encased by rock wall.	Add multiple water bars with infiltration trenches; add erosion control mulch to path; add infiltration steps to end of trail where it steepens before reaching the water; plant shade and acidic soil loving shrubs along access way.	Medium	0.24	0.29	0.71	$2,000	$5,000	4

SITE ID	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION			ESTIMATED COST		RANKING
					TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	Est. Low Cost	Est. High Cost	Low-High Impact-Weighted Cost Per TP Load Reduction
1-05	Boat ramp/dam off Route 25	Road surface erosion of dirt parking area directly into lake. Edge of paved road on entrance is breaking up and needs to be redone. Silt fence around dam but isn't working properly.	Rebuild entry to lot and consider either paving or permeable pavers on lot. Needs maintenance. Pave/paver launch. Add a vegetated buffer around dam. Great spot to install signage or other educational material on existing kiosk.	High	0.87	1.56	1.93	$30,000	$60,000	5
1-01	Rte. 25 just before Jennifer's Path	Unstable culvert inlet under Route 25, road shoulder erosion, and unstable drainage and culvert feeding into stream. Culvert under driveway is concrete and outlet location is unknown, likely causing pooling and slumping above the outlet of a small pvc culvert. Water is redirected around pvc and causing concentrated runoff into stream. Crossing under 25 is ok, could use inlet stabilization.	Stabilize culvert inlet. Replace culvert under driveway and stabilize flowpath to stream.	High	0.38	0.75	1.83	$20,000	$25,000	6
1-19	Camp Quinebarge	Two significant areas of erosion evident: (A) trail from main hall down steep slope to a shorefront cabin had gully formations and movement of sediment down under the cabin to the lake; (B) severe erosion and gully formations from main hall down to new cabins (fresh cedar construction), washouts and sediment piles evident and leading directly into the lake.	Regrade access roads with water diversions, turnouts, and/or broad-based dips; mulch trails and add water bars; mulch walking areas about cabins; consider bioretention areas or sediment forebays in high impact areas.	High	0.23	0.54	2.09	$20,000	$50,000	7
1-12	Stream crossing under Red Hill Rd, right near intersection with Bean Rd	Road shoulder near outlet of culvert is eroding into stream. Culvert hanging about 1' above stream.	Stabilize around culvert outlet and road shoulder.	Low	0.06	0.13	0.29	$1,500	$3,000	8
1-06	Avon Shores Rd	Two cross culverts pulling water across road to a very straight stream channel (wooded) that goes to the lake. Heavy flow at time of survey. Second culvert inlet collapsed and receiving no flow. Significant bank erosion but road surface looks fine.	Armor ditch with stone, check dams, and/or grass and reshape/vegetate shoulder. Replace and enlarge culvert.	Medium	0.20	0.40	0.91	$10,000	$20,000	9
1-10	Steam crossing on Indian Carry Rd	Erosion from road uphill of stream crossing. Road over stream eroding and unstable.	Vegetate and stabilize road/install turnout. Stabilize culvert inlet and outlet. Expense fix may include replacement and enlargement of twin culverts. Need engineering advice.	High	0.44	0.54	1.14	$20,000	$75,000	10
1-13	Culvert under Deer Crossing	Small culvert along road has significant standing water on inlet and outlet side with some erosion.	Recommend formalizing/stabilizing inlet with vegetative swale. Infiltrate/slow water at outlet side with check dams or bioretention.	Medium	0.09	0.19	0.11	$5,000	$15,000	11

SITE ID	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION			ESTIMATED COST		RANKING
					TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	Est. Low Cost	Est. High Cost	Low-High Impact-Weighted Cost Per TP Load Reduction
1-09	Bean Rd crossing	Sediment buildup in culvert outlet. Likely a result of winter sand and slight road shoulder erosion over time. Not much flow even today after the rains.	Clean out culvert so sediment isn't transported during storm event.	Low	0.03	0.04	0.09	$500	$1,500	12
1-18	95 Burton Rd, two residential properties	Uphill, backlot residential property had evidence of gravel driveway erosion (gully formation) that crossed over Burton Rd down the gravel driveway of a vacant shorefront residential property, severe gully formation evident down to parking area and ultimately the lake; steep grade.	Regrade gravel driveway surfaces with larger stone material, reestablish crown and add water diversions to side woods or lawn areas, consider bioretention areas for added infiltration.	Medium	0.13	0.32	0.77	$10,000	$30,000	13
1-11	Bean Rd along pond, just south of Old Harvard Rd	Road shoulder goes straight into lake. Almost no buffer with bare soil. Not much room to work with.	Vegetate and stabilize shoulder as much as possible.	Medium	0.32	0.45	3.72	$10,000	$50,000	14
1-02	Outlet of Route 25 crossing discussed in site 1-01.	Poor culvert headwall on outlet; Perched about 8"; bank undercutting. Also concentrated flow entering from upstream left; mulch sock in place to reduce concentrated flow.	Stabilize outlet headwall and bank. Install bioretention system to store and infiltrate concentrated flow from upstream left.	Medium	0.10	0.19	1.59	$8,000	$18,000	15
1-07	End of Avon Shores Rd	Low impact site. Generally, the end of this road has an unstable ditch with periodic cross culverts. Cross culverts go to wooded drainage areas that vary in effectiveness. See photos of two examples.	Install/reshape ditch, Reshape/vegetate shoulder	Low	0.09	0.11	0.22	$3,000	$5,000	16
1-17	Burton Rd	83' from right convergence to road (if facing the lake), 35' from right/left convergence to lake, 52' from left convergence to road for culvert (if facing the lake), culvert 35' in length; recent excavation of inlet culvert area, loose sediment present, drains water from upland wooded area; Burton Rd surface runoff from both directions enters the woods just to the right of the culvert outlet (if facing the lake), loose sediment pile evident and travels through the woods to converge with the culvert outflow channel before both flow to the lake.	Rework existing road grade, establish grassed swale ditches with check dams and/or add sediment forebay to sediment pile area; install sediment forebay to culvert inflow area for easy future clean outs, consider enlarging the culvert; add rock lined plunge pool at culvert outflow.	Medium	0.31	0.37	0.88	$20,000	$50,000	17
1-04	Gas station retention pond (known site 08)	Retention pond for gas station. Likely needs maintenance but unable to assess performance. End of pond on west side enters area that is very wet with a bunch of mulch socks (known site 03). Blow-out on downhill side of pond resulting in saturated area flowing towards lake. Outlet of gas station cross culvert (known site 04) on the west end. See photos with riprap. Lake visible.	View original designs and inspect performance of pond. Restore/maintain pond to spec. Cost does not include possible restoration/maintenance of the pond.	Medium	0.13	0.36	2.85	$20,000	$75,000	18

SITE ID	LOCATION	PROBLEM	RECOMMENDATION	IMPACT	LOAD REDUCTION TSS (metric tons/yr)	TP (kg/yr)	TN (kg/yr)	ESTIMATED COST Est. Low Cost	Est. High Cost	RANKING Low-High Impact-Weighted Cost Per TP Load Reduction
1-14	Sibley Rd bridge	Head wall of outlet is unstable and eroding into stream. Crossing blocked with woody debris. Potentially beaver activity.	Clean out culvert. Stabilize inlet and/or outlet. Redirect flow along Sibley Rd.	Low	0.08	0.09	0.23	$5,000	$10,000	19
1-15	Road flooding on Bishop Shore Rd	Ponding of water along road and ditch. Slowly flowing to culvert and small stream at end of road. Culvert perched and heavy direct flow to lake.	Install/reshape ditch and armor ditch with stone or grass. Build up road/ add surface material.	Low	0.05	0.11	0.04	$10,000	$20,000	20
1-21	Evergreen Rd	End of Evergreen Rd (before it turns into an access trail) steepens down to a wetland complex; evidence of road surface erosion and washout; sand piles present in woods leading to wetland.	Regrade road with water diversions and turnouts; establish swale ditch or settling basin to collect material.	Low	0.09	0.09	0.23	$15,000	$25,000	21
1-08	Stream crossing on Bean Rd	Erosion of culvert outlet bank. Culvert outlet perched by 2'.	Reshape/vegetate shoulder and culvert outlet. Remove winter sand. Replace culvert at grade.	Low	0.03	0.05	0.12	$10,000	$20,000	22
				TOTAL	**9.96**	**11.49**	**30.25**	**$260,000**	**$647,500**	