Bolton Lakes & Watershed Management Plan

Prepared by Northeast Aquatic Research LLC

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This plan was prepared by:

Hillary Kenyon, Certified Lake Manager
Northeast Aquatic Research LLC
Email contact: hillary.kenyon@gmail.com

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The information in this report follows a period of over eight years of lake and watershed monitoring, coupled with continuous aquatic invasive species and cyanobacteria management at Lower and Middle Bolton Lakes. The majority of the data collection and plan development was funded by a Connecticut Small Town Economic Assistance (STEAP) grant awarded to the Town of Bolton. In recent years, the Town of Vernon has funded the monitoring and management of Middle Bolton Lake, in concert with the Friends of Bolton Lakes. The Towns, the Friends of Bolton Lakes, and the Bolton Lakes Watershed Conservation Alliance have been integral in community outreach, volunteer monitoring, and continued advocacy for sustainable water resources management.

The Watershed Management Section of this plan was written to address the Nine Key Elements identified by the Environmental Protection Agency (EPA) that constitute a watershed remediation and/or protection plan.

Management Plan Presented in Partnership By:

Town of Bolton
Town of Vernon
Town of Tolland
Town of Coventry
Friends of Bolton Lakes
Bolton Lakes Watershed Conservation Alliance
CT Department of Energy & Environmental Protection
Northeast Aquatic Research LLC

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Glossary of Acronyms

AIS	Aquatic Invasive Species
Alum	Aluminum sulfate
BLWCA	Bolton Lakes Watershed Conservation Alliance
BLWMP	Bolton Lakes and Watershed-based Management Plan
BMPs	Best Business Management Practices
CAES	CT Agricultural Experiment Station
CLEAR	Center for Land Use Education and Research
CSIRO	Commonwealth Scientific and Industrial Research Organization
CWA	Clean Water Act
DEEP	CT Department of Energy and Environmental Protection
DEM	Digital Elevation Model
DPH	CT Department of Public Health
EPA	Environmental Protection Agency
ERT	CT Environmental Review Team
FBL	Friends of Bolton Lakes
GIS	Geographic Information System
HABs	Harmful Algal Blooms (cyanobacteria)
HDR	High Density Residential (HDR)
IC	Impervious Cover
LIDAR	Light Detection and Ranging
LDR	Low Density Residential
LBL	Lower Bolton Lake
LID	Low Impact Development
LLRM	Lake Loading Response Model
MBL	Middle Bolton Lake
NEAR	Northeast Aquatic Research
P	Phosphorus
POCD	Plans of Conservation and Development
RTRM	Relative Thermal Resistance to Mixing
STEAP	Small Town Economic Assistance Program
STEPL	EPA Spreadsheet Tool for Estimating Pollutant Loads
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
UBL	Upper Bolton Lake
WMP	Watershed Management Plan
WQS	CT Water Quality Standards

1 Introduction

This Bolton Lakes and Watershed-based Management Plan (BLWMP) has been developed for the residents of the Towns of Bolton, Vernon, Coventry, and Tolland. The BLWMP serves as a historical record of past management efforts and also as a guide to future lake and watershed management. The plan includes a review of lake science terminology and identifies data-based water quality goals. Watershed and in-lake management principally aims to prevent the lakes from slipping into *Impaired* status, as defined by CT Water Quality Standards (WQS) and reported to Congress in the Clean Water Act Section 305(b) CT Integrated Water Quality Report and 303(d) list of *Impaired* waters. This report is revised every two years by the CT Department of Energy and Environmental Protection (DEEP). Water quality data reviewed within this management plan has been provided to CT DEEP. If any of the Bolton Lakes are subsequently listed as *Impaired*, the information in this management plan can be used to remediate lake conditions. If the Bolton Lakes are not listed in the near future, this management plan will be used to prevent impairment and preserve conditions that meet CT WQS.

Nutrient pollution in American lakes is managed given the framework of the Clean Water Act (CWA, 1972 amendments). The State of Connecticut published a Draft Statewide Lake Nutrient Total Maximum Daily Load (TMDL) in July 2021, to fulfill CWA TMDL requirements for pollutants to surface waters (https://portal.ct.gov/-/media/DEEP/water/watershed_management/BantamLake/CT-Statewide-Lake-Nutrient-TMDL_Core-Document_Draft.pdf). Though the initial draft of the BLWMP was brought before the Steering Committee in December 2020 prior to the statewide draft nutrient TMDL, this updated draft takes into account the CT DEEP proposed process to translate the state narrative nutrient criteria into numerical criteria for specific waterbodies. The narrative nutrient criteria are used to determine if a waterbody meets *designated uses*. Lakes with prolific Harmful Algal Blooms (HABs/cyanobacteria) may be listed as *not-fulfilling* the designated use for *Recreation* and/or *Habitat*.

More information about the state approach to lake nutrient management is available at the link above. A key component in the CT approach to lakes is whether or not a lake's conditions are considered human-caused versus natural. This is particularly difficult to define for impoundments like the Bolton Lakes. The data reviewed in this plan will aid CT DEEP in determining if any of the Bolton Lakes should be added on the 303(d) list of impaired waters in the future, and it will serve as the foundation for future in-lake and watershed-based management.

Key stakeholder groups intend to use this plan to aid decision making and to define semi-formal management procedures, including public-private partnerships that foster water quality protection, sustainable land use, and proactive aquatic invasive species management.

1.2 Value in Balance

The Bolton Lakes are an essential part of the local community and economy. The lakes provide recreational fishing, swimming, and boating, as well as year-round activities like ice-fishing, skating, bird watching and cross-country skiing. Each of the three lakes has its own State-owned public access area, which allows nearby residents to connect with nature.

Lake and watershed management attempts to achieve harmony between human resource use and ecology. Aspects of lake management usually attempt to slow down the rate of landscape and waterbody change over generations. Sometimes, lake management attempts to slow human-caused changes and, occasionally, lake management will also attempt to slow natural nutrient-enrichment processes in order to preserve open water lake habitat and recreational value.

The Bolton Lakes are treasured by local residents in mid-eastern CT, and the lakes are particularly valuable to Vernon and Bolton. Both Towns have municipally-owned parks with beach access for residents. Collective lake and watershed management will improve the value of surrounding land and the Towns over time. The lakes and surrounding land serve as habitat for fish and wildlife, and are part of the greater Hop River, Willimantic River, and ultimately the Thames River watershed, one of the largest river systems in Connecticut.

1.3 Management Objectives & Identified Threats

The overarching objectives of the Bolton Lakes and watershed management program are to:

- Protect water quality and prevent *Impairment*
- Prevent and manage harmful cyanobacteria blooms
- Preserve the health of the lakes' aquatic ecosystems & biodiversity
- Manage existing invasive species & prevent further infestations
- Aid in collaborative and environmentally-focused land-use across the four watershed Towns
- Engage stewards & increase public awareness of lake and watershed management
- Maintain the economic and intrinsic value of watershed lands
- Provide educational and outreach opportunities

The identified threats to the Bolton Lakes are intertwined and related:

- Invasive species
- Cyanobacteria/algae
- Excess nutrient loading (phosphorus & nitrogen)
- Sedimentation
- Overdevelopment & stormwater runoff
- Littoral zone disturbances
- Loss of riparian function
- Climate change
- Loss of passive and active recreational use
- Loss of ecosystems services

1.4 Historical Perspective

Bolton Lakes history dates back to the time of Native Americans, but the earliest map on record is from 1811, which indicates that the Bolton Lakes watershed contained two small ponds at the time. The ponds were separated by the Vernon-Bolton Town border, with a series of mills operating along the river. In 1855, the Bolton Reservoir and water power company created two earthen dams, one that raised the level of Lower Bolton Lake, and another that created Middle Bolton Lake out of the northern pond. The lakes underwent a series of major changes in the 1930s. After the 1938 hurricane caused a Lower Bolton dam failure, the lakes were turned over to the State of Connecticut, in an effort to preserve public recreational and scenic value. Today, the State of CT owns limited land in the watershed, the dams, and the lakes themselves. The State made dam repairs in 1941 and again in 1994. The most recent dam repairs were updates to the spillway from Upper to Middle Bolton Lake in winter 2021-2022.

Residential development of the shoreline seems to have begun in the 1930s, as homes and cottages were built along Grier Road on the shore of Middle Bolton Lake. Some of the residential area was transitioned into the Brae Marr summer camp in the 1950s. Camp Newhoca, in Vernon, was originally private Camp Oak Hill but was renamed in 1960. The Town of Vernon purchased the land in 1971.

Residential development was heaviest in the 1950-1970s. Pictured below is an aerial comparison photo of the Keeney Drive neighborhood on the southern shore of Lower Bolton Lake from 1951 to 1970 (Photos 1 & 2). The residential neighborhoods along the shoreline and lake-access communities also slowly transitioned from seasonal cottages to full-time residences.

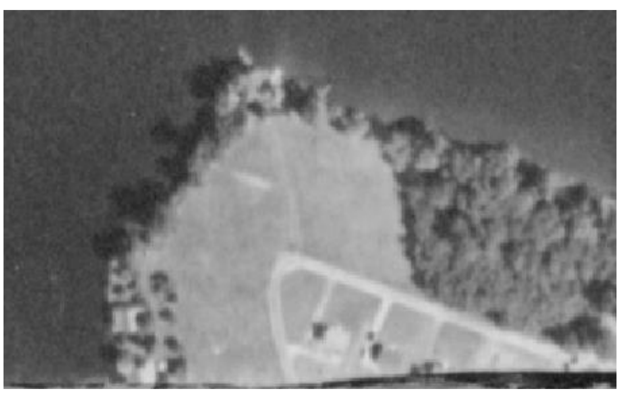


Photo 1: 1951 Aerial Image

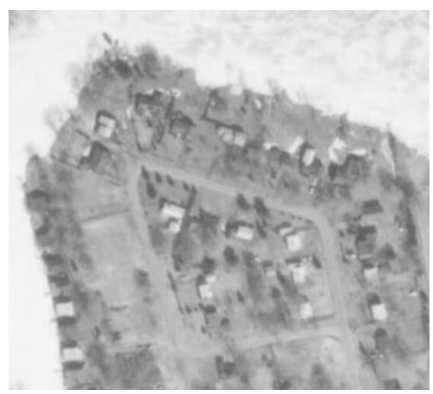


Photo 2: 1970 Aerial Image

Overall, historical aerial photos of the lakes show that there was substantial deforestation and development in the watershed in 1951 (Photo 1 & 3: Aug 6, 1951), but by 1970 (Photo 2: March 10, 1970) there were substantially more residential homes along the shoreline. By 1990 there was much more residential development, particularly in the Lynwood Ave. neighborhood (Photo 4: April 19, 1990). The Lower Bolton Lake public beach and Indian Notch Park were created at some point between 1970-1986, and the park was greatly expanded between 1990-1995, based on aerial imagery (Photo 5: April 25, 1995).

All historical aerial imagery can be viewed at:
https://connecticut.maps.arcgis.com/apps/View/index.html?appid=044e8e6266aa44dc8ccc9b6e2eecacb4&extent=-74.8197,40.6374,-70.2054,42.4665

Photo 3: 1951 Lakes Aerial

Photo 4: 1990 Lakes Aerial

Photo 5: 1995 Lakes Aerial

The increased public use, watershed development, and onsite wastewater requirements put pressure on the lakes' water quality. By 1985, the developed area in the watershed was roughly 11.3% - which was already on the cusp of affecting lake water quality based on the known impacts of impervious cover on aquatic life (Lee and Dunbar, 2009; Bellucci, 2007).

From the 1970-1990s, there were a series of initial watershed assessments, diagnostic water quality studies, and several wastewater studies.

Table 1: Historical Lake & Watershed Studies 1970-1990s

Historical Studies 1970-1990s	Date	Content
CT Environmental Review Team Report	1978	Survey of Bolton Lakes Watershed
Phase I Diagnostic/Feasibility Study of Middle and Lower Bolton Lakes by CT DEP, Water Compliance Unit	1979	Review & survey of Middle and Lower Lakes, with Watershed Management Recommendations and Lake Management Alternatives
CT Agricultural Experiment Station Chemical and Physical Properties of Connecticut Lakes	1984	Statewide preliminary assessment of 70 CT lakes
Pilot Study of Lake Management Techniques for MBL Assoc. by Ecosystem Consulting Services	Oct 1986	Analysis intended to define management approaches for Middle Lake and noting concern for effects on Lower Lake

Draft Facilities Plan for Wastewater Disposal by Lombardi Associates	1992	Study of soil septic suitability and residential onsite wastewater inspections
Fuss and O'Neill Memo from Chris Ecsedy re: Bolton Lakes Water Quality Evaluation	Aug 1995	A summary of significant water quality issues for the Bolton Lakes using previous water quality analyses and calculations of loading factors and predicted P concentrations
Draft report, Bolton Lakes wastewater management study By Fuss & O'Neill	Jan 1997	Planning for potential lake district wastewater sewer project

Based on the findings of the subsurface wastewater disposal studies, the CT Department of Energy and Environmental Protection (CT DEEP) ordered the Towns of Vernon and Bolton to create the Bolton Lakes Regional Water Pollution Control Authority. After multiple years of planning and discussion, the Towns commenced the centralized sewer construction project in 2008, slowly servicing the majority of direct Middle and Lower Bolton Lake watershed homes. The sewer hookups were completed in 2015.

The Friends of Bolton Lakes (FBL), a nonprofit resident stakeholder group, was formed in 2013 after a severe cyanobacteria bloom in 2012 had garnered state-wide attention. The Bolton Lakes Watershed Conservation Alliance (BLWCA) was formed in 2014. Both groups had central goals of unifying the efforts of the four watershed towns: Bolton, Vernon, Coventry, and Tolland. FBL has since become essential to long-term lakes management, by increasing public outreach and engagement.

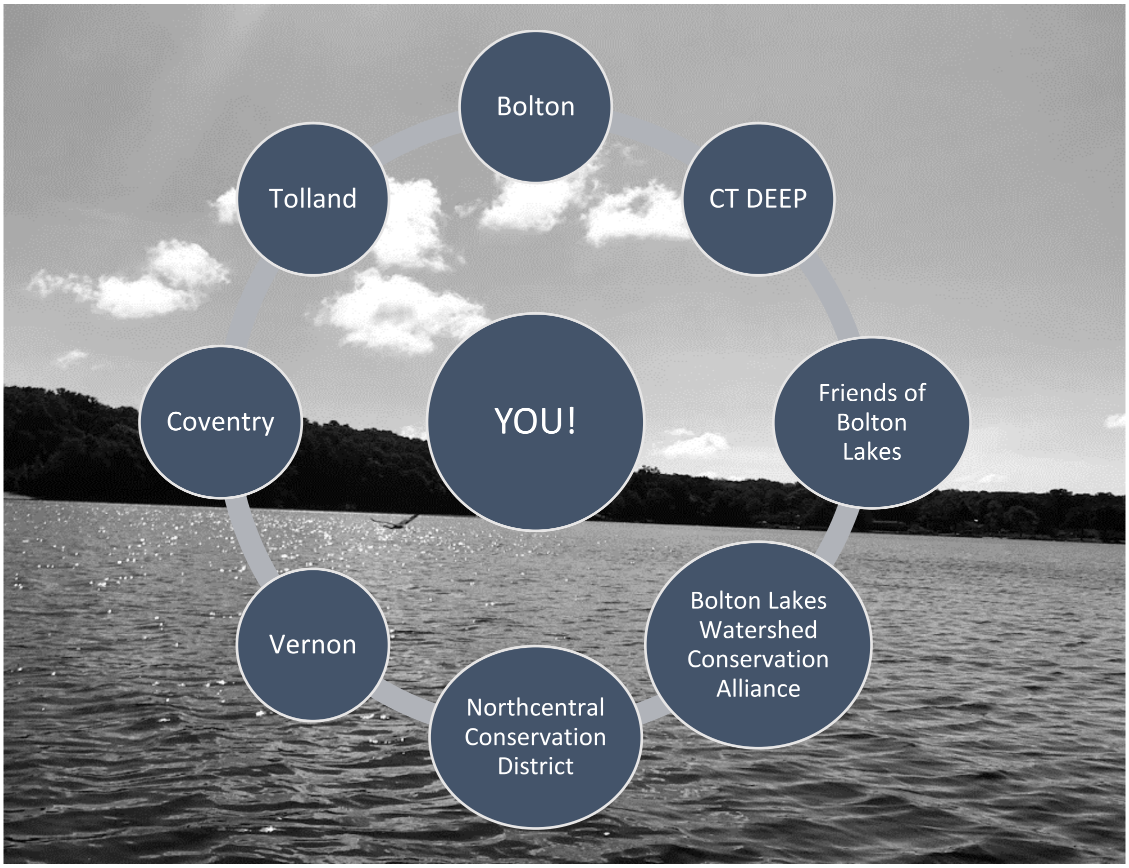
Staff from Northeast Aquatic Research conducted two volunteer water quality monitoring trainings for FBL, in summer 2013 and spring 2019. Residents have since committed to maintaining ongoing and regular water quality monitoring into the future, with oversight from the towns of Bolton and Vernon. The BLWCA now serves to increase communication and collective action of the four town Conservation and Inland Wetlands Commissions, as well as town employees responsible for land-use planning and Town property maintenance. BLWCA aims to unify conservation and development actions of the towns, and is a diligent land preservation advocate that fosters partnerships with local land-trusts and research groups. The following table presents a list of the archived studies and relevant Bolton Lakes publications since 2000.

Table 2: Historical Lake Reports 2000-2020

Historical Reports 2000-2020	Date	Content
Memo from Laurence Shaffer, Vernon Town Administrator	Jun 2001	Referenced water quality and phosphorus calculations and communication with Peter Grose and Chris Escedy
Monitoring report for Middle Bolton Lake for the Town of Vernon, by Dr. George Knoecklein, Northeast Aquatic Research	2002	Report on Middle Bolton Lake aquatic plant survey and review of management alternatives for invasive species control (Variable-leaf milfoil)
CT Agricultural Experiment Station Invasive Aquatic Plant Program plant surveys	July 2005 & 2010	Lake-wide surveys and mapping of aquatic plants
UCONN MS Thesis by Christopher McDowell (#18120)	2012	Summary of 2006-2009 DEEP Dept. of Fisheries & UCONN study on the effects of 3-yrs of 6ft drawdowns on fish spawning (5 lake comparison including Middle Lake)

Dr. George Knoecklein, Northeast Aquatic Research, presentation to residents	Nov. 2012	Power-point summary of Lower Bolton Lake aquatic plants, algae, and water quality status
CT Environmental Review Team, updated assessment	April 2014	Requested by the Conservation Commissions of the 4 Watershed Towns-Bolton, Coventry, Tolland and Vernon. Suggested to use STEAP grant for watershed assessment of all three interconnected Bolton Lakes
Northeast Aquatic Research Lower Bolton Lake reports and public presentations	2012 to 2019	Monitoring summaries, educational interpretation, and analysis of Lower Bolton water quality & inflows; invasive aquatic species surveying & management; reports on annual phytoplankton abundance and cyanobacteria management
University undergraduate student projects: lead by Dr. Timothy Ku (Wesleyan University) & Dr. William Ouimette (UCONN)	2017 to 2019	Undergraduate students from each University performed a series of unique sediment core samplings and geochemistry tests on Upper, Middle, and Lower Bolton lakes. The Upper Bolton Lake vibracore project was completed through UCONN in partnership with the Natural Resources Conservation Service (NRCS) subaqueous soils mapping project in CT. FBL maintains copies of the student presentations.
Northeast Aquatic Research, aquatic plant surveys and water quality assessment summary reports of Middle Bolton Lake, by Hillary Kenyon	Feb 2019	Memo to the Town of Vernon on Feb 26th re: aquatic plant management of Vernon waterbodies, includes information about Upper and Middle Bolton Lakes. Feb 28th evaluation of Friends of Bolton Lakes volunteer-collected water quality data for Middle Bolton Lake.
CT Agricultural Experiment Station aquatic plant survey on Middle and Lower lakes	2020	In addition to plant surveys conducted by Northeast Aquatic Research, the CAES staff performed a full lake survey on both Middle and Lower Bolton lakes. Survey results are provided on the CAES website.

1.5 Bolton Lakes Key Stakeholders



1.5.1 Town of Vernon

The Town of Vernon supports the continuation of the annual water quality monitoring of Middle Bolton Lake, performed by the resident volunteers. Additionally, they support the aquatic invasive species surveying and the water management of the Middle Lake. Vernon is currently financing the Middle Bolton Lake management program through the Department of Parks and Recreation's annual budget for all Vernon lakes. The Vernon Parks and Recreation Director has been a key communicator with the Vernon Town Council and Town Administrator, and the department has been successful in securing funds to engage in rapid-response against the management of invasive species. Northeast Aquatic Research has served as a private consultant to the Town of Vernon, on an as needed basis since 2002. Since 2017, the Fanwort infestation and dedicated volunteer-monitoring program has shown that funding is needed to maintain the water quality of Middle Bolton Lake.

1.5.2 Town of Bolton

We recommend that the Town of Bolton continue to financially contribute to annual volunteer water quality monitoring, chemical analysis of water samples, and invasive Curly-leaf pondweed management in Lower Bolton Lake. The STEAP grant funding, allocated through CT DEEP to the Town of Bolton, was used to investigate the causes and remedies for cyanobacteria blooms. Since that time, the water quality data suggests that the initial bloom was a result of a number of coinciding factors. Bloom frequency and severity has decreased in recent years. STEAP funding supported the entire Lower Bolton Lake aquatic invasive species and plant management program since 2013, including plant surveying and physical and chemical management. The Bolton STEAP grant also funded a total of fifteen stormwater sampling events in the Bolton lakes watershed since 2014. Additionally, STEAP funding supported the purchase and installation of water temperature and water level loggers that will record continuous data and aid in the future planning of drawdowns and refills, in coordination with CT DEEP. After discussion with CT DEEP, it was determined that remaining STEAP grant funds could not be extended for another year and would have to be used by the end of 2020. This Lakes and Watershed Management Plan is the culmination of the monitoring, management, and watershed planning work completed under the STEAP grant funding opportunity.

Both Bolton and Vernon anticipate applying for available state and federal grants to continue to support their short and long-term lake management work.

1.5.3 Towns of Coventry & Tolland

Coventry and Tolland do not have direct waterfront properties or municipal park access to Middle or Lower Bolton Lakes. However, more than half of Upper Bolton Lake lies in Coventry. At present, Coventry and Tolland do not financially contribute to the Bolton lakes management effort. It should be expected that Coventry and Tolland will commit to improved communication with Bolton and Vernon, and that Coventry and Tolland will consider enacting the recommendations made for town land-use and management in the Watershed Management Plan section of this document.

1.5.4 Friends of Bolton Lakes

The Friends of Bolton Lakes (FBL) is a nonprofit organization that was established in 2013. As a concerned group of citizens, FBL is dedicated to preserving the Bolton lakes and watershed through research, education, and public awareness. FBL fills an essential role of unifying the voice of the local community and increasing public engagement and awareness. FBL continues to maintain an active collaboration with the towns, the state agencies, and the lake consultants. FBL has sponsored their own volunteer water monitoring program and will continue to provide responsible volunteers to maintain the long-term monitoring programs. FBL has sponsored multiple invasive species identification training programs and has a streamlined process for residents to report suspicious plants through their website. Through frequent communications, FBL encourages its members to be more involved in maintaining the health of the Bolton lakes and promotes responsible use of the precious natural resources. FBL has taken the initiative to participate in the EPA Regional Cyanobacteria Monitoring Collaborative and now has capabilities of collecting phytoplankton samples and uploading microscopic images to Cyanoscope, a federally funded crowd-sourced cyanobacteria photo identification and bloom recording platform, started in 2016. One of the more important roles of FBL is that it maintains close contact with roughly 150 local member residents. FBL keeps record of and readily disperses information, fosters community, and their volunteer program will hold an increasing role in cooperative Bolton lakes management.

1.5.5 Bolton Lakes Watershed Conservation Alliance

The BLWCA was formed to unify land-use planning and management efforts of Bolton, Vernon, Coventry, and Tolland in the Bolton lakes watershed. The group consists of the Conservation and Inland Wetlands Commission members, Friends of Bolton Lakes, and the North Central Conservation District. BLWCA also aims to partner with northern CT land trusts and Bolton lakes residents. As previously stated, the BLWCA is central to increased communication between the watershed towns. The group works towards land preservation, with recent efforts focused on preservation of the Atlantic White Cedar stand in the Upper Bolton watershed. BLWCA engages town planners and urges the towns to include the Bolton lakes in their updates to Plans of Conservation and Development.

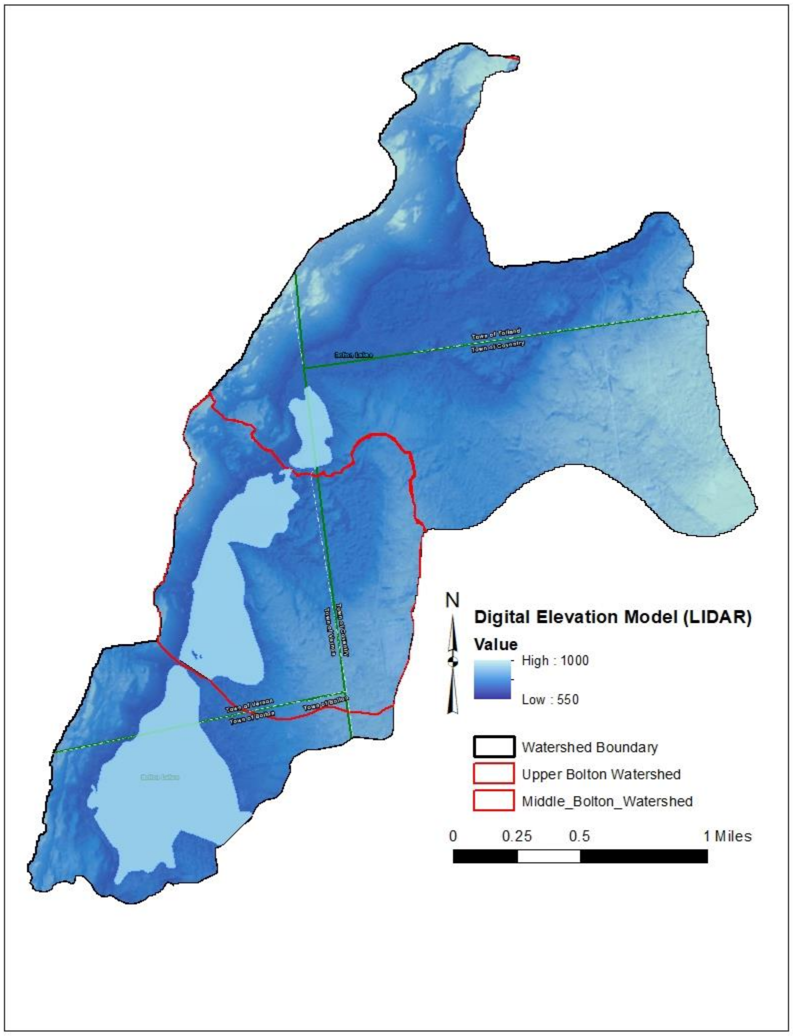
1.5.6 State of Connecticut

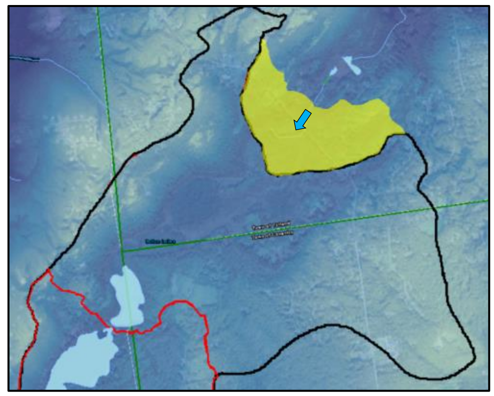
The State of Connecticut owns the Bolton lakes and the dams that divide them. The State of CT also owns public access boat ramps and parking lots at Middle and Lower lakes, as well as a carry-top boating access point for Upper Lake. The State owns a large tract of partially forested land to the west of the Middle Bolton Lake dam, which serves as an additional public access and dam maintenance road. The CT DEEP currently manages the Bolton lakes fisheries and conducts their own limited water quality monitoring. The CT Agricultural Experiment Station has also played a role in the Bolton lakes management, providing three detailed aquatic plant surveys in 2005, 2011 (Middle and Lower), 2018 (Lower Lake), and 2020 (Middle). The CT Department of Public Health also holds ultimate responsibility for posting advisories for both E. coli bacteria and/or cyanobacteria that are harmful to human health. The State of CT provided Small Town Economic Assistance Program (STEAP) funding to Bolton in 2013. Since that time, Lower Bolton Lake monitoring and management efforts have been planned and approved on an annual basis between Bolton, the consulting limnologist/lake manager Northeast Aquatic Research, and CT DEEP.

1.6 Bolton Lakes General Information & Watershed Boundaries

The Bolton Lakes are a chain of artificially impounded waterbodies that flow north to south. The unique three-lake system adds to the complexity of management and underscores the importance of municipal cooperation. The total topographic watershed was field-verified in several locations and edited in ArcGIS. The 1-meter Digital Elevation Model used for topographic watershed delineation was downloaded from UCONN Center for Land Use Education and Research (CLEAR). The LIDAR watershed boundary is very similar to what has been previously delineated and totals 2,402 acres.

Map 1: Bolton Lakes Watershed Boundary





There is a questionable flow area along Mile Hill Road and Gehring Road in the northeast. The topographic flow contours indicate that water flows north under Mile Hill Road, but that was not the case during the field inspection in November 2020, where water was observed flowing south. The additional proposed watershed area needs more investigation and could add roughly 180 acres to the Upper Bolton watershed. However, this questionable area would flow to the Upper Bolton wetlands, meaning it should not substantially influence the water quality of Middle and Lower Bolton Lakes.

The Environmental Review Team publication also mentions questionable water flow in the Upper Bolton wetland area:

"Note that the northern-most sub-basin is separated from the rest of the watershed. It drains into a wetland that is crossed by a power line. Local property owners report that an access road constructed by the power company effectively diverts the flow of that sub-basin into a northerly draining system. That report was not field checked by this writer. The watershed of the lakes is diminished by several hundred acres if that is the case."

Based on the new high resolution LIDAR elevation data, the northcentral wetland area does appear to flow northwards, meaning that the northern wetlands could be the lowest elevation, and actual flow direction is groundwater-dependent.

1.6.1 Upper Bolton Lake

Upper Bolton "lake" is a shallow, eutrophic, wetland-dominated waterbody. The upper northeastern half of the waterbody is a transition area. The northern swamp transitions to a mucky peatland with roughly four to eight inches of water depth. The southern half of Upper Bolton Lake is on average three feet deep, but becomes as deep as five feet in the channel close to the outlet culvert to Middle Bolton Lake. During the spring through fall, the Upper Bolton Lake is almost completely covered by water lilies.

The topographic drainage basin (as defined by all prior watershed delineations) of Upper Bolton Lake is roughly 1,296 acres, including the waterbody area. The actual acreage of Upper Bolton depends on what is considered to be the edge of open water. Waterlily coverage extends to roughly 48.9 acres, but only about 35.1 acres is accessible by canoe. The CT DEEP considers Upper Bolton to be only 23.5 acres, which is the area that is roughly three feet deep. The aerial image includes the largest Upper Bolton total waterlily extent, overlaid by the CT DEEP Upper Bolton Lake polygon of 23.5 acres. The yellow line marks the farthest accessible point by canoe, prior to lake drawdown. East of the pink dotted line, only a central channel was accessible via canoe at normal water level in 2020. The areas closer to shore are intermixed with emergent wetland plants and lilies and very shallow.

Map 2: Upper Bolton Water vs. Wetland

Photo 6: Upper Bolton - October 2020

Photo 7: Upper Bolton - View North, Oct. 2020

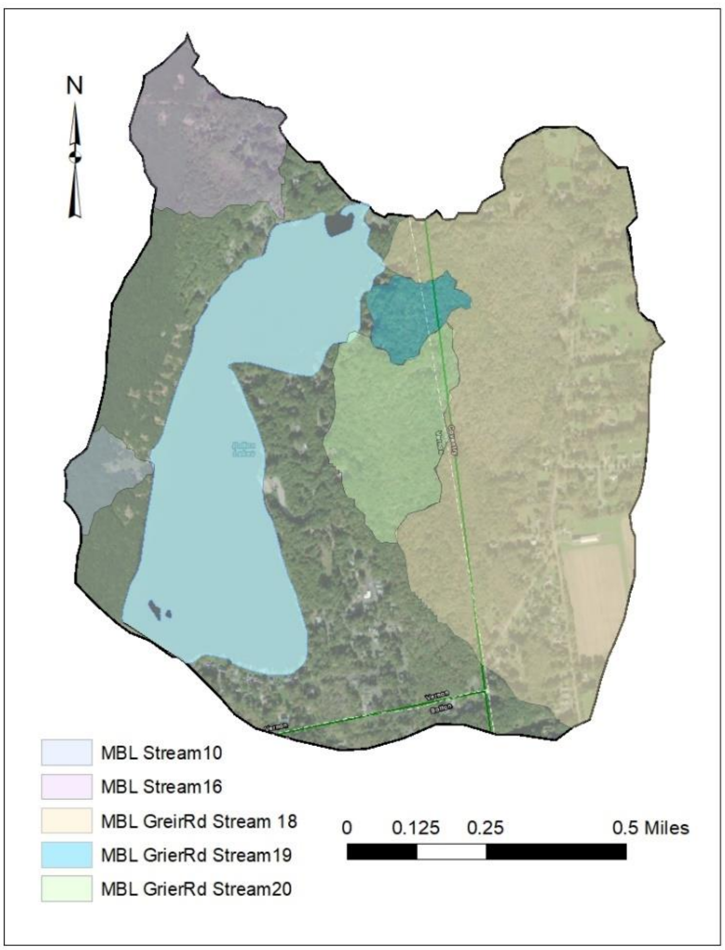
The above Upper Bolton Lake photos were taken roughly at the central location of the yellow line. Waterlilies were dying back in October 2020 and water depth at the time was roughly eight inches. The second photo shows the transition area, from water/lily-coverage to peat-lands and swamp, with the Atlantic White Cedar Forest to the northeast. The red arrow points roughly north.

1.6.2 Middle Bolton Lake

The Middle Bolton Lake drainage basin encompasses the entire Upper Bolton watershed, as well as an additional 624 acres, including the surface area of Middle Lake itself, which is roughly 121.4 acres. The Middle Bolton drainage basin has four subbasins that flow to the lake as wetland streams. The remaining watershed flows to the Middle Lake via direct drainage and road runoff. The major annual inflow is the Upper Bolton culverts at Hatch Hill Road, but these two culverts typically do not have measurable flow from the end of June to October. On some occasions, the flow appears to even reverse, with a small flow from Middle to Upper Bolton. The highest flows from Upper to Middle Bolton occur during the annual winter drawdowns and during the spring season refill.

Middle Bolton Lake has a maximum depth of 18ft and a mean depth of roughly 9.3ft. The flushing rate of Middle Bolton Lake is roughly 295 days, or 1.2 times per year.

Map 3: Middle Bolton Lake Direct Watershed



Middle Bolton Lake (MBL) outflow to Lower Bolton occurs over the dam spillway at the south end. Water is also released, during winter predetermined drawdowns, to Lower Bolton Lake through the underwater 36'' culvert on the western side of the earthen dam. Water flow over the Middle Bolton spillway is minimal from the end of June through the fall but depends on seasonal rainfall. Flows between the lakes vary heavily from one year to the next based on annual patterns of precipitation. The main MBL inlet streams are delineated in Map 3 and respective acreages displayed in Table 3.

Table 3: MBL Subbasins

Subbasin -Inlet WPT#	Area (acres)
MBL Stream - 10	10.0
MBL Stream - 16	38.4
MBL Stream - 18	224.6
MBL Stream - 19	12.1
MBL Stream - 20	40.7
Direct Drainage	~176.8

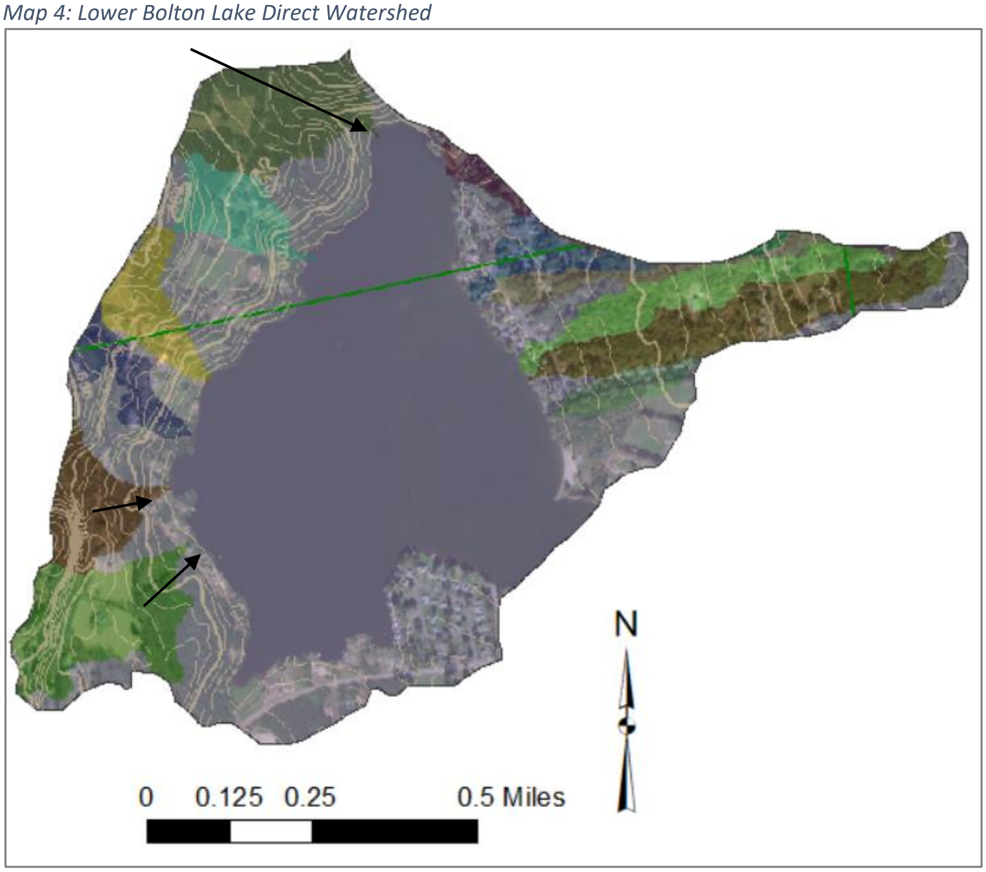
1.6.3 Lower Bolton Lake

Lower Bolton Lake is roughly 176 acres in size. The maximum depth is approximately 19ft deep, while the mean depth is 9.5ft. Roughly 145 acres, 82% of the lake's surface area, is littoral and can support the growth of aquatic plants.

The area of direct watershed drainage to Lower Bolton Lake is approximately 305 acres. The flushing rate of LBL is roughly 2.8 times per year (129 days). Lower Bolton Lake discharges via the southern dam. The spillway is 24ft wide, and there is usually no outflow from late June to October. Yet again, outflow is dependent on summer rainfall.

The figure below shows the direct drainage subbasins to Lower Bolton Lake. The eastern and southern sides of the lake are relatively flat, and water flow is primarily through stormwater runoff from the surrounding neighborhoods. The western ridge is steeper and has two small stormwater streams that flow onto Vernon Road and into the roadside swales during heavy rain. The northern wetland stream is the only Lower Bolton inlet stream that has water flow during non-storm conditions, but it typically runs dry from July to October, except during heavy downpours. The black solid arrows represent the general direction of water flow. The additional colored overlays show the general direction of concentrated water/base-flow towards the lake at the location of the wetland stream. For the purposes of this watershed plan, the Lower Bolton immediate watershed is all considered direct drainage. The annual drawdowns are pre-approved by CT DEEP and coordinated between the Towns of Bolton and Vernon each fall, through the 30'' culvert that is positioned 9' below the normal surface water level.

Map 4: Lower Bolton Lake Direct Watershed



2 Lake & Watershed Management Goals

2.1 In-lake Water Quality Targets

Long term in-lake water quality goals for Lower Bolton Lake were initially established in 2017. Though, after multiple years of water quality monitoring, these goals have been revisited and are restated below. Target conditions for Middle and Lower Bolton lakes were identified in order to preserve designated lake uses and to ensure the Bolton lakes water quality meet CT WQS standards. Upper Bolton Lake targets are stated as a narrative with limited numeric criterion intended to maintain designated uses. Swimming is not a designated use in Upper Bolton Lake.

2.1.1 Nutrients

Phosphorus – Total phosphorus is most frequently the limiting nutrient in cyanobacteria growth. Too much phosphorus causes harmful cyanobacteria blooms. To ensure adequate water quality, the upper tolerable level of total phosphorus is 20 µg/L (ppb) in the upper water column. The total in-lake phosphorus mass target is below 45 kilograms.

Nitrogen – Nitrogen concentrations are also linked to cyanobacteria increases.
Monitoring data suggests a target total nitrogen goal upper tolerable level is 600 µg/L (ppb) in surface waters, with preferred concentrations near 400 µg/L (ppb). The total in-lake nitrogen mass target is below 800 kilograms.

2.1.2 Additional Parameters

Water Clarity – The Secchi disk depth is a measure of plankton density, as well as mineral or organic turbidity. The long-term goal for water clarity is >3 meters at Lower Bolton Lake, and >2.5m at Middle Bolton Lake. Tolerable clarity, as related to cyanobacteria blooms at both lakes, is >2m (6.5ft).

Cyanobacteria – Increasing cell numbers causes diminished water clarity and increased likelihood of cyano-toxins. The goal for bloom-forming cyanobacteria taxa in open water is <20,000 cells/mL, as counted using *Standard Methods for Phytoplankton Analysis*. The upper tolerable level of cyanobacteria is 70,000 cells/mL. Additionally, target water quality conditions aim to prevent cyanobacteria growth in an amount harmful to human health based on toxin thresholds set by the US Environmental Protection Agency and recommended by CT DEEP in the 2021 updated guidance to local health directors.

Dissolved Oxygen – Dissolved oxygen loss in bottom waters is common in the Bolton Lakes and is accelerated by anthropogenic nutrient input. Oxygen is also indirectly related to bottom-water nutrient concentrations. Long-term goals for dissolved oxygen should be above 5ppm at all depths, with the exception of deep-water in summer months. Dissolved oxygen below 1 mg/L (ppm) should ideally not occur above 1m off of the bottom sediment at the Lower Bolton Lake long-term monitoring station. Dissolved oxygen below 1 mg/L (ppm) should not occur above 1.5m off the sediment at the Middle Bolton Lake long-term monitoring station.

2.1.3 Upper Bolton Water Quality Targets

Upper Bolton Lake is an entirely different type of waterbody, and the long-term water quality goals will be extremely different from the Middle and Lower lakes. The extreme accumulation of organic matter and dense vegetation make the Upper Bolton water clarity very poor (< 1m), and nutrients may be higher than in Middle and Lower Bolton Lakes during parts of the year. Upper Bolton serves as a nutrient sink for the large upper Bolton Lakes watershed, but during certain times of the year the Upper Lake also acts as a source of nutrients to the Middle and Lower Lakes. Dissolved oxygen in Upper Bolton is very low, typically less than 1 mg/L throughout the waterbody in summer and fall, when measured below dense plant growth. That low oxygen is a combined result of great sediment biochemical oxygen demand and limited wind mixing due to surface vegetation. This is natural in wetland transition areas. The ultimate long-term water quality goal for Upper Bolton is for total phosphorus to be less than 20 µg/L (ppb) where water travels through the Hatch Hill culvert, particularly in the summer months. The spillway updates were completed by CT DEEP in winter 2021-2022.

2.2 Aquatic Invasive Species (AIS) Goals

Lower Bolton Lake has an ongoing management program for invasive Curly-leaf pondweed (*Potamogeton crispus*). Middle Bolton Lake has an ongoing management program in place for invasive Fanwort *(Cabomba caroliniana*) and Variable milfoil (*Myriophyllum heterophyllum*). It is essential that these programs continue to receive Town funding from Vernon and Bolton. Both Town officials and community members are aware of the detriments of letting invasive aquatic plant species go unmanaged in a waterbody. There is currently a good partnership between the Towns, the consulting limnologist Northeast Aquatic Research, and the Friends of Bolton Lakes volunteers.

Specific AIS goals include:

- Prevent downstream spread of invasive Fanwort from Middle to Lower Bolton Lake.
- Continued management of Fanwort and Variable milfoil in Middle Bolton Lake.
- Continued management of Curly-leaf pondweed in Lower Bolton Lake.
- Aquatic plant surveys to scan for potential new infestations and to quantify the extent and density of both native and invasive species.
- Continued support and communication between the Town's consulting Certified Lake Manager and resident volunteers. Rapid reporting, identification, and follow-up management of AIS through the FBL and Lower Bolton Lake Commissioner.
- Review and track annual AIS management activities to adapt actions as needed.
- Prevent new infestations, particularly through public outreach and awareness.
- Continue to support an active volunteer program of boat ramp inspectors, particularly for days with expected high lake use.
- Install more visible signage about invasive species presence and prevention tips at the Middle and Lower Bolton Lakes CT DEEP boat ramps.

CT DEEP provides general information about aquatic invasive species on their website: https://portal.ct.gov/DEEP/Fishing/General-Information/Aquatic-Invasive-Species

Photo 8: Invasive Aquatic Plants in Bolton Lakes

2.3 Watershed & Land-Use Goals

Cooperation between the four watershed Towns: Bolton, Vernon, Coventry, and Tolland, will be vital for the long-term management of the Bolton Lakes. The Towns must commit to including the lakes in their respective Plans of Conservation and Development (POCD), when updated. The Bolton Lakes Watershed Conservation Alliance will maintain communication between the Town Conservation Commissions and Inland Wetland Commissions to ensure lake-smart land-use decisions are made. The Town Planning and Zoning Commissions should also remain abreast of lake and watershed management plans.

Overarching Watershed Goals:

- Habitat preservation
- Maintain and improve open space and public use
- Encourage 'Lake Smart' homeowner practices
- Implement Low Impact Development (LID) in the watershed
- Prevent excessive nutrient runoff from the watershed
- Erect road signage that identifies the Bolton Lakes regional watershed

The Watershed Management Plan (WMP) section of this document has specific recommendations for various sites in the watershed. The overarching goal is to adequately follow through with the WMP.

2.4 Procedural Goals

2.4.1 Drawdown/Refill

The main goal for drawdown and refill operations for Upper, Middle, and Lower Bolton Lakes is to ensure stakeholders develop strategies and procedures that increase the effectiveness and efficiency of the existing lakes drawdown protocols. This effort to coordinate drawdown goals began in 2011 and CT DEEP approved an annual joint Bolton and Vernon Memorandum of Understanding in 2019. Since that time, the Towns have proceeded with annual formal requests to CT DEEP for an 18-inch winter drawdown in Middle and Lower Bolton Lakes. Residents wish to further increase communication with CT DEEP about the procedures used for opening and closing the three flow valves. CT DEEP has recently provided FBL information on Middle and Lower dam valve operations, which will help calculate the volume of water flowing through the Bolton lakes during the winter to spring season.

In November 2020, two temperature and water level loggers were installed, one in Middle and one in Lower Bolton Lake. These loggers will continue to provide information about the seasonal and stormwater-related changes in lake water volume, which is important for estimating nutrient mass inflows and outflows. Volunteers have been trained to periodically download water level logger data and the information will continue to inform both drawdown and refill goals, as well as improve the understanding of the lakes' hydrology. FBL is the lead entity responsible for maintaining water level loggers and data organization. The goal of drawdown is not aquatic plant management, as much of the existing aquatic invasive species grow in water depths greater than 6ft deep in Middle and Lower Bolton Lakes. Further reasoning is provided in the Aquatic Plant Management section.

2.4.2 Fisheries Management

The Towns of Vernon and Bolton would like to have meaningful dialogue with CT DEEP Fisheries Department and would like to request formal planning, notification, and documentation of fisheries management actions from CT DEEP. Fish are a critical ecological and recreational component to the Bolton lakes, and improved communication between the Town, consulting Lake Managers, and DEEP are vital to maintaining a balance between the many desired lake uses. Bolton and FBL should retain the raw data for the phytoplankton and zooplankton monitoring to date.

2.4.3 Public Engagement

Continue to promote resident engagement in the management of the Bolton Lakes through a variety of outreach events and educational seminars.

- Educational welcome brochure distribution and updates
- AIS Training – formal through CT DEEP Invasive Investigators Program & through the FBL program
- FBL bi-annual forums & public endowment program
- FBL portal to report invasive plants and aquatic life questions from residents
- Promote the FBL website that links visitors to various resources about caring for and sustaining a healthy watershed
- Annual 'state-of-the-lakes' review for Town Counsel members of each Town in the Bolton Lakes watershed
- Maintain representation of all four watershed Towns on the Bolton Lakes Watershed Conservation Alliance
- Town of Bolton website, including history and record of past reports

2.4.4 Volunteer Monitoring

Maintain funding for the ongoing volunteer water quality monitoring program at Middle and Lower Bolton Lakes. Funding should be allocated annually as a line item in Vernon and Bolton's Town budgets, for Middle and Lower lakes respectively. Maintain open lines of communication between the consulting Lake Manager, DEEP, and volunteers. Follow the approved Bolton Lakes Volunteer Monitoring Quality Assurance Plan. Please see the Volunteer Monitoring Quality Assurance Plan for the proposed seasonal sampling plan and predicted annual monitoring costs. Note that actual monitoring costs may change slightly based on updated management goals and actions.

2.4.5 Cyanobacteria Bloom Notifications

Maintain a line of communication between residents, FBL, the Lower Bolton Lakes Commissioner, the Middle Bolton Lakes liaison and/or the consulting Lake Manager. Residents should be able to report a suspected cyanobacteria bloom with photos, approximate locations, and time and date to the Lower Bolton Lake Commissioner through the FBL website. The Commissioner will formally notify CT DEEP, CT Department of Public Health, and the consulting Lake Manager of the potential bloom. Residents should be notified of initial professional comments and recommendations based on reported photos, within a reasonable time period. CT DPH and/or DEEP will notify the Town of Vernon and Town of Bolton Selectpersons and Town Managers if they plan to post a cyanobacteria bloom advisory or beach closure. The Towns will follow up with appropriate communication to residents. Residents may also report cyanobacteria blooms via additional channels, such as directly to the CT DEEP, through the Environmental Protection Agency (EPA) Region 1 Cyanobacteria Bloom Monitoring Program app.

3 Bolton Lakes Management Program & Waterbody Status

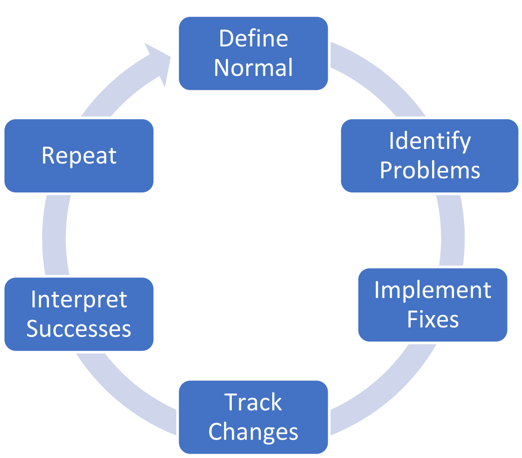
Since the momentous 2012 cyanobacteria bloom, the Bolton Lakes Management program has been led by the Towns of Bolton and Vernon, the Friends of Bolton Lakes nonprofit, and Northeast Aquatic Research, as a consultant to both Towns individually.

Lake management requires adequate scientific monitoring and professional oversight. Lakes are complicated ecological systems, and inadequate monitoring or understanding of an ever-changing system will lead to misuse of funds and unintended negative consequences. In many ways, the 2012 cyanobacteria bloom was a wake-up call for the entire state of Connecticut. There are countless examples across the country where inadequate monitoring and management led to rapid deterioration of lake condition, in terms of both water quality and the dominance of aquatic invasive species. As a public resource, the Bolton lakes are inherently threatened by overuse and the *Tragedy of the Commons* (G. Hardin, 1968). Ongoing and collective management and funding are required to keep the lakes in a condition suitable for recreation and to continue to meet CT Water Quality Standards designated waterbody uses. The rate of development that the Bolton lakes have seen since the 1950s is not sustainable, and it is now, more than ever, critical to maintain balance and preserve the natural beauty that the lakes exemplify.

The following diagram represents a simplified cycle of successful 'Lake Management.' It is essential to define the bounds of normal conditions through routine monitoring. Monitoring data and analysis serve as early warning signs for impending or passing threats. Monitoring data guides lake management implementation decisions and helps lake managers interpret successes or failures, often to lead Towns through long-term adaptive management.

'Lake Management' is also community management. Stakeholders will inevitably have competing interests, and sometimes lake management decisions are most heavily weighed by public perception. With the STEAP grant financial aid, the Town of Bolton has done an outstanding job increasing public awareness and understanding of lakes, including the intricacies of cyanobacteria bloom management. The Town of Vernon and Friends of Bolton Lakes have also been incredibly successful at managing the new infestation of invasive Fanwort, since its discovery in July 2017. Conversations about lake management *have* begun to change in a positive way.

Scientific Monitoring to Track Change & Success



Lead Stakeholders

1. Towns Bolton, Vernon, Coventry & Tolland
2. Lake property owners associations
3. Friends of Bolton Lakes
4. Bolton Lakes Watershed Conservation Alliance
5. Northcentral Conservation District
6. CT DEEP
7. CT DPH

3.1 Water Quality Status Assessment

This section serves to detail the lake monitoring, data collection, and analysis in recent years. There is an initial discussion of the CT Water Quality Standards and state trophic classifications. Then the text builds on previous water quality reports for Lower and Middle lakes by presenting the current understanding of the Bolton lakes physical, chemical, and biological conditions. The majority of the data collected since 2012 is from Lower Bolton Lake, but Middle Bolton Lake data is also included.

3.1.1 Monitoring Components Overview

The text from the following section has been reproduced from the Lower Bolton Lake 2019 Status Update report (NEAR, 2020).

Water clarity measurements use an 8-inch circular black and white **Secchi disk** attached to a measuring tape. The disk is lowered into the water on the shady side of the boat. Using a view scope to shade out light in one's peripheral vision, the Secchi disk is lowered until it disappears from view in the water column. The depth at which the Secchi disk disappears from view is considered the water clarity measurement. Secchi clarity is dependent on light penetration. Light penetration is affected by phytoplankton, suspended sediments, and microscopic organic matter in the water column. Clearer waterbodies have greater Secchi transparency values. Lakes and ponds experience fluctuations in Secchi clarity throughout the season, typically driven by increases or decreases in nutrients that stimulate phytoplankton growth.

Phytoplankton samples are collected using a 3-meter algae tube to collect a composite of the top three meters of water, and sub-samples are examined microscopically after preservation with Lugol's iodine. Identification and enumeration follow Standard Methods. Potentially toxigenic cyanobacteria cells/mL are used to evaluate the potential human health risks. Toxin testing is only performed if the lake meets the Connecticut Public Health Recreational Guidelines for Cyanobacteria Visual Rank Category 3. Testing would be performed by the CT DPH. https://portal.ct.gov/-/media/Departments-and-Agencies/DPH/dph/environmental_health/BEACH/Blue-Green-AlgaeBlooms_June2019_FINAL.pdf?la=en

Temperature in lakes and ponds in the northeast follows a seasonal pattern of warming and cooling. Following ice-melt in early spring, lakes and ponds will be more or less uniform in temperature from top to bottom. Temperature measurements should be made at one-meter increments from the lake surface to the bottom on at least a monthly basis. Combined, measurements at all 1-meter depth increments are referred to as a lake profile. Profile measurements change as the sun's rays penetrate into the water column. Clearer water allows for greater sunlight penetration and deeper warming during the summer. The depth and development of a **thermocline**, or the zone of rapid temperature change, is dependent on water depth, surface area of the lake, climatic conditions, and water clarity. A thermocline effectively isolates top and bottom waters during summer months because warm water at the surface is less dense than the cold water at the bottom of the lake. In the fall, the lake cools off as air temperatures drop, resulting in a weakening thermocline and eventually water "turn-over." Lake turnover simply means that the temperature becomes uniform from top to bottom and that there is no longer a thermocline. In lakes deeper than 20ft in the northeast, this turnover traditionally occurs in the spring and the fall. Shallower lakes are more dependent on weather and may experience multiple thermal mixing events in a season. Very large and deep lakes often have more complicated temperature dynamics that require multiple monitoring sites.

Dissolved oxygen in a lake is essential to aquatic organisms. At the surface of a lake, the water is in direct contact with the air, and atmospheric oxygen is dissolved into the water as a result of diffusion. Water mixing, driven by wind and temperature currents, circulates this oxygen throughout the water column during spring and fall mixing periods. Yet because lakes warm non-uniformly, the thermocline that develops in summer months will temporarily cut off the bottom waters from surface water circulation of oxygen. In lakes with very little decomposing plant material at the bottom, this is not usually a problem because there is enough oxygen to sustain the lake through the summer months. More nutrient-rich lakes, however, can be depleted of oxygen in the bottom waters below the thermocline. This phenomenon results in **anoxic** (<1mg/L) conditions in deeper waters of many lakes. An absence of oxygen changes the bottom chemistry for multiple months. It is critical to track oxygen loss beneath the thermocline and/or the level of the **anoxic boundary**. The anoxic boundary is defined as the depth of water at which dissolved oxygen is depleted in the summer. Anoxia typically worsens towards the end of summer, just before fall 'turn-over,' which will eventually replenish oxygen to the bottom, even in polluted lakes. Anoxia also tends to worsen over time. However, recent 2020 monitoring data demonstrates that Lower Bolton Lake anoxia varies substantially based on severe weather events. Lakes and ponds with severe oxygen problems during summer months experience increased nutrient levels at the lake bottom. This is the result of changing chemistry due to the presence or absence of oxygen, termed “internal loading.”

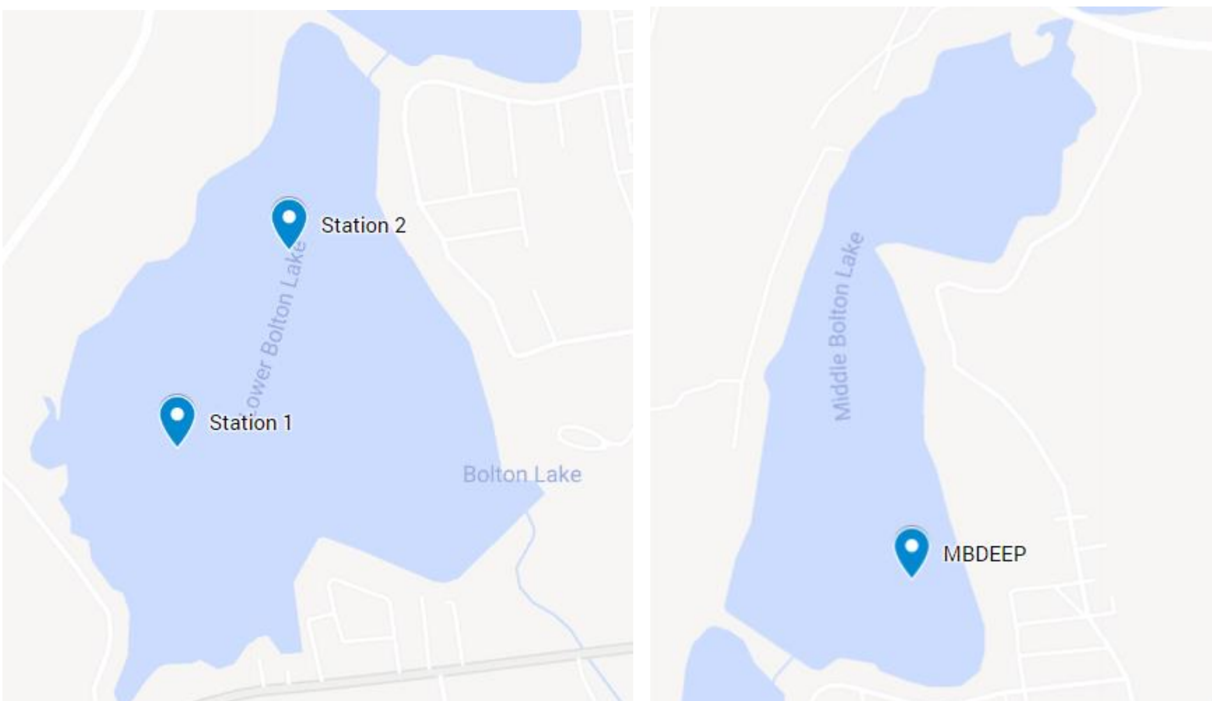
Lake Nutrients Samples: Water samples are collected monthly to bi-monthly from April to October in the deepest part of the lake. At Lower Bolton, a second monitoring station was sampled from 2016-2019 to ensure that data from the deep spot was representative of the entire lake. The most critical times for sampling are early spring, mid to late summer, and the fall. Sampling depths usually incorporate top, middle, and bottom depths. Water samples are typically analyzed for total phosphorus, total nitrogen, ammonia nitrogen, and nitrate nitrogen. In baseline assessments, a number of additional parameters are also needed. ***Phosphorus*** and ***Nitrogen*** are the two principal plant nutrients that drive aquatic plant and algae growth. Due to lake temperature stratification, these nutrients are not usually present in the same quantities throughout the lake. Typically, the bottom of the lake has more phosphorus and nitrogen as the summer progresses because bottom-sediments release nutrients when oxygen is depleted from the bottom waters. Just as anoxia increases over time, phosphorus and nitrogen also tend to increase over time as a waterbody becomes more eutrophic, meaning dominated by plants and algae. Nutrient results are compared to identify patterns in internal sediment release versus external watershed loading. All water quality management decisions rely on accurate nutrient testing with very low limits of detection.

Relative Thermal Resistance to Mixing (RTRM) is a unit-less ratio that describes the difference in water density between each meter. Higher numbers indicate stronger thermal **stratification**. Stratification is the result of density differences as warming surface waters become less dense than cold deeper water. The RTRM is a relative number that distinguishes the intensity and depth of the thermocline. RTRMs describe how the lake is or is not mixing with respect to layers of water at specific depths. RTRMs also show when the lake becomes de-stratified as the result of temperature changes or excessive wind energy that can overcome thermal density boundaries. RTRM measures are important for predicting cyanobacteria blooms, because cyanobacteria thrive during periods with very high RTRM values in the water column.

Percent Oxygen Saturation is the percentage of dissolved oxygen at a given depth, relative to the water's capacity to hold oxygen, which is based on its temperature. For instance, 50% O_2 saturation means that the water contains only half of the dissolved oxygen that it is able to hold at its current temperature. In essence, anything less than 100% means that the biological oxygen demand, or rate at which oxygen is used up, is depleting the water of oxygen at a rate faster than it can be replenished. A percentage greater than100% is frequently a result of excessive phytoplankton production of oxygen that causes the water to be supersaturated.

Metals & other lab tests: Other metals that are involved in the amount and availability of phosphorus (the key plant nutrient in most freshwaters), are Iron and Manganese. Calcium and chloride levels may also be tested, though less frequently as they tend to be more conservative, showing little change across seasons. Other parameters tested at the Bolton lakes are Alkalinity, pH, and conductivity.

Map 5: Lake Monitoring Locations at the Bolton Lakes: 5A. Lower Bolton Lake, 5B. Middle Bolton Lake



3.1.3 CT Water Quality Standards for Lakes

The Connecticut Water Quality Standards (WQS) Section 22a-426-6 (a) defines the "Lake Trophic Categories" based on ranges of Total Phosphorus, Total Nitrogen, Chlorophyll-a, and Secchi disk transparency, and/or (b) the percentage of the lake's surface area covered by aquatic plants. CT DEEP uses these standards to assess the quality of the state's lakes and ponds and to report on whether the lake is or is not meeting designated uses, primarily recreation and habitat. On average, both Middle and Lower Bolton fall into the mesotrophic category, but both lakes have also presented temporary eutrophic summer conditions.

The term *Impaired* refers to the formal classification and listing of a waterbody on the 303d list of *Impaired Waters*. If CT DEEP determines that a waterbody no longer meets the designated uses, then it will be listed in the CT Integrated Water Quality Report to EPA and Congress, and listed as *Impaired*.

CT Water Quality Standards
https://portal.ct.gov/-/media/DEEP/water/water_quality_standards/wqsfinaladopted22511pdf.pdf

Table 4: CT State Water Quality Standards - Trophic State Parameters

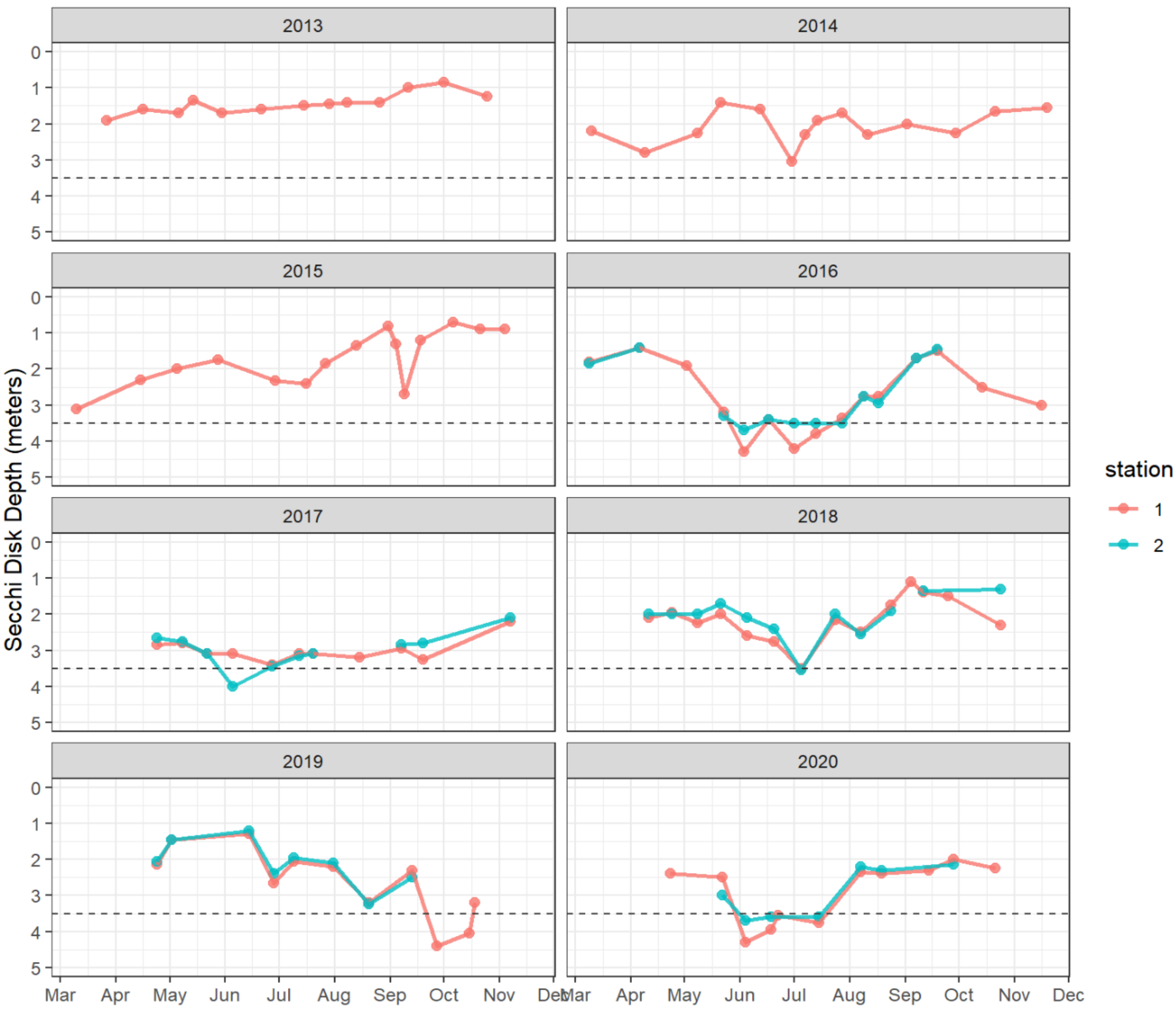
Parameters and Defining Ranges for Trophic State of Lakes in Connecticut		
Trophic State Based on Water Column Data	**Parameters**	**Defining Range**
Oligotrophic	Total Phosphorus	0-10ug/L spring and summer
	Total Nitrogen	0-200 ug/L spring and summer
	Chlorophyll-a	0-2 ug/L mid-summer
	Secchi Disk Transparency	6+ meters mid-summer
Mesotrophic	Total Phosphorus	10-30 ug/L spring and summer
	Total Nitrogen	200-600 ug/L spring and summer
	Chlorophyll-a	2-15 ug/L mid-summer
	Secchi Disk Transparency	2-6 meters mid-summer
Eutrophic	Total Phosphorus	30-50 ug/L spring and summer
	Total Nitrogen	600-1000 ug/L spring and summer
	Chlorophyll-a	15-30 ug/L mid-summer
	Secchi Disk Transparency	1-2 meters mid summer
Highly Eutrophic	Total Phosphorus	50+ ug/L spring and summer
	Total Nitrogen	1000+ ug/L spring and summer
	Chlorophyll-a	30_ ug/L mid-summer
	Secchi Disk Transparency	0-1 meters mid-summer

3.1.5 Water Quality Data

Lower Bolton Lake water quality data was collected at least monthly from spring to fall from 2013-2020. The Lower Bolton data presented in the following sections was collected by Northeast Aquatic Research under the STEAP grant program, overseen by CT DEEP. Beginning in 2018, FBL also began collecting limited Middle Bolton water chemistry data. The FBL and NEAR data have been organized into the same format so that it can be easily shared and compared into the future. The following data assessment is the basis for previously stated water quality targets for Middle and Lower Bolton Lakes.

Water clarity (Secchi disk depth)

Figure 1: Lower Bolton Water Clarity (for consistency only NEAR values in this figure)



Horizontal dashed line, above, indicates the approximate depth of Station 2 sampling area

Table 5: Lower Bolton Mean Jul-Oct Transparency - Mesotrophic

CT WQS Trophic Classifications	Secchi Transparency
Oligotrophic	6+ meters summer
Mesotrophic	2-6 meters summer
Eutrophic	1-2 meters summer
Highly Eutrophic	< 1 meter summer

Lower Bolton 2012-2021 mean summer Secchi = 2.3 meters (upper Mesotrophic category, but sometimes Eutrophic)

Figure 2: Lower Bolton 2021 Water Clarity (measured by FBL volunteers w/view scope)

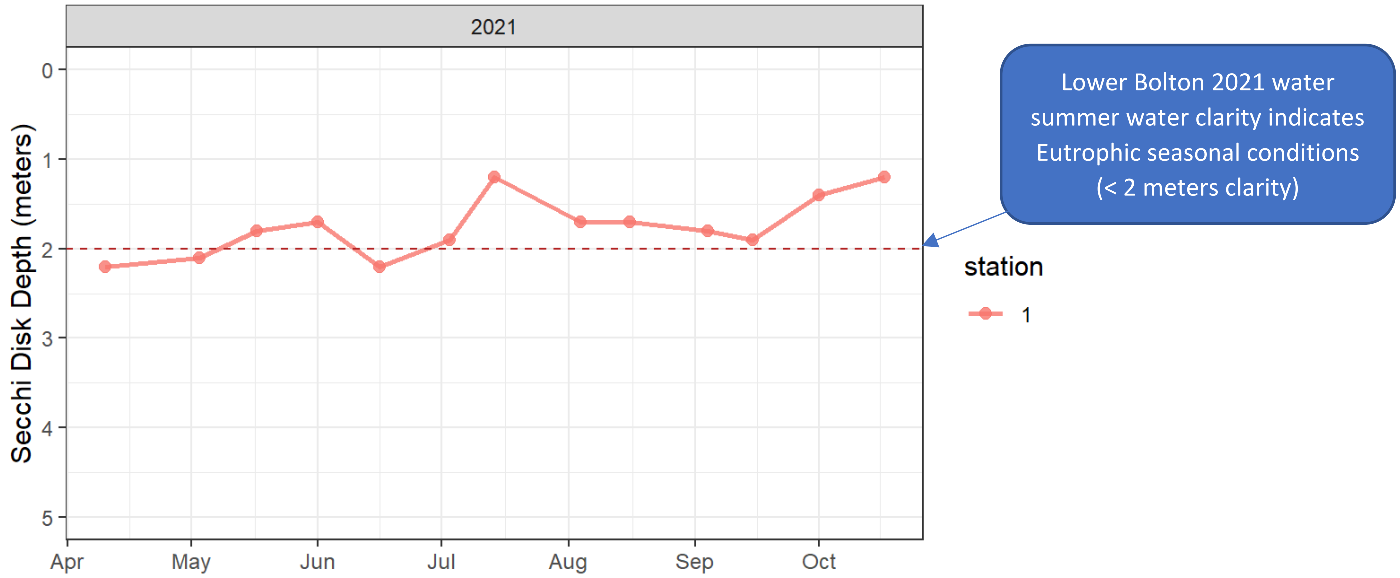


Figure 3: Middle Bolton Water Clarity, 2019-2021

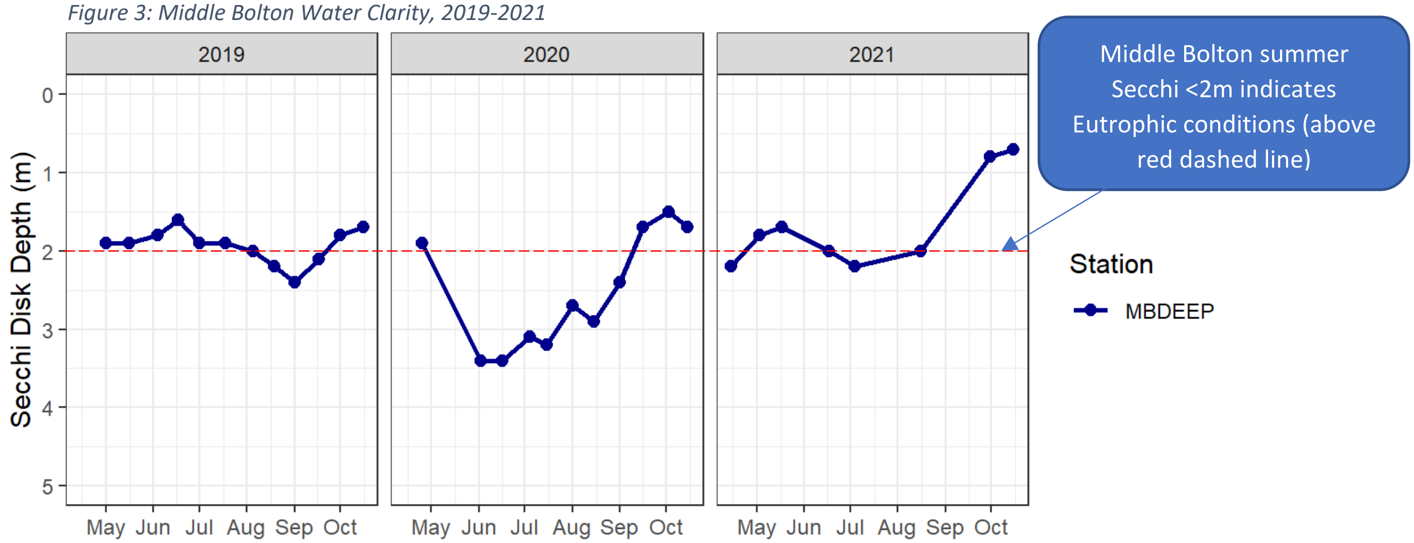


Table 6: Middle Bolton Mean Transparency - Mesotrophic

CT WQS Trophic Classifications	Secchi Transparency
Oligotrophic	6+ meters mid-summer
Mesotrophic	2-6 meters mid-summer
Eutrophic	1-2 meters mid-summer
Highly Eutrophic	< 1-meter mid-summer

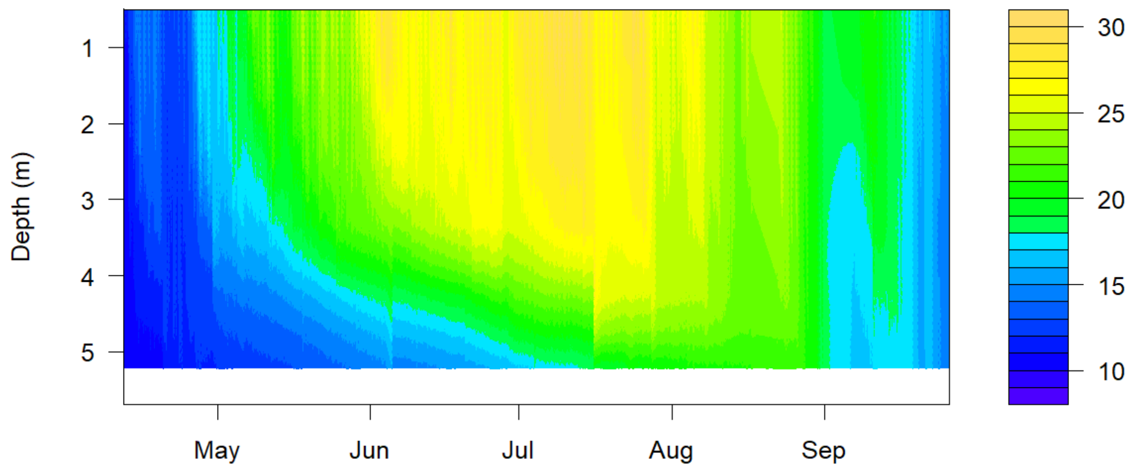
Middle Bolton 2019-2021 mean summer Secchi = 2.3 meters (upper Mesotrophic category)

Note that 2019, 2020, and 2021 were very different years for Middle Bolton water clarity. MBL experienced very poor clarity during a cyanobacteria bloom in September and October 2021.

Temperature

Temperature data was collected in two ways at Lower Bolton Lake: during monitoring visits in conjunction with dissolved oxygen profile monitoring, and through a string of continuous data loggers sponsored and maintained by FBL. Logger data, shown below, provides a detailed view of the thermal stratification and mixing events throughout the **Lower Bolton 2020 season**, much beyond what the traditional temperature and oxygen profile measures provide. It is the thermal stratification that allows for potential oxygen depletion in the deeper waters of the lake. Additional temperature profile data for Lower and Middle Bolton Lakes is available in raw data format, including high resolution 2021 temperature data.

Figure 4 - High Resolution 2020 Lower Bolton Temperature Isopleth



Dissolved Oxygen

Dissolved oxygen profiles were measured during field visits by NEAR and FBL. Oxygen data loggers are considerably more expensive, roughly ten to twenty times the cost of a single temperature continuous logger, and so there is no high-resolution temporal oxygen monitoring data. However, the bimonthly field visits by NEAR and FBL have provided good understanding of the seasonal oxygen loss dynamics. The data collected in 2020 shows that Lower Bolton Lake is definitively partially polymictic – where large wind-driven mixing events occur throughout the summer. This has implications for internal phosphorus loading from benthic sediments.

The average number of anoxia days was used in the determination of the internal sediment-release phosphorus mass estimates. As previously mentioned, the Middle Bolton goal for dissolved oxygen is for the anoxic boundary to be less than 1.5m off the lake bottom, or roughly 3.5m deep, indicated by the horizontal red dashed line. The goal for Lower Bolton is a 4m anoxic boundary in the deep hole station. The 2021 FBL monthly profile monitoring recorded the worst oxygen conditions of the season in June and July, with both values worse than the 4m target anoxic boundary (3.5m was the worst/shallowest anoxic boundary of 2021, recorded in mid-June).

Figure 5: Lower Bolton Lake Anoxic Boundary 2013-2021

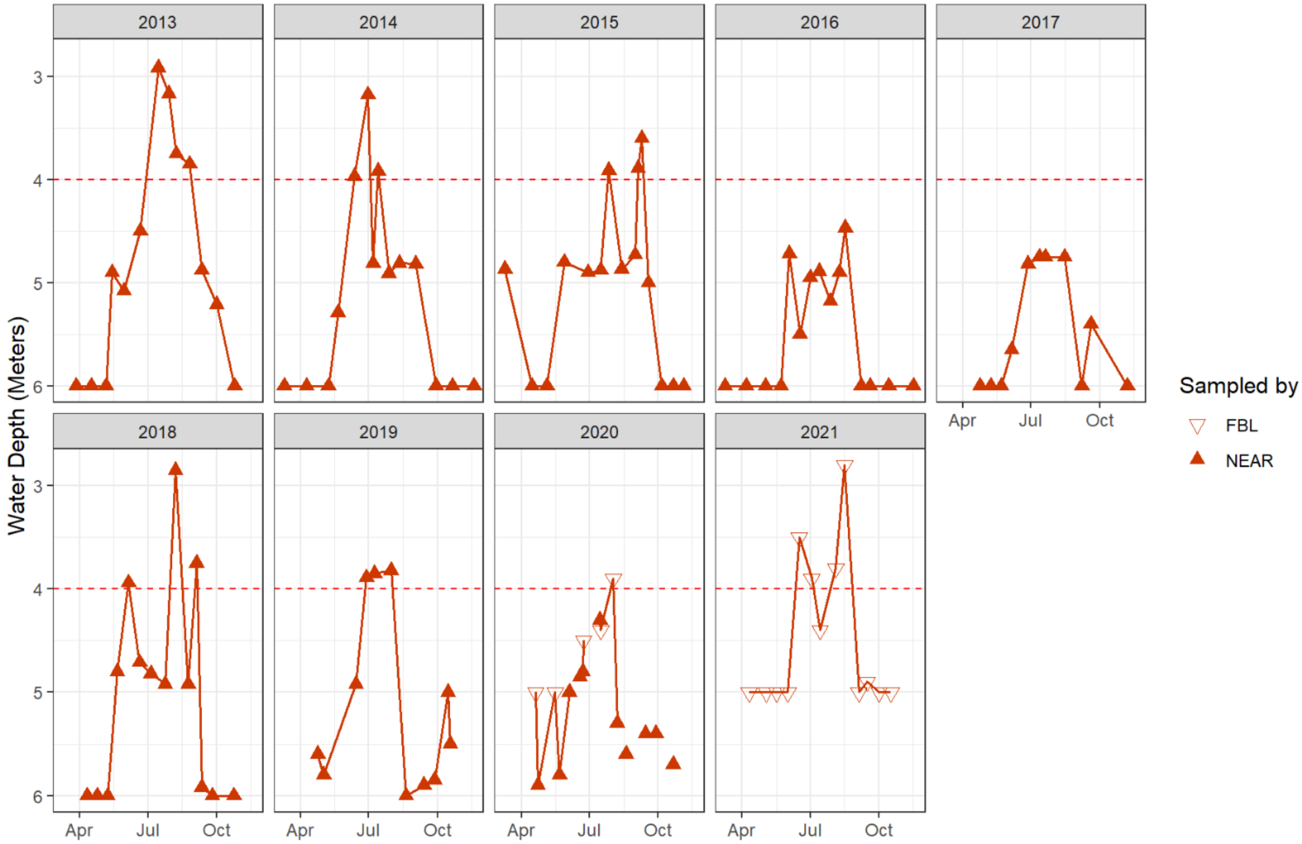


Figure 6: Middle Bolton Lake Anoxic Boundary 2019-2021 (sampled by FBL volunteers, Hach LDO meter)

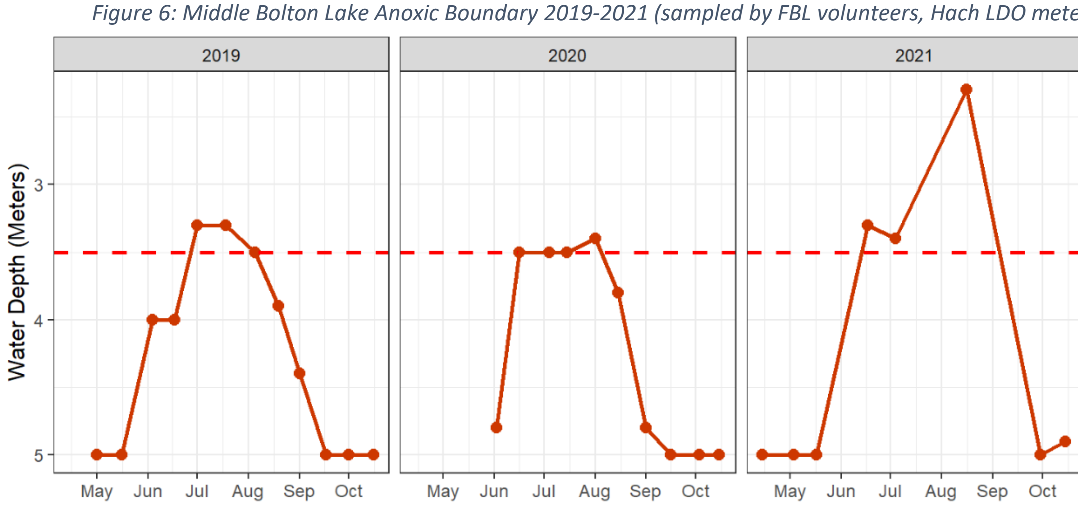
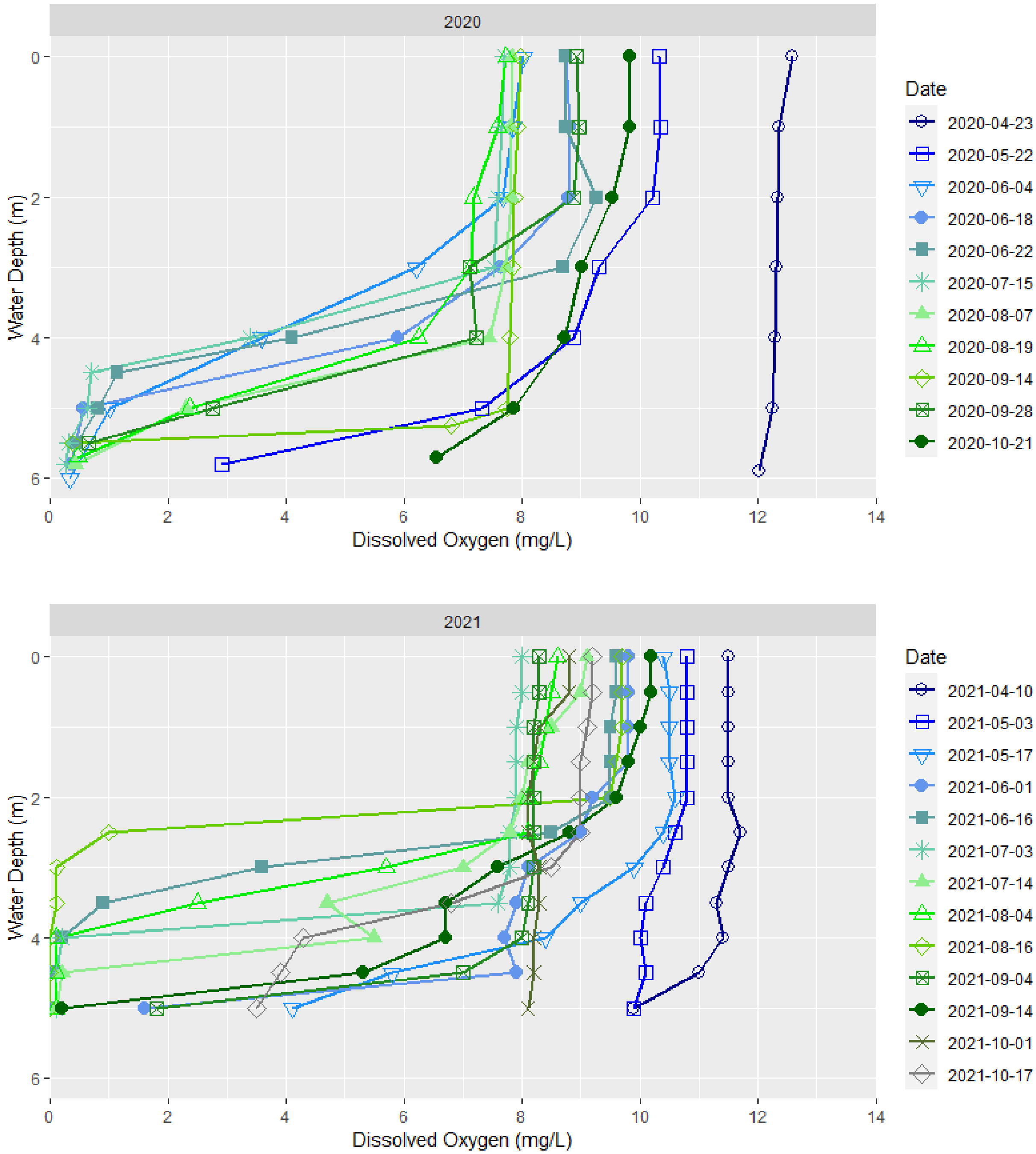


Figure 7: (A) Lower Bolton 2020 & (B) 2021 Dissolved Oxygen Concentration Profiles (NEAR+FBL data in 2020, FBL data in 2021)



Additional Profile Data

On NEAR sampling visits, conductivity profiles were measured from top to bottom. FBL volunteers also measured pH profiles. In previous years, NEAR measured both pH, redox potential, and light. All sampling data has been tabulated and is available for public sharing through the Town of Bolton and FBL.

The normal pH range for Middle Bolton Lake surface waters is 6.7 – 7.3. The normal pH range for Lower Bolton Lake surface waters is 6.8 to 7.4. Redox potential is highly variable and dependent on the oxygen loss severity and placement of the thermocline in the water column. The lowest redox potential measured at the bottom of Lower Bolton Lake was -252 mV. Iron-bound phosphorus dissolution typically occurs at redox potential values less than 100-200 mV. Redox potential greater than 300 mV is expected throughout the oxygenated water column, and redox potential below the anoxic boundary declines rapidly. The conductivity (specific conductance) range in Lower Bolton surface waters in 2020 was 143 to 159 µS/cm.

Phosphorus

Total Phosphorus concentrations from Lower Bolton Lake are displayed below. Surface TP has been significantly lower in most recent years, with few values exceeding the target threshold of 20 µg/L (ppb). There were no surface exceedances of the eutrophic 30 µg/L (ppb) threshold from 2017-2020, however 2021 experienced increased surface TP with multiple sampling dates above the 20 and 30 µg/L (ppb) target water quality. No St2 samples were taken in 2020 or 2021.

Figure 8: Lower Bolton 1-meter Total Phosphorus Concentrations (Station 1 & 2)

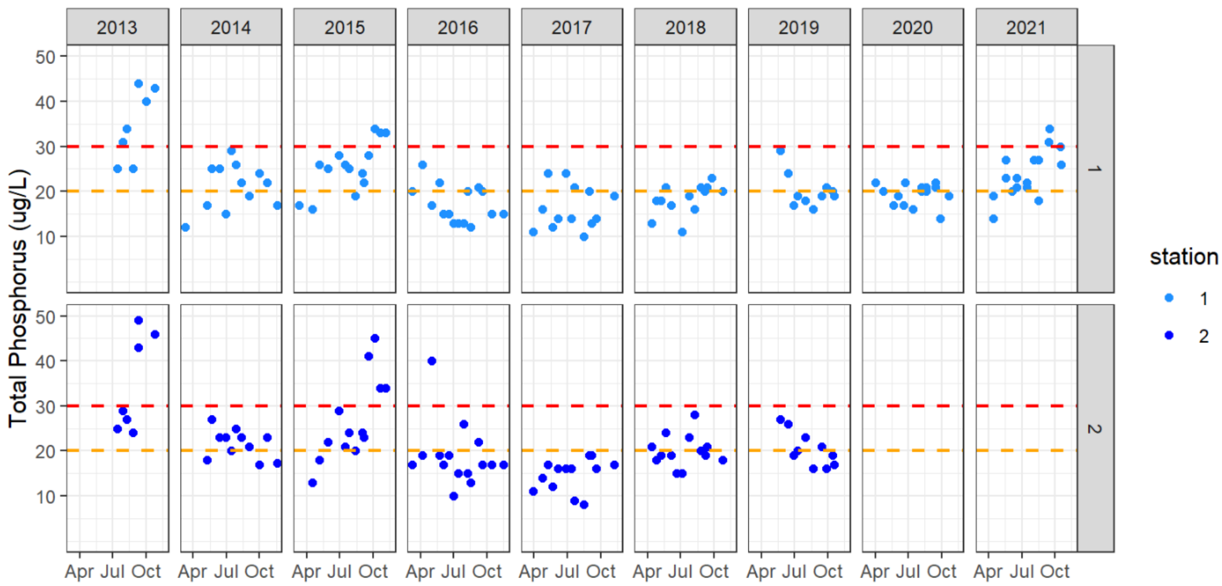
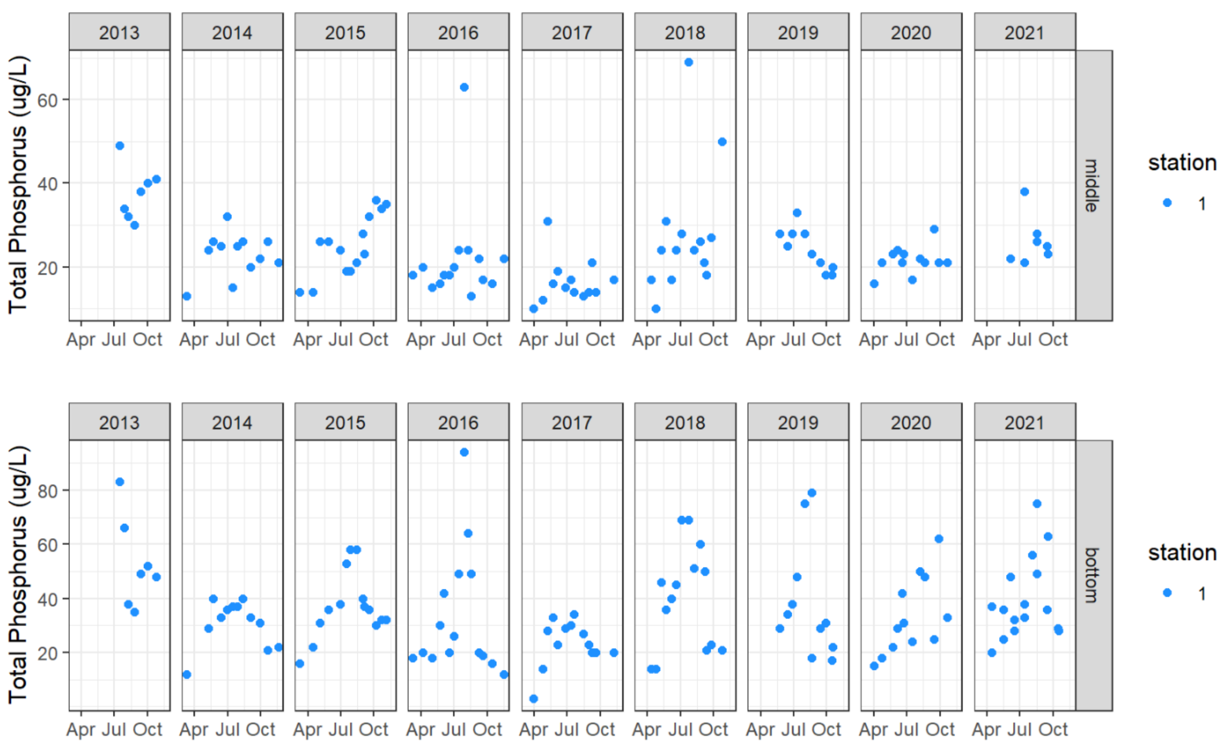
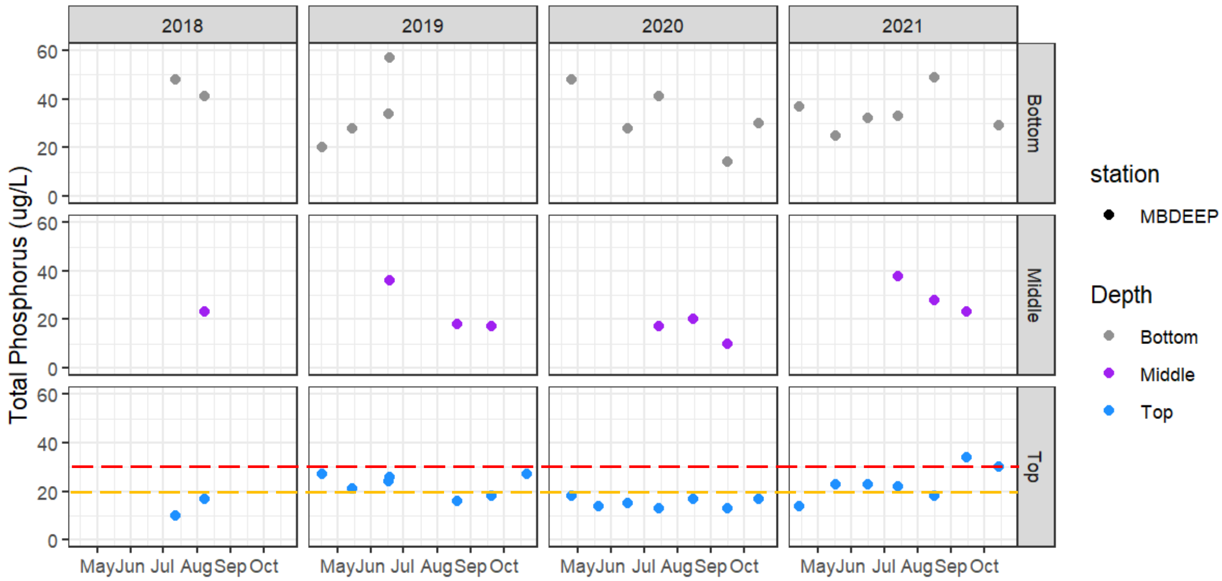


Figure 9: Lower Bolton Station 1 (Middle and Bottom-water Total Phosphorus concentrations)



Note that middle and bottom concentrations are significantly higher than surface concentrations, due to internal P loading.

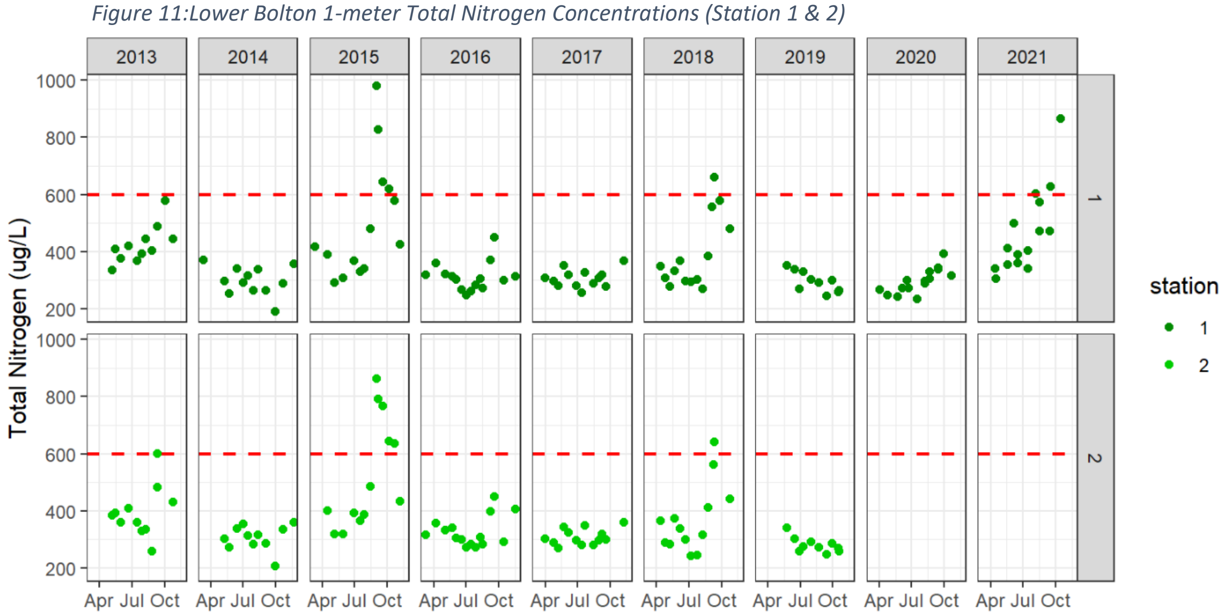
Figure 10:Middle Bolton Total Phosphorus Concentrations



Nitrogen

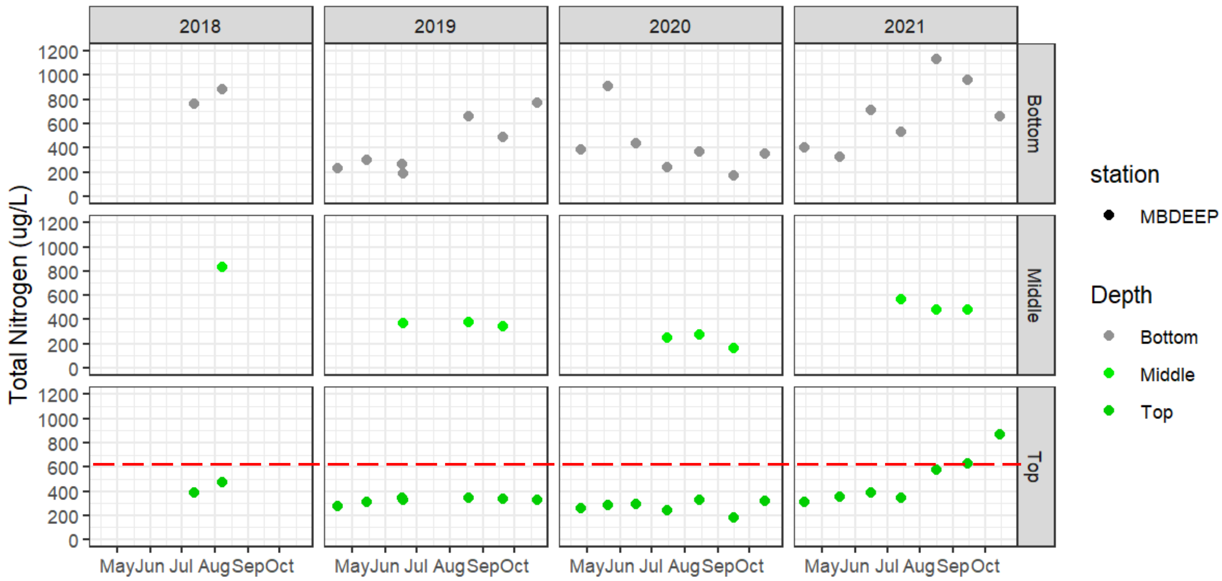
Surface nitrogen in Lower Bolton Lake during the 2012 cyanobacteria bloom reached over 2000 µg/L (ppb). Total Nitrogen has not been that high in Lower Bolton since that time. The TN increases in Lower Bolton in 2015 and 2021 coincided with prolonged cyanobacteria blooms. Surface TN has almost always been below the 600 µg/L (ppb) eutrophic threshold, but in 2021 that threshold was exceeded at the end of the season. The 2019 and 2020 TN values were very good, but the 2021 values were subpar, placing the lake in the Mesotrophic-Eutrophic (CT WQS) categories, depending on the year. Additional nitrogen fractions data from Lower Bolton Lake is available through FBL and the Town of Bolton.

Figure 11:Lower Bolton 1-meter Total Nitrogen Concentrations (Station 1 & 2)



Surface (Top) TN at Middle Bolton Lake exceeded the 600 µg/L (ppb) eutrophic threshold on two sampling dates at the end of 2021, but on none of the prior samplings since 2018. The high TN in September and October 2021 coincided with a cyanobacteria bloom.

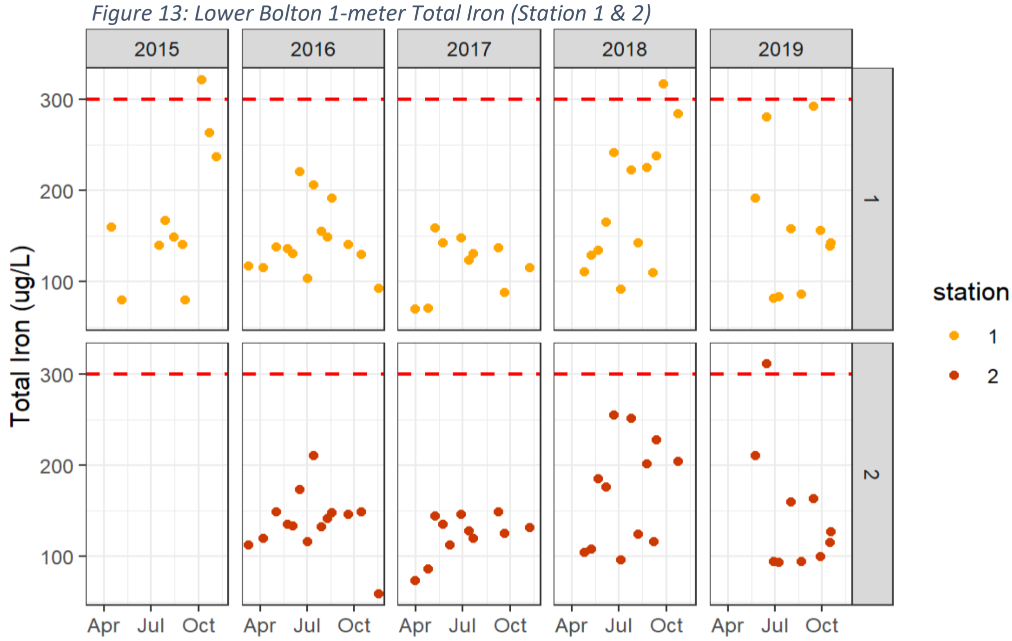
Figure 12: Middle Bolton - Total Nitrogen concentrations



3.1.5.4 Additional Water Chemistry Data

Total iron was measured in Lower Bolton Lake only. No iron data was measured in 2020. A subset of surface iron data, from 2015 through 2019, is displayed below. Initial investigation into the cyanobacteria bloom causes at Lower Bolton suggested that iron was a contributing factor, but recent years of water quality suggest that measuring total iron is not a good indicator of Lower Bolton Lake water quality, and high iron in surface waters does not always correlate with high phosphorus or nitrogen.

Figure 13: Lower Bolton 1-meter Total Iron (Station 1 & 2)



Volumetric Nutrient Mass Models

As part of the in-lake nutrient mass modeling effort, the Lower and Middle Bolton Lakes 3ft contour bathymetry maps were used to create a 0.25ft resolution estimate of the surface area and volume vs. depth. The red points represent the depths of the CT DEEP contour lines for Lower Bolton Lake, which were used to calculate the volume curve. The 0.25ft model contours were then converted to metric units and three distinct volume layers were summed; representing the top, middle, and bottom layers of the lake and corresponding to the sampling depths for nutrient testing. Mass calculations were emphasized for Lower Bolton only, because there was much more data available. Mass calculations can be done for Middle Bolton, but the error range would be high, given Middle Bolton has two distinct basins and only one monitoring location. MBL volunteers should consider adding a second long-term monitoring site in the shallow basin, primarily for nutrient monitoring.

Figure 14: Lower Bolton Volume vs. Water Depth

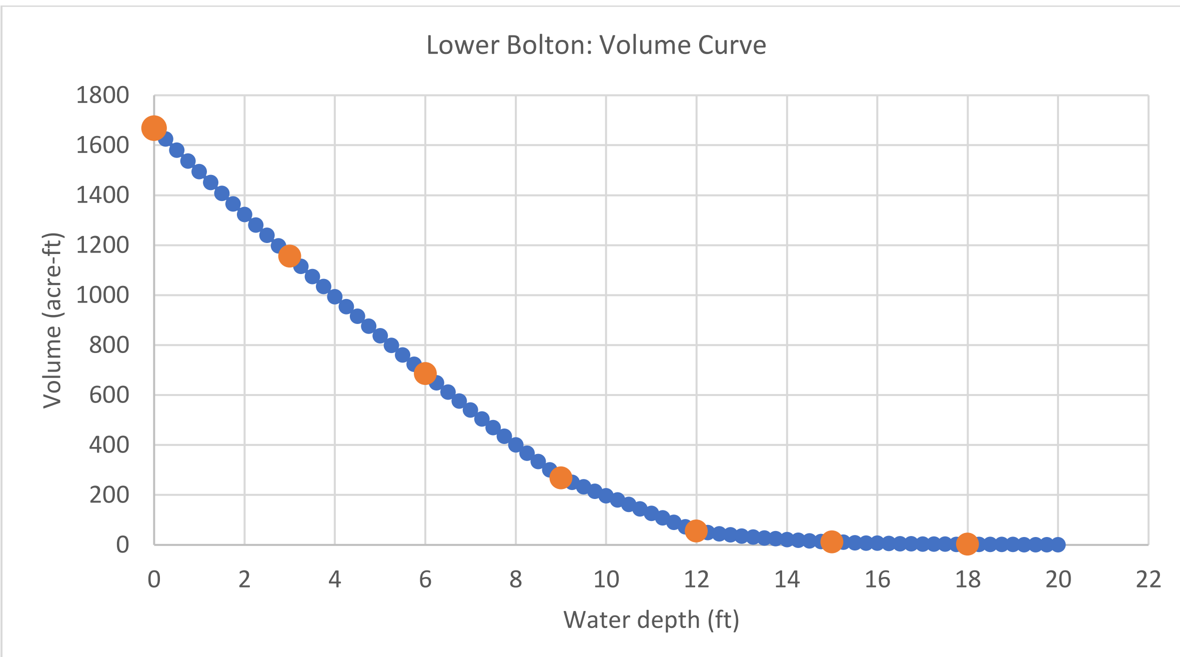


Table 7: Lower Bolton Volume Mass Calculation Model Parameters

Volume for Lower Bolton Mass Calculations				
Layer (meters)	**Volume (ac-ft)**	**Volume (m3)**	**Sample Depths (m)**	**Nutrient Values**
0-1.9	1056.42	1,303,074	1	Mean St.1 & 2
2.0-4.0	580.60	716,154	3	Mean St.1 & 2
4.0-6.0	31.34	38,653	5	St. 1 only

Mass estimates for Lower Bolton Lake are included in this report because both internal and external nutrient loading is quantified using mass (kilograms per year). Nutrient concentration data is transformed into nutrient mass, by multiplying the respective concentrations and volumes of each layer. This calculation was done across all sampling dates for Lower Bolton Lake, for total phosphorus and total nitrogen. The summary statistics of the 2014-2020 mass model results are shown below.

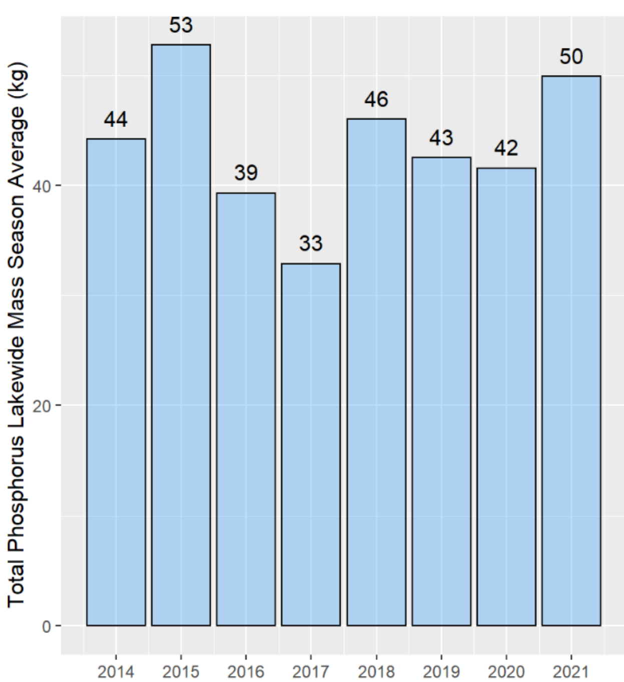
Table 8: Lower Bolton Nutrient Mass Modeled Estimates by Year

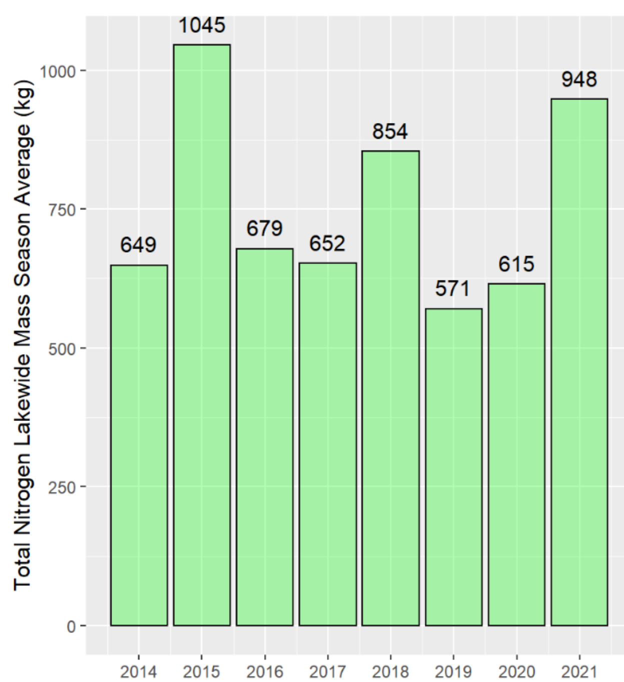
Lower Bolton: Lake-wide Phosphorus Mass (kilograms)							
Year	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Max-Min
2014	25.4	41.7	45.7	44.2	48.9	53.7	28.3
2015	29.8	46.2	50.0	52.7	64.2	77.0	47.2
2016	26.7	34.0	38.6	39.3	42.8	57.0	30.2
2017	20.7	31.6	33.6	32.9	37.0	44.3	23.6
2018	31.2	38.5	46.1	46.0	51.9	61.5	30.4
2019	17.2	38.2	42.9	42.5	47.6	57.7	40.5
2020	34.0	39.3	41.4	41.6	43.8	49.8	15.8
2021	39.1	43.6	49.9	49.9	56.7	59.7	20.6

Lower Bolton: Lake-wide Nitrogen Mass (kilograms)							
Year	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Max-Min
2014	450	601	663	649	694	793	343
2015	668	747	883	1045	1288	1796	1128
2016	532	611	658	679	700	991	459
2017	579	615	627	652	693	760	181
2018	637	672	756	854	939	1340	703
2019	202	550	607	571	637	712	510
2020	489	542	609	615	661	802	313
2021	710	826	936	948	1043	1270	560

Annual means are shown graphically for Total Phosphorus and Nitrogen.

Figure 15: Lower Bolton Seasonal Mean Mass (kilograms) Estimates by Year





Mass data also demonstrates a rough correlation with water clarity, where very high nitrogen mass in Lower Bolton Lake is correlated to poor clarity, less than 2.0 meters. Total phosphorus mass in the lake also correlates with Secchi transparency, particularly high TP to low Secchi values, but the phosphorus mass correlation is not as strong as nitrogen. This suggests that both nitrogen and phosphorus must be controlled in order to prevent future cyanobacteria blooms. The black arrows represent an estimated nutrient mass critical threshold to maintain >2.0 meters of water clarity and Mesotrophic conditions in Lower Bolton Lake. Note that in-lake nutrient mass estimates have a high error-range and these target values simply provide a reference point for understanding the external watershed vs. internal-recycling nutrient loads on an annual basis.

Figure 16: LBL Phosphorus Mass vs. Secchi

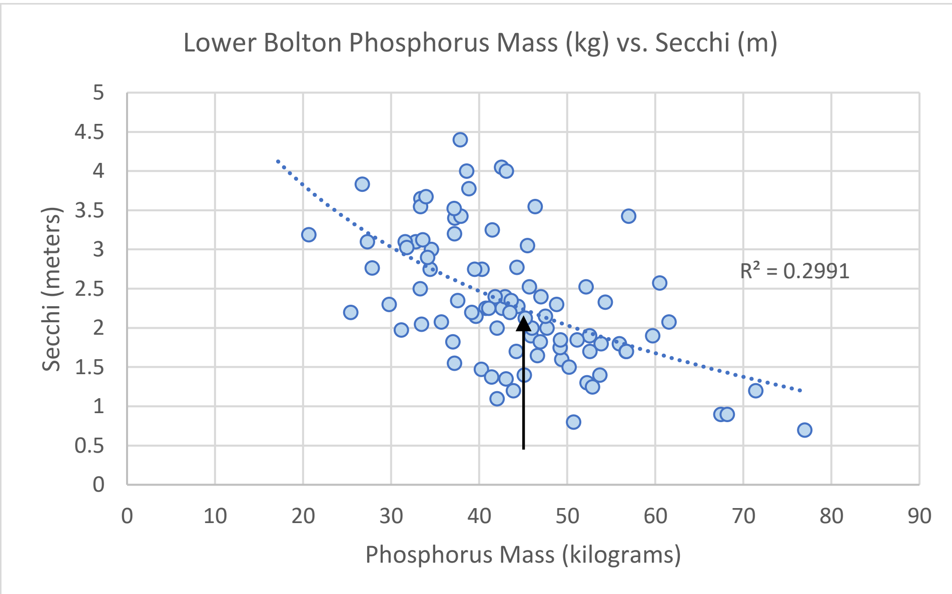
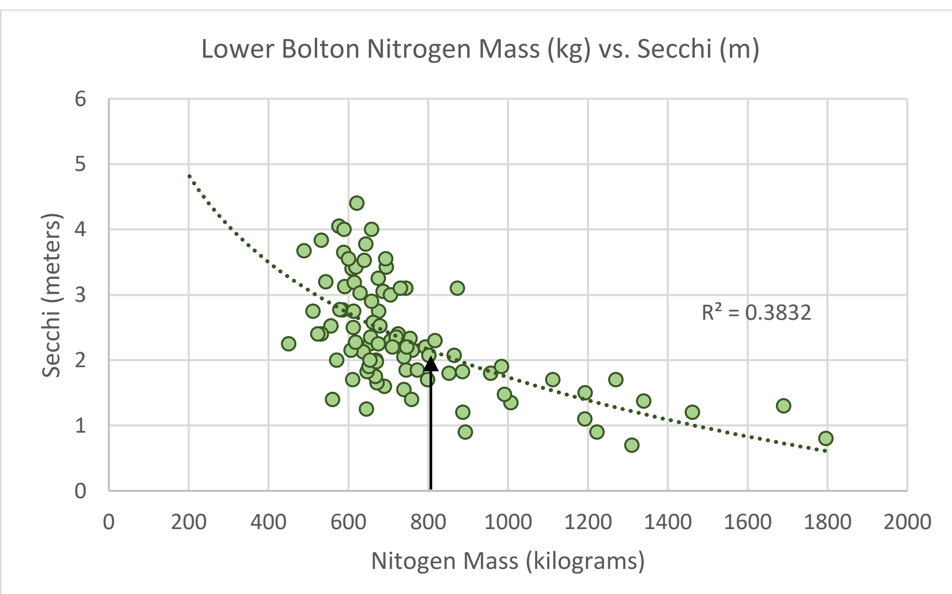


Figure 17: LBL Nitrogen Mass vs. Secchi



Sediment Nutrient Extraction Results & Load Estimates

Sediment samples were taken from both Lower and Middle Bolton Lakes in fall 2020, over one month after lake stratification had ended. Samples were collected with an Ekman dredge and represented roughly the top ten centimeters of hypolimnetic sediment. Samples were analyzed according to standard procedure for internal load assessments:

Successive extractions: NH4Cl, Bicarbonate/Dithionite, NaOH, and HCl were performed and analyzed for phosphorus. One part of Organic P was determined by digesting the residue after the inorganic fractions were extracted. Organic P includes the P after the inorganic fractions plus Biogenic P. Total P is the sum of all fractions minus Biogenic P, which is part of the Organic P fraction.

Parameter	Total-P	Loosely-bound P (NH4CL)	Fe-bound P (DITHIONATE)	Al-bound P (NAOH)	Biogenic-P	Ca-bound P (HCL)	Organic-P	Total Fe
Method#	Calc.	SM18 4500PF	SM18 4500PF	SM18 4500PF	EPA 365.1	SM18 4500PF	EPA 365.1	EPA 6010
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
L. Bolton St. 1 (LBDEEP)	2682	<2.0	748	74.2	1601	62.8	1797	28635
L. Bolton St. 1 (Dup.)	2635	<2.0	721	72.9	1542	67.1	1774	29552
L. Bolton wpt 53 (18ft)	2953	<2.0	919	79.7	1664	83.3	1871	31523
L. Bolton AVG	***2757***	***<2.0***	***796***	***76***	***1602***	***71***	***1814***	***29903***
M. Bolton St. 1 (MBDEEP)	2157	<2.0	660	1065	317	<2.00	432	27437

Sediment results demonstrate that both of the Bolton lakes have high total phosphorus in lake sediments, but roughly only 30% of the total phosphorus likely contributes to the annual anoxic internal load (loosely-bound and Fe-bound P are the largest contributors to sediment-released phosphorus in anaerobic bottom waters). The following internal phosphorus load mass calculations used an empirical model based on sediment phosphorus fractionation data (Nurnberg, 1998 & 2005). This P-load estimate will vary significantly based on the acreage of anoxic water over a season, which seems to be weather and watershed-load dependent.

Equations:
(1) Anoxic Factor (AF) = 90 days x 20-acre area / Surface Area (175ac LBL)
(2) Log(Release Rate) = 0.8 + 0.76log(Psed)
(3) AF x RR = P Load Internal (mg P/ m2)
(4) Internal load (kg) = area m^2 x mgP/m^2

Results:
AF = [Estimate used an anoxic boundary of 3.75m]
RR = [Uses mean sediment TP – could alternatively use the reducible P fraction, but that is not how this model is typically used.]
AF x RR = 140 mg P / m^2 released annually
P internal load = area in m^2 x mgP/m^2 = 11.3 kilograms / year (Lower Bolton Lake)

Input parameters make this mass a moderate estimate, as the anoxic area and duration changes from year to year. A higher-range 30-acre estimate yields ~25kg/year. Based on Middle Bolton sediment samples and anoxic boundary, the internal P load will be lower than LBL annually.

4 In-Lake Water Quality Management Options

While watershed management is critical to long-term water quality and lake health, in-lake management may become necessary at some point in the future of the Bolton lakes, particularly for Lower Bolton Lake. Artificial impoundments are predisposed to experience eutrophic conditions. The native soils of the Bolton lakes region are high in iron-bound phosphorus.

4.1 Internal vs. External Nutrient Loading

Watershed management will address external nutrient loading and reduce the quantity of nitrogen and phosphorus that move from the watershed and into the Bolton lakes on an annual basis. Internal nutrient load is a quantity of nutrients that are recycled annually from the lake sediments and organic material in the lake. Bottom nutrient concentrations are indicative of the amount of "internal" nutrient loading. Yet, the bottom nutrient concentrations are actually a combination of the true internal load from the benthic sediments and the nutrients that fall out of the water column to slowly settle to the lake bottom (to become part of the true internal load eventually). Decaying organic matter will settle during periods of stratification and contribute to the total phosphorus and nitrogen concentrations in bottom waters. For that reason, the measured internal load from year to year varies based on watershed conditions and external loading.

Similarly, true internal sediment release of nutrients during periods of summer stratification are increased due to oxygen loss and reductive dissolution of iron-phosphate. Oxygen loss can be exacerbated by poor spring water clarity, in that good (high) water clarity increases the volume of the lakes' epilimnion (surface layer of water that is oxygenated). It does so because the improved clarity will cause the thermocline to form deeper in the water column. It is important to also note that the 2012 bloom was almost certainly related to the massive Naiad growth and severe oxygen loss, which could have released nutrients from mid-depth sediments (3.5-meter zone). The waters at such depths typically do not lose oxygen or substantially contribute to the anaerobic internal load, but may do so during unusual conditions.

Higher external loads theoretically cause higher internal loads, both by increasing the amount of settling material, via decreased clarity, and movement of nutrients from littoral sediments to open water – all tied back into increased oxygen loss: a positive feed-back loop. Calculating the extent of the relationship between internal and external loading at any given lake is very difficult, largely because of the challenges in estimating load variability from year to year. The weather, particularly air temperatures and wind events, also complicate the lake mixing dynamics and indirectly influence the annual internal load. That is why the estimates for annual nutrient loading are just estimates – modeled using available information and subject to change from one year to another.

4.1.1 Cyanobacteria Bloom Formation & Management

A large part of the lake & watershed management plan revolves around nutrient reduction in order to preserve in-lake water quality and to prevent persistent summer algae/cyanobacteria blooms. However, residents must understand that some naturally occurring freshwater cyanobacteria are capable of blooming in relatively low nutrient conditions. These types of cyanobacteria blooms are notably different from the prolonged poor clarity and surface scums (as was seen initially in 2012 and less severely in fall 2021). In late May 2020, there was a *Dolichospermum* (*Anabaena*) cyanobacteria bloom that caused the CT DEEP to post beach and boat ramp advisories at Lower and Middle Bolton Lakes. This bloom occurred even during a period with overall good water clarity and low nutrients. Internal loading had not yet begun at either of the lakes. However, the bloom quickly dissipated and residents were able to resume safe recreation just a few days after the bloom was reported and sampled. Residents and Town officials must be aware that short, early summer cyanobacteria blooms like what was seen in 2020 may occur in future years despite both watershed and internal nutrient reduction efforts. Similarly, the cyanobacteria bloom conditions seen in autumn 2021 at both Lower and Middle Bolton Lakes were dramatically different from conditions present around the same time of year in 2020. The difference is primarily linked to fact that water quality decline from excess nutrients is often self-reinforcing. Increased summer rainfall and watershed nutrient loading, followed by poorer clarity and oxygen loss, will facilitate worsened internal release of sediment nutrients and further contribute to water quality decline in a given season.

The watershed and internal nutrient loading efforts are geared towards preventing dense and prolonged cyanobacteria blooms, which, because of high nutrients, do not dissipate or naturally decline. In-lake options exist for nutrient and cyanobacteria control, but due to the relationship between internal and external nutrient cycling, the Bolton lakes inevitably need to implement the watershed plan to prevent worsened internal loading in future years. Internal load control can be pursued alongside considerable effort towards watershed improvement, and internal nutrient binding techniques may provide faster cyanobacteria relief, where significant watershed improvements will take many years.

4.1.2 Physical Internal Loading and Cyanobacteria Management Techniques

Circulation Aeration – not recommended at this time

There are many types of commercially available lake and pond circulation “aeration” systems. Many lake and pond restoration companies refer to their circulation systems as “aeration” systems because the end result of circulating a pond or lake is a natural replenishment of oxygenated water via artificially mixing bottom water to the surface. This process replenishes oxygen by stimulating spring/fall mixing conditions, where atmospheric oxygen is replenished. Circulation aeration systems use a series of compressed air hoses and diffuser plates, placed along the bottom sediment. A large shoreline air compressor station is required. The compressed air creates an upwards bubble stream that causes the surrounding water to move upwards, creating an artificial upwelling current in the water immediately near the diffuser plate. Multiple diffusers and upwelling currents are necessary, and depend on the size of the plates. Very little of the compressed air actually dissolves into the water, because the bubbles are too large to be readily dissolved. Bubbles also increase in size as they move upwards through the water column.

Circulation systems are best used in shallow ponds and lakes (typically less than 12ft deep), where thermal stratification is not as intense as in deeper waterbodies. When circulation systems are used in deeper waters, more energy is needed to disrupt natural summer thermoclines, and summer heat waves can make it so that circulation systems are not able to adequately de-stratify a waterbody. This situation may result in periodic anoxia at the sediment-water interface, release of iron-bound phosphorus, and then subsequent mixing of the high dissolved nutrients into the surface waters. In cases where circulation systems have been undersized, they can worsen cyanobacteria blooms by continuously supplying bottom nutrients to the surface.

Circulation systems are also used to disrupt cyanobacteria buoyancy control. In lakes that experience persistent summer surface cyanobacteria scums, circulation systems may shift an algal community away from scum-forming cyanobacteria, particularly *Microcystis* and *Dolichospermum* (*Anabaena*). A circulation system allows for higher numbers of Diatoms and Green algae cells, which prefer water column mixing and may outcompete cyanobacteria. However, it is also possible that the cyanobacteria community will shift to a combination of other cyanobacteria taxa alongside non-cyanobacteria algae taxa. Circulation systems may be capable of disrupting surface-scum formation, but they do not sufficiently improve water clarity and do not always reduce surface nutrients (Wagner, 2019). Circulation systems also uniformly mix heat throughout the water column, which can present significant ecosystem changes relevant to fisheries management. At this time, circulation is NOT recommended for the Bolton lakes.

Aeration/oxygenation – *not recommended at this time*

There are many types of non-circulation aeration and oxygenation systems that aim to maintain summer stratification and do not disrupt the thermocline. Oxygenation systems use 100% oxygen, while aeration systems use air, which only has 21% oxygen. The following list provides a general categorization of non-circulation aeration and oxygenation systems (Wagner, 2019):

1. Unconfined diffused air
2. Unconfined diffused oxygen
3. Hypolimnetic aeration chambers
4. Downflow bubble contact chambers
5. Side stream supersaturation oxygen chambers

Aeration and oxygenation have been used for more than 50 years in reservoirs and there are many types of available technologies. The non-circulation aeration and oxygenation systems tend to be more expensive and complex than circulation aeration systems. Instead of relying on atmospheric oxygen replenishment, non-circulation systems directly resupply oxygen to anoxic bottom waters and are capable of preventing iron-bound phosphorus release from deep lake sediments. These systems are more effective in reducing overall nutrient concentrations in lakes than circulation systems.

Both circulation and non-circulation aeration/oxygenation systems require constant electricity and maintenance. When the systems are shut down, they are no longer able to reduce internal loading or disrupt cyanobacteria blooms. There are no cases where any type of circulation, aeration, or oxygenation system can be used for a period of time and then "restore" long term water quality after the system is switched off. If Bolton or Vernon decides that an aeration system is needed in the future, it is a long-term commitment, often more than $40,000 per year, without definite control of cyanobacteria or nutrients, particularly due to the high influence of watershed nutrients. For that reason, aeration/oxygenation systems are also NOT recommended for the Bolton lakes at this time.

Liquid-phase Aluminum-based Phosphorus Binders – possible treatment option

Aluminum sulfate (Alum) is the most common liquid-phase phosphorus binder used in lake management. Alum technologies emerged from use in the water treatment process, where it is used to remove phosphorus and other impurities from water. Alum has been used in lake management to bind phosphorus, both in the water column and in sediments, as an internal phosphorus loading treatment. Unlike iron, aluminum hydroxides are not subject to reductive dissolution of phosphate, meaning that a successful Alum treatment can bind phosphorus in the lake sediments even during summer periods of anoxia.

When applied to surface waters, or injected to hypolimnetic waters, aluminum sulfate reacts with water to form aluminum hydroxide, a form that has a high affinity to binding available phosphate and a form of Al that is not bioavailable or harmful to organisms. The aluminum hydroxide "floc" is whiteish in appearance and frequently makes a lake temporarily appear bright blue. Because the reaction releases hydrogen ions, the reaction of Alum in water has the ability to dramatically lower the water pH, which can be dangerous for fish and other organisms. For that reason, it is imperative to stabilize the lake water pH by using a buffering agent during the treatment, most commonly sodium aluminate. The Bolton lakes have very low natural alkalinity (9-12mg/L), which makes any Alum treatment more difficult and requires a substantial amount of pH buffering agent. The amount of dissolved organic matter in the water column also affects the ability of aluminum hydroxide to bind with available phosphorus.

An Alum treatment was proposed and preliminarily investigated for Lower Bolton Lake in 2016, but a sufficient treatment to tackle internal loading sediments would cost more than $50,000 for a 15-acre treatment (based on the amount of chemically reducible phosphorus in Lower Bolton anoxic sediments). Similarly, there is increasing awareness of how added sulfate hinders the ability of iron to naturally bind phosphorus over time, particularly for shallower surface-oxygenated sediments. For that reason, some lake aluminum treatments use polyaluminum-chloride instead of aluminum-sulfate, which would be slightly more costly for raw products. An aluminum treatment is not recommended at this time for Middle Bolton Lake, but could be a viable option in the future for Lower Bolton Lake, depending on future monitoring conditions and the successful implementation of the Watershed Management Plan. A deep-water aluminum treatment may be more effective in reducing cyanobacteria blooms than watershed management alone, because it would systematically remove bioavailable nutrients from a specific location known to incubate cyanobacteria (lake bottom/beneath thermocline).

Solid-phase Phosphorus Binders

Solid phase phosphorus binders are used much less frequently than liquid aluminum products for internal loading control. The three main types of solid-phase phosphorus binders are Lanthanum-clays (Phoslock), Iron oxides/hydroxides, and Zeolites (natural or modified aluminosilicate minerals).

Phoslock - recommended internal phosphorus control technology for Bolton Lakes

Phoslock is the trade name for a commercially available Lanthanum-modified bentonite clay. The product was originally invented in the late 1990s by the Land and Water division of Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO), but it has only recently been commercialized on a large scale. Phoslock contains 5% Lanthanum by weight. One-hundred kilograms of

Phoslock stoichiometrically binds roughly one kilogram of phosphorus. The manufacturing process of Phoslock locks the lanthanum into the bentonite clay structure so that free La is not released into the water, limiting aquatic toxicity. The lanthanum can either react with free phosphate, or remain in the clay structure.

Phoslock is used very similarly to liquid aluminum treatments, in that it can be used to bind free phosphorus in the water column or to bind phosphorus in the sediments to prevent internal loading under anoxic conditions. Similar to aluminum hydroxide, the lanthanum phosphate mineral (Rhabdophane) is stable in anoxic conditions. Unlike with liquid aluminum treatments, however, Phoslock has very good binding efficiencies at wide pH ranges and the addition of Phoslock does not reduce the pH, so it poses much lower risk to aquatic life. When Phoslock is applied to the lake and/or sediments, it forms a thin layer across the surface and continues to bind free phosphate through adsorption reactions. Current research indicates that Phoslock has a greater capacity to bind sediment-released phosphate than aluminum hydroxide because over time, the aluminum hydroxide crystalizes, reducing its surface area for phosphate binding. That is not the case for Phoslock. If either Lower Bolton or Middle Bolton experiences worsening cyanobacteria blooms in the future, Phoslock is a good choice for permanently reducing the internal available phosphate load.

Based on the amount of releasable phosphorus in the Lower Bolton Lake sediments, a 15-acre sediment-locking dose of Phoslock would cost roughly $75,000; an approximate dose of 373 g/m² Phoslock (100:1 ratio of Phoslock to reducible sediment phosphorus). In terms of phosphorus reduction, this direct application of Phoslock captures and immediately binds much more bioavailable phosphorus than watershed implementation projects proposed for the Bolton lakes. This treatment also has the potential to bind available phosphorus from decaying phytoplankton/organic matter that settles to the lake bottom in future years. A Phoslock treatment of this size and dose has not yet been attempted in Connecticut, but there are good case studies from around the country, including several northeastern lake treatments in the last three years. It is also possible to treat more acreage at a lower dose for similar effects and costs.

Eutrosorb – Phoslock-based product recommended for watershed filtration

SePro technologies manufactures a Phoslock-based product called Eutrosorb, which is sold in varied particle sizes and bags that can be used as filters in shallow-water areas that repeatedly receive stormwater nutrient inputs. Based on the knowledge of how phosphorus minerals form, these types of filters should work best with longer contact times. Placing them in areas with rapidly flowing water will not necessarily provide the kind of reductions that would be possible by placing them at the mouth of slow-flowing streams or culverts. These products would likely perform best during the many smaller precipitation events. SePro is also working towards the registration of a new in-lake treatment product that will involve a Lanthanum salt water-column stripping technique, named Eutrosorb WC. If and when this product becomes registered and commercially available in CT, this may be an appropriate water column short-term nutrient reduction treatment instead of algaecide usage.

Iron Oxides/Hydroxides – not recommended

Iron oxides/hydroxides are the primarily existing compound that binds phosphate in the Bolton lakes water and sediment. Iron is high in the natural soils of the Bolton lakes region and serves as a good phosphate binder in oxygenated lake sediments. However, iron cannot sufficiently bind phosphate in anoxic conditions, which is why internal lake sediment phosphate loading occurs and why aeration is implemented – to restore the ability of iron to adsorb phosphate. Iron oxide applications to lakes are more appropriate in combination with aeration or oxygenation systems, and are best used in lakes with low iron-binding capacity. The Bolton lakes have naturally high iron and this technique is not suitable for phosphate sequestration in the deeper waters.

Zeolites – Unknown if permitted in CT

Zeolites are aluminosilicate minerals that are naturally occurring in the environment. Zeolites can also be modified to include Al into the cage structure (such as Aqual-P products) or La-oxide precipitates. Due to the chemical structure of Zeolites, they also have the capacity to bind NH_4^+ ions and serve as both nitrogen and phosphorus binders. Use of Aqual-P is much less common, particularly in large lakes and for sediment binding high-dose treatments. More information and case study reviews are required before such a product should be used at the Bolton lakes. There may be mixtures of other Zeolite-based products, possibly mixed with carbon-based binding products like BioChar, that are also on the market under new or revised trade names. It is extremely important to understand what a product is, what its mode of action is, and how to appropriately calculate a dosage for a given amount of phosphorus binding. Cheaper products may be cheaper because they do not have the same level of binding capacity as more costly products. There is a wealth of information available on all types of liquid and solid phase internal nutrient loading treatments (Cook et al., 1993; Steinman & Spears, 2020).

Sediment Removal – not recommended

Physical sediment removal via suction dredging is expensive and is typically not an adequate method of deep-water internal loading control, simply due to the costs and technical difficulties. Suction dredging is typically used in shallow water areas and is subject to strict state and local permit requirements. Excavation of accumulated bottom muck is only possible if the lakes were to be almost completely drawn down. Sediment removal is not a feasible technique for phosphorus management at the Bolton lakes.

Bacteria Products – not recommended at this time

“Bacteria” use in ponds is largely unregulated on a federal and state level. There is little to no scientific information that suggests that available commercial products do what they claim. Products are often a blend of soil bacteria and fungi, and their use in aquatic systems stemmed from use in agriculture (mixed into soils). Some preliminary academic research suggests that various *Bacillus* species of bacteria may have natural cyano-bactericidal properties and may act similarly to a chemical algaecide, providing a certain level of temporary bloom relief. This is an emerging field. Bacteria use in waterbodies may soon become regulated in CT because most bacterial products are also high in phosphorus (NEAR laboratory testing). Available third-party research investigating bacteria use on pond sediments revealed no statistical change in sediment composition, but presumably the added bacteria increase mineralization of organic sediment, which may increase nutrient recycling from settled sediments. Bacteria use is not recommended at the Bolton lakes at this time. More research and third-party case studies are required to verify biopesticide properties of certain bacteria strains.

Algaecides – use sparingly, only for emergencies

Copper algaecide products directly kill algae and cyanobacteria. The CT DEEP tracks algaecide usage in lakes and ponds, and a permit is required for use. Copper products may only be applied by a CT licensed herbicide applicator and the dosage is strictly regulated. Copper products, depending on the dosage, can have adverse toxicity impacts on insects, zooplankton, and small fish. Copper also accumulates in lake sediments over time after years of continued use. Lakes with a 20+ year history of annual lake-wide Copper treatments often have long-term sediment accumulations that become problematic for the ecosystem, particularly for zooplankton. Copper algaecides are a symptomatic remedy, not a long-term nutrient management solution. Copper treatments have been used at Lower Bolton Lake on two occasions since the initial 2012 cyanobacteria bloom. Copper treatments were applied by Solitude applicators on June 27, 2013 and September 2, 2015. Treatments were specifically intended to stop cyanobacteria blooms and to keep the Lower Bolton Lake open for summer recreation. Middle Bolton Lake has not been treated with copper algaecides since CT DEEP began tracking use in the state. There is little to no historical treatment information available.

Peroxide-based algaecides also directly kill phytoplankton, including cyanobacteria. Peroxides have not been used to control algae in the Bolton lakes, as these products tend to be much more expensive and have similar effects on algae. Both types of algaecides do not guarantee successful seasonal control of cyanobacteria blooms. There are many cases where algaecide use may provide less than two weeks of bloom relief, before algae and cyanobacteria cells are able to repopulate. Algaecides do not control nutrient concentrations.

Hypolimnetic Withdrawal – not recommended

Hypolimnetic withdrawal is a technique that relies on piping deep-water that has high phosphorus and no oxygen, during summer months, out of the lake and downstream. This technique was more common in the 1980-1990s, and was used temporarily at Lake Waramaug, CT. Due to concerns of discharging poor-quality water downstream, this technique was halted in CT. The Bolton lakes both have underwater outlet structures, but these culverts are not close enough to the Middle or Lower Bolton deep holes to adequately remove deep-water. Similarly, water flow through the dam culverts is only from late fall to early spring, during the time when the lake is drawn down for winter. Hypolimnetic withdrawal is a technique meant for the summer months to remove water beneath the thermocline. The water flushing through the dam culverts in fall through winter is not a nutrient management technique, and in order to maintain adequate lake level during the summer months, summer culvert flows are unrealistic.

Overview of Internal Loading Options

In summary, internal loading of phosphorus occurs in both Middle and Lower Bolton Lakes. In Lower Bolton Lake, some years the internal load supported cyanobacteria bloom formation, but the pattern of internal loading was not consistent from year to year and the watershed is a known contributor of high phosphorus and nitrogen. If summer cyanobacteria blooms worsen or become more frequent or persistent at either Middle or Lower Bolton Lakes, then a Phoslock treatment may be the best in-lake nutrient management option. However, ephemeral spring and early summer cyanobacteria (*Dolichospermum*) blooms may not be controlled via a phosphorus reduction Phoslock treatment, simply because early-season blooms are not a result of summer anoxia and internal phosphorus loading. A Phoslock treatment is recommended to remedy summer persistent cyanobacteria blooms, should they become more problematic in the future.

5 Aquatic Plant Management

Nuisance and invasive aquatic plants plague lakes and freshwaters across the world. Invasive aquatic plants are as much of a threat to lakes as cyanobacteria blooms and high nutrients. Aquatic invasive species (AIS) are detrimental to water quality and the natural ecosystem balance. AIS, as well as an overabundance of native nuisance species, can rapidly dominate entire littoral zones. In relatively shallow lakes, such as Middle and Lower Bolton Lakes, invasive species have the capacity to colonize more than half the lake surface area. Without management, AIS and nuisance aquatic plants inhibit recreation and can harm the long-term value of lakefront properties.

Public lakes are incredibly vulnerable to new AIS infestations. There are only two CT lakes with public boat-trailer access that do not have AIS (Winchester and West Hill). Both of these communities support annual detailed aquatic plant surveys. This type of scanning has successfully found and eradicated invasive species before they became too widespread to eradicate. Eradication is only possible during a short period after infestation. The cost of management goes up exponentially if the species is left unmanaged in the first or second year.

Lower Bolton Lake successfully found and eradicated both invasive Fanwort and Variable-milfoil in this way. Similarly, the Middle Bolton Lake aquatic plant management program is fighting potential eradication of Fanwort, made possible by the Rapid Detection and Early Response (RDER) actions of FBL and the Town.

Another critical component to aquatic vegetation mapping is to document the growth of native species, including any drastic expansion in range and density. Rooted aquatic plants require nutrients to grow, and they acquire these nutrients from lake sediments. The major 2012 cyanobacteria bloom at Lower Bolton Lake coincided with a severe overgrowth of native Naiad, which was thought to have delivered nutrients from shoreline areas into open water just before the bloom.

5.1 Upper Bolton Lake Plants

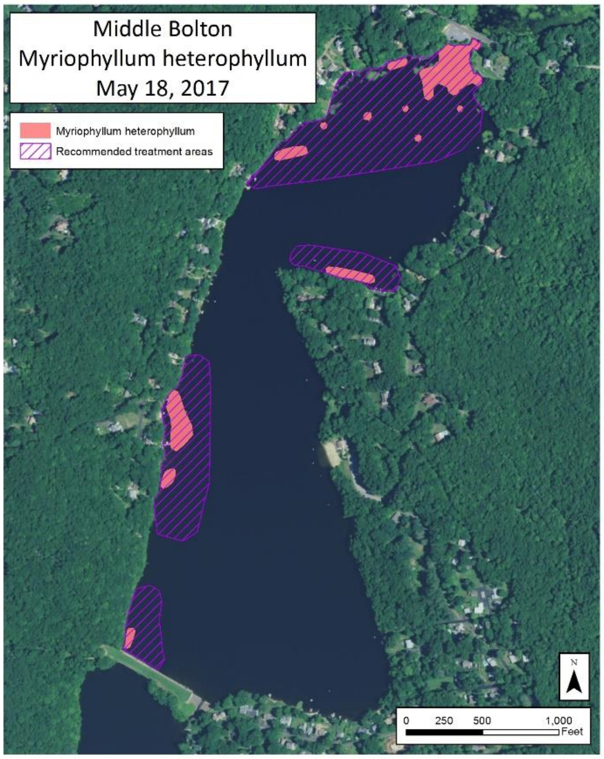
Upper Bolton plant management efforts are minimal, because the lake is eutrophic and almost completely dominated by floating-leaf native plants. The lake is not used for swimming. There is a small narrow channel that can be accessed by canoe or kayak. The Upper Bolton area just next to the Hatch Hill dam does have invasive Variable milfoil and has been hand-removed in the past, with some regrowth. However, the very poor clarity and dense lily cover seems to keep the milfoil from rapidly expanding in this area. Upper Bolton plant management is a lower priority than at Middle and Lower Bolton because the larger lakes are used for boating, swimming, fishing, etc.

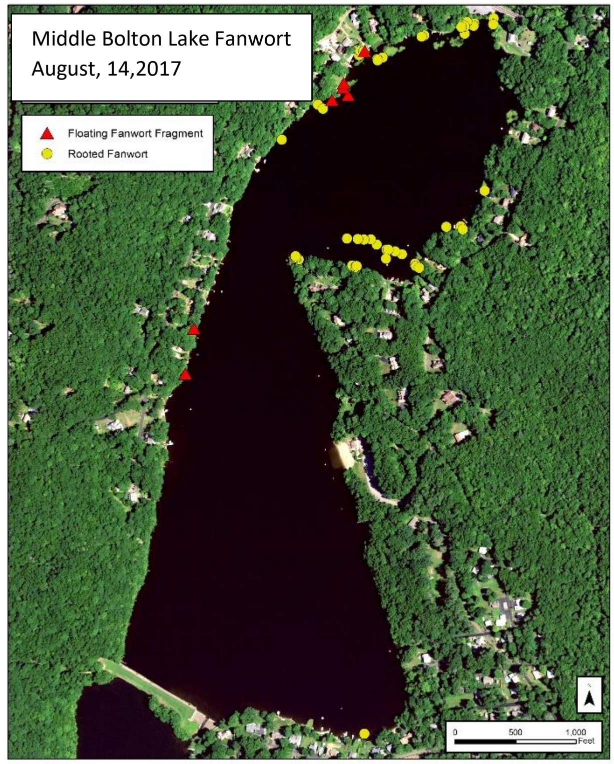
5.2 Middle Bolton Lake Plants

Currently, the Town of Vernon financially supports aquatic herbicide treatments to manage both the invasive Fanwort (*Cabomba caroliniana*) and Variable milfoil (*Myriophyllum heterophyllum*). Prior to 2012, Variable milfoil control efforts used deep water level winter drawdowns. With minimal plant survey data during this time, it is unknown how effective those drawdowns were. The Variable milfoil at Middle Bolton also tends to grow in the 4-8ft range, meaning that a large amount of milfoil cannot be controlled via drawdown. Fanwort in Middle Bolton Lake has been found in water as shallow as 1.5ft and as deep as 12ft.

Fanwort was found in Middle Bolton Lake for the first time in July 2017. A full-lake aquatic plant survey conducted by NEAR found multiple locations that had Fanwort fragments or single rooted plants. All observed Fanwort fragments and single rooted plants were removed during the survey. Quick management action successfully secured a Clipper (flumioxazin) permit from CT DEEP, and the large Fanwort patches were treated by Solitude applicators in September 2017, within the first year of apparent infestation. Since the initial treatment, no Fanwort has been seen in the primary locations. The following maps show the locations of 2017 invasive Variable milfoil and Fanwort from their respective plant survey days. Because Fanwort tends to grow later in the season than Variable milfoil, full-lake Fanwort surveys tend to be conducted after mid-June.

Map 6: (A) 2017 Invasive Variable milfoil (Myriophyllum heterophyllum) & (B) Fanwort (Cabomba caroliniana)

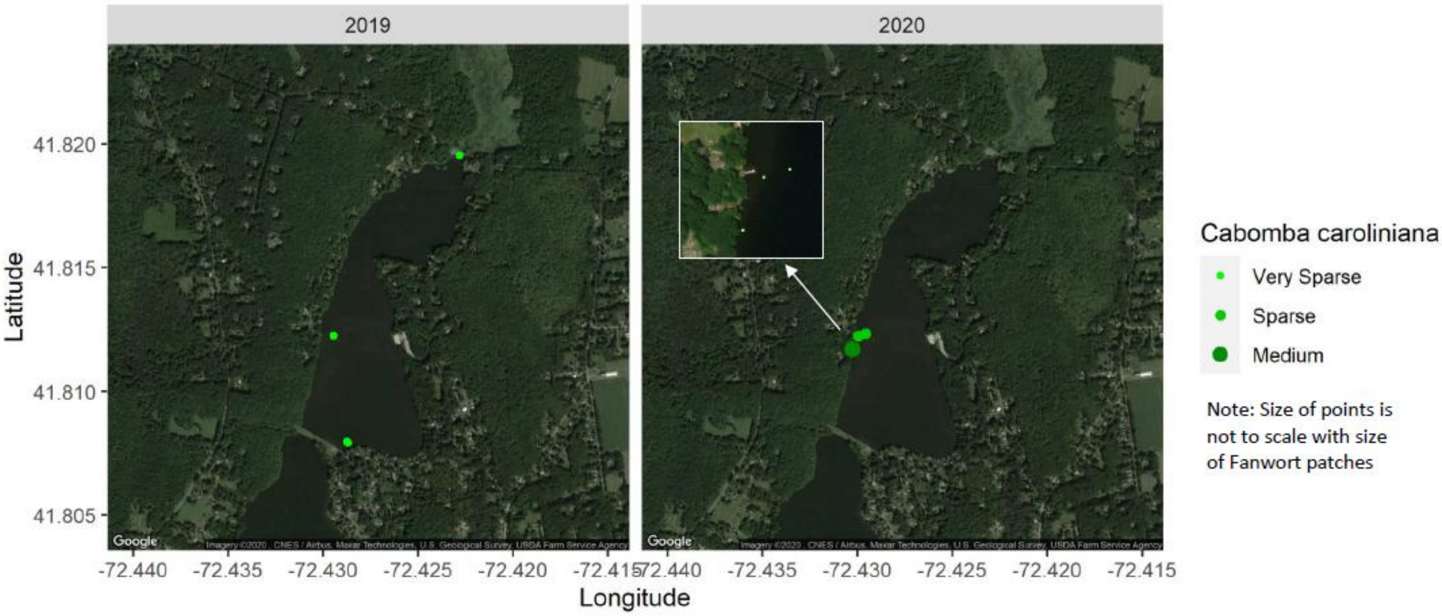




In 2018, only one small patch of Fanwort was found in MBL, at the Upper Bolton culvert outlet near the state boat ramp. This patch was hand-removed. FBL members remained vigilant and set up a suspicious plant reporting system and helped residents learn to identify Fanwort. Unlike Variable milfoil, invasive Fanwort is capable of growing in up to 20ft of water and rapidly grows to the surface. Fanwort could easily take over nearly the entire lake. No Fanwort treatments were performed in 2018.

In 2019 and 2020, aquatic plant surveys found Fanwort growing in three small patches each year. In 2019, two small patches were removed by NEAR divers, and the slightly larger patch near the Middle Bolton dam was treated again with flumioxazin. The treatment was again performed by Solitude applicators and pre- and post-treatment aquatic plant inspections were performed. The area that was treated in 2019 had no rooted Fanwort in 2020. Only a cluster of small Fanwort patches were found in 2020. It was decided that hand-removal was not adequate and that an additional year of spot flumioxazin treatment was needed to control and potentially eradicate Fanwort in Middle Bolton Lake. The decision to treat the Fanwort in 2020 was made jointly by NEAR, CAES, FBL, and the Town of Vernon. The 2019 and 2020 locations of Fanwort are shown below.

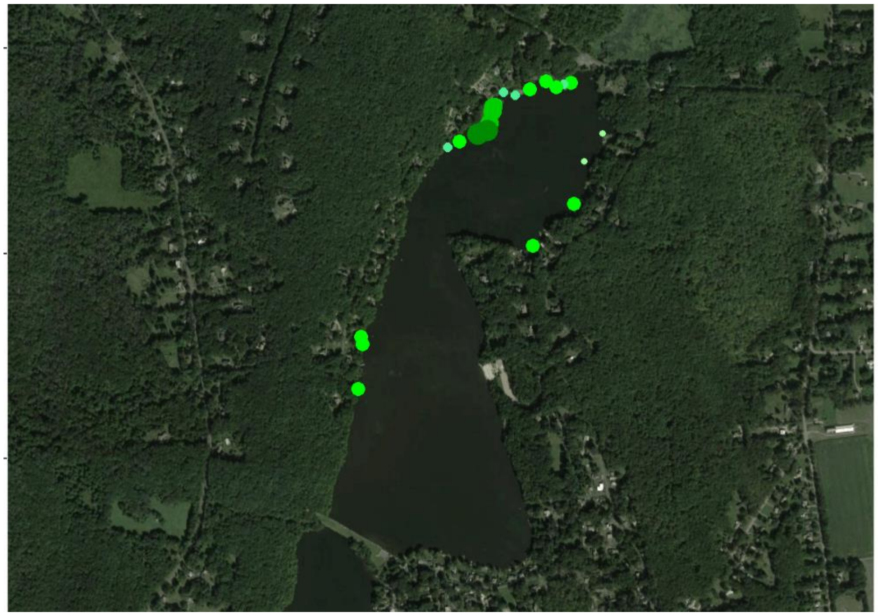
Map 7: Middle Bolton Lake 2019 & 2020 Invasive Fanwort Locations



Unfortunately, in 2021 there were newly observed Fanwort patches in several areas. FBL and NEAR worked with the Town of Vernon and Solitude applicators to treat Fanwort in areas observed. It was difficult to assess the success of the treatment in fall 2021 due to the very poor water clarity in late summer to fall. Several live Fanwort fragments were found at the boat ramp in less than 3ft of water during the October follow-up survey visit in 2021. Fanwort fragments were removed when seen and there was no recognizable trace of Fanwort in the recently treated areas.

As in many cases of AIS infestation, management requires persistent effort to prevent spread. Based on other case studies of Fanwort management in the state using the herbicide Clipper, we have observed that the success of a particular treatment depends heavily on the dosage and the ability of the applicator to treat directly onto the area with the plants. To ensure any future Fanwort treatment accuracy, we recommend joining the herbicide applicators in the field on the day of the treatment to show them exactly where each patch of Fanwort is located, instead of the applicators simply relying on treatment maps. The pretreatment July 2021 Fanwort and Variable milfoil maps are included below.

Map 8: Middle Bolton Lake Invasive Variable milfoil, pre-treatment on July 21, 2021



Variable Milfoil Density

- Very Sparse
- Sparse
- Medium
- Dense
- Very Dense

Map 9: Middle Bolton Lake Invasive Fanwort, pre-treatment on July 21, 2021

Fanwort Density

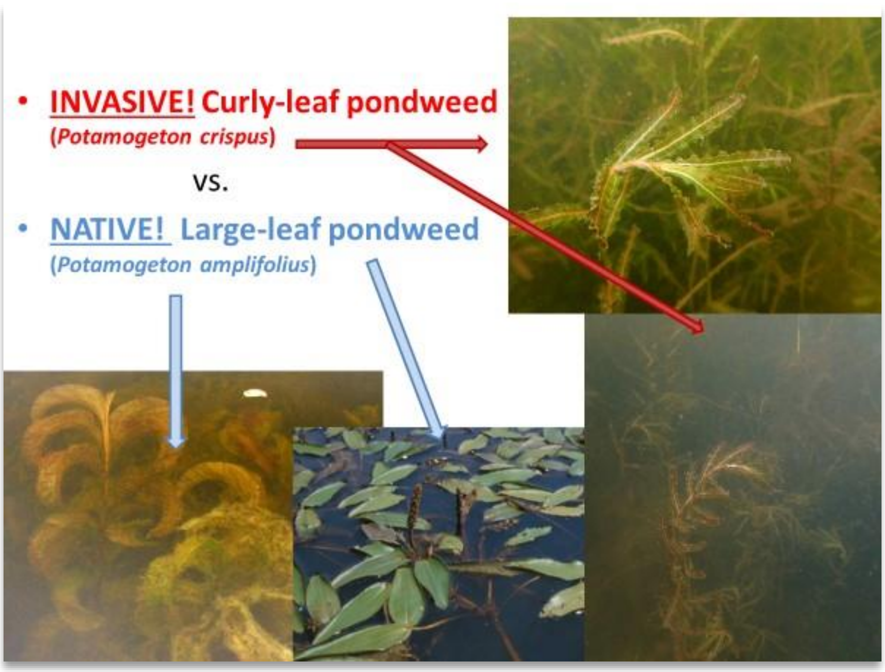
- Very Sparse
- Sparse
- Medium
- Dense

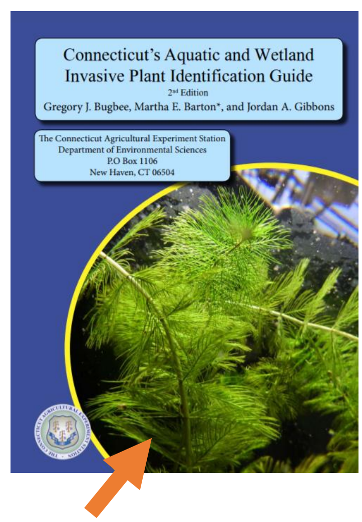
5.3 Lower Bolton Lake Plants

Beginning in 2013, Lower Bolton Lake aquatic plant management involved a full-lake Sonar (fluridone) herbicide treatment in order to control the massive overgrowth of native Naiad. The Naiad had seemingly played a part in the 2012 cyanobacteria bloom, and fluridone – a systemic herbicide – was chosen as the best course of action. The fluridone successfully controlled Naiad and the new Fanwort infestation in Lower Bolton Lake. Fanwort has not been found since that 2013 treatment, and Naiad growth has been minimal in comparison to 2010-2013. Plant management in subsequent years did not use *systemic* herbicides, only sparing use of *contact* herbicides.

Invasive Curly-leaf pondweed (*Potamogeton crispus*) was first found in Lower Bolton Lake in 2015. Curly-leaf pondweed is a rapid-growth invasive species that spreads primarily through seed-like turions. Curly-leaf pondweed tends to grow earlier in the season than other invasive aquatic plants, and is usually visible by early May (whereas several other invasive species, such as Fanwort, tend to grow later in the season with peak growth in August-September).

Curly-leaf pondweed is often confused with the native Large-leaf pondweed (*Potamogeton amplifolius*), which has much larger and broader leaves and does not have serrated edges. Large-leaf pondweed also has large floating leaves that reach the surface. The photos below demonstrate the difference between the leaves.





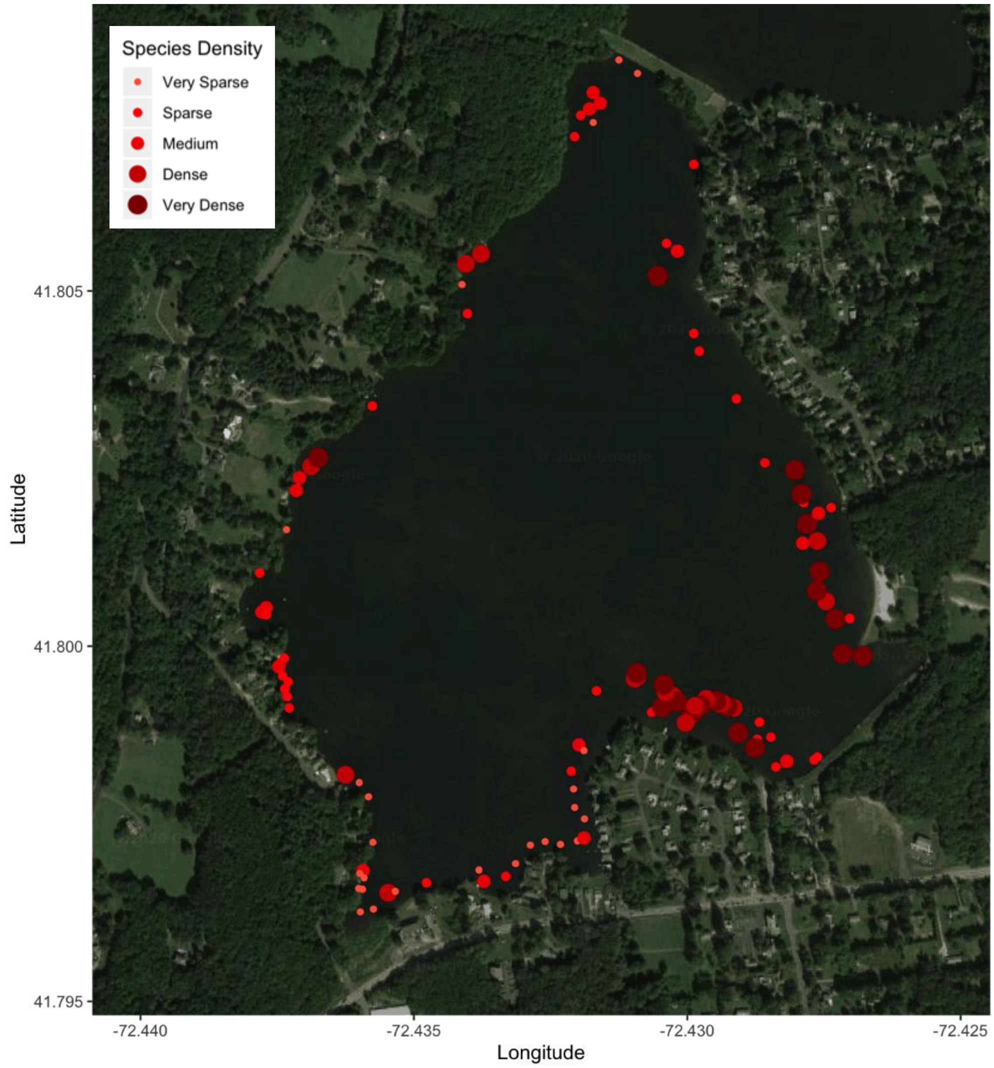
The CT Agricultural Experiment Station (CAES) also has a very good invasive plant identification guide available at: https://portal.ct.gov/-/media/CAES/Invasive-Aquatic-Plant-Program/Publications/Plant-Identification/CAES-IAPP-Field-Guide-2012.pdf

Table 9: Lower Bolton Lake Historical Herbicide Treatments

Date	Treatment	Contractor
May 20, 2013	Fluridone (Sonar Genesis-liquid)	Aquatic Control Tech. (Solitude)
June 27, 2013	Booster Fluridone & Copper algaecide	ACT (later became Solitude)
September 5, 2013	Final Fluridone booster (Sonar Q-granular) in Fanwort cove	ACT/Solitude
2014	No treatments	
September 2, 2015	Diquat (Reward) spot treatment of Curly-leaf pondweed – 15gal.	ACT/Solitude
June 21, 2016	Diquat (Reward) spot treatment of Curly-leaf pondweed	Solitude
June 26, 2017	Diquat (Reward) spot treatment of Curly-leaf pondweed	Solitude
2018	No treatments	-
2019	No treatments – Curly-leaf patches hand-removed by divers	New England Aquatic Services
June 30, 2020	Diquat (Reward) spot treatment of Curly-leaf pondweed – 10gal.	Solitude
June 2021	Diquat (Reward) littoral zone treatment, minus area near LBL spillway (east of boat ramp)	Solitude

The typical late June treatments for Curly-leaf pondweed are not ideal, the treatments should ideally occur before turions begin to form in early June. There have been multiple years where CT pesticide permits were not received in time to attack Curly-leaf pondweed prior to turion formation. As of 2020, CT DEEP has begun to grant multi-year lake treatment permits to avoid permit delays that negatively impact management. FBL and the Town of Bolton must work with the applicator and CT DEEP to ensure that treatment happens prior to the time when turions develop to avoid spread.

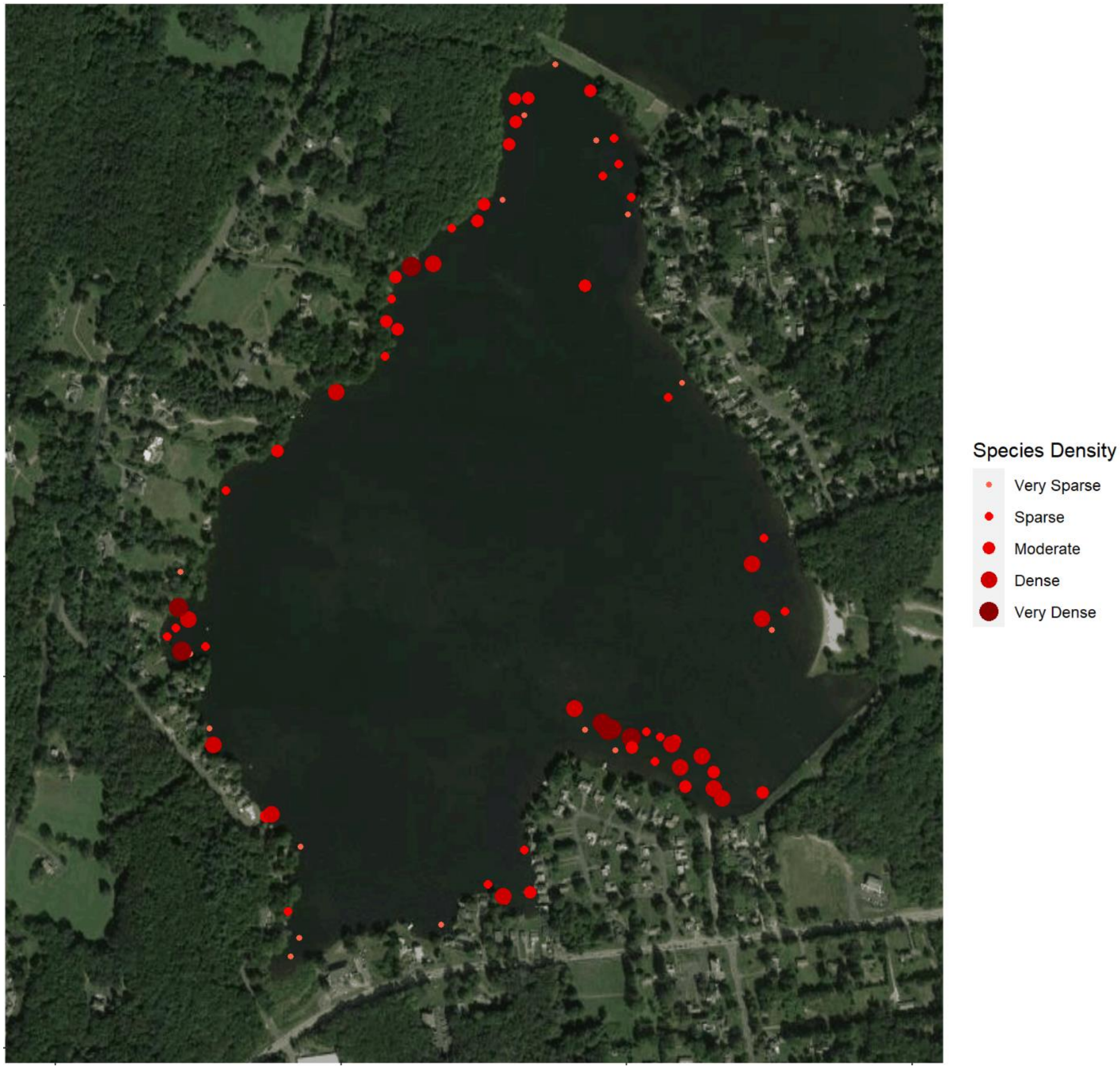
Map 10: Lower Bolton Invasive Curly-leaf pondweed (Potamogeton crispus) May 22 & Jun 22, 2020



Because of a permit issue, there was no herbicide treatment in 2019. The permit issue was resolved by the applicator in 2020, but by late June 2020, the invasive species had spread to new areas, particularly along the southwestern shore. The turion formation had begun prior to the 2020 treatment date, so we expected that another Curly-leaf treatment will be needed in 2021.

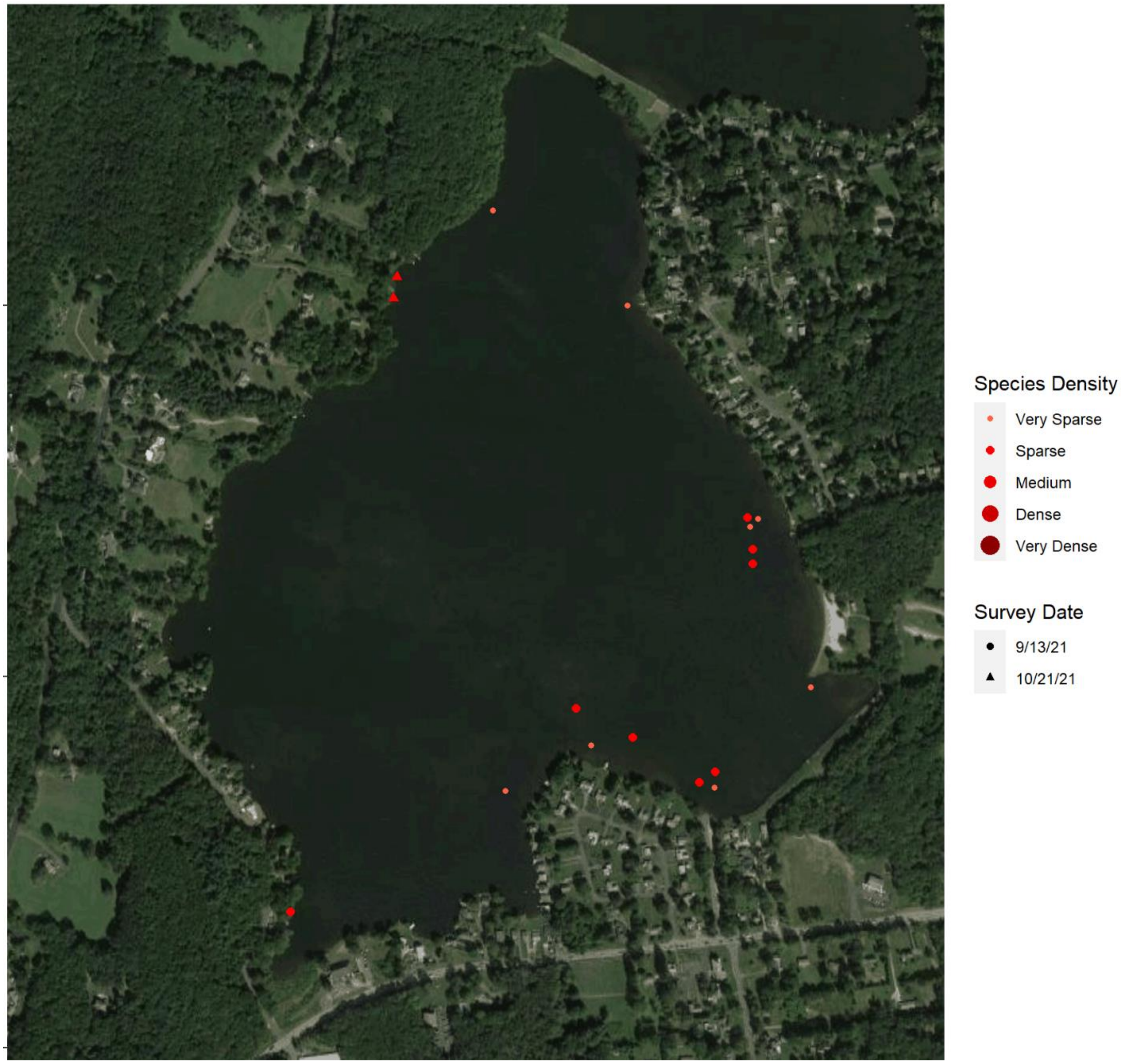
The 2021 pre-treatment survey found Curly-leaf pondweed again along most of the shoreline. The dense patches were present in the 3-7ft water depth range along the shore to the west of the boat ramp.

Map 11: Lower Bolton 5-24-21 Curly-leaf pondweed



Many areas where Very Sparse invasive Curly-leaf pondweed was found during the pre-treatment 2020 survey appear to have been successfully controlled by the 2020 treatment, as there were many locations found in 2020 that were not found during the 2021 pretreatment survey. There were, however, several new locations along the northwestern shore – likely a result of previous turion spread.

Map 12: Lower Bolton September-October 2021 Invasive Curly-leaf pondweed re-growth (from sprouted turion seed bank in sediments)



5.4 Aquatic Plant Species Lists

As part of the CT DEEP permit conditions for herbicides treatments, both Middle and Lower Bolton Lake required pre- and post-treatment aquatic plant assessments. NEAR staff performed full aquatic plant surveys in Lower Bolton Lake from 2013-2018 and in 2020-2021. The 2019 surveys only documented invasive and nuisance species.

NEAR Lower Bolton Species List (2019 surveys were for Invasive/Nuisance species only)

Species List	2013	2014	2015	2016	2017	2018	2019	2020	2021
Large-leaf pondweed *(Potamogeton amplifolius)*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Southern naiad *(Najas guadalupensis)*	Yes	Yes	Yes	Yes	-	Yes		Yes	Yes
Coontail *(Ceratophyllum demersum)*	Yes	-	-	-	-	-		Yes	Yes
Tape-grass *(Vallisneria americana)*	Yes	-	Yes	Yes	Yes	Yes		Yes	Yes
Snail-seed pondweed *(Potamogeton bicupulatus)*	-	Yes	-	-	-	Yes		-	-
Slender pondweed (*Potamogeton pusillus*)	-	-	-	-	-	-		-	Yes
Elodea *(Elodea nuttallii)*	-	-	-	-	-	-		Yes	Yes
Floating bladderwort *(Utricularia radiata)*	-	-	-	-	-	-		-	-
Arrowhead *(Sagittaria graminea)*	-	-	Yes	Yes	-	-		Yes	Yes
Bushy pondweed *(Najas flexilis*)	-	Yes	-	-	Yes	Yes		Yes	Yes
Fanwort *(Cabomba caroliniana)*	**Yes**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Mudmat *(Glossostigma* sp.)	**-**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**		**Yes**	**Yes**
Quillwort *(Isoetes sp.*)	-	-	-	-	-	-		-	-
White waterlily *(Nymphaea odorata)*	-	-	-	-	-	-		-	-
Watershield (*Brasenia schreberi*)	-	-	-	-	-	-		-	Yes
Variable leaf milfoil *(Myriophyllum heterophyllum)*	**-**	**-**	**-**	**-**	**-**	**-**		**-**	**-**
Red-leaf pondweed *(Potamogeton epihydrus)*	-	-	-	-	-	-		-	-
Muskgrass *(Nitellla* sp.)	-	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Stonewort *(Chara* sp.)	-	Yes	Yes	Yes	-	Yes		-	-
Hedgehyssop (Gratiola sp.)	-	Yes	-	-	-	-		-	-
Curly-leaf pondweed (*Potamogeton crispus*)	-	-	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Needle spikerush *(Eleocharis acicularis)*	-	-	-	-	-	-		Yes	Yes

NEAR Middle Bolton Species List

Species List	2019	2020	2021
Aquatic moss (*Fontinalis sp.*)	Yes	Yes	Yes
Arrowhead (*Sagittaria graminea*)	Yes	Yes	Yes
Broadleaf arrowhead (*Sagittaria latifolia*)	-	Yes	Yes
Cattail (*Typha sp.*)	Yes	Yes	Yes
Common bladderwort (*Utricularia macrorhiza*)	-	Yes	-
Common reed (*Phragmites australis*)	Yes	Yes	Yes
Cyanobacteria benthic mat (*Lyngbya*)	Yes	Yes	-
Emergent bur-reed (*Sparganium sp.*)	-	Yes	Yes
Emergent spikerush (*Eleocharis sp*.)	Yes	-	-
Fanwort (*Cabomba caroliniana*)	Yes	Yes	Yes
Filamentous algae	Yes	Yes	Yes
Floating bladderwort (*Utricularia radiata*)	Yes	Yes	Yes
Floating bur-reed (*Sparganium sp*)	-	Yes	Yes
Humped bladderwort (*Utricularia gibba*)	-	Yes	-
Lesser bladderwort (*Utricularia minor*)	-	Yes	Yes
Low watermilfoil (*Myriophyllum humile*)	-	Yes	-
Mudmat (*Glossostigma cleistanthum*)	Yes	-	Yes
Needle spikerush (*Eleocharis acicularis*)	Yes	Yes	Yes
Pickerelweed (*Pontederia cordata*)	Yes	Yes	Yes
Primrose-Willow (*Ludwigia* sp.)	-	Yes	-
Purple bladderwort (*Utricularia purpurea*)	Yes	Yes	Yes
Quillwort (*Isoetes sp.*)	Yes	Yes	Yes
Ribbon-Leaf pondweed (*Potamogeton epihydrus*)	Yes	Yes	Yes
Slender naiad (*Najas flexilis*)	-	Yes	Yes
Small pondweed (*Potamogeton pusillus*)	Yes	Yes	Yes
Snailseed pondweed (*Potamogeton bicupulatus*)	-	Yes	-
Softstem bulrush (*Schoenoplectus sp*.)	-	Yes	Yes
Spotted pondweed (*Potamogeton pulcher*)	Yes	Yes	Yes
Stonewort (*Nitella sp.*)	Yes	Yes	Yes
Variable-Leaf watermilfoil (*Myriophyllum heterophyllum*)	Yes	Yes	Yes
Watershield (*Brasenia schreberi*)	Yes	Yes	Yes
White water lily (*Nymphaea odorata*)	-	Yes	Yes
Yellow water lily (*Nuphar variegata*)	Yes	Yes	Yes

Both the Lower and Middle Bolton aquatic plant surveys suggest that herbicide treatments have not had prolonged impacts to the diversity of native species.

5.5 Aquatic Herbicide Alternatives

Aquatic plant management has very limited practical alternatives to aquatic herbicides. Existing alternatives to aquatic herbicides include:

- Diver hand-removal or diver-assisted suction harvesting
- Benthic barriers to cover small patches
- Mechanical harvesting (NOT RECOMMENDED)
- Aquatic plant-eating triploid Grass carp (NOT RECOMMENDED)

<u>Each of these herbicide alternatives has some level of impracticality for large-scale AIS management.</u> Recommendations are explained below.

5.5.1 Diver Removal – Use economically, when appropriate

Both diver hand-removal and diver-assisted suction harvesting have been used at the Bolton Lakes. Diver hand-removal involves underwater divers weeding the lakebed and systematically removing small patches of plants by the roots. Suction-harvesting is similar, but instead of an underwater catchment bag, a suction device is used to pump the plants onto a platform to be screened and collected onboard. Suction-harvesting is usually used in larger areas that are impractical for hand-removal.

Diver hand-removal was used at both Lower and Middle Bolton Lakes to control small patches of Curly-leaf and Fanwort, respectively. Success was varied. The patches of Curly-leaf pondweed that were hand-removed in 2015 grew back quickly and it was too difficult to remove the roots or to prevent turions from falling to the sediments. Diver hand-removal at Middle Bolton was successful in removing Fanwort from three areas, but in two of the five targeted areas, Fanwort grew back in subsequent years. In both cases, diver hand-removal is best used on very small scattered single plant clumps, which are too sparse to justify treatment.

Suction harvesting was also used in 2019, because of the herbicide permit problem. Yet, based on the 2020 Curly-leaf pondweed distribution, it was clear that the suction harvesting was not able to adequately control spread or regrowth of the invasive pondweed. Similarly, use of suction harvesting on Fanwort at other CT waterbodies has seen very minimal year-over-year success. **Diver removal generally costs ~$2,000 / day**, and daily coverage and success depends heavily on plant density and sediment type.

5.5.2 Benthic Barriers – Use on small to moderate patches, when appropriate

Benthic barriers are appropriate in relatively flat, non-rocky areas that are less than 8ft deep. The presence of rocks, boulders, or steep slopes make barriers unable to adequately cover aquatic vegetation. Barriers are typically used in areas less than 1,500 square feet and must be maintained via seasonal removal and cleaning. There are specific types of benthic barriers with holes and vents that allow sediment gas buildup from decomposition to pass through the barrier. Barriers must also be appropriately weighted down with steel rebar rods, so they do not move or become raised and billowy. Benthic barriers are suitable around personal docks and/or beach areas, but generally are not a lake-wide approach. Similarly, the shoreline of both Middle and Lower Bolton Lakes are quite rocky, making barrier use less effective.

Benthic barriers would be best utilized as a control tool in any regrowth of Middle Bolton Fanwort, particularly on very small patches, less than 5-10ft in diameter, if they occurred in a low-sloped area. In some cases, dense patches of invasive species have been known to grow laterally underneath the barrier and then begin to grow up and around the barrier edges. The use of barriers is very case specific and should always consider the practical difficulties and chance of success. Barriers typically cost **$1,500-$4,000 per 1,000 sq. ft., depending on the type of barrier material used.** Materials to consider: Bottom blanket, vented landscape fabric, Muck-Mat Pro rigid barrier.

5.5.3 Mechanical harvesting – NOT Recommended

Mechanical harvesting generally involves a large lawn-mower-like machine that cuts plants beneath the water line. Mechanical harvesters are usually used as a last resort plant control method, where biomass is so great that boating access is severely limited. Mechanical harvesting is not a good method of plant control, because it is very messy and creates fragments that will spread to new areas of the lake. Thankfully, the multiple years of plant control at the Bolton lakes has prevented both invasive species from colonizing the entire littoral zones of Middle and Lower lakes.

5.5.4 Triploid Grass Carp – Generally NOT Recommended

Sterile triploid Grass Carp use is somewhat controversial. Grass carp are widely used in the south to control invasive *Hydrilla* in large lakes, but many northern states do not allow their use. Grass carp are currently not permitted in lakes in MA, RI, NH, VT, or ME. Triploid Grass carp are permitted for use in CT and NY. NY has much wider use of grass carp than CT, however, and many of the early stocking in NY that occurred in the 1990s resulted in complete and long-standing eradication of all aquatic plants. Over-stocking these fish can have severe ecological consequences. CT DEEP generally allows for Grass carp stocking in small ponds, with a DEEP permit, but very few lakes have been permitted to stock triploid Grass carp.

The main management difficulty with Grass Carp is that it is impossible to control where, what, and how much the carp eat. It is well documented in the scientific literature that Grass carp prefer to consume most native plant species, rather than invasive species (with *Hydrilla* being an exception). The carp also live for 10-20 years, making any unintended impacts very long lasting. These fish grow to 3ft long and can generally only be removed via bow-hunting. Again, Grass carp use is generally NOT recommended for the Bolton lakes, especially given the type and abundance of invasive species present.

5.7 Future Plant Management

5.7.1 Prevention of New AIS

Boat ramp monitoring and watercraft inspections during peak boating hours will be the on-ground defense against potential new AIS. FBL has committed to increased resident training and spearheading this continued volunteer effort.

In addition to preventing invasive Fanwort, Variable milfoil, or Curly-leaf pondweed from exchanging between the lakes, the top AIS threats to the Bolton Lakes are:

- Eurasian milfoil (*Myriophyllum spicatum*)
- Hydrilla *(Hydrilla verticillata)*
- Water chestnut (*Trapa natans*)

All three of these species exist in nearby CT waters, including other lakes and ponds in Coventry and Vernon.

5.7.2 Early Detection and Rapid Response Plan

FBL has been absolutely critical in the fight against invasive species at the Bolton lakes. The FBL web-based 'Suspicious plant reporting form' has allowed direct community participation in ongoing surveys and scans for AIS. Uploaded photos are screened by FBL directors and the Bolton Lakes Commissioner, and if further identification is needed, photos are sent to NEAR personnel. The end result of this open line of communication is increased public awareness and lake-wide vigilance.

5.7.3 Plant Management Funding Sources

As a result of (2019) Public Act No. 19-190, AIS Boat Registration Stamp Fee funds are now available. Bolton, Vernon, and FBL jointly submitted and were awarded AIS grant funding in 2021 to continue their efforts for invasive Curly-leaf pondweed, Fanwort, and Variable milfoil. Funds were used to pay for the chemical analysis of volunteer-collected water samples, and also for new educational signage and to support public outreach events hosted by FBL. The second round of grant applications are due in February 2022 and the Towns and FBL have plans to submit another application. Funding from this continuous source should be available annually for in-lake AIS management, educational outreach, prevention, and research.

6 Nine Elements Watershed-Based Management Plan

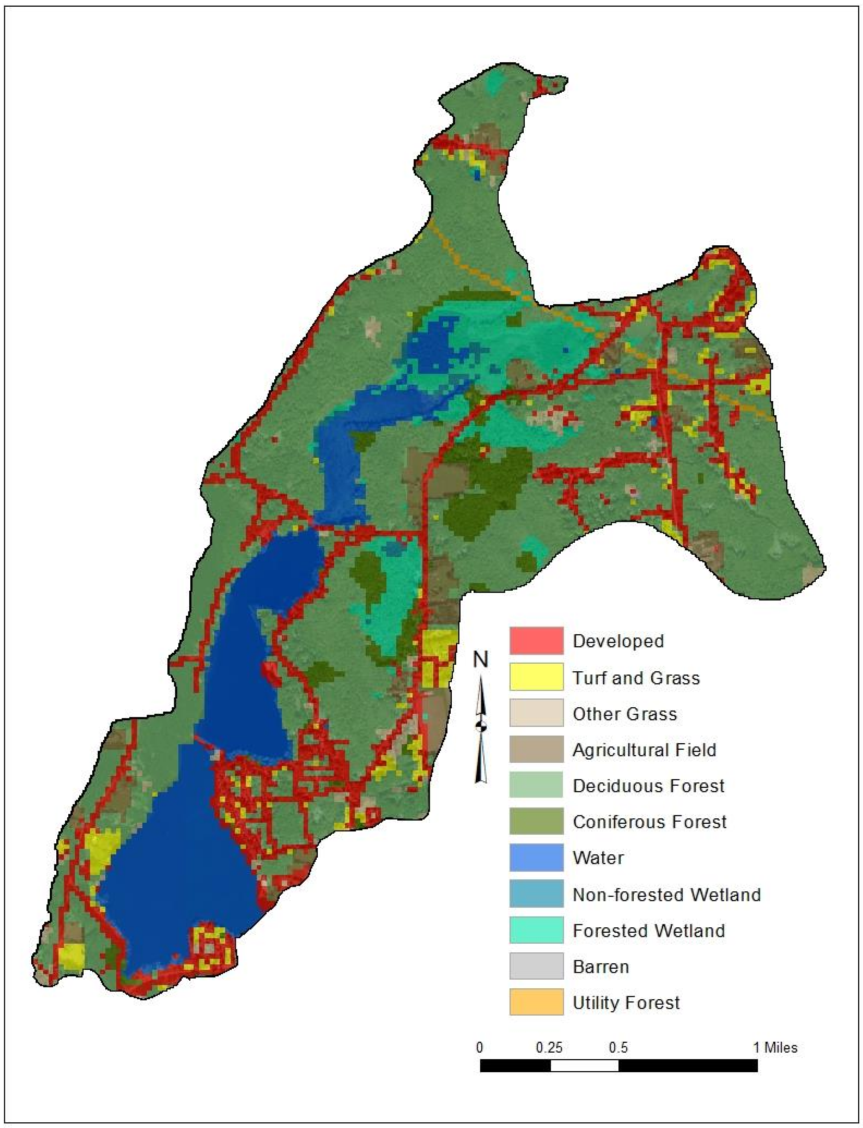
This section of the BLWMP provides updated information about the watershed, reviews recent monitoring data, and addresses the EPA Nine Key Elements required for a Watershed-based Management Plan to address nonpoint source pollution.

6.1 Watershed Overview

Maps provided use the original watershed delineation boundary and can be updated if future investigations determine that the Upper Bolton watershed does indeed extend above Mile Hill Road or if the UBL wetland does not entirely drain to UBL.

6.1.1 UCONN Center for Land-use Education and Research (CLEAR) 2016 Land-Cover

Map 13: CLEAR 2016 Land-Use Coverage



Land-Use	% of watershed
Developed	14.9%
Turf/Grass	3.5%
Other Grass	1.7%
Agricultural Field	4.8%
Deciduous Forest	46.5%
Coniferous Forest	4.4%
Water	16.1%
Non-forested Wetland	0.6%
Forested Wetland	6.9%
Barren	0.1%
Utility Forest	0.6%

The 2014 ERT has detailed information about watershed wildlife, forests, wetlands, and changing land use:

Forest cover within the watershed decreased from 49% to 31%, a loss of 18% since 1978. This is the greatest loss of any of the cover types. Agricultural land decreased by 1% to the present 4%. Wetlands decreased to 11%, a loss of 2%.

The percentage of the total watershed acreage in water and municipal parks remained unchanged, 13% and 2% respectively.

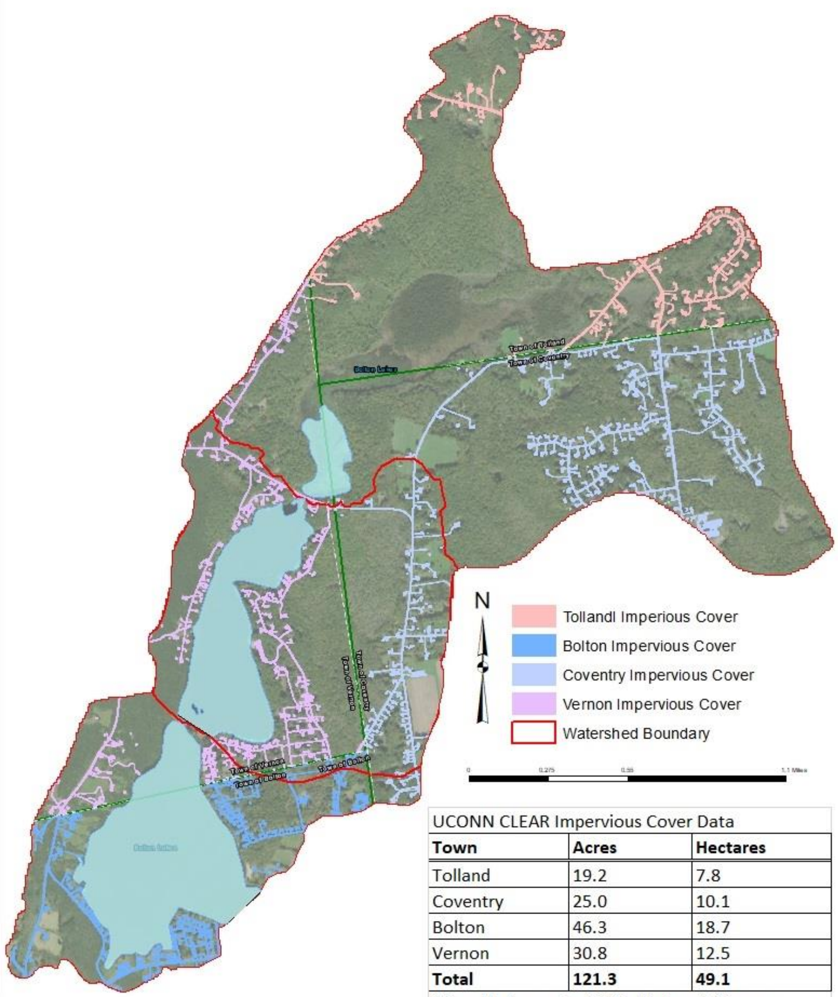
Between 1985-2006, the basin went from 11.3% developed to 14.6% developed (UCONN CLEAR).

To view historical 1985 and 2006 land cover maps & percentages please see the Environmental Review Team 2014 Publication: https://ctert.org/pdfs/Bolton_BoltonLakesWatershed_631.pdf

6.1.2 UCONN CLEAR Impervious Cover Data

Over 50% of the Bolton Lakes watershed impervious cover (IC) is “disconnected” from the direct flows. Nearly all of the impervious cover in the Upper Bolton watershed is considered “disconnected” because it flows through extensive wetlands or to forested areas where stormwater may infiltrate into the soils or be substantially altered by the wetlands themselves. Nearly all of the Cedar Swamp Road (Coventry) IC does not flow directly to the Bolton lakes. As part of the four Town land-use planning and management effort, GIS layers of all catch-basins in the Bolton Lakes watershed should be compiled and exact MS4 conveyances detailed for future reference. This will better refine the “Connected IC.” Some households with disconnected roof runoff should also be considered “disconnected.” The UCONN CLEAR Land-Use “Developed” classification acreage is not readily comparable with the IC dataset. The IC dataset is more precise.

Map 14: UCONN CLEAR Impervious Cover (IC)



UCONN CLEAR Impervious Cover Data

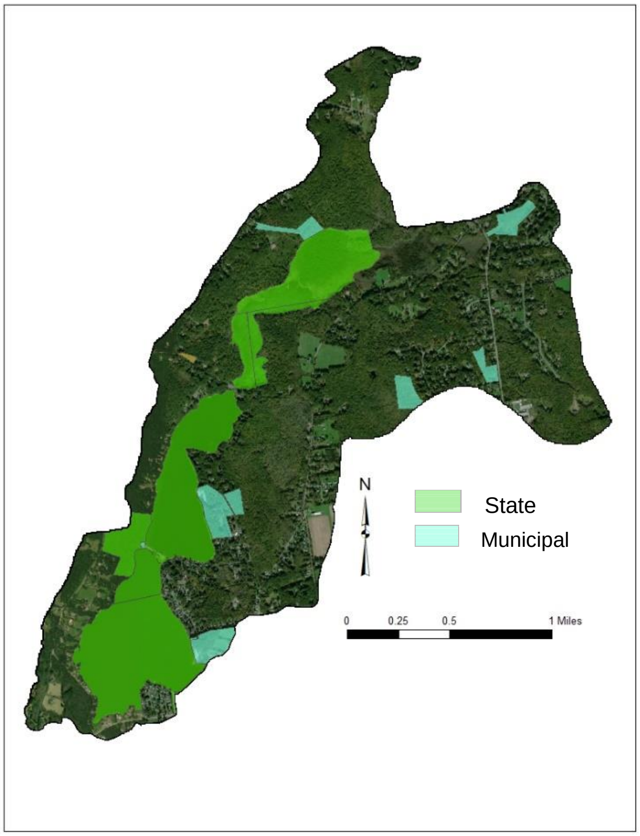
Town	Acres	Hectares
Tolland	19.2	7.8
Coventry	25.0	10.1
Bolton	46.3	18.7
Vernon	30.8	12.5
Total	**121.3**	**49.1**

"Directly Connected IC" in Bolton & Vernon = roughly 77.1 acres (31 ha).

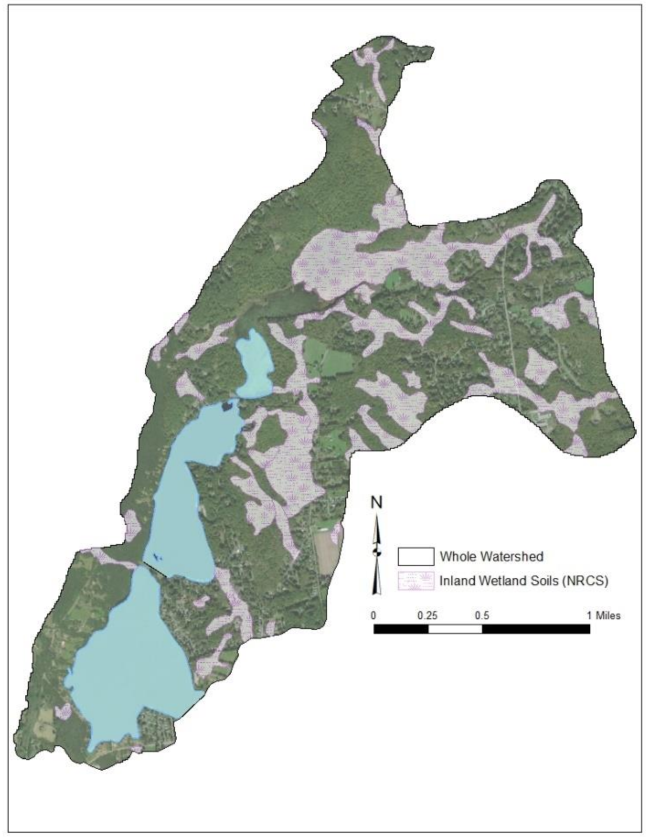
6.1.3 Public Lands & Mapped Wetlands

Note that the mapped wetlands constitute wetland areas that are generally larger than 3-acres in size. Smaller wetlands exist within the watersheds, but are usually only mapped locally, when needed for building or inland wetlands permits.

Map 15: Public Lands in Bolton Lakes Watershed



Map 16: Hydric Soils (Inland Wetlands) in Bolton Lakes Watershed



6.2 Watershed Nutrient Pollution

This section addresses EPA Elements:

A. Identify causes and sources of pollutants.
C. Develop management measures to reduce pollutants
D. Identify technical and financial assistance needed to implement plan
F. Develop implementation schedule

6.2.1 Structural Stormwater Nonpoint Nutrient Pollution Sources & Management Measures

The following table presents a list of structural nutrient pollution sources in the Bolton Lakes watershed. The list is organized into High, Medium, and Low priorities. Priority ranking was determined based on: nutrient concentrations in runoff, water flows/volume, ease of implementation, costs, feasibility of public-private partnerships, and degree of secondary benefits via educational and project visibility.

Table 10: Watershed Improvement Sites, Estimated Costs, & Proposed Timeframe

Watershed Site	Estimated Engineering Costs	Estimated Construction or Implementation Costs	Priority Level	Proposed Timeframe	Nutrient Reduction Potential
CT DEEP Lower Bolton Boat Ramp	$	$$$$	High	Depends on DEEP	High
Route 44 Apartments	$	$$$	High	2022-2024	Moderate
Lower Bolton Rd. Wetland Enhanced Filtration	$	$$-$$$	Low	After high priority	High
Vernon Rd. Catch Basins	NC	$$	High	2022-2024	High
Keeney Drive Road Runoff/Swale	$	$$-$$$	High	2022-2024	Moderate-High
Rosedale Beach	NC	$	High	2022-2024	High
Runoff from Juniper & Colonial Rds to Rosedale	$	$$$	High	2022-2024	High
Garth Lane & Colonial Rd. Unpaved Sections	$	Unknown	Medium	Unknown	More information necessary
Llynwood-Plymouth: Preserve Undeveloped Parcels	NC	$$$$	High	2022-2023	Prevention Only
Wildwood Road	NC-$	$$	High	2022-2024	High
Residential Buffer Zones & Erosion Control	NC	$-$$	High	2022-onwards	Moderate
Middle Bolton CT DEEP Boat Ramp / Lot	$	$$$-$$$$	High	Depends on DEEP	High
Camp Newhoca Park	$	$-$$$	Medium	2022-onwards	Moderate
Bolton Lake Shores Association Beach	$	$$-$$$	High	2022-2023	High
Grier Road Wetland Streams / Road Runoff	$-$$	$$-$$$	Low	After high priority	Moderate-High
Middle Bolton Dam Investigation	NC	$	Low	Limited ability to change	Unknown

Costs Range: $ = $0 - $5,000 $$ = $5,000-$10,000 $$$ = $10,000-$50,000 $$$$ = $50,000+

6.2.1.1 Watershed Sites Description of Proposed Nutrient Pollution Measures

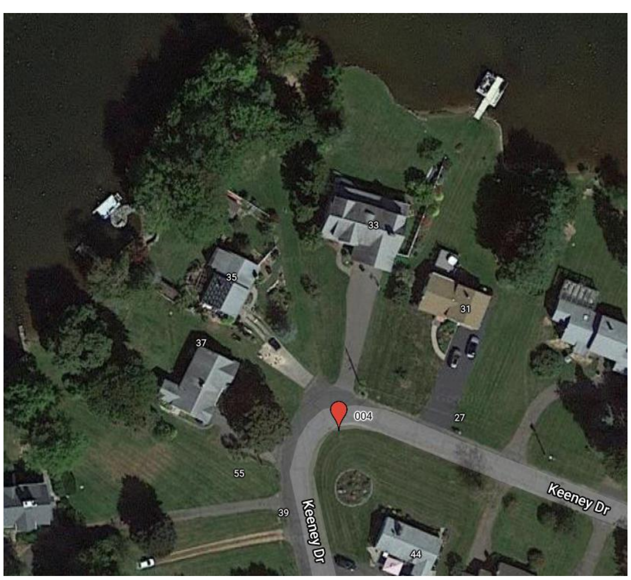
Proposed nutrient pollution measures will be modified based on engineering designs.

CT DEEP Lower Bolton Boat Ramp: Establish grass on lower gravel area, or extend pavement to the sign (area pictured in first photo). Manage stormwater by creating a tiered grassy bioretention area just upslope of the grass/new pavement to capture runoff from the upslope gravel and paved driveway. This will need a berm just after the handicap parking spaces, to route water away from the lake. The ultimate goal would be to reduce water runoff that makes its way through the small culvert and to the Lake.

Alternatively, establish pervious interlocking pavers, filled with pea gravel, in the parking area to minimize water runoff and erosion. Sheet flow collects on the edge of the grass (third photo) because there is no break in the long, paved driveway, sloped to the lake. Reduce sheet flow with two horizontal trench drains in the pavement that route water to the west side of the driveway into the densely vegetated swale.



Keeney Drive Road Runoff: The corner of Keeney Drive receives stormwater overland flow from both directions. Some of the water flows underground through culverts to the lake, while some runoff is channeled through a surface stream along a private property boundary, pictured in the photo below. It may be possible to direct more of the road runoff into this vegetated channel instead of direct culvert flow to the lake. The channel would need to be more densely vegetated and could serve as a grassy/wildflower property barrier – whatever grows best with a 'no-mow' policy.



Apartments on Route 44 & Vernon Rd. along Lower Bolton Lake: The old parking lot of the apartment building has large areas of exposed sediment that increase the turbidity of local stormwater runoff. Because this property is private, there has been very limited stormwater inspection. The first photo included was taken during a small rain event and does not fully demonstrate the extent of flooding and erosion that occurs on the lower half of this property. The second photo demonstrates how rainwater washes through the old driveway and picks up turbidity before flowing to the lake. It is worth pursuing a public-private partnership to improve general stormwater practices for the entire parcel. It is also possible to improve the section of the driveway closest to Rt. 44 and direct driveway runoff into a large bioretention area in the grassy area along Rt. 44, or to the east of the property.

After the large de-vegetation and soil disruption event in October 2019, it is clear that the lakes management effort would benefit from improved communication with this property owner. The photo of the silt fence was taken from the water, but it took months to properly seed this area, and a well-vegetated shoreline buffer was lost. It is unknown if there was Inland Wetlands oversight or enforcement at the time.




Bolton Road Wetland Enhanced Filtration: A large amount of direct road runoff from the watershed's northern half of Bolton Road flows through two large cement culverts under the CT DEEP-owned walkway. While the wetland does a good job dispersing and storing such large quantities of water during the drier summer months, the water could be better dispersed through both the north and south sections of the wetland via a series of natural level-spreaders. Level-spreaders are designed to create temporary and shallow pools of water across wide sections of wetlands to increase maximum flood-storage capacity of the wetland and increase the amount of nutrients and organic matter that can settle out (by increasing retention time).

The level-spreaders are similar to dam jams or weir boards that allow water to flow over them during peak flow and then slowly lower the water level through a small opening closer to the bottom of the board. The area just uphill and downhill of the cement culverts would be the best place for this type of system as water already naturally pools in those areas and site access would be easy. The exact location is marked with a Google Maps pins below.

Similarly, the lower reach of the wetland, just before the stream enters Lower Bolton Lake, could be further dechannelized. The simplest method of doing so would be to place several medium sized rocks/small boulders upslope of the inlet. Rocks disperse water energy and decrease channel erosion, which is present at the inlet during almost all rainstorms (less during summer months, due to recent drought conditions – inlet location visible third photo).

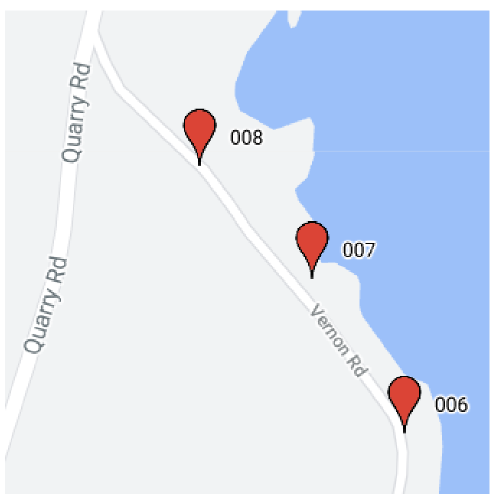
The Environmental Protection Agency Spreadsheet Tool for Estimating Pollutant Loads (STEPL) rates wetland detention as effective in removing 20% nitrogen and potentially up to 44% effective for phosphorus removal, mainly from higher settling (Region 5 model).

Vernon Road: Of all of the streets that surround the lakes, Vernon Road is the closest to the lake. Small lot sizes in this area make it difficult to capture stormwater runoff from both the road and the private homes. Homeowners should be encouraged to route roof runoff to vegetated depressions.

The first photo below provides an example of where water runoff from the road accumulates and runs onto people's properties. In low flows, water pooling is common, but during intense rainstorms the water from the eastern side of the road accumulates, picking up sediment before flowing into a catch basin. Creating a small vegetated rain garden would prevent erosion and decrease stormwater turbidity and nutrients.

The second image shows the three major stormwater flows to the lake along Vernon Road.
Flow is highest at inlets 7 (third photo) and 8. The storm drains at sites 7 and 8 are good candidates for catch basin phosphorus filters, such as those manufactured by Fabco. The uphill swales are well vegetated and should not be disturbed because they prevent heavy erosion. However, the swales can be improved by adding a series of small check dams to slow flow and increase infiltration. Similarly, the water that flows down these swales enters the catch basins 7 and 8 from below. If filter inserts were used, this swale flow could be redirected to flow through the top of the grates. Discussion with the Public Works Dept. should follow.

The STEPL and Region 5 models estimate up to 38% phosphorus removal efficiency for sand filters, and the Fabco phosphorus filters would likely see further enhanced phosphorus removal and significant nitrogen reduction, simply from entrapment of fine organic material.

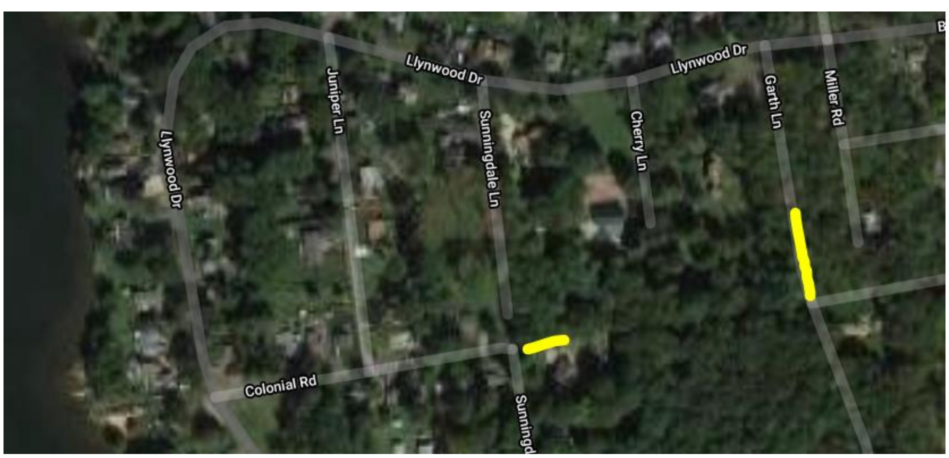


Rosedale Beach has high phosphorus, nitrogen, and turbidity from uphill sources. There are a series of residential gardens in the area that have a combination of open sediment and mulched segments that are very close to the road. When it rains heavily, the garden soil has been seen washing onto the street and into the culvert. There have also been small residential construction projects, such as driveway refinishing and stockpiling soil, that did not have proper erosion control. This tightly knit residential area deserves focused outreach and signage about homeowner BMPs to prevent soil loss and reduce fertilizer use.

Indian Notch Park, Bolton: A large section of Indian Notch Park is within the Lower Bolton Lake watershed. The forested area is one of only two forested shoreline parcels and this area must continue to be preserved, as is the intent of the Town. The Town must also aim to use fertilizers very sparingly on the baseball field, if fertilizers are needed at all. Nitrogen travels easily through soils and percolates with groundwater, so fertilizer use, even without direct runoff, can still impact water quality over time.

The Town beach area allows public access to Lower Bolton Lake, and any additions of beach sand should use only washed, low phosphorus sand. Silt fences during the winter season can help minimize sand loss over years.

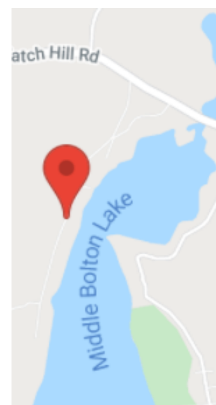
Unpaved Private Roads in Lower Bolton watershed:
Garth Lane (first photo), Section of Colonial Rd. (second photo)
Open soil on unmaintained unpaved surfaces, either roads or private driveways, has the potential for stormwater-induced soil erosion. These roads are relatively flat, which greatly reduces the chance that high turbidity stormwater runoff will reach the lake directly from these streets, but the area needs further investigation. Evidence of water pooling and erosion on the unpaved roads is present, and vehicle traffic tracks soil onto the paved road, which contributes to high turbidity and phosphorus in stormwater runoff to the lake. The yellow lines in the aerial image, below, indicate the sections of road from the photos. This was a major problem in 2021.

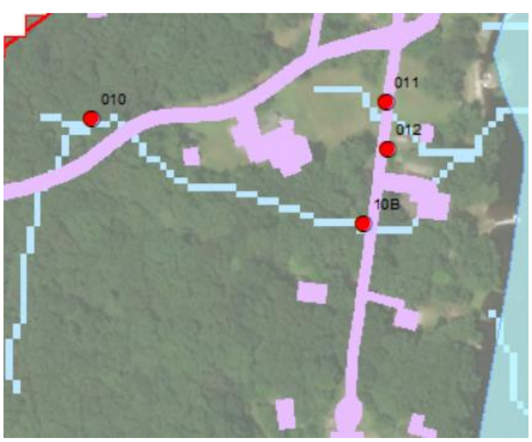


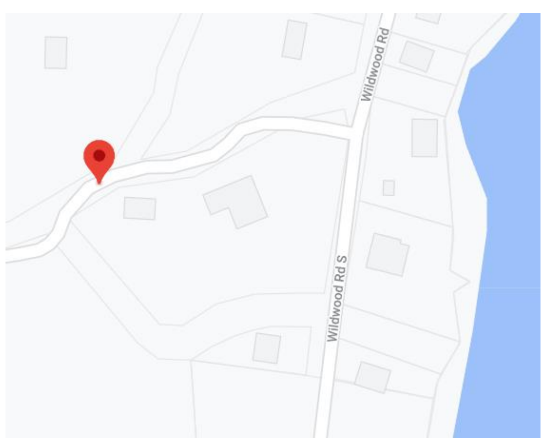
Wildwood Road along Middle Bolton: The section of Wildwood Road that runs parallel to Middle Bolton Lake has a steep and eroding western road bank. Eroding banks have great potential for soil loss and phosphorus transport through stormwater, which flows into the roadside ditch to the downhill catch basins. Effort should be made to stabilize the eroding bank, but the large amount of exposed rock will make that difficult in certain sections. In the meantime, catch basins can be retrofitted to fit replaceable fine sediment filters, such as the Fabco phosphorus filters. The first two photos show the upper and lower reaches of the roadside erosion.

There is also a stream that runs underneath Wildwood Road at sampling point 10, before intersecting the lower Wildwood Road S. at sampling point 10B. The water quality of this stream has been good, but any increased development in the forested area could impact the stream and increase nutrient loading. Preserving this forested section of the watershed should be a priority. The second aerial image displays the property parcels and the location where the stream crosses the road.

The sampling points 11 and 12 are very small streams that appear to flow only during heavy rain (>2’’). Nutrient concentrations from 2014-2015 were very high, but those values were a result of poor erosion control during construction at the time. There are no updated stormwater samples and these sites were not flowing during recent stormwater samplings.

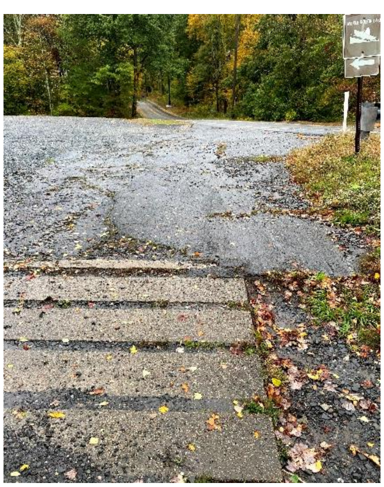


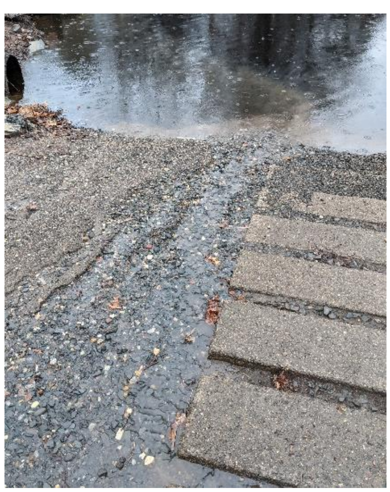




Wheeler Road and Lakeview Drive Middle Bolton Residential Communities: These two residential unpaved roads in the Middle Bolton near-shore watershed have high potential for erosion and phosphorus loading to Middle Bolton Lake. This area should be a priority for further watershed reconnaissance, led by the community members. At present, there are two small streams (sampling points 15 and 16) that flow from the forested area and under the roads. Flow from the larger stream (16) is interrupted by a pond on private property on Lakeview Drive. Depending on the private pond maintenance, it could either improve or degrade the stream water quality. Increased water storage allows settling of particles, but if the pond is dug deep enough, it could increase orthophosphate if oxygen loss occurs during summer.

Middle Bolton CT DEEP Boat Ramp & Parking Lot: The Middle Bolton public boat ramp is heavily used and has been an ongoing source of high nutrient runoff to the lake for years. The runoff from past years was significantly greater due to active construction and poor erosion control, but even today, the gravel lot has many pot-holes and evidence of erosion. During heavy rain, sheet flow runoff carries silt and gravel across the boat ramp and channelizes along the Hatch Hill side of the boat ramp. The photos below do not show the full extent of the stormwater runoff, but frequent sediment plumes are witnessed after and during rainstorms, indicating high phosphorus loading potential. There are many potential LID and stormwater infiltration projects that could improve the water quality impact of this large parking lot. It is unknown if the Hatch Hill dam reconstruction project will impact this site, but any amount of erosion is not good for water quality. In the future, this boat ramp site would be a good spot for a large infiltration rain garden and educational stormwater signage.





Camp Newhoca – Vernon Public Park, shore of Middle Bolton Lake: Camp Newhoca is owned and operated by the Town of Vernon. The Park offers beach access to Middle Bolton Lake. The Newhoca Park offers use and rental of the Town-owned and maintained pavilion and lodge. This large parcel of municipal land should have maintenance practices that aim to reduce stormwater runoff and overall impact to the lake's water quality. Beach maintenance should only use washed sand, which is cleaner and low in phosphorus. The large beach parking lot area deserves further inspection and may benefit from LID and/or bioretention areas in the future.

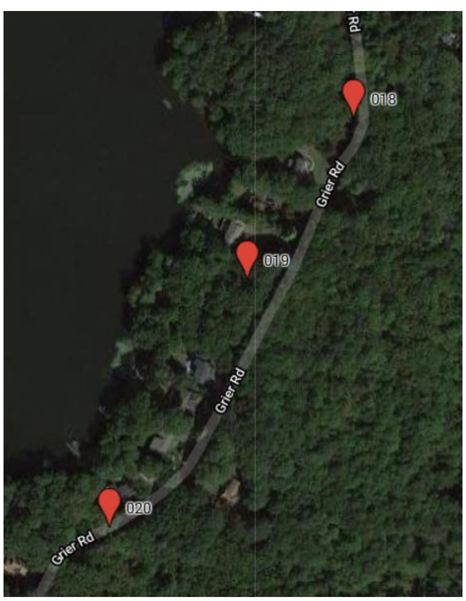
The second beach zone, which is separate from the main public beach, appears to have infrequent use. Depending on the Town's proposed future use of this area, it would be a good example for private property owners if the Town allowed a driveway buffer area to grow and fill in on the upslope side of the retaining wall. Native wildflowers and grasses require little effort to establish, and would have visual and functional utility.

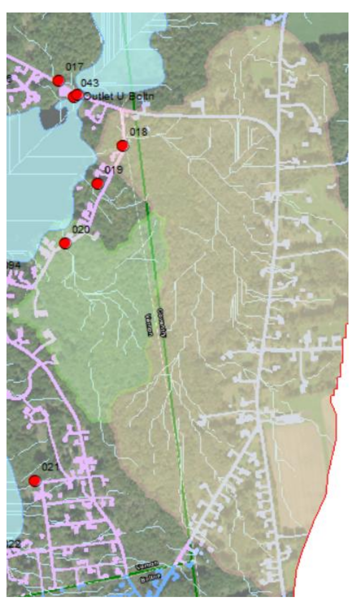
Bolton Lake Shores Association Area (Middle Bolton Lake): The Bolton Lake Shores Association beach has a catch basin that receives runoff from Anchorage and Miller Roads (sampling point 21). There are no recent stormwater runoff samples from this location, but the underground culvert from the catch basin is directed to the lake. There is a gravel entrance way that is presumably used as a parking or loading area, but since all members are local, the gravel area space may be suitable for a stormwater bioretention area (rain garden). A soil test pit would be required to determine if the soils have adequate infiltration abilities to completely infiltrate a 1-2'' rainstorm. The rain garden overflow could be directed back into the catch basin.

Middle Bolton Dam: The native rock that was used for the construction of the Middle and Lower Bolton dams has a large amount of Brimfield Schist, described as sulfidic schist and gneiss. The ERT report makes note that these rocks contain iron-sulfide minerals that easily break down and erode to iron oxide powder. Iron oxide rapidly binds available phosphate, and high iron concentrations in Lower Bolton have been linked to increased cyanobacteria abundance. Samples from the dam should be taken and put through a series of sediment phosphorus extractions to determine the amount and potential bioavailability of phosphorus from degrading dam materials. The extraction should be as follows: water soluble P, loosely-sorbed P (NH_4Cl extraction), reductant soluble P (CDB extraction).

Grier Road Wetland Streams & Road Runoff to Middle Bolton: There are three wetland streams that cross under Grier Road (sampling points 18, 19, and 20). Road runoff from Grier Road makes its way to these streams during heavy rain and increases the nutrients that feed into Middle Bolton Lake. The wetland streams, themselves, also contribute phosphorus and nitrogen to the lake. A wetland's ability to retain nutrients is dependent on the amount of settling time and plant growth. The wetland that feeds stream 18 is channelized and most of the water flow runs closely alongside Grier Road, shown in the first and second photos. A wetland enhancement project could reroute some of the water across more wetland surface, with the goal of increased settling and nutrient storage. Though, stormwater concentrations of these wetland areas are relatively low compared to other locations noted in this watershed plan, meaning this is not a high priority management site.

The Grier Road runoff currently flows to the roadside forested areas, and due to the low slope, does not have issues with erosion. It is unknown whether the Town does roadside vegetation maintenance, but roadside ferns and grasses enhance stormwater infiltration, before overflowing to the wetlands. The second photo shows the approximate sub-watersheds and flow direction for streams 18 and 20, created using the CT 1m LIDAR DEM data. The forested area that flows to these inlets is important to preserve.





6.2.2 Non-Structural Nonpoint Nutrient Pollution Sources & Management Measures

Additional non-structural nonpoint nutrient pollution sources are those that are more maintenance-based and from runoff from private and/or public property that is unassociated with a specific watershed site.

Winter Road and Driveway Maintenance Practices

The current road salting and/or sanding practices for the watershed roads should be reviewed. Coordinated discussion with the town Public Works Departments are recommended. Informational conversations about current winter road maintenance will reduce water quality impacts on a Town level. Snow plowing on narrow residential streets tends to also disturb roadside soils. Spring-cleanup and roadside erosion maintenance should be a priority.

Fertilizer Use

In general, phosphorus fertilizers should not be used in the near-shore areas of the Middle or Lower Bolton Lakes. Gardening fertilizers and soil disturbances should be limited to flat areas or those that will not readily be disturbed by large rain events. It is generally good practice to allow natural shoreline buffers such as tall grasses and wildflowers to root along shore, instead of attempting to cultivate specific garden plants that may require more fertilizers and soil amendments. Use of fertilizers in gardens or on lawns must be extremely frugal. Nitrogen from fertilizers readily travels through the groundwater with every rain event, and should only be applied if a soil test determines that a yard is nitrogen deficient. Most lawns do not require fertilization, and homeowners could instead opt to cut grass slightly higher, which aids in root development and fuller lawns. Similarly, some lawn and garden soils may be acidic and would benefit from a slight increase in pH in order to maintain vigorous plant growth. pH adjustments use garden lime-based products or wood-ash and will help soil nutrients already in the soil become more available for plant roots. Residents are encouraged to get their soils tested by the UCONN soil testing lab.

Erosion

Erosion is a serious problem for lakes. Erosion naturally carries nutrients, specifically phosphorus, from the watershed to the lakes. It is important for all watershed property owners to minimize the amount of erosion taking place on their own properties. Erosion is most common near locations where water moves quickly along edges of impervious surfaces, such as along driveways or roads. Homeowners can reduce erosion on their properties by diverting roof and driveway runoff away from public roads, as well as letting grass grow slightly taller than usual, particularly on hillsides. Setting a lawn mower to a higher setting allows grasses to develop stronger root structures that more readily hold soils together and prevent erosion. Many of the nutrient pollution hot-spots identified in the Structural Nonpoint Source Pollution Sources section aim to reduce erosion from public property and roads, but private property erosion can also be problematic when it ends up flowing onto the roads and into public storm drains.

Legacy nutrients from soils, wetlands, and groundwater

Onsite wastewater legacy nutrients in near-shore soils may still contribute to the annual Bolton Lakes watershed nutrient load. It is likely that rainstorms deliver pulses of old wastewater-related legacy nutrients through seepage groundwater; inputs will inevitably be reduced over time since the sewer construction. It is unrealistic to attempt to manage legacy nutrients in soils and groundwater seepage, but the load impact should at least be considered when attempting to understand the effect of rainstorms on the Bolton Lakes. Any properties that have not connected to the public sewer system should consider doing so.

Nutrients from the wetland that is Upper Bolton Lake contribute to the Middle and Lower Bolton Lake annual nutrient load. The Upper Bolton Lake wetland and sediments serve as both a sink and source of nutrients, depending largely on the time of year, location within the wetland, and the amount of plant growth and/or burial of nutrients in sediments. Presumably the wetland acts as an overall nutrient sink, but it is very difficult to quantify and differs from one season to another. At the normal Middle Bolton Lake water level during summer months, there is often little flow from Upper to Middle Lake, but during annual drawdown periods there is a large transfer of nutrients from Upper to Middle Lake. No targeted nutrient management at Upper Bolton Lake is proposed at this time, but further sampling of Upper Bolton Lake inflows to Middle Lake should be considered a research priority. Upper Bolton Lake stores an enormous quantity of nutrients, and the mass nutrient flows from Upper to Middle ultimately depend on weather patterns. Upper Bolton Lake does contribute large quantities of anoxic water and nutrients to Middle Lake during the year-end drawdowns. The construction of the Hatch Hill Road dam, separating Upper and Middle Bolton Lakes, will allow for better water level control and flows.

Other Nonpoint Nutrient Sources

Waterfowl – Controllable by reducing Canadian geese populations through limited large grassy areas along shore. Geese prefer waterbodies where they are able to walk from the water onto a grassy shore; adequate shoreline buffer plantings limit Geese from doing so. Plantings are recommended to be at least 3ft tall by 3ft wide. The Geese populations at Lower Bolton Lake are significant in the southwestern cove, but their overall nutrient load is low compared to primary sources of stormwater and internal loading sources.

Sewer integrity – Maintain vigilance and regular communication with the regional Bolton Lakes Water Pollution Control Authority to ensure adequate functioning of sanitary sewers.

Reduce salting and sanding during winter by following list of winter maintenance BMPs:

Homeowner and Business Best Management Practices

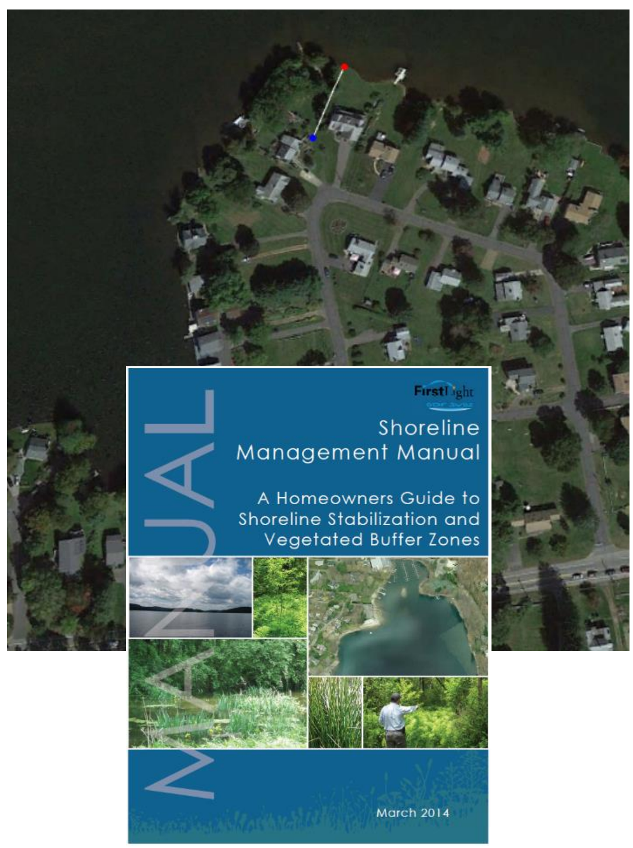
of Lake George in order to test its use reducing salt application in the Lake George watershed.

- **Shovel early and often:** It stands to reason that when you remove snow and ice by shoveling, you'll need less salt and the de-icing material will be more effective. Begin your cleanup work as early as you can and keep up with the snowfall (unless freezing rain is forecast to follow the snow) so the sun can get at the pavement/sidewalk and melt it away. You may even decide that salt isn't needed.
- **Use an ice chipper:** A specialized ice-chopping tool (not an ice pick) will allow you to work faster and more efficiently removing ice or a hard buildup of snow than a standard snow shovel.
- **Apply only what's needed:** Sprinkle de-icing material on icy areas only, and follow the manufacturer's instructions for working temperatures and application rates. Winter salt is most effective between 32 degrees F and 10 degrees F. If the temperature is above or below that, you can consider alternatives such as using a small amount of sand for traction, or chopping and removing the built up snow/ice with an ice chipper or shovel.
- **Apply protectively:** Keep salt application away from any storm drain, or where melted runoff can mix with salt and then flow into a storm drain. In many communities, storm drains lead directly into the Lake.
- **Reposition downspouts:** Make sure downspouts are pointed away from paved (or other hardened) areas so that water isn't draining onto your walkways or driveways where it can refreeze.
- **Reposition snow piles:** Shovel unsalted snow to lower areas of your property or onto lawns to direct melting snow away from paved areas.
- **Do your homework:** Research de-icing materials before you purchase them to determine which is best for your specific property and need. Not all products have the same ingredients. Consider purchasing a de-icier that is chloride free.

https://lakegeorgeassociation.org/act-now/reduce-salt

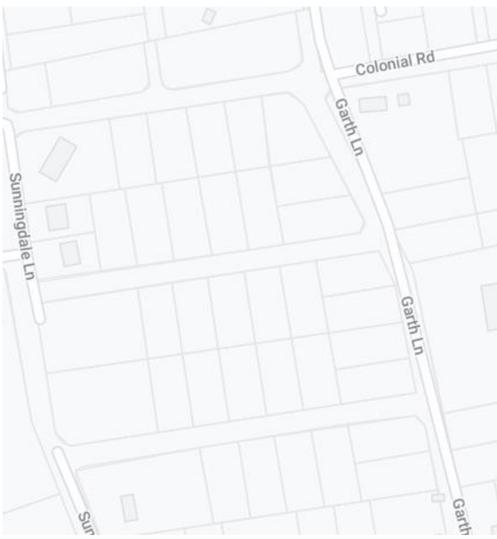
Whole Watershed Shoreline- Encourage Private Residential Buffer Zones: There are a number of private residential properties around Lower Bolton Lake (first image) that have room to improve their shoreline buffer zones. Ideally, a buffer zone should be 150ft wide, measured perpendicular to the lake shoreline. An example of 150ft is shown on both aerial images. While there is not enough room to establish 150ft buffer zones along the more densely populated shoreline, lakefront homeowners with smaller lots can still aim to reduce the lawn coverage and establish narrower no-mow zones, or densely vegetated shores, to limit lawn run-off.

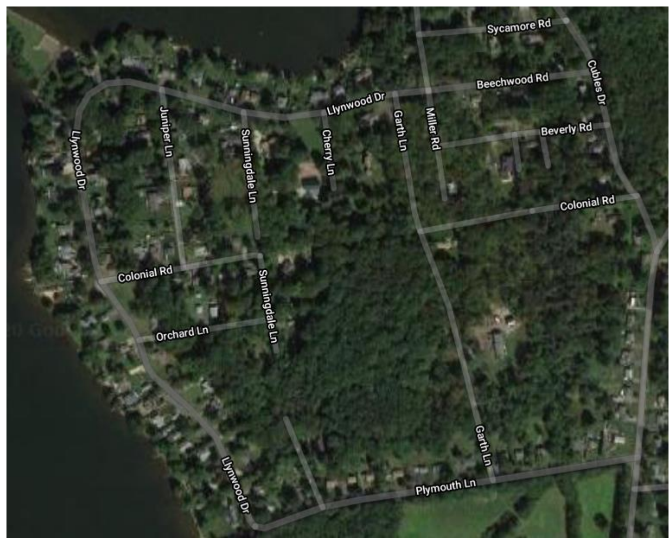
FirstLight Power published a Shoreline Management Manual for homeowners in 2014. This is a great resource and provides planting lists and good visual examples of various types of shoreline stabilization and buffer plantings. Bolton Lakes residents should be aware that the manual provides recommendations for natural replacements to sea-walls and that many of the designs are specifically for dissipating high wave energy that is generated by boat traffic on large Candlewood Lake. Due to the low speed and horse-power limits for boating at the Bolton lakes, shoreline stabilization is not quite as much of a problem at the Bolton lakes and some of the recommendations from the manual may not be directly applicable to Bolton lakes shoreline property owners. The document can be viewed at: https://firstlightportal.myadept.com/pdf/Shoreline-Management-Manual-Current.pdf Residents should also be mindful that any construction to repair or replace a sea-wall must have adequate erosion control practices. In some cases, disturbing an existing sea-wall is detrimental to water quality. The best and cheapest type of shoreline buffer is to simply allow native tall grasses and deep-rooted wildflowers to establish themselves through a no-mow strip. More information on various types of buffer zones will be provided through educational outreach seminars.

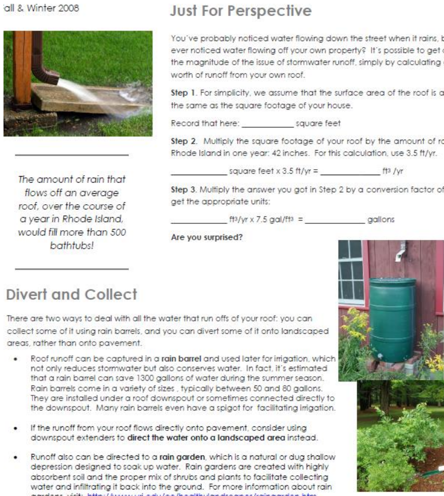


Preserve Undeveloped Parcels in greater Lynwood – Plymouth Neighborhood & Focus-Area to Encourage Community Stormwater Management: The neighborhood that borders Middle Bolton Lake to the north and Lower Bolton Lake to the west, between Lynwood Drive and Plymouth Lane, is one of the most densely populated areas of the watershed. There is a central forested area between Sunningdale and Garth Lanes that appears to have already been subdivided for additional residential lots. Most of the undeveloped area lies in the Town of Bolton, just over the border from Vernon. It would benefit water quality if the Town purchased these lots for the purpose of conservation, minimizing further increases to impervious cover in this neighborhood. Alternatively, if the parcels are to be developed, there should be a goal to retain as much stormwater runoff on site as possible.

This neighborhood is also a good place to advocate for a community water-catchment program. Residents are often surprised to know just how much water runs off their properties. The RI Stormwater Solutions web page has good handouts that instruct homeowners how to calculate their runoff and divert it to rain barrels or rain gardens.







www.ristormwatersolutions.org

know where it goes — take simple steps to reduce stormwater pollution

Is Your Yard A Sponge?

all & Winter 2008

Just For Perspective

You've probably noticed water flowing down the street when it rains, but have you ever noticed water flowing off your own property? It's possible to get an idea of the magnitude of the issue of stormwater runoff, simply by calculating one year's worth of runoff from your own roof.

Step 1. For simplicity, we assume that the surface area of the roof is approximately the same as the square footage of your house.

Record that here: ___________ square feet

Step 2. Multiply the square footage of your roof by the amount of rain typical for Rhode Island in one year: 42 inches. For this calculation, use 3.5 ft/yr.

___________ square feet x 3.5 ft/yr = ___________ ft^3 /yr

Step 3. Multiply the answer you got in Step 2 by a conversion factor of 7.5 gal/ft^3 to get the appropriate units:

___________ ft^3/yr x 7.5 gal/ft^3 = ___________ gallons

Are you surprised?

The amount of rain that flows off an average roof, over the course of a year in Rhode Island, would fill more than 500 bathtubs!

Divert and Collect

There are two ways to deal with all the water that run offs of your roof: you can collect some of it using rain barrels, and you can divert some of it onto landscaped areas, rather than onto pavement.

- Roof runoff can be captured in a **rain barrel** and used later for irrigation, which not only reduces stormwater but also conserves water. In fact, it's estimated that a rain barrel can save 1300 gallons of water during the summer season. Rain barrels come in a variety of sizes , typically between 50 and 80 gallons. They are installed under a roof downspout or sometimes connected directly to the downspout. Many rain barrels even have a spigot for facilitating irrigation.
- If the runoff from your roof flows directly onto pavement, consider using downspout extenders to **direct the water onto a landscaped area** instead.
- Runoff also can be directed to a **rain garden**, which is a natural or dug shallow depression designed to soak up water. Rain gardens are created with highly absorbent soil and the proper mix of shrubs and plants to facilitate collecting water and infiltrating it back into the ground. For more information about rain gardens, visit: http://www.uri.edu/ce/healthylandscapes/raingarden.htm

www.ristormwatersolutions.org

know where it goes — take simple steps to reduce stormwater pollution

Is Your Lawn Care Stormwater-Friendly?

Green Gardening

Achieving a lush green lawn, beautiful spring flowers, and hearty summer crops are understandable gardening goals, and applying pesticides and fertilizers is a common practice for many gardeners. Unfortunately, those lawn care chemicals often wind up washing right into local waters. The excess nutrients from fertilizers can cause drinking water contamination, massive algal blooms, and fish kills. The contaminants from pesticides can result in waters that are not fishable or drinkable.

Here are a few gardening tips that will help minimize the effect that fertilizers and pesticides have on water resources:

- Fertilize sparingly. If you must fertilize, September is the best month. And be sure to use slow-release fertilizer.
- If you want to fertilize more than once, don't fertilize in the spring until you have mowed the lawn three times.
- More is not always better! Skip the "step programs" offered by many lawn care companies, and be sure to apply fertilizers and pesticides only as directed. Using less will save you money, too! If you do use a lawn care company, ask them about their environmental options and certifications.
- Go natural: mow high and leave grass clippings on the lawn. It helps improve the lawn's health and quality, and you're less likely to need fertilizer.
- Avoid using fertilizers or pesticides near wellheads or within 75 feet of waterways.
- Check the weather forecast before applications, and don't apply fertilizers or pesticides when there is rain predicted.

Stormdrains lead directly to local waters. No filters. No treatment. Pollutants that enter stormdrains wind up in the water we drink, fish, and swim.

Agriculture in the Upper Bolton Lake watershed (Coventry): Several private properties on Cedar Swamp Road are used for agriculture. The yellow circled property is used for cattle grazing and has a small stream that feeds Upper Bolton Lake through a wetland. No water sampling has occurred, but due to the nature of livestock, this stream presumably presents a substantial nutrient load to Upper Bolton. Property owners are always encouraged to work with the Natural Resources Conservation Service (NRCS) to reduce the impact of agricultural land on nearby waterways. Upper Bolton Lake, however, is a highly eutrophic swamp and should adequately capture most of the nutrient inputs, so the farm likely has little impact on the Middle or Lower Bolton water quality.

The white dashed circled farmland appears to not be used for livestock grazing. The Town of Coventry should continue to work with farm owners and operators to minimize future nutrient loading to Upper Bolton Lake through sustainable agricultural practices. Again, the NRCS will be a valuable partner organization.

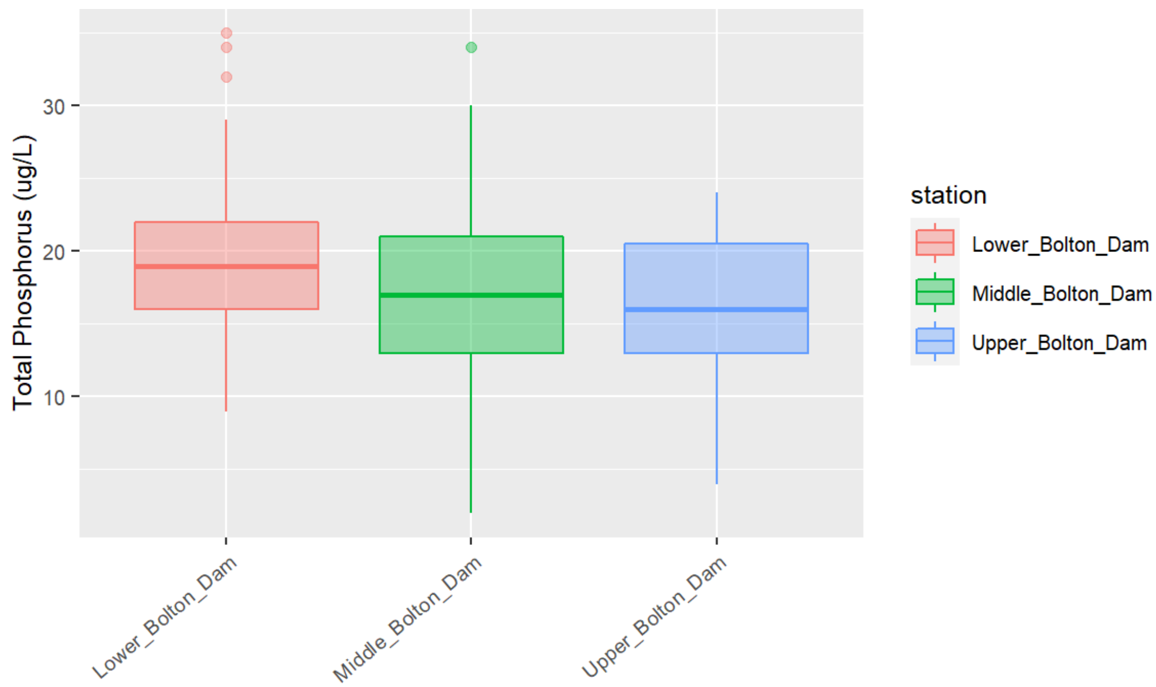
6.2.3 Background Inflows Sampling Data

Dams Flow Sampling

Samples were collected from the Lower Bolton Lake and Middle Bolton Lake outlet dam spillways. Water flows were also measured on all LBL sampling visits since 2014 on dates where water flowed over the spillway. There were many summer dates where little to no water flowed out of the lakes. Samples collected from dam culverts were removed from this analysis, as they tended to be higher in nutrients and only a couple of culvert samples were collected. Sampling Upper Bolton inflow to Middle Bolton was more challenging, as this culvert rarely had measurable or visible flow during summer months, and on several inspections even appeared to backflow. Only seven Upper Bolton flow samples were taken during the sampling period and are less comparable to the Middle and Lower Bolton mean/median values. It is notable, however, that Middle Bolton spillway concentrations are on average lower than the Lower Bolton outflow concentrations.

Upper Bolton dam mean/median concentrations: TP = 16 µg/L, TN = 323/349 µg/L (*n = 7 observations*)
Middle Bolton dam mean/median concentrations: TP = 17 µg/L, TN = 323/238 µg/L (*n = 81 observations*)
Lower Bolton dam mean/median concentrations: TP = 19 µg/L, TN = 327/346 µg/L (*n = 63 observations*)

Figure 18: Total Phosphorus at Bolton Lakes Dams



Dam water flows were measured during sampling events and used to estimate mass of phosphorus from Middle to Lower Bolton via the spillway. The 2019 estimates were approximately 25kg TP from April 17th to October 19th, with almost all flow occurring before mid-June. Water rarely flows over the Middle Bolton spillway from late June to October, except in years with high summer rainfall. An additional nutrient flush from Upper to Middle to Lower Lake occurs during the annual drawdowns. Based on 2020 estimated calculations, the TP mass transfer from Middle to Lower during drawdown is around 10kgs, depending on in-lake concentration. The understanding of nutrient mass transfer during drawdowns will be updated based on the detailed water level logger data, but generally these rough nutrient mass estimates align with range of in-lake measured phosphorus mass per year, which were used to determine target nutrient mass thresholds to maintain Mesotrophic conditions in Lower Bolton Lake. Target nutrient mass thresholds were not calculated for Middle Bolton Lake, given a lack of significant historical in-lake sampling.

6.2.4 Inlet Stormwater Sampling

Stormwater sampling was conducted periodically during rain events greater than 1-inch from 2014-2020. An analysis of stormwater sampling results indicated that the 2014 and 2015 concentrations were dramatically higher than recent years. We attributed many of the very high stormwater concentrations in 2014-2015 to the active erosion in the watershed during sewer construction, which created an unusual amount of soil disturbance and excessively high nutrient loading from the watershed during. Since the completion of the sewer construction, the stormwater concentrations in most areas have been considerably and consistently lower. Unfortunately, no stormwater sampling was done in 2021, but the volunteer residents documented a number of erosion events and stormwater concerns in areas previously identified (Table 10).

Of over 73 stormwater samples collected from direct inputs to Lower Bolton Lake, the median concentration was 118 µg/L TP and 939 µg/L TN. Of approximately 39 samples collected from the direct inflows to Middle Bolton Lake, median concentrations were 63 µg/L TP and 554 µg/L TN. Median stormwater concentrations into Middle Bolton Lake are notably lower because there were notably fewer road runoff samples and these concentrations reflect mostly stormwater stream concentrations (sites 10, 10B, 16, 18, 19, 20). Table 11 identifies the site description and type of inflow.

Map 17: Stormwater Sampling Locations & Inflows to Bolton Lakes

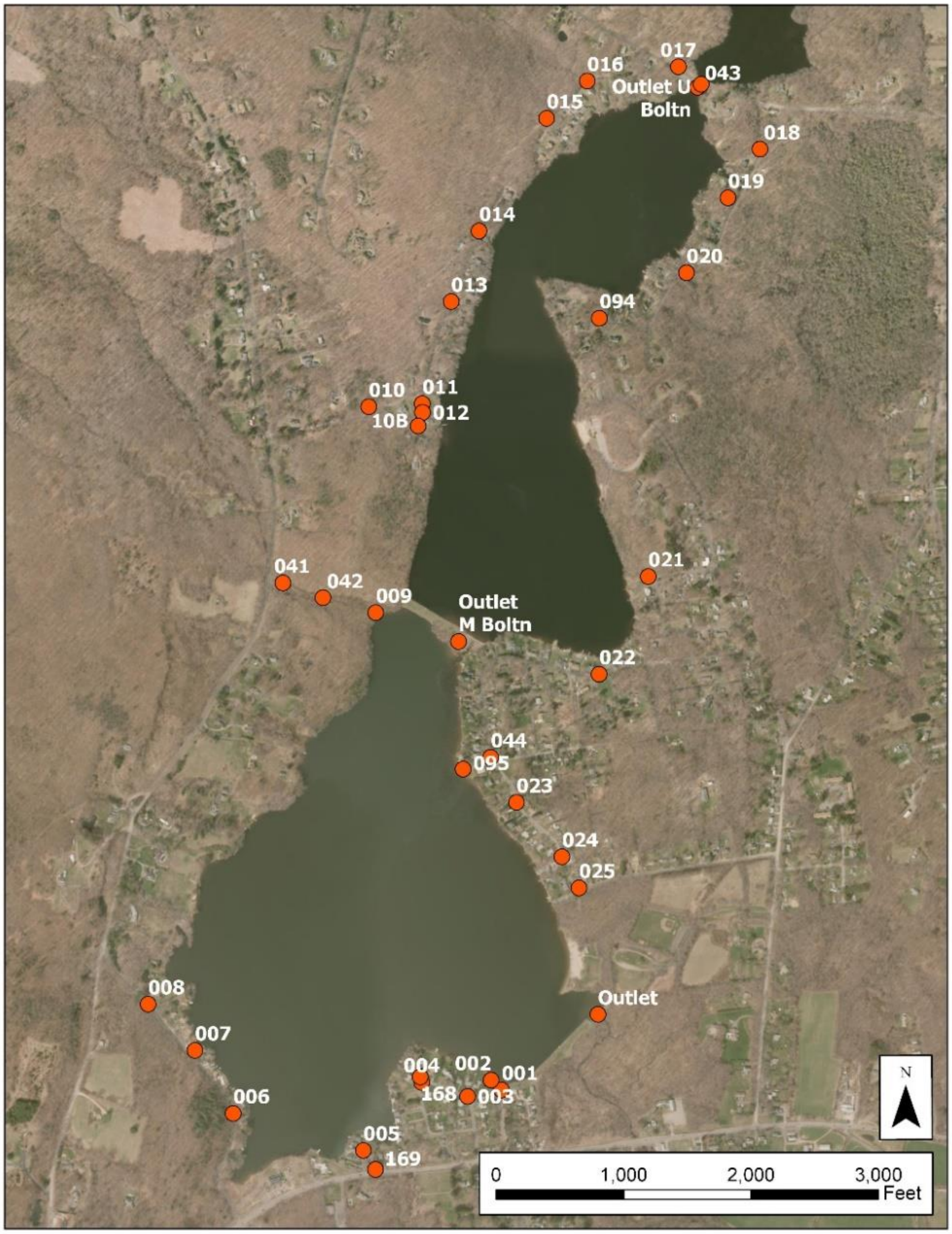


Table 11: Sampled Stormwater Sources of Nutrient Pollution & Site Descriptions

Site/Waypoint #	Description	Type
1	Overland flow, boat ramp	Overland flow
2	Flow through swale	Swale
3	Keeney Drive, road runoff into culvert	Catch basin/culvert
4	West Keeney Drive, road runoff to swale	Catch basin to swale
5	Route 44 road runoff from both directions	Catch basin to swale
6	Vernon Road, runoff to lake	Catch basin to swale
7	Vernon Road, runoff to lake	Catch basin to swale
8	Vernon Road, runoff to lake	Catch basin to swale
9 (from 41 & 42)	Wetland stream that receives excessive stormwater flows from Bolton Road	Wetland stream
10	Forest stream uphill	Stream
10b	Stream downhill	Stream
11	Wildwood Road, under-road flow to lake	Roadside swale
12	Wildwood Road, road runoff	Catch basin
13	Wildwood Road, road runoff	Catch basin
14	Wildwood Road, road runoff	Catch basin
15	Lakeview Drive, road runoff	Catch basin
16	Stream under Lakeview Drive, from private pond on Wheeler Drive	Stream
17	Hatch Hill Road, runoff to UBL	Road runoff/swale
43	Middle Bolton boat launch runoff	Overland flow
18	Grier Road stream from wetland, also receives road runoff	Stream
19	Grier Road stream, also receives road runoff prior to sampling point	Stream
20	Grier Road stream	Stream
94	Grier Road, road runoff to catch basin	Catch basin/culvert
21	Anchorage & Miller Roads to catch basin	Catch basin/culvert
22	Llynwood Drive, road runoff	Catch basin/culvert
44	Llynwood Drive, road runoff	Catch basin/culvert
95	Rosedale Beach culvert	Culvert
23	Llynwood Drive, road runoff	Catch basin/culvert
24	Llynwood Drive, road runoff	Catch basin/culvert
25	Llynwood Drive & Plymouth Lane, road runoff	Catch basin/culvert

Repeat consistent stormwater sampling across multiple years and storms was performed at the main stormflow locations to Lower Bolton Lake (mainly sites 1-9). The figures below demonstrate the range in concentrations of TP and TN measured at the major stormwater sampling locations.

Figure 19: Lower Bolton Main Stormwater Inflow Concentration Ranges (Phosphorus)

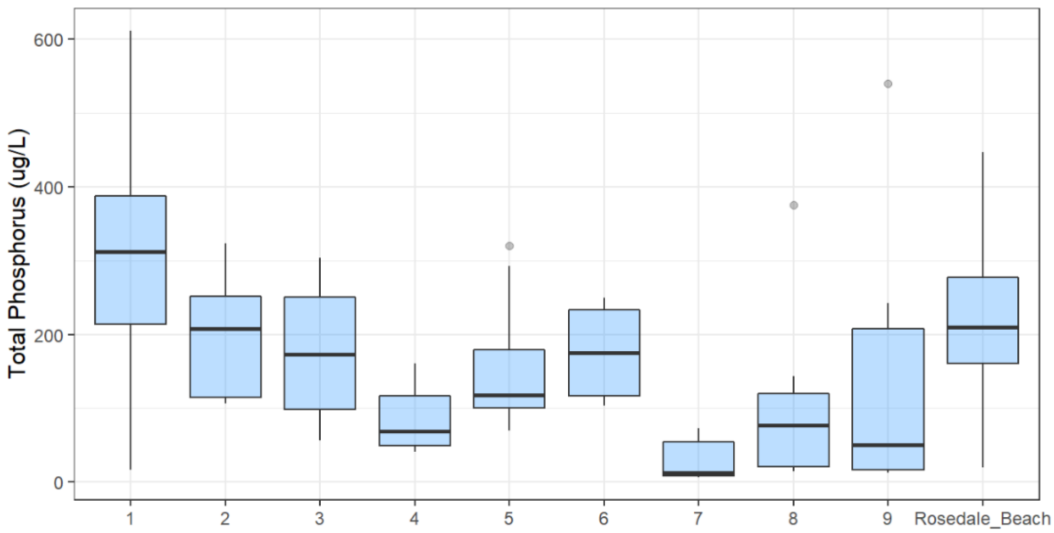
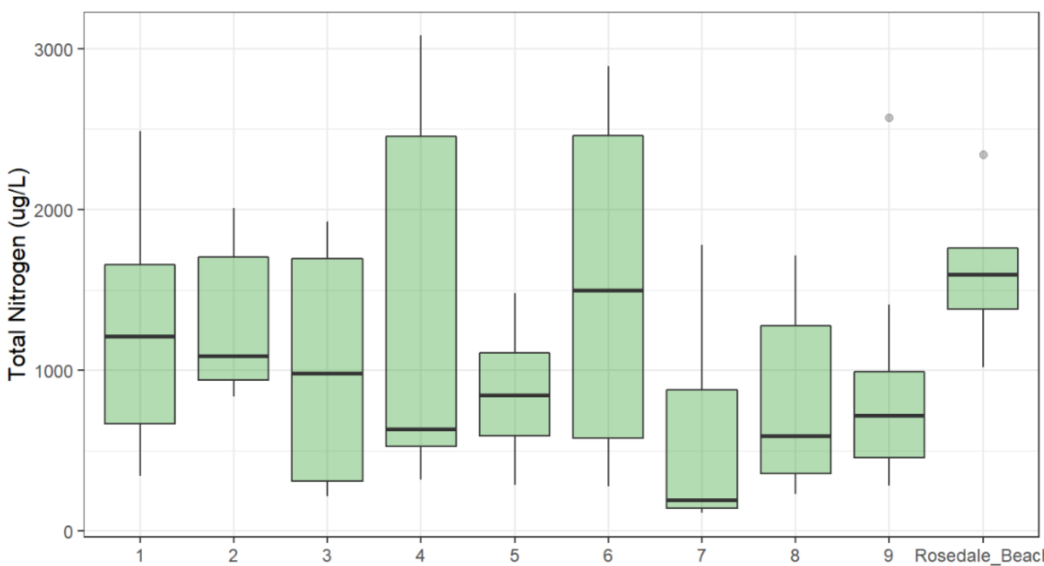


Figure 20: Lower Bolton Main Stormwater Inflow Concentration Ranges (Nitrogen)



6.3 Nutrient Load Estimates

This section addresses EPA Elements:

B. Determine pollutant load reductions needed.

Target water quality thresholds to maintain mesotrophic conditions are no more than 45 kilograms of in-lake Total Phosphorus or 800 kilograms of in-lake Total Nitrogen. In-lake respective target concentrations are no more than 20 µg/L TP and 600 µg/L TN, with preferred TN levels near 400 µg /L. In-lake mass estimates seem to infer that Lower Bolton Lake is currently able to maintain moderately-good (Mesotrophic) water quality conditions given the existing development and recent years of combined watershed and internal loading. However, the lakes are at a critical 'tipping-point' where implementation of BMPs and LID in the watershed is needed to stabilize water quality into the future.

The 2021 season saw frequent large rainfall events, which led to noticeably more stormwater runoff than in 2019 or 2020. Both TP and TN target concentrations and in-lake total mass targets were exceeded in 2021. It is presumed that watershed loading increases also facilitated higher than average internal nutrient recycling/loading in 2021, which can also be exacerbated by wind-driven summer partial mixing events that entrain nutrients from bottom to surface waters. Altogether, the lakes experienced moderate to high levels of cyanobacteria in summer to fall 2021. The 2021 Lower Bolton Lake in-lake TP exceeded target thresholds by roughly 5 kilograms, while TN mass thresholds were exceeded by roughly 148 kilograms.

The impact of weather is a combination of the size and frequency of large storm events and watershed runoff, as well as the pattern of wind and temperature. The best long-term defense against cyanobacteria blooms is to address watershed stormwater runoff, while simultaneously investing in in-lake treatments to reduce annual recycling of nitrogen and phosphorus. Internal nutrient loading is predicted to become more severe as climate challenges affect northeastern lakes (Mullin et al., 2020).

As noted during the 2014-2015 stormwater sampling events, higher stormwater nutrient loads appear to have pushed Lower Bolton Lake into the Eutrophic category. The same was true for 2021, particularly for nitrogen. There was a tremendous reduction in nutrient loading with the sewer project, which was completed at the end of 2015. However, legacy onsite wastewater nutrient loading in seepage groundwater may still be periodically problematic, particularly with very large rain events. Similarly, frequent large rain storms will result in high nutrient stormwater runoff. Public and private property must be considered. The Watershed Nutrient Pollution Sources section identifies many locations where stormwater management needs improvement, as well as important nutrient sources from private property. Future effort to reduce watershed loading will ensure the Bolton lakes continue to meet their designated use water quality standards, even during years with high rainfall or frequent large summer storms.

6.3.1 Empirical Annual Phosphorus Mass Load Estimates

Spring total phosphorus has long been used in empirical estimates for total phosphorus mass load (kilograms/year). A series of classic empirical lake spring phosphorus load models were run given the following Lower Bolton Lake and watershed parameters. The load from LBL represents the load from the entire watershed. This model was modified from the original work of Kortmann, 1980.

Table 12: Entire Bolton Lakes Watershed Parameters & Lower Bolton Lake Characteristics

Lower Bolton (Entire Watershed Load Estimate)	English Units		Metric Units	
Lake Surface Area =	176	acres	712,247	m2
Estimated Littoral Area =	145	acres	586,795	m2
Profundal Area	31	acres	125,453	m2
Watershed Area (Total)	2402	acres	9,720,558	m2
Lake/Watershed Area	7	%		
Lake Volume	1665.0	acre-ft	2,054,610	m3
Mean Depth	9.46	feet	3	m
Maximum Depth	19	feet	5.8	m
Residence Time	0.4	years	129	days
Flushing Rate	2.8	times / year		

The models assumed 48-inches of precipitation and an effective precipitation of 23.6-inches per year (minus estimated annual evaporation from lake surface & watershed). The models assumed a spring water column TP concentration of 20 µg/L (75th percentile of all values and maximum target concentration). Results are displayed below. Model equations and assumed values are included on the following page.

Table 13: Classic TP Load Empirical Model Results

Empirical Watershed Model	mgP/m^2yr^{-1}	gP/m^2yr^{-1}	kgP/year
***Kirchner* & *Dillon*, 1975**	428	0.43	305
***Vollenweider*, 1975**	364	0.36	259
***Jones* & *Bachmann*, 1976**	201	0.20	143
Chapra, 1975	484	0.48	344
Average	**369**	**0.37**	**263**

If these models were to use the mean spring LBL TP value of 16.2 µg/L, the average model estimate would be 213 kg/year for the entire Bolton Lakes watershed load to Lower Bolton Lake.

As evidenced by the high range in classic empirical model estimates, modeling annual load tends to be subject to high error. Similarly, the load is expected to change from year to year. Land-use export coefficients and models are also frequently used to better account for large differences in developed vs. undeveloped watersheds, but even those models have limitations and should be used simply for planning purposes.

Table 14: Classic TP Loading Models Assumed Values & Equations; modified from Kortmann, 1980.

Assumed Values:				
Symbol	Value	Units	Meaning or Definition	
TP	**20.0**	**mgP/m^{-3} (ppb)**	**Spring Total Phosphorus Concentration**	
-z-	2.88	m	Mean Depth	
F	2.84	times/year	Flushing Rate	
S	0.29	non-dim fraction	TP Leaving Lake/ TP Entering Lake	
qs	8.18	m / year	Areal Water Load (-z- * F)	
v	0.65	m/year	Apparent Settling Velocity (-z- * S)	
R	0.65	non-dim fraction	Retention Coefficient (estimated)	
Rp	0.62	non-dim fraction	Retention Coefficient (Water Load)	
Kirchner and Dillon 1975				
Prediction of L from TP,-z-,F, and Rp:				
L = TP (-z-) (F) / (1-Rp)				
		Observed TP=	20.0	mg P/cubic meter
Predicted L =		**0.43**	g P / square meter / year	
Predicted TP Load			305	kg/year
Vollenweider 1975				
Prediction of L from TP, -z-, F, and S:				
L= TP * (-z-(S+F))		where S= 10/-z-	S=	3.467
Predicted L=		**0.36**	g P/square meter / year	
Predicted TP Load=			259	kg/year
Jones and Bachmann 1976				
Prediction of L from TP, -z-, F, and S:				
L= TP * (-z-(S+F))		S=0.65		
Predicted L=		**0.20**	g P/square meter / year	
Predicted TP Load=			143	kg/year
Chapra 1975				
Prediction of L from TP, R, -z-, and S:				
L = (TP)(-z-)(F) / (1-R		where R=v/qs+v and v=16	R=	0.66
		Observed TP=	20	mg P/ cubic meter
Predicted L=		**0.48**	g P/square meter/year	
Predicted TP Load=			344	kg/year

6.3.2 Land-use & Runoff Calculations - Nutrient Load Models

Modern watershed nutrient load modeling relies on land-use export coefficients for phosphorus and nitrogen. Export coefficients based on various types of land-use have been developed through research over the past fifty years and consistently refined as more empirical monitoring data became available.

The Lake Loading Response Model (LLRM), a spreadsheet-based nutrient load model that calculates phosphorus mass loads from subbasins within a lake or river watershed, was also used as a preliminary estimate of total watershed load to Lower Bolton Lake. The model requires data of the lake volume, flushing rate, watershed land-use fractions, tributary information, septic systems, and more. It has flexibility to change export coefficients per land-use type, based on the most applicable publications, or combination of references. Like all land-use watershed nutrient loading models, LLRM allows for adjustments to precipitation and subbasin water attenuation. No adjustments were made to subbasin water attenuation. The results of models are generally up to professional judgment and verification with field data. Unlike other types of watershed-based nutrient load models, LLRM also incorporates an internal loading model that can be used if appropriate.

LLRM relies on land-use areas per subbasin, such as those provided by the UCONN CLEAR 2015 Land-Use Cover raster GIS dataset. Though, because there are inherent errors within the UCONN CLEAR 2015 Land-Use Cover GIS dataset, the LLRM model was approached in two different ways. Both utilized a single watershed approach, not a 3-lake basins approach, which would have complicated the basic estimate. Instead, the surface waters of UBL and MBL were considered open-water land-uses for both model scenarios. The first used the CLEAR 2015 Land-Use acreages, while the second estimate used the UCONN CLEAR Impervious Cover acreages classified as "High Density Residential." Scenario 2 used more accurate acreages of wetlands and forested areas given the Hydric Soils of CT GIS layer. Impervious cover is defined as any developed area that does not allow rainfall to pass into the underlying soils, generating stormwater runoff from the entire surface. Paved roads, sidewalks, driveways, houses, and other buildings are all impervious – unless specially designed to infiltrate stormwater onsite. Though the impervious cover dataset does not directly equate to "High Density Residential (HDR)" classification, it is close. The water runoff coefficient for HDR was 0.6 (or 60% runoff), which is the model standard. To the right, a comparison of the overlapped layers is shown to demonstrate the GIS data differences. Both layers are displayed in the same projected coordinate system (NAD_1983_StatePlane_Connecticut_FIPS_0600_Feet) in the image.

Figure 21: Difference between UCONN CLEAR 2015 Land-Use Pixels & Impervious Cover High Resolution Polygon Layer

Preliminary LLRM mass estimates yielded 203 (Scenario 2)-240 (Scenario 1) kgs/year Total Phosphorus watershed load, similar to the empirical spring-phosphorus model results, given the same watershed area of 2,402 acres and 48 inches precipitation model parameters. Basin areas are shown in the LLRM model (Table 15); note the difference in the two scenario acreages of the two GIS datasets. In Scenario 2, the "Low Density Residential" (LDR) category was separated into HDR (impervious cover layer) and upland forest, and the respective forest acreage was adjusted based on the wetlands area from the Hydric Soils layer. The respective total drainage basin acreages were the same. All other model parameters remained the same. These LLRM model estimates are not meant to be quantitative. There are additional features of the LLRM model that were not used. Instead, estimates are meant to demonstrate a similarity to the previous empirical TP load estimates and to provide insight into the annual P and N loads from natural and non-natural sources.

Table 15: LLRM Scenarios for a Whole-Watershed Land-Use Nutrient Load Approach

BASIN AREAS	Scenario 1	Scenario 2
	CLEAR LAND USE	IC & Hydric Soils
	Whole Watershed	Whole Watershed
LAND USE	AREA (HA)	AREA (HA)
Urban 1 (LDR)	144.6	0.0
Urban 2 (MDR/Hwy)	0.0	0.0
Urban 3 (HDR/Com)	0.0	49.1
Urban 4 (Ind)	0.0	0.0
Urban 5 (P/I/R/C)	0.0	0.0
Agric 1 (Cvr Crop)	0.0	0.0
Agric 2 (Row Crop)	47.1	47.1
Agric 3 (Grazing)	0.0	0.0
Agric 4 (Feedlot)	0.0	0.0
Forest 1 (Upland)	494.0	534.6
Forest 2 (Wetland)	72.2	184.4
Open 1 (Wetland/Lake)	86.6	86.6
Open 2 (Meadow)	57.3	0.0
Open 3 (Excavation)	0.0	0.0
Other 1		
Other 2		
Other 3		
TOTAL Drainage Basin	901.8	901.8
Lower Bolton total(subtracted from water ha)	70.1	70.1
TOTAL WATERSHED (including LBL) HA	972	972
TOTAL WATERSHED (including LBL) Acres	2,402	2,402

Table 16: Modified LLRM – Lower Bolton Watershed Load Estimates

Partial LLRM Whole-Watershed Approach	**Scenario 1**	**Scenario 2**
Total Phosphorus Load Watershed Estimate (kg/yr)	240	203
Total Nitrogen Load Watershed Estimate (kg/yr)	5178	4261

Because a large part of the annual watershed load is not readily controllable, the "Impervious Cover" (IC) dataset was also used to estimate a potentially manageable stormwater load estimate.

Table 17: Impervious Cover Area by Town

Source: (UCONN CLEAR Impervious Cover Dataset)		
Impervious Cover (IC) Area in Towns w/in Watershed		
Town	**Area (acres)**	**Area (ha)**
Vernon	30.8	12.5
Bolton	46.3	18.7
Coventry	25.0	10.1
Tolland	19.2	7.8
Total	*121.3*	*49.1*

Roughly all of the IC area in Coventry and Tolland is disconnected from the Bolton lakes because water flows through soils and wetlands, as it is deposited indirectly in upland areas prior to drainage and streams that lead to Middle and Lower Bolton Lake. Thus, roughly 77.1 acres of IC should be used in the Simple Method (Schueler, 1987) IC nutrient loading calculations. The modifications made to the Simple Method estimations for phosphorus export were based on EPA guidance for MS4 Permitting, as referenced in Appendix 3 of the Connecticut Watershed Response Plan for Impervious Cover:
https://portal.ct.gov/DEEP/Water/Stormwater-Planning-Tool-for-Impervious-Cover
https://portal.ct.gov/-/media/DEEP/water/IC/watershed_response_plan_for_IC/Appendix3ICinCTMunicipalitiespdf.pdf

Results should be used for planning purposes only, as this is an oversimplification of stormwater nutrient loading. A fraction of the IC, primarily residential roofs that may drain to grassy areas instead of driveways/roads, will reduce this estimate. The theoretical maximum load estimate from the directly connected IC is roughly 104lbs P / year, or **47 kgs P / year**, given the chosen IC runoff TP value of 0.118 mg/L (118 µg/L), which is equal to the median TP stormwater concentration from all Lower Bolton stormwater samples. This value of 118 µg/L translates to roughly 0.61 kg/ha/year TP runoff coefficient from impervious surfaces. This runoff value is very close to the base LLRM proposed coefficient for residential development (0.65 median kg/ha/year). The Simple Method typically uses a higher concentration value, but literature from the Center for Watershed Protection suggests that modified concentrations are appropriate where there is existing field data to support their use. The Lake Champlain basin program uses a Simple Method Pollutant Loading Calculation Worksheet, which was used for this IC P-runoff general estimate. The Simple Method equations are defined below in Figure 21. The total site area for the equation was determined to be 420 acres, which is the sum of the Middle Bolton and Lower Bolton watershed basins (not including lake area), minus the acreage in the Town of Coventry[1]. This area accounts for the disconnected IC in Coventry. Overall, the direct stormwater runoff load from IC is likely less than 47 kgs P / year and represents a potentially manageable fraction of the total watershed load.

There is only so much that can be done to reduce nutrient loads from natural sources such as forestland, wetlands, and grassy areas. Priority should be on the known and sampled 'hot-spots' for nutrient pollution in the Bolton lakes watershed, particularly closest to the Middle and Lower Bolton Lake shoreline (Tables 10 & 11). The impact of IC and poor-quality stormwater is exponentially greater in the immediate shoreline areas. Similarly, a watershed loading model cannot adequately quantify the use of residential fertilizers or local erosion. The reduction of such practices and addressing the key stormwater pollution sites is critical to overall nutrient load reduction. Each stormwater-related watershed improvement project will effectively "disconnect" additional IC, which can be tracked over time on a project-by-project basis, including improvements permitted on private property.

It is also important to note that the entire Upper Bolton watershed nutrient load is captured in the dense wetlands of Upper Bolton Lake itself. Upper Bolton is a geological sink for watershed nutrients that have accumulated over hundreds of years. Nutrient cycling in large wetlands is heavily impacted by seasonal plant growth and organic matter stabilization. Preserving natural lands in the Upper Bolton watershed should be a priority to ensure that the wetland system can continue to capture and store nutrients over time. However, the Upper Bolton watershed impervious cover does not pose as severe a risk as the runoff from near-shore Middle and Lower Bolton areas. Additional monitoring of the Upper Bolton culvert outflow is recommended, following the updates to the Hatch Hill (CT DEEP-owned) dam. The updates to the Hatch Hill dam will determine how water flows from the Upper to Middle watershed in future years. Construction was scheduled to begin in early December 2021.

[1] Simple Method typically uses individual smaller areas, but runoff values should be similar when all combined.

Figure 22: Simple Method Pollutant Loading Calculation Worksheet - Phosphorus

Simple Method Pollutant Loading Calculation Worksheet- Phosphorus

$$L = 0.226 * P * P_j * R_v * A * C$$

Where:

- **L** = Annual load (lbs)
- **P** = Yearly rainfall depth (in)
- P_j = Fraction of rainfall events producing runoff (use 0.9)
- **A** = Site area (acres)
- **C** = Average annual pollutant concentration (mg/l), see 'Guidance'
- **0.226** = Unit conversion factor

And:

$$R_v = 0.05 + 0.009 * I_a$$

Where:

- R_v = Runoff Coefficient
- I_a = Whole number percent impervious

Offset Calculations

Project Name:	Lower Bolton Impervious Cover
P_j	0.9
Project **P***	48
*http://www.ncdc.noaa.gov/cdo-web/datatools/normals	

Pre-Development Condition

For undeveloped sites use these equations:

Existing Land Use	Loading Rate	Site area (ac)	Load (lbs)
Choose Land Use	0.00		0.00
Choose Land Use	0.00		0.00

OR

For sites with existing development, use the Simple Method : (Just Bolton & Vernon IC)

Simple Method	Land Cover type	Site Area (ac)	Imp. Area (ac)	I_a (%)	R_v	C (mg/L)	Load (lbs)
Existing Conditions	Developed	420	77.1	18	0.215214286	0.118	104.13
		170	*31*			**Pre-Dev. Total**	**104.13**
		(hectares)	*(hectares)*				

6.4 Achieving Plan Goals

This section addresses EPA Elements:

C. Develop management measures to reduce pollutants and achieve goals.
D. Identify technical assistance needed to implement the plan.
E. Develop information/education components.

One of the major watershed management goals is to prevent further increases in stormwater runoff, which can be achieved through Town regulations, educated Town Commissioners, land-use planning, and community partnerships.

6.4.1 Town Regulations & Commissions

The Inland Wetlands and Zoning regulations of the four watershed Towns are the primary method of land-conservation. These regulations allow for limited Town oversight of development on private property. Future land conservation efforts and stormwater management will rely heavily on the verbiage of these regulations, as well as decisions made by Commission members. Implementation of the Bolton Lakes Watershed Management Plan will require informed and dedicated town Commission members. Commission members from Bolton and Vernon will be faced with land management decisions that directly impact the vulnerable shoreline areas of Middle and Lower Bolton Lakes. Commission members will need confidence in deciding whether particular proposed actions will indeed cause a significant impact to wetlands or waters in the Town. Members should be encouraged to engage in educational dialogue with residents during the permit acquisition process. This permitting process is a good opportunity for community outreach on a personal level.

The Bolton Inland Wetland regulations were last updated/drafted in 2015 and can be viewed at: https://cdn.branchcms.com/EzoynNLyL2-1704/docs/boards/wetlands/BOLTON_IW_REGULATIONS_-_Final_05-26-2015.pdf

The Vernon Inland Wetland regulations were last updated in 2013: http://vernon-ct-archive.imageworksllc.com/planning-development

Both Bolton and Vernon regulations use an upland review area of 100ft from a wetland or watercourse. The Town of Vernon lists several specific waterbodies that have a 200ft upland review area, but the Bolton lakes are not mentioned. Increasing the upland review area around the Bolton lakes to 300ft would provide better oversight and long-term protection of water quality.

The Town of Vernon has several other stormwater-focused initiatives, including their website reference for planting native plants and a published (2013) Low Impact Development Stormwater Quality Manual for proposed future development. While the publication is geared more towards commercial development areas, this manual is generally a good reference for residents who wish to learn more about how LID may fit into their own landscape design. The document discusses and provides pictures of various types of LID, such as bioswales, porous pavers, and bioretention design principles. The information provided in this document is not specific to the Town of Vernon, and there is useful information for all of the watershed Towns.

http://www.vernon-ct.gov/files/VernonGuidelinesStormWater_2013.pdf

Town Plans Of Conservation and Development

Future Town Plans of Conservation and Development (POCDs) may reference the Bolton lakes to ensure that conservation and development plans do not clash with the needs and efforts of water quality management. The Bolton Lakes Watershed Conservation Alliance (BLWCA) will be the lead organization to communicate with Towns as they update their POCDs.

6.4.2 Watershed Partnerships & Technical Assistance

The BLWCA is the bridge between the Towns, FBL, local land trusts, and other conservation-focused entities. The BLWCA should continue to seek partnerships with the CT Land Conservation Council and the following local land trusts and notify respective trusts if watershed land becomes available for purchase.

Joshua's Tract Conservation and Historic Trust
Bolton Land Trust
Eastern CT Forest Landowners Association/Wolf Den Land Trust
Manchester Land Conservation Trust, Inc.
Northern CT Land Trust

Contact information is available through the CT Land Conservation Council webpage: https://ctconservation.org/

The Northcentral CT Conservation District will also continue to be a valuable resource and partner. https://conservect.org/northcentral/

The Public Works Departments in Vernon and Bolton, as well as Town Engineers, will be key in implementing the recommendations made for public property and Town roads. The Town Public Works Departments will be key partners in any future watershed improvement grant applications, designs, and construction. Public Works will work with the Friends of Bolton Lakes and other key stakeholder groups to ensure plan implementation and adherence to watershed best management practices (BMPs). Both Public Works and FBL will continue to work with contracted watershed experts, engineers, and construction firms to ensure the proposed plan structural improvements come to fruition.

FBL will continue to be a key ally by advocating for plan implementation measures on a Town level.

The State of CT owns the Bolton Lakes, dams, and public boat launch properties. CT DEEP is a primary partner for plan implementation, specifically for any improvements made to state properties. Technical assistance was sought for the development of this plan and the stakeholder groups will continue to work alongside the state agency for long-term watershed management.

6.4.3 Public Education & Outreach Plan

Continued Public Presentations

Since 2012, the Town of Bolton has sponsored annual public outreach presentations at Town Hall. In the wake of the 2012 cyanobacteria bloom, nearly 100 residents were in attendance. Presentations in subsequent years had roughly 20-40 attendees annually. These presentations helped local residents understand the intricacies of lake water quality and overall management. Many residents now have a general knowledge of water quality parameters. Since FBL began their volunteer monitoring program, FBL has also made a concerted effort to engage residents in the ongoing data collection process. FBL sends out monthly reports on lake temperature, oxygen, and water clarity, which has dramatically increased the conversation about lake-friendly practices.

FBL hosts both annual public outreach forums and annual presentations by experts and students, where guest speakers are able to reach residents. Past presentations were made by UCONN, Wesleyan University, CAES, DEEP, landscaping professionals, and NEAR. The FBL forums have become a social aspect of living around or in the watershed of the Bolton lakes. The Town of Bolton will support a 'LakeSmart' webinar series, where homeowners can ask questions about property maintenance and watershed science.

Additional FBL Outreach

The FBL plans to continue bi-annual lake forums and will continue to engage residents in 'LakeSmart' homeowner practices. FBL has published an educational welcome brochure, which can be downloaded from their website:

https://www.friendsofboltonlakes.org/uploads/3/0/0/0/30007939/welcome_brochure_2020_fbl.pdf

FBL is also engaged in the EPA Regional Cyanobacteria Monitoring Collaborative and takes part in statewide CT Federation of Lakes events. FBL has also agreed to serve as the lead entity for ensuring that the Town Councils from all four watershed towns are provided a formal 'State-of-the-Lakes' annual review. FBL will also continue to engage residents by serving as a communicator between the Towns and the lake-front homeowners.

Steps Towards Best Management Practices

1. FBL will spearhead homeowner lawn/soil community testing programs.
2. Continue to invite landscape designers to discuss buffer zones at FBL forum, demonstrating beauty & utility.
3. Encourage homeowners to leave lawn clippings in place on low-sloped areas, to naturally replenish nitrogen.
4. Discourage private sand beaches & fill.
5. Encourage shoreline BMPs instead of sea-wall reconstruction projects in low-sloping areas.
6. Ensure all future construction projects in the watershed follow appropriate soil and erosion control measures.
7. Maintain communication between Town officials, residential stakeholder groups, and CT DEEP.
8. Continue BLWCA meetings and formal record-keeping from Towns, agencies, & residents.

The Environmental Review Team publication (2014) makes additional suggestions for local homeowners and for general municipal practices. An excerpt from the ERT report is included below. FBL and the BLWCA will continue their BMP outreach and coordination efforts among homeowners and Town Commissions.

Homeowner and Municipal Practices:

Four practical and successful suggestions are offered here, though the limited list is not meant to dismiss numerous other practices that abound in relevant publications and outreach presentations.

- A strong focus should be place on turf lawns as a source of nutrient runoff from developed areas in this watershed. With so-called urban fertilizer management, a critical message is to promote regular soil testing BEFORE any fertilizer application. There are several avenues to obtain quality test results, including the University of Connecticut Soil Lab. Wherever the results come from, do follow the recommendations (which may very likely indicate little or no fertilization is necessary for optimal turf health and appearance).
- Consider alternatives to full turf lawns, including conservation landscapes that replace some turf with plants typically native to the area. Municipalities can provide high visibility demonstration areas at their town parks, playgrounds, conservation properties and roadside right of ways.
- Keep collected leaves, lawn clippings, yard debris and pet/livestock waste out of street drainage system, stream channels and wetlands.
- Protect your riparian areas - allow nature to do its thing! These streamside and lakeside areas are important ecological as well as environmental attributes. They provide for stream or lakeside shore stability. The surface and subsurface properties are often very productive in pollutant trapping and assimilation before they discharge into the waterway. They are somewhat specialized wildlife habitat corridors. They can provide for effective visual and sound buffering between natural(ized) water bodies and more intensive human development areas. Where human alterations have impacted their corridors in a particular watershed (e.g. turf lawn running down to water's edge, broadcast clearing of tall vegetation for unobstructed views or access, replacement of native plant species with those that often require more management and care), degraded water quality conditions and aquatic habitats often result.

6.5 Measurable Progress

This section addresses EPA elements:

G. Describe interim measurable milestones
H. Identify performance criteria for plan implementation
I. Include a monitoring component

6.5.1 Tracking Public Engagement

The four watershed Towns have come together to poll local residents using an online public survey. The questionnaire was roughly 50 questions long and has had over 250 responses. This survey was heavily geared towards residents living in the watershed of the Bolton lakes, but it also included questions about lake use and land-use practices, relevant to all local residents.

The survey included several questions about lake management and water quality to gauge the existing level of public awareness. The intent is to use this survey as a metric of public engagement over time and to resurvey residents within ten years.

Additionally, the survey asked residents to provide their email contact information if they wanted to be emailed about future Bolton lakes management. At the time of the initial public survey, only 30% of survey respondents said that they currently participate in either FBL or BLWCA outreach events, and only 24% of respondents said they had attended any of the Bolton public presentations by Northeast Aquatic Research. In ten years, the Towns and FBL/BLWCA hope to dramatically increase their community participation rates.

Similarly, roughly 93% of respondents answered that they were either 'Very Concerned' or 'Fairly Concerned' about the Bolton lakes water quality, yet 60% of respondents also answered that they were not aware of their local inland wetlands and watercourses regulations. There is an obvious disconnect and a need for additional public outreach efforts.

A more detailed analysis of the survey results will help the Towns and stakeholder organizations to better engage local residents, and a future resurvey will provide insight into public engagement progress and overall awareness of lake and watershed issues.

6.5.2 Measurable Milestones

Additional measurable milestones to track implementation include but are not limited to the following:

- Grant application submittals aimed at watershed improvement projects & awarded funds
- Improvements to Town Inland Wetland & Zoning Regulations to conserve watershed lands
- Number of implemented site improvements
- Number of catch basins cleaned annually
- Number of installed catch-basin filters
- Acreage purchased and conserved by local Land-Trusts or Towns
- Increased communication between lake officials and Town Public Works Departments
- Number of attendees to public outreach events
- Development of maintenance plans for structural watershed improvements

6.5.3 Performance Criteria & Future Monitoring

To build on measurable milestones, major performance criteria include the level of public education and engagement, inter-Town cooperation, and successful implementation of the suggested watershed projects over time.

FBL and BLWCA volunteers actively monitor stormwater flows to identify locations of new or continued erosion. These organizations will be able to track the success of watershed improvement efforts through their direct observations.

In-lake performance criteria are equivalent to the *In-Lake Water Quality Targets*. Future water quality data will be collected by FBL volunteer science committee members, under the guidance of the formal *Quality Assurance Plan for Friends of Bolton Lakes Volunteer Monitoring*, which has been developed as part of this overall Bolton Lakes and Watershed Management Plan.

6.6 Funding Sources for Lake & Watershed Management

This section elaborates on EPA elements:

D. Technical & financial assistance

For stormwater improvements to public property, there will need to be financial contributions from the watershed Towns, primarily Vernon and Bolton, for projects aimed at disconnecting impervious cover in the Middle and Lower Bolton Lake watersheds. We anticipate that the state of CT will also be a financial resource for stormwater improvements on state lands, or through grant applications. The following is a list of grants with potential for financial contribution towards watershed plan implementation measures. Most grants require either a monetary or 'in-kind' percentage of matching funds.

319 Grant Funding for Watershed Plan Implementation – specific project engineering, construction, and follow up monitoring

CT Open Space and Watershed Land Acquisition Grant – Purchase of watershed lands to prevent development

NRCS Regional Conservation Partnership Program (RCPP) – potential statewide effort for potential land purchases to preserve open space

US Forest Service Community Forest Program – forest land purchases by a municipality, open space preservation and management

CT Lakes Grant Program Public Act 07-7 Section 13(d)(5) and Section 32(d)(4)– need to be reinstated by local legislature

Public Act No. 19-190: AIS Boat Registration Stamp Fee – funds will hopefully be available soon for management prevention of aquatic invasive species and cyanobacteria

Small Town Economic Assistance Program (STEAP) – the Town of Vernon may be eligible to apply for STEAP funding for a combination of watershed implementation projects, aquatic invasive species management, and water quality monitoring. The Bolton STEAP grant successfully funded seven years of monitoring and management and Vernon could apply for a similar grant.

EPA Environmental Education Grants – Increase public awareness about pressing environmental issues

Wildlife Conservation Society Climate Adaptation Grants – Planned shift in 2021 project funding focus may open way for lake management and outreach grants

Contributions from community not-for-profit organizations, businesses, and residential stakeholder groups will be key to implementing watershed improvements on private community property such as private roads and beaches. Stakeholder groups will continue to foster relationships with local elected officials and legislators in order to allocate financial resources to critical watershed improvements.

7 Management Summary & Action Plan

One of the most important steps the Towns can take to protect the Bolton Lakes is to take a close look at their Inland Wetlands regulations and consider increasing the upland review area to 300ft, and making modifications to better protect lake water quality and near-shore areas. The rare stand of Atlantic White Cedar at the northern edge of Upper Bolton Lake is critical habitat and would be protected by an increased upland review area of 200-300ft.

The draft Quality Assurance Plan for FBL volunteer-monitoring should be reviewed and discussed with the Towns and FBL Science Committee members. In the winter of 2021-2022, the Towns of Bolton and Vernon will begin planning for the 2022 aquatic plant management and monitoring season. The Towns of Vernon and Bolton have begun discussions to fund the water quality laboratory analysis and professional oversight of FBL data-collection in 2022. FBL will continue to work towards submitting grant applications for aquatic invasive species management, given the Town's matching abilities. The Towns and FBL will work together with lake management professionals to decide if it is worth pursuing in-lake nutrient-locking treatments to reduce the impacts of internally recycled nutrients on cyanobacteria blooms in Middle and Lower Bolton Lakes in the coming years.

FBL and the Towns can work together to pursue grant applications for watershed plan implementation projects, including engineering designs, purchase of catch basin filters, construction funds, and educational outreach programs. The BLWCA has agreed to aid the Town Public Works Departments in tracking annual construction and maintenance in the watershed in a way that can be formally reported to the ad hoc Lake & Watershed Management Steering Committee, made up of leaders from each Town and stakeholder group.

The Bolton Lakes & Watershed Management Steering Committee should commit to at least biennial updates to a *Lake & Watershed Management Summary,* based on progress year over year. This type of a summary report will address the measurable milestones, potential target water quality exceedances, and identify updated short-term action steps. This summary should provide EPA Region 5 model estimates for the pounds/kilograms of phosphorus and nitrogen removed for each specific structural watershed improvement implemented. We also encourage implemented project summaries to estimate the area of impervious cover that has been "disconnected" from the Bolton Lakes and to incorporate follow-up recommendations for maintenance. Maintenance tracking will be incredibly important as watershed structural improvements are implemented in the future.

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