NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation | Department of Health | Agriculture and Markets

HARMFUL ALGAL BLOOM ACTION PLAN CHAUTAUQUA LAKE

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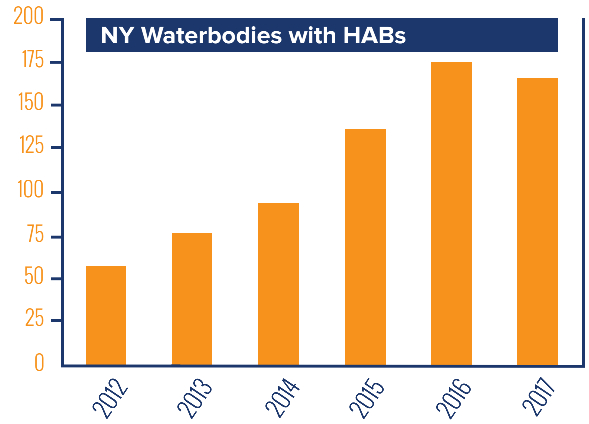
EXECUTIVE SUMMARY

SAFEGUARDING NEW YORK'S WATER

Protecting water quality is essential to healthy, vibrant communities, clean drinking water, and an array of recreational uses that benefit our local and regional economies.

Governor Cuomo recognizes that investments in water quality protection are critical to the future of our communities and the state. Under his direction, New York has launched an aggressive effort to protect state waters, including the landmark $2.5 billion Clean Water Infrastructure Act of 2017, and a first-of-its-kind, comprehensive initiative to reduce the frequency of harmful algal blooms (HABs).

New York recognizes the threat HABs pose to our drinking water, outdoor recreation, fish and animals, and human health. In 2017, more than 100 beaches were closed for at least part of the summer due to HABs, and some lakes that serve as the primary drinking water source for their communities were threatened by HABs for the first time.



GOVERNOR CUOMO'S FOUR-POINT HARMFUL ALGAL BLOOM INITIATIVE

In his 2018 State of the State address, Governor Cuomo announced a $65 million, four-point initiative to aggressively combat HABs in Upstate New York, with the goal to identify contributing factors fueling HABs, and implement innovative strategies to address their causes and protect water quality.

Under this initiative, the Governor's Water Quality Rapid Response Team focused strategic planning efforts on 12 priority lakes across New York that have experienced or are vulnerable to HABs. The team brought together national, state, and local experts to discuss the science of HABs, and held four regional summits that focused on conditions that were potentially affecting the waters and contributing to HABs formation, and immediate and long-range actions to reduce the frequency and /or treat HABs.

Although the 12 selected lakes are unique and represent a wide range of conditions, the goal was to identify factors that lead to HABs in specific water bodies, and apply the information learned to other lakes facing similar threats. The Rapid Response Team, national stakeholders, and local steering committees worked together collaboratively to develop science-driven Action Plans for each of the 12 lakes to reduce the sources of pollution that spark algal blooms. The state will provide nearly $60 million in grant funding to implement the Action Plans, including new monitoring and treatment technologies.

FOUR-POINT INITIATIVE

1. **PRIORITY LAKE IDENTIFICATION**
Identify 12 priority waterbodies that represent a wide range of conditions and vulnerabilities—the lessons learned will be applied to other impacted waterbodies in the future.

2. **REGIONAL SUMMITS**
Convene four Regional Summits to bring together nation-leading experts with Steering Committees of local stakeholders.

3. **ACTION PLAN DEVELOPMENT**
Continue to engage the nation-leading experts and local Steering Committees to complete Action Plans for each priority waterbody, identifying the unique factors fueling HABs—and recommending tailored strategies to reduce blooms.

4. **ACTION PLAN IMPLEMENTATION**
Provide nearly $60 million in grant funding to implement the Action Plans, including new monitoring and treatment technologies.

TO LEARN MORE ABOUT HABs, VISIT: on.ny.gov/hab www.health.ny.gov/HarmfulAlgae

CHAUTAUQUA LAKE

Chautauqua County

Chautauqua Lake, a 13,422-acre waterbody in Chautauqua County, is one of the 12 priority lakes impacted by HABs. The lake, which consists of two basins (North and South) is used for swimming, fishing and boating. In addition, Chautauqua Lake is a drinking water source for residents and businesses, the Chautauqua Institution, Chautauqua Lake Estates, and the Chautauqua Heights Water District. Ten thousand people receive drinking water through the Chautauqua Utility District and about 500 people obtain drinking water from Chautauqua Water District #2.

Water supplies used in both the North and South basins are designated as impaired due to elevated nutrient and algae levels. Although there are no significant limitations or restrictions on water uses, specific uses may occasionally be discouraged based on water quality conditions.

Chautauqua Lake exhibits several factors that make the lake susceptible to HABs:

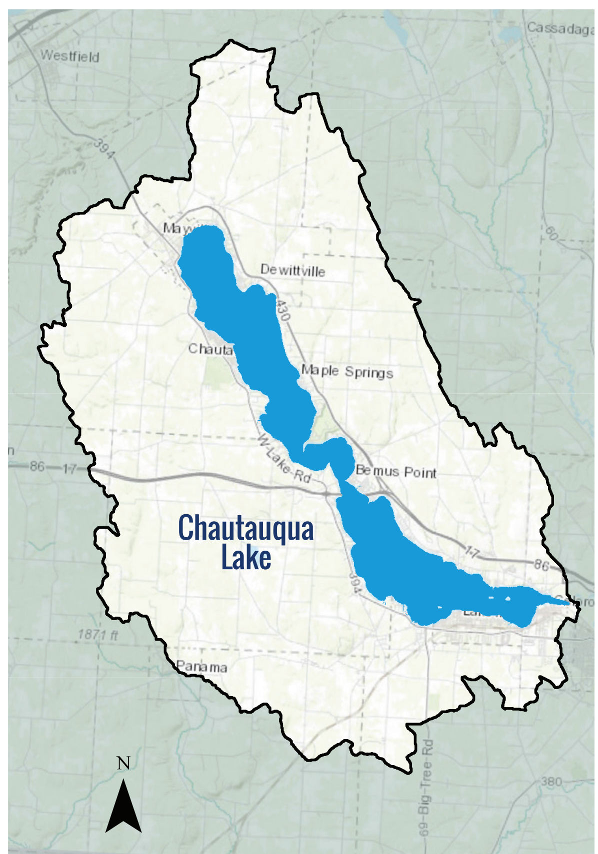
- Elevated phosphorus concentrations, from sources such as wastewater treatment plants (WWTPs), septic systems, and fertilizer runoff from farms and yards;
- Internal loading of phosphorus from in-lake sediments;
- Nonpoint source sediment and nutrient inputs from the contributing watershed (e.g., agricultural lands, forests, ditches and streambank erosion) and;
- Stormwater runoff and failing septic systems.

There have been more than 298 reported HABs occurrences in the lake since 2012, including 82 confirmed HABs in 2017, with 14 confirmed with high toxins. These blooms have caused 22 beach closures since 2012, including five in 2017, and led to 286 lost beach days.

Although the causes of HABs vary from lake to lake, phosphorus pollution—from sources such as wastewater treatment plants, septic systems and fertilizer runoff—is a major contributor. Other factors likely contributing to the uptick in HABs include higher temperatures, increased precipitation, and invasive species.

With input from national and local experts, the Water Quality Rapid Response Team identified a suite of priority actions (see Section 13 of the Action Plan for the complete list) to address HABs in Chautauqua Lake including the following:

- Build capacity of county agencies and local nonprofits in the watershed to implement Best Management Practice (BMP) work on croplands and non-agricultural lands, increase education/outreach, perform site inspections for municipalities, acquire conservation easements on sensitive sites and BMP-installed sites, and conduct upland water management projects on both public and private lands;
- Implement the South and Central Chautauqua Lake Sewer District expansion project and roadside ditch program;
- Complete a landscape assessment to identify nutrient sources and recommend BMPs to minimize nutrient export;
- Purchase and deploy an additional sampling buoy and conduct additional tributary sub-watershed and in-lake monitoring to help determine the stresses that lead to HABs; and
- Complete studies on the application of nutrient inactivants and evaluate the potential efficacy of adding additional treatment to public water systems.



The black outline shows the lake's watershed area: all the land area where rain, snowmelt, streams or runoff flow into the lake. Land uses and activities on the land in this area have the potential to impact the lake.

CHAUTAUQUA LAKE CONTINUED

NEW YORK'S COMMITMENT TO PROTECTING OUR WATERS FROM HABS

New York is committed to addressing threats related to HABs, and will continue to monitor conditions in Chautauqua Lake while working with researchers, scientists, and others who recognize the urgency of action to protect water quality.

Governor Cuomo is committed to providing nearly $60 million in grants to implement the priority actions included in these Action Plans, including new monitoring and treatment technologies. The New York State Water Quality Rapid Response Team has established a one-stop shop funding portal and stands ready to assist all partners in securing funding and expeditiously implementing priority projects. A description of the various funding streams available and links for applications can be found here: https://on.ny.gov/HABsAction.

This Action Plan is intended to be a 'living document' for Chautauqua Lake and interested members of the public are encouraged to submit comments and ideas to DOWInformation@dec.ny.gov to assist with HABs prevention and treatment moving forward.

NEW YORK STATE RESOURCES

Drinking Water Monitoring and Technical Assistance:

The state provides ongoing technical assistance for public water suppliers to optimize drinking water treatment when HABs and toxins might affect treated water. The U.S. EPA recommends a 10-day health advisory level of 0.3 micrograms per liter for HAB toxins, called microcystins, in drinking water for young children.

Public Outreach and Education:

The **Know It, Avoid It, Report It** campaign helps educate New Yorkers about recognizing HABs, taking steps to reduce exposure, and reporting HABs to state and local agencies. The state also requires regulated beaches to close swimming areas when HABs are observed and to test water before reopening.

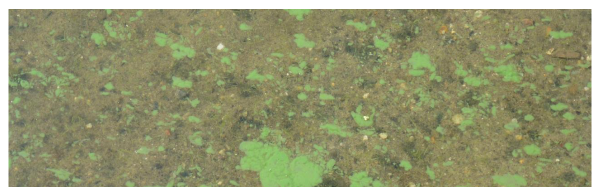
Research, Surveillance, and Monitoring:

Various state agencies, local authorities and organizations, and academic partners are working together to develop strategies to prevent and mitigate HABs. The state tracks HAB occurrences and illnesses related to exposure.

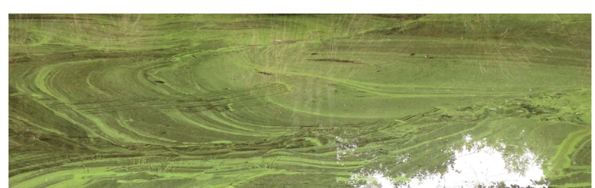
Water Quality and Pollution Control:

State laws and programs help control pollution and reduce nutrients from entering surface waters. State funding is available for municipalities, soil and water conservation districts, and non-profit organizations to implement projects that reduce nutrient runoff.


Pea soup appearance


Floating dots or clumps


Spilled paint appearance


Streaks on the water's surface

CONTACT WITH HABs CAN CAUSE HEALTH EFFECTS

Exposure to HABs can cause diarrhea, nausea, or vomiting; skin, eye or throat irritation; and allergic reactions or breathing difficulties.

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1. Introduction

1.1 Purpose

New York State's aquatic resources are among the best in the country. State residents benefit from the fact that these resources are not isolated, but can be found from the eastern tip of Long Island to the Niagara River in the west, and from the St. Lawrence River in the north to the Delaware River in the south.

These resources, and the plants and animals they harbor, provide both the State and the local communities a wealth of public health, economic, and ecological benefits including potable drinking water, tourism, water-based recreation, and other ecosystem services. Harmful algal blooms (HABs), primarily within ponded waters (i.e., lakes and ponds) of New York State, have become increasingly prevalent in recent years and have impacted the values and services that these resources provide.

This HABs Action Plan for Chautauqua Lake has been developed by the New York State Water Quality Rapid Response Team (WQRRT) to:

- Describe existing physical and biological conditions
- Summarize the research conducted to date and the data it has produced
- Identify the potential causative factors contributing to HABs
- Provide specific recommendations to minimize the frequency, duration, and intensity of HABs to protect the health and livelihood of its residents and wildlife.

This Action Plan represents a key element in New York State's efforts to combat HABs now and in the future.

1.2 Scope, Jurisdiction and Audience

The New York State HABs monitoring and surveillance program was developed to evaluate conditions for waterbodies with a variety of uses (public, private, public water supplies [PWSs], non-PWSs) throughout the State. The Governor’s HABs initiative focuses on waterbodies that possess one or more of the following elements:

- Serve as a public drinking water supply
- Are publicly accessible
- Have regulated bathing beaches

Based on these criteria, the Governor’s HABs initiative has selected 12 New York State waterbodies that are representative of waterbody types, lake conditions, and vulnerability to HABs throughout the State. Chautauqua Lake, with its public beaches, recreational opportunities, use as a potable water source, and a history of HABs, was selected as one of the priority waterbodies, and is the subject of this HABs Action Plan.

The intended audiences for this HABs Action Plan are as follows:

- New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health (NYSDOH), and New York State Department of Agriculture and Markets (NYSDAM) officials associated with the HABs initiative.
- State agency staff who are directly involved in implementing or working with the NYS HABs monitoring and surveillance program.
- Local and regional agencies and organizations involved in the oversight and management of Chautauqua Lake (e.g., County Soil and Water Conservation Districts [SWCDs], Departments of Health [DOHs], Chautauqua Lake Association [CLA], the Chautauqua Institution, the Chautauqua Watershed Conservancy [CWC], the Chautauqua Lake and Watershed Management Alliance, and other local organizations).
- Lake residents, managers, consultants, and others that are directly involved in the management of HABs in Chautauqua Lake.
- Members of the public interested in background information about the development and implications of the HABs program.

Analyses conducted in this Action Plan provide insight into the processes that potentially influence the formation of HABs in Chautauqua Lake, and their spatial extents, durations, and intensities. Implementation of the mitigation actions recommended in this HABs Action Plan are expected to reduce blooms in Chautauqua Lake.

1.3 Background

Harmful algal blooms in freshwater generally consist of visible patches of cyanobacteria, also called blue-green algae (BGA). Cyanobacteria are naturally present in low numbers in most marine and freshwater systems. Under certain conditions, including the presence of high nutrient (*e.g.*, phosphorus) concentrations and warm temperatures, cyanobacteria may multiply rapidly and form blooms that are visible on the surface of the affected waterbody. Several types of cyanobacteria can produce toxins and other harmful compounds that can pose a public health risk to people and animals through ingestion, skin contact, or inhalation. The NYSDEC has documented the occurrence of HABs in Chautauqua Lake, and has produced this Action Plan to identify the primary factors triggering HAB events, and to facilitate decision-making to minimize the frequency, intensity, and duration of HABs.

2. Lake Background

2.1 Geographic Location

Chautauqua Lake is located entirely within Chautauqua County, the western-most county in New York. It covers parts of the Towns of Chautauqua, North Harmony, Busti, Ellicott, and Ellery (NYSDEC 2016, **Figures 1 and 2**).

2.2 Basin Location

Chautauqua Lake is located within the Chautauqua Lake watershed, which covers approximately 115,349 acres, and is a part of the larger Allegheny River basin, which covers 7,518,080 acres in New York and Pennsylvania (NYSDEC 2016, National Wild and Scenic River 2018). The Chautauqua Lake watershed can be divided into 14 primary subwatersheds, and includes portions of 14 municipalities: 9 towns and 5 villages. Nine of the municipalities are located along the lake. The Allegheny-Ohio-Mississippi drainage system eventually drains into the Gulf of Mexico (Bergmann et al. 2010).

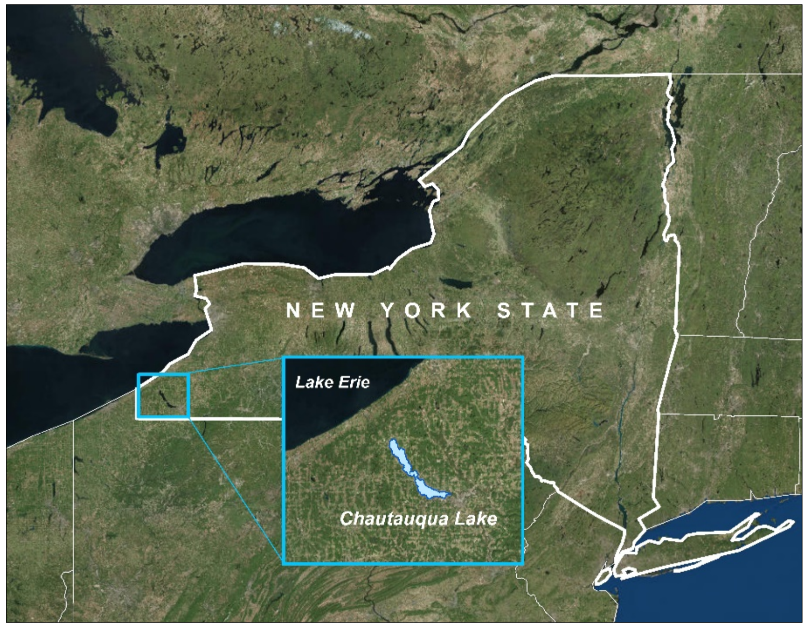

Figure 1. Location of Chautauqua Lake within New York State.

2.3 Morphology

Figure 2. Political boundaries within the Chautauqua Lake watershed.

Chautauqua Lake is a 13,422-acre lake with a mean depth of approximately 7.8 meters (25.6 feet), length of approximately 26 km (16 miles), and 68 km (42.5 miles) of shoreline (NYSDEC 2016, Audubon 2018, NYSDEC 2018a). The North and South basins of Chautauqua Lake behave as two distinct waterbodies due to depth differences and a constriction that separates the two basins (**Figure 3**). The North basin covers approximately 7,000 acres, while the South basin covers approximately 6,000 acres. Along with Conesus and Honeoye, Chautauqua Lake falls into a group of large lakes with relatively shallow water. The South basin is shallower than the North basin with a mean depth of 3.3 m (11 feet), whereas the North basin has a mean depth of 7.9 m (26 feet) (Bergmann et al. 2010). The morphology of the North basin is such that the hypolimnion is relatively thin and stratification leads to relatively high phosphorus concentrations that are eventually mixed with the epilimnion later in the summer as the two layers begin to mix, which may lead to elevated nutrient levels.

The volumes of the North and South basins are estimated to be approximately 59 billion and 23 billion gallons, respectively (CLA 2018a). The overall lake area is about one ninth of the watershed area. This relatively high watershed to lake ratio is often associated with lower water retention times, as well as relatively high sedimentation rates and land-based loading of phosphorus and other nutrients (e.g., nitrogen).

The wind rose in **Appendix A** indicates that the prevailing wind directions influencing Chautauqua Lake are south/southwest and northwest, as measured from the Chautauqua County/Jamestown Airport. This results in a maximum fetch approximately the length of the lake over which wind and wave action can mix the water and drive water-borne nutrients and algae, generally towards the north-northeast and southeast ends of the lake. This relatively long fetch suggests that buoyant HABs may move via wind action and accumulate in the north-northwest or south-southeast portions of the lake in the vicinity of beaches (e.g., Lakeside Park and Long Point State Park in the North basin; Lakewood Beach in the South basin, **Figure 3**) and other recreational uses in these areas. However, HABs have been documented in all parts of the lake over the last several years.

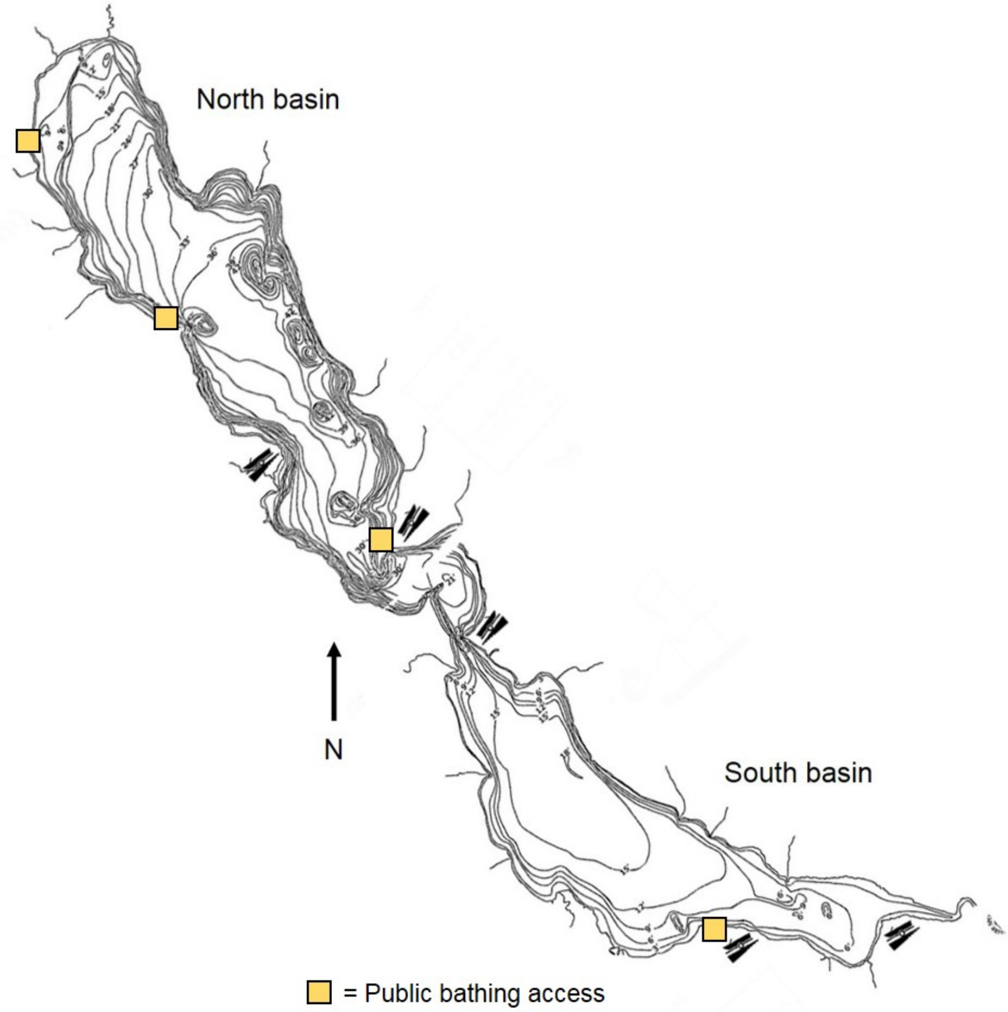

Figure 3. Bathymetric map of the North and South basins of Chautauqua Lake (Source: NYSDEC). Public bathing beaches are depicted (yellow squares).

2.4 Hydrology

The North basin of Chautauqua Lake has a hydraulic retention time, or amount of time it takes water to pass through the lake, of 514 days, while the South basin has a hydraulic retention time of 102 days (CLA 2018a). Each basin drains approximately 50,000 acres of watershed (Bergmann et al. 2010). From Chautauqua Lake, water flows south to the Chadakoin River, followed by the Conewango, Allegheny, and Ohio Rivers, then onto the Mississippi River where it eventually flows to the Gulf of Mexico (CLA 2018a). During the summer, the North basin stratifies with a thermocline occurring around 9 meters (30 feet), below which anoxic conditions can exist from July through August (NYSDEC 2018a).

Figure 4. Chautauqua Lake watershed (*Source*: Chautauqua Lake Bergmann et al. 2010).

Runoff and stream flow are estimated to provide approximately 78% of Chautauqua Lake's annual source water with 17% from precipitation and the remainder (5%) comes from groundwater input. Stream input is largely from 11 streams: Ball Creek, Bemus Creek, Big Inlet, Dewittville Creek, Dutch Hollow Creek, Goose Creek, Lighthouse Creek, Little Inlet, Maple Springs Creek, Mud Creek, and Pendergast Creek (CLA 2018a).

2.5 Lake Origin

Chautauqua Lake was formed by the northward retreat of the last Ice Age glacier about 19,000 years ago. As the glacier melted and retreated it paused three times, depositing glacial debris. The first glacial pause deposited a mound on top of solid bedrock, which formed a dam at the south end of Chautauqua Lake. Because the Chadakoin River (Chautauqua Lake's outlet) overlays this solid bedrock, the river elevation remained relatively constant, thereby preventing the draining of Chautauqua Lake. The second glacial pause, about 16,000 year ago, deposited debris that partially separates the North and South basins. The third and final pause, about 14,000-15,300 years ago, deposited several ridges of glacial debris, which prevents Chautauqua Lake from draining into Lake Erie, forcing the lake to drain southward (Bergmann et al. 2010, CLA 2018a).

3. Designated Uses

3.1 Water Quality Classification – Lake and Major Tributaries

Chautauqua Lake is a Class A waterbody (NYSDEC 2017) which means that it is a source of water supply for drinking and culinary or food processing purposes, and is suitable for primary and secondary contact recreation, fish propagation and survival, and fishing. These waters, if subjected to approved and appropriate treatments, will meet New York State Department of Health (NYSDOH) drinking water standards and will be considered safe and satisfactory for drinking water purposes.

Ball Creek, Bemus Creek, Big Inlet, Lighthouse Creek, Mud Creek, Little Inlet, and Dewittville Creek are Class C waterbodies (Chautauqua Lake Watershed WI/PWL 2014, Environmental Resource Mapper 2018), which means that they are best used for fishing, fish propagation and survival, and primary and secondary contact recreation, although other factors may limit their use for these purposes. These waterbodies are not suitable as water supplies or for public bathing uses.

Goose Creek is primarily a Class C waterbody, with one small portion designated as Class B (Chautauqua Lake Watershed WI/PWL 2014), which means that portion is best used for primary and secondary contact recreation, fishing, and fish propagation and survival. Prendergast Creek is a Class C waterbody, with some portions having a class C(T) designation, meaning they are designated for trout survival, defined by the Environmental Conservation Law Article 11 (NYS, 1984b) as brook trout, brown trout, red throat trout, rainbow trout, and splake (Chautauqua Lake Watershed WI/PWL 2014).

Dutch Hollow Creek is a Class B waterbody and Maple Springs Creek is a Class A waterbody (Chautauqua Lake Watershed WI/PWL 2014).

More information about the New York State classification system is provided in **Appendix B**.

3.2 Potable Water Uses

Chautauqua Lake is used by lake residents and visitors as a source of drinking water. It serves as a drinking water source for the Chautauqua Institution, Chautauqua Lake Estates, and the Chautauqua Heights Water District (Bergmann et al. 2010, Chautauqua County 2011). Ten thousand people are served within the Chautauqua Utility District, many of them during summer tourist season only, and 500 people are served in Mayville within the Chautauqua Water District #2 (NYSDOH 2017). The Chautauqua Utility District's water intake is 30-35 feet from the surface, offshore from the Chautauqua Institution (Ford 2011). It is also likely that other lakefront residents draw from the lake for drinking water through individual potable water intakes. As recommended by the NYSDOH, it is never advisable to drink water from a surface source unless it has been treated by a public drinking water system regardless of the presence HABs. Surface waters may contain bacteria, parasites or viruses that can cause illness. If residents choose to explore in-home treatment systems, they risk exposure to blue-green algae and their toxins and other contaminants. Those who desire to use an intake for non-potable use, and treat their water for contaminants including HABS, should work with a water treatment professional to obtain credible third-party certifications such as National Sanitation Foundation standards (NSF P477; NYSDOH 2017).

The U.S. Environmental Protection Agency (USEPA) sets health advisories to protect people from being exposed to contaminants in drinking water. As described by the USEPA: "The Safe Drinking Water Act provides the authority for USEPA to publish health advisories for contaminants not subject to any national primary drinking water regulation. Health advisories describe nonregulatory concentrations of drinking water contaminants at or below which adverse health effects are not anticipated to occur over specific exposure durations (e.g., one-day, 10-days, several years, and a lifetime). Health advisories are not legally enforceable federal standards and are subject to change as new information becomes available."

Health advisories are not bright lines between drinking water levels that cause health effects and those that do not. Health advisories are set at levels that consider animal studies, human studies, vulnerable populations, and the amount of exposure from drinking water. This information is used to establish a health protective advisory level that provides a wide margin of protection because it is set far below levels that cause health effects. When a health advisory is exceeded, it raises concerns not because health effects are likely to occur, but because it reduces the margin of protection provided by the health advisory. Consequently, exceedance of the health advisory serves as an indicator to reduce exposure, but it does not mean health effects will occur.

In 2015, the USEPA developed two 10-day drinking water health advisories for the HAB toxin microcystin: 0.3 micrograms per liter (μg/L) for infants and children under the age of 6, and 1.6 μg/L for older children and adults (USEPA 2015). The 10-day health advisories are protective of exposures over a 10-day exposure period to microcystin in drinking water, and are set at levels that are 1000-fold lower than levels that caused health effects in laboratory animals. The USEPA's lower 10-day health advisory of 0.3 μg/L is protective of people of all ages, including vulnerable populations such as infants, children, pregnant women, nursing mothers, and people with pre-existing health conditions. The NYSDOH has used the health advisory of 0.3 μg/L as the basis for recommendations, and a do not drink recommendation will be issued upon confirmation that microcystin levels exceeds this level in the finished drinking water delivered to customers.

In 2015, the USEPA also developed 10-day health advisories for the HAB toxin cylindrospermopsin. (USEPA 2015). Although monitoring for cylindrospermopsin continues, it has not been detected in any samples from the extensive sampling performed in New York State. New York State HAB response activities have focused on the blooms themselves and microcystin given it is by far the most commonly HAB toxin found.

Water system operators should conduct surveillance of their source water on a daily basis. If there is a sign of a HAB, they should confer with NYSDOH and NYSDEC as to whether a documented bloom is known. The water system operator, regardless of whether there is a visual presence of a bloom, should also be evaluating the daily measurements of their water system. If there is any evidence—such as an increase in turbidity, chlorine demand, and chlorophyll—then the water system operator should consult with the local health department about the need to do toxin measurement. The local health department should consult with NYSDOH central office on the need to sample and to seek additional guidance, such as how to optimize existing treatment to provide removal of potential toxins. If toxin is found then the results are compared to the EPA 10-day health advisory of 0.3 µ/L, and that the results of any testing be immediately shared with the public. NYSDOH also recommends that if a concentration greater than the 0.3 µg/L is found in finished water, then a recommendation be made to not drink the water. NYSDOH has templates describing these recommendations that water system operators and local officials can use to share results with customers. Additionally, public water systems that serve over 3,300 people are required to submit Vulnerability Assessment /Emergency Response Plans (VA/ERP); in situations where a water system is using surface waters with a documented history of HABs, NYSDOH will require water system operators to account for HABs in their VA/ERP (which must be updated at least every five years).

3.3 Public Bathing Uses

While much of Chautauqua Lake's shoreline is private property, municipal and state-owned lands exist. Long Point State Park, Mayville Lakeside Park, Richard O. Hartley Park/Lakewood Beach, and Chautauqua Institution (**Figure 3**) all offer public bathing beaches (Tour Chautauqua 2018). The Chautauqua Institution maintains four bathing beaches for public use (CHQ 2018).

3.4 Recreation Uses

Chautauqua Lake is a popular summer destination because it offers a wide variety of recreation opportunities to residents and tourists, including boating, swimming, fishing, waterskiing, and kayaking. Public boat launch sites are available at Long Point State Park, Bemus Point, Prendergast Point, Lakewood Community Park and Launch, Lucille Ball Memorial Park, Mayville Lakeside Park, and McCrae Point Park (CLA 2018b). Several parks along the shoreline also offer picnic areas, playgrounds, athletic fields, camping, and other forms of recreation. The Chautauqua Lake Fish and Wildlife Management Area offers hiking, hunting, trapping, fishing, and wildlife viewing opportunities (NYSDEC 2018b).

3.5 Fish Consumption/Fishing Uses

Both open water and ice fishing are permitted in Chautauqua Lake in accordance with general statewide fishing regulations. **Table 1** details the special fishing regulations that also apply (NY Freshwater Fishing 2018). The NYSDOH does not have a specific fish consumption advisory for Chautauqua Lake, but a general advisory for all waters is eating no more than four, half pound meals of fish per month (NYSDOH 2018).

Table 1. Chautauqua Lake fishing regulations.

Species	Open Season	Minimum Length	Daily Limit	Method
Trout	April 1 - Oct 15	Any size	5 – with no more than 2 longer than 12"	Ice fishing permitted
Muskellunge and Tiger Muskellunge	Last Sat in May - Nov 30	40"	1	Ice fishing permitted

3.6 Aquatic Life Uses

Fish

Consistent with its waterbody classifications, Chautauqua Lake is suitable for fish propagation and survival. The lake supports coolwater and warmwater fish communities, including (NYSDEC 2018a):

- largemouth bass, (*Micropterus salmoides*)
- smallmouth bass, (*Micropterus dolomieu*)
- muskellunge, (*Esox masquinongy*)
- walleye, (*Sander vitreus*)
- yellow perch, (*Perca flavescens*)
- brown bullhead, (*Ameiurus nebulosus*)
- white perch, (*Morone americana*)
- panfish, including bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), and black crappie (*Pomoxis nigromaculatus*)

These species may use the extensive weed beds found in the South basin and extreme northern portion of the North basin, shoal areas, or deeper areas of the lake where water temperature is cooler in the summer. Chautauqua Lake ranks among the top lakes in New York State for bass, muskellunge, and walleye. Chautauqua Lake is annually stocked with 13,000 fall muskellunge fingerlings (8.5-9 inches), 130,000 50-day walleye fingerlings, and 130,000 pond walleye fingerlings (NYSDEC 2018a).

Although the sport fishery in many lakes such as Chautauqua is carefully managed by NYSDEC, the presence of invasive fish species may have cascading regulating effects on lower trophic levels that potentially contribute to HAB formations. Common carp (*Cyprinus carpio*), an invasive cyprinid species present in Chautauqua Lake, can increase sediment suspension and associated nutrients in the water column based on its preference for benthic invertebrate prey in lakebed sediments. The increased suspended sediment liberated by the common carp's benthic feeding behavior contains nutrients that may be utilized by cyanobacteria (see **Section 6.3**).

Aquatic Plants

Chautauqua Lake's aquatic plant community composition and abundance varies annually, likely influenced by the survival of plant structures and propagules through the winter. Plant communities have been evaluated in at least part of the lake through aquatic plant surveys (see **Section 6.3**) conducted by Racine-Johnson Aquatic Ecologists (2017a). Changes to available light and water temperature may also affect submersed plant growth (Cornell 2005).

3.7 Other Uses

Many birds and mammals rely on Chautauqua Lake and its shoreline for foraging, roosting, and nesting. The lake supports a high number of individual waterfowl and a large variety of waterfowl species year-round and particularly during migration and winter. At least 270 species of waterfowl have been documented (Audubon 2018).

4. User and Stakeholder Groups

Chautauqua Lake residents and tourists flock to the area to enjoy the myriad of recreational opportunities that are available.

Several citizen advocacy groups have formed with the shared goal of protecting the water resources of Chautauqua Lake. These include:

- The Chautauqua Lake Association (CLA) was first incorporated as a non-profit 501(c)3 corporation in 1953 with the goal of performing environmentally-sound plant control practices, undertaking scientific monitoring and relevant research, servicing the shoreline to maintain healthy conditions, and promoting educational efforts to enhance public understanding of lake association methods and lake needs. The CLA has sponsored lake improvement projects, performed lake maintenance services, and facilitated on-going scientific monitoring and research (CLA 2018c).
- The Chautauqua Watershed Conservancy (CWC) was incorporated in 1990 as a not-for-profit 501(c)3 corporation with the goal of preserving and enhancing the water quality, scenic beauty and ecological health of the lakes, streams and watersheds of the Chautauqua region. The CWC develops educational workshops, presentations, and programs, and hosts outings, cleanups, and plantings. It has established 25 nature preserves, protected four environmentally-sensitive sites throughout Chautauqua County, and conserved more than 1,000 acres of land county-wide and 2 miles of shoreline along Chautauqua Lake and its outlet (CWC 2018).
- The Chautauqua Lake & Watershed Management Alliance (Alliance) formed from the Chautauqua Lake Management Commission (CLMC) in 2014. The CLMC

was created in 2005 as an advisory committee to the County Legislature and was active for over a decade, including leading the effort to create usable guidance documents for both watershed and in-lake management. The CLMC evolved into the Alliance, which was incorporated as a non-profit 501(c)(3) in January 2015, and whose mission it is to collaborate with lake and watershed-related organizations, municipalities, and other stakeholders to promote and facilitate the implementation of recommendations from the *Chautauqua Lake Watershed Management Plan* and the *Chautauqua Lake Macrophyte Management Strategy* (Bergmann et al. 2010, Chautauqua County 2017). The Alliance prioritizes projects, secures funding, and allocates resources to achieve the goals for the watershed (Chautauqua Lake & Watershed Management Alliance 2018).

5. Monitoring Efforts

5.1 Lake Monitoring Activities

Chautauqua Lake and its watershed have been the subject of many water quality monitoring programs for decades due to its socioeconomic value to western New York. Results from these studies are summarized in **Section 6**.

The New York State Conservation Department (the predecessor of the NYSDEC) sampled Chautauqua Lake throughout 1937 as part of a biological survey of the Allegheny River basin (NYSCD 1937).

The State University of New York (SUNY) Fredonia and Jamestown Community College conducted studies between 1971 and 1976 to gain a better understanding of environmental problems affecting Chautauqua Lake, physically, biologically, and chemically. The goal was to use this information to assess future ecological change and to better inform lake management practices. The results were published between 1972 and 1977 in reports commonly referred to as the *1970's Benchmark Studies* (Bergmann et al. 2010).

In 1972 the United States Environmental Protection Agency (USEPA) collaborated with the NYSDEC and New York National Guard to conduct a study of Chautauqua Lake's nutrient sources and concentrations to assess the impact of nutrients on the lake and potential management actions. The study was part of a larger national eutrophication survey during which 26 lakes in New York were assessed (USEPA 1974).

Between 1988 and 1989 SUNY Fredonia conducted surveys to study macrophytes, fish spawning and nursery areas, and sediments in Chautauqua Lake in collaboration with the Chautauqua County Department of Planning and Development. The main purpose of the surveys was to characterize nearshore areas based on these parameters. The results are summarized in the report, *Report on Characterizing the Biomass and Species Composition of Macrophytes, Fish Spawning and Nursery Areas, and Sediments in Chautauqua Lake, New York in 1988 and 1989* (Winter et al. 1989).

The study behind Chautauqua County's *Chautauqua Lake—Entering the 21st Century: State of the Lake Report* (Wilson et al. 2000) was conducted by the Chautauqua County Department of Planning and Development to investigate watershed impacts on the quality of Chautauqua Lake and provide recommendations to address these impacts. The report identifies eleven topics connected with the lake and adjacent areas: land use, hydrology, tributary and lake chemistry, watershed loading budget, bacteria, chlorophyll-a, phytoplankton, zooplankton, macrophytes, macroinvertebrates, and fisheries (Wilson et al. 2000, Bergmann et al. 2010, Chautauqua Lake Watershed WI/PWL 2014).

In 2007, the overall health and productivity of Chautauqua Lake was assessed through a general water quality sampling study. This study was meant to supplement CSLAP efforts and the *State of the Lake Report*. Water quality of Chautauqua Lake was monitored at locations similar to previous studies. The results are summarized in the *Chautauqua Lake Water Quality Monitoring Report October 2007* (Bergmann et al. 2010, Princeton Hydro 2008).

During the summer and early fall of 2007, aquatic plant and aquatic macroinvertebrate surveys were conducted at 716 locations to evaluate populations in Chautauqua Lake for Chautauqua County's CLMC (Racine-Johnson 2008).

The Chautauqua Institution and the State University of New York College of Environmental Science and Forestry (SUNY ESF) collaborated to evaluate HABs at several locations within the Institution's domain (NYSDEC 2016).

CSLAP sampling has been conducted on Chautauqua Lake from 1987 to 1995 and 1997 to 2017 at two locations: one in the North basin (2017 shifted slightly North) and one in the South basin (see **Section 6**) over most of the same period. This has included both water quality monitoring and, since the late 2000s, targeted monitoring to evaluate the presence of harmful algal blooms.

5.2 Tributary Monitoring Activities

The Chadakoin River in Jamestown has been monitored through the NYSDEC Rotating Intensive Basins (RIBS) program and/or stream biomonitoring programs. The most downstream location, near the mouth, is located in Falconer, and was sampled in 1995, 1996, 2001, 2002, 2006, 2011, and 2012. Goose Creek in Ashville was also sampled during these years. Results indicate the following:

- The water quality in the Chadakoin River has been moderately impacted for most of the years it was monitored. High flow events have changed this to slightly impacted.
- Water column sampling as part of the Chadakoin River RIBS monitoring in Falconer was conducted in 2002. Copper was identified through water column sampling as a parameter of concern, and was present in concentrations above the assessment criteria in two of the five samples. Toxicity testing of the water

column showed no significant impacts (Chautauqua Lake Watershed WI/PWL 2014).
- Elevated levels of metals and PAHs have been documented in the Chadakoin River sediments and in invertebrate tissues at the downstream location in Falconer.
- A 1995 macroinvertebrate study of 5 sites from Jamestown to Falconer deemed all sites as moderately impacted except one, which was slightly impacted. Municipal/industrial inputs have been identified as the primary stressor.
- Water quality in Goose Creek was deemed slightly impacted based on a macroinvertebrate sample from 2001, while the fauna seemed to indicate toxic stress, understanding impoundment effect was also a factor (NYSDEC 2016). Sampling results from 2011 and 2012 in Goose Creek reflected fair water quality with overall species richness of the macroinvertebrate community less than what is expected under natural conditions; results were similar to what was found in 2001 (Chautauqua Lake Watershed WI/PWL 2014).

During the same study that produced the *Chautauqua Lake Water Quality Monitoring Report October 2007* (Princeton Hydro 2008), water quality conditions in Big Inlet, Little Inlet, Dewittville Creek, Pendergast Creek, Goose Creek, Dutch Hollow Creek, and Chadakoin River were monitored. Results indicate the following:

- Tributary temperatures were lower than in-lake temperatures, except for the Chadakoin River, which is directly affected by Chautauqua Lake.
- During the study, all dissolved oxygen (DO) concentrations were above the given criteria of 5 mg/L, with the highest recorded in Dutch Hollow Creek and Dewittville Creek.
- Elevated concentrations of nitrate were detected in Dewittville Creek and the Chadakoin River during the sampling period.
- Total phosphorus (TP) data are limited, but indicate that baseflow is not a major source of phosphorus entering Chautauqua Lake. Flows during and immediately after storm events are believed to be the major contributors. (Princeton Hydro 2008).

The Chautauqua County Department of Planning & Economic Development sponsored a 2009-2010 study on two watersheds of Chautauqua Lake: Dewittville Creek and Crescent Creek. The report, *Chautauqua Lake and Watershed Management Pre-Implementation Studies* (ANS and Bergmann 2013), was submitted to the New York State Department of State (NYSDOS) and was published in March of 2013. Nutrient sources and concentrations, erosion, and sedimentation of the watersheds were studied to determine the feasibility of developing and implementing site-specific management practices. Sampling was conducted at nine stations in the Dewittville drainage, and indicate the following:

- TP concentrations ranged from 0.001 to 0.086 mg/L

- Total nitrogen (TN) concentrations ranged from 0.14 to 1.23 mg/L (ANS & Bergmann 2013).

Additional tributary water quality results, including dissolved oxygen (DO), total suspended solids (TSS), and soluble reactive phosphorus (SRP) are detailed in the listed reports.

6. Water Quality Conditions

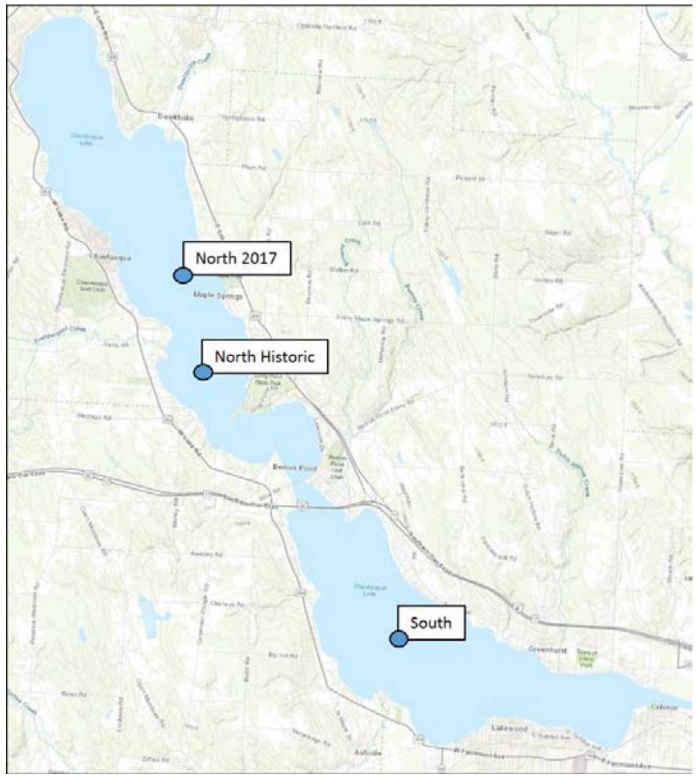

Figure 5. CSLAP sample locations in Chautauqua Lake.

Trends in water quality were assessed using data collected as part of CSLAP from 1987 to 2017 in the North basin and from 1991 to 1994, 2000, and 2002 to 2017 in the South basin (**Figure 5**). Statistical significance of time trends was evaluated with Kendall's tau trend test using annual average values. This nonparametric correlation coefficient determines if trends over time were significantly different than zero, or there was no trend. A significant difference was assumed for p-values less than 0.05. Water quality data used in this analysis were limited to those that were collected under a State-approved Quality Assurance Project Plan (QAPP), and analyzed at a laboratory certified under the NYSDOH's Environmental Laboratory Approval Program (ELAP). Note that long-term trends presented below are intended to provide an overview of water quality conditions, and that continued sampling will better inform trend analyses over time.

Table 2 provides a regional summary of surface total phosphorus (TP) concentrations (mg/L) from Chautauqua Lake compared to New York State lakes. In freshwater lakes, phosphorus is typically the nutrient that limits plant growth; therefore, when excess phosphorus becomes available from point sources or nonpoint sources, primary production can continue unchecked leading to algal blooms. Note that phosphorus form is an important consideration when evaluating management alternatives (**Section 13**).

Table 2. Regional summary of average surface total phosphorus (TP) concentrations (mg/L, ± standard error) for New York State lakes (2012-2017, CSLAP and Lake Classification and Inventory (LCI)), and the average surface TP concentration (± standard error) in the North and South basins of Chautauqua Lake (2012-2017, CSLAP).				
Region	**Number of Lakes**	**Average TP (mg/L)**	**Average TP North Basin Chautauqua Lake (mg/L) 2012-2017**	**Average TP South Basin Chautauqua Lake (mg/L) 2012-2017**
NYS	521	0.034 (± 0.003)	-	-
NYC-LI	27	0.123 (± 0.033)	-	-
Lower Hudson	49	0.040 (± 0.005)	-	-
Mid-Hudson	53	0.033 (± 0.008)	-	-
Mohawk	29	0.040 (± 0.009)	-	-
Eastern Adirondack	112	0.010 (± 0.0004)	-	-
Western Adirondack	88	0.012 (± 0.001)	-	-
Central NY	60	0.024 (± 0.005	-	-
Finger Lake region	45	0.077 (± 0.022)	-	-
Finger Lakes	11	0.015 (± 0.003)	-	-
Western NY	47	0.045 (± 0.008)	0.051 (± 0.007)	0.079 (± 0.008)

Regionally, the data provided in **Table 2** indicate that the average TP concentrations in the North and South basins were greater than the average concentration found in other lakes in western New York. Additionally, average TP concentrations from both basins exceeded the New York State water quality guidance value of 0.02 mg/L. This finding suggests that future management actions to protect water quality should likely focus on reducing TP concentrations.

Water clarity (based on Secchi depth, m), TP (mg/L), and chlorophyll-a (µg/L) concentrations are used to assess trophic state using New York State criteria (**Table 3**).

Table 3. New York State criteria for trophic classifications (NYSFOLA 2009) compared to average values in Chautauqua Lake (2017, ± standard error).					
Parameter	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Chautauqua – North 2017**	**Chautauqua – South 2017**
Transparency (m)	>5	2-5	<2	2.5 (± 0.37)	0.97 (± 0.21)
TP (mg/L)	<0.010	0.010-0.020	>0.020	0.049 (± 0.007)	0.083 (± 0.013)
Chlorophyll a (µg/L)	<2	2-8	>8	16.9 (± 5.7)	56.1 (± 16.3)

As described in **Section 2**, the lake is divided into the North and South basins, delineated by the point where the lake narrows to 820 feet wide. Compared to average water quality values in 2017, the North basin of Chautauqua Lake is generally indicative of eutrophic conditions (based on TP and chlorophyll-a concentrations; note that 2017 average transparency in the North basin is suggestive of a mesotrophic state) (**Table 3**). Trophic indicators in the South basin indicate a eutrophic system (**Table 3**).

6.1 Physical Conditions

Results from Past Studies

According to data compiled for Chautauqua County's *State of the Lake Report*, the North basin of Chautauqua Lake experiences strong seasonal thermal stratification during the summer. The lower stratified layers in the North basin are then mixed with the upper layers during fall turnover, based on Chautauqua County's 2007 water quality study. In the South basin, Wilson et al. (2000) suggested that thermal stratification is not strong, with near homogenous temperatures through the summer.

Current Study

Water clarity can be related to the amount of suspended material in the water column including sediment, phytoplankton, and zooplankton. The north basin of Chautauqua Lake has higher water clarity and lower nutrient and algae levels than other lakes in the western region, while in the South basin these levels are consistent with those in the shallower western region lakes. Aquatic plant coverage is higher than in many of these other lakes, particularly in the north basin. Chloride levels were between the 25th and 50th percentile for New York State lakes in the North basin and between the 50th and 75th percentile in the south basin, indicating potential for impacts to aquatic life from road salt (although no impacts have been reported). Specific factors that appear to have contributed to water clarity in the lake are provided in the following sections.

Long-term trends in water clarity as represented by average Secchi depth were not observed in either the North ($\tau = 0.044$) or South basins ($\tau = -0.029$) over time (**Figure 6**). Secchi disk transparency readings exceed the minimum New York State Sanitary Code requirements for siting new bathing beaches (1.2-meter, or 4 ft., minimum NYSDOH 2018) regularly in the North basin and occasionally in the South basin. Monitoring water clarity should continue to document potential changes over time.

The minimum Secchi depth, or the shallowest recorded value for a given year, has not changed over time (North – $p = 0.326$, $\tau = -0.128$; South – $p = 0.460$, $\tau = -0.126$) (**Figure 6**). Note that Secchi depths tend to be greater earlier in the growing season, likely due to zooplankton grazing of phytoplankton resulting in a "clear water phase" during this time of the year (Lampert et al. 1986).

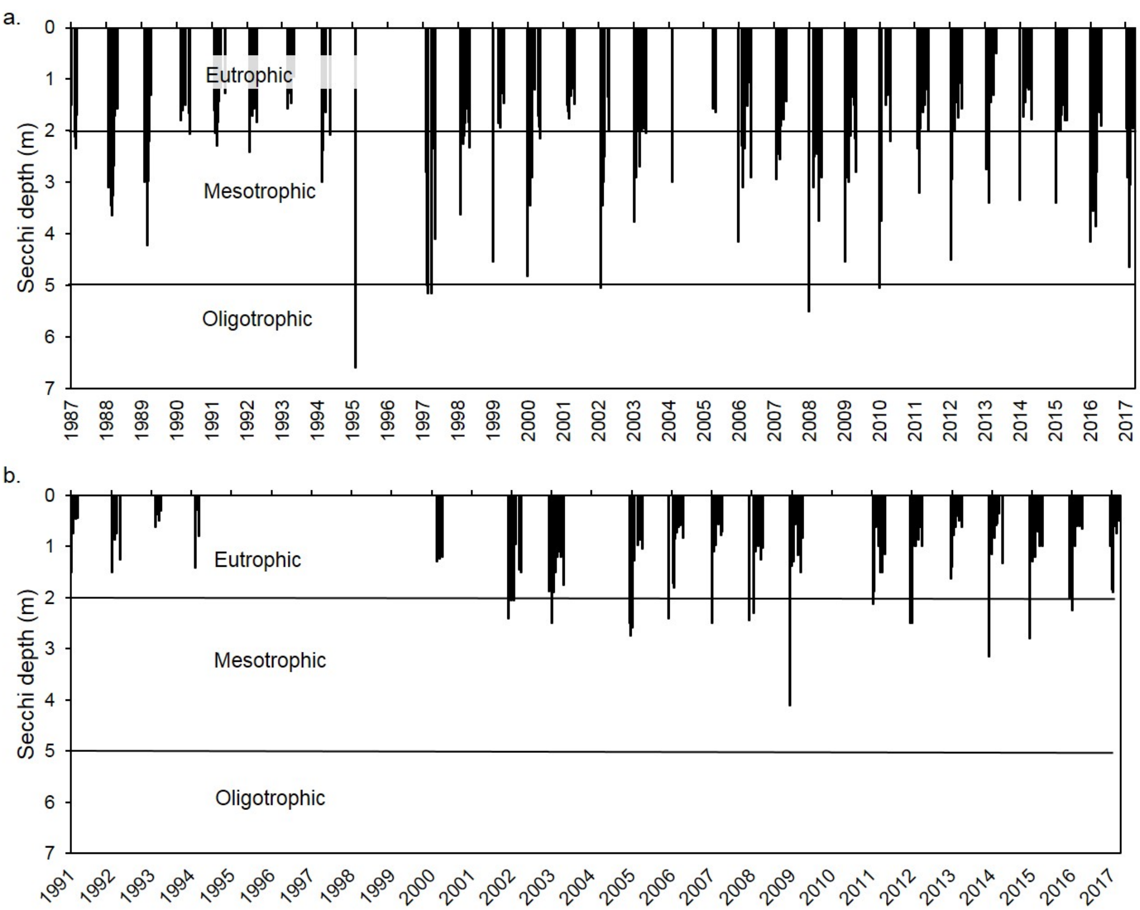

Figure 6. (a) Secchi depth measured at the north sampling location in Chautauqua Lake from 1987 to 2017 (CSLAP and LCI). (b) Secchi depth measured at the south sampling location in Chautauqua Lake from 1991 to 1994, 2000, and 2002 to 2017 (CSLAP and LCI).

The available temperature data represented in **Figure 7** illustrates the following trends:

- There was not a long-term trend in either average (p = 0.888, τ = -0.020) or maximum (p = 0.887, τ = -0.021) annual temperatures in the North basin over time (**Figure 7a**).
- Additionally, the average (p = 0.902, τ = 0.022) and maximum (p = 0.554, τ = 0.110) annual temperatures in the South basin did not significantly change over time (**Figure 7b**).

Understanding temperature changes within a waterbody (both seasonally and annually) is important in understanding HABs. Most cyanobacteria taxa grow better at higher temperatures than other phytoplankton which give them a competitive advantage at higher temperatures (typically above 25°C) (Paerl and Huisman 2008). Seasonal temperature data should continue to be monitored in both lake basins.

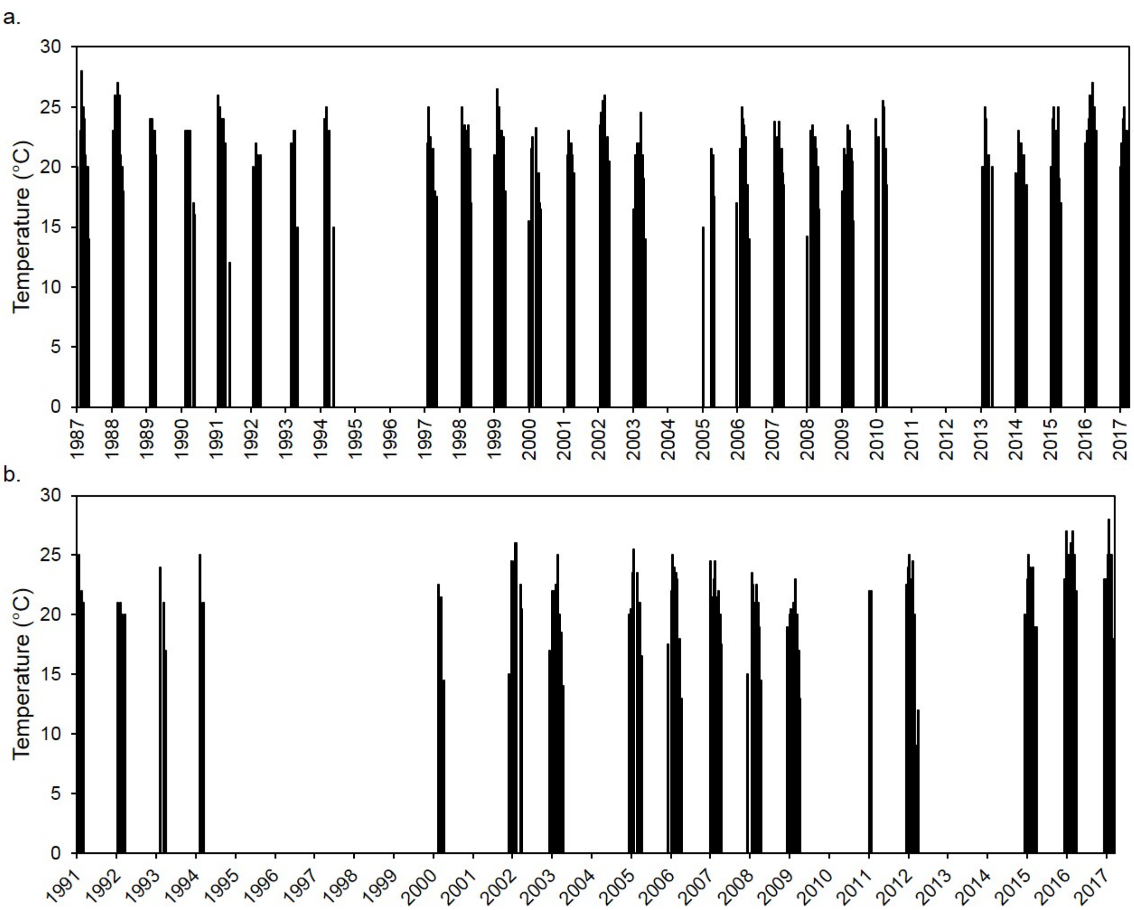

Figure 7. (a) Surface water temperature (°C) measured at the north sampling location in Chautauqua Lake from 1987 to 2017 (CSLAP and LCI). (b) Surface water temperature (°C) measured at the south sampling location in Chautauqua Lake from 1991 to 1994, 2000, and 2002 to 2017 (CSLAP and LCI).

6.2 Chemical Conditions

Results from Past Studies

The NYSCD’s 1937 Allegheny River basin survey indicated that DO deficits within Chautauqua Lake occur starting at depths between 4.6 and 7.3 m (15 and 24 feet). While water quality conditions seemed to be comparable to those measured through the CSLAP program, field notes from the 1937 survey reported that copper sulfate treatments had occurred for the three previous years (NYSCD 1937).

Data from the USEPA’s 1972 study indicate Chautauqua Lake was eutrophic and algal growth was limited by nitrogen. Nitrogen to phosphorus ratios were less than 9:1 during the sampling period (USEPA 1974).

Data collected during Chautauqua County’s 2007 water quality study indicated that Chautauqua Lake was hypereutrophic, with elevated TP concentrations primarily the result of loading from tributary inputs (Princeton Hydro 2008). The report concluded that the elevated phosphorus concentrations contribute to the excessive amounts of submerged aquatic vegetation (SAV) and algal blooms in Chautauqua Lake, and that a holistic, watershed-based Management Plan should be developed to reduce algal blooms and educate long-term watershed management (Princeton Hydro 2008).

Current Study

Based on annual total phosphorus (TP) concentrations, Chautauqua Lake can be characterized as eutrophic to hypereutrophic (**Table 3**). Total phosphorus concentrations in both the North and South basins of the lake generally follow a seasonal pattern, with increased concentrations of phosphorus mid-season (**Figure 8**). Annual average and/or maximum TP concentrations have increased over time in both the North and South basins:

- North basin
    - Average annual TP increased (τ = 0.530, p = <0.001).
    - Maximum annual TP increased (τ = 0.481, p = <0.001).
- South basin
    - Average annual TP increased (τ = 0.275) though the trend is not statistically significant (p = 0.100).
    - Maximum annual TP increased (τ = 0.462, p = 0.006).

Increasing TP is consistent with increased algal growth and more frequent HABs.

The thin hypolimnion that forms within the North basin of Chautauqua Lake during thermal stratification suggests the potential for internal loading of phosphorus from the sediments during periods of anoxia. Although there are no dissolved oxygen (DO) data for this lake, at least as collected through NYSDEC Division of Water monitoring programs, the TP concentrations for samples collected from deeper depths (between 9.5 and 11 m) are generally significantly higher than the concentrations in surface samples, suggesting that TP is being released from the sediment during anoxic conditions within the hypolimnion. This phosphorus is then introduced to the epilimnion during mixing periods, when it can then stimulate algal growth.

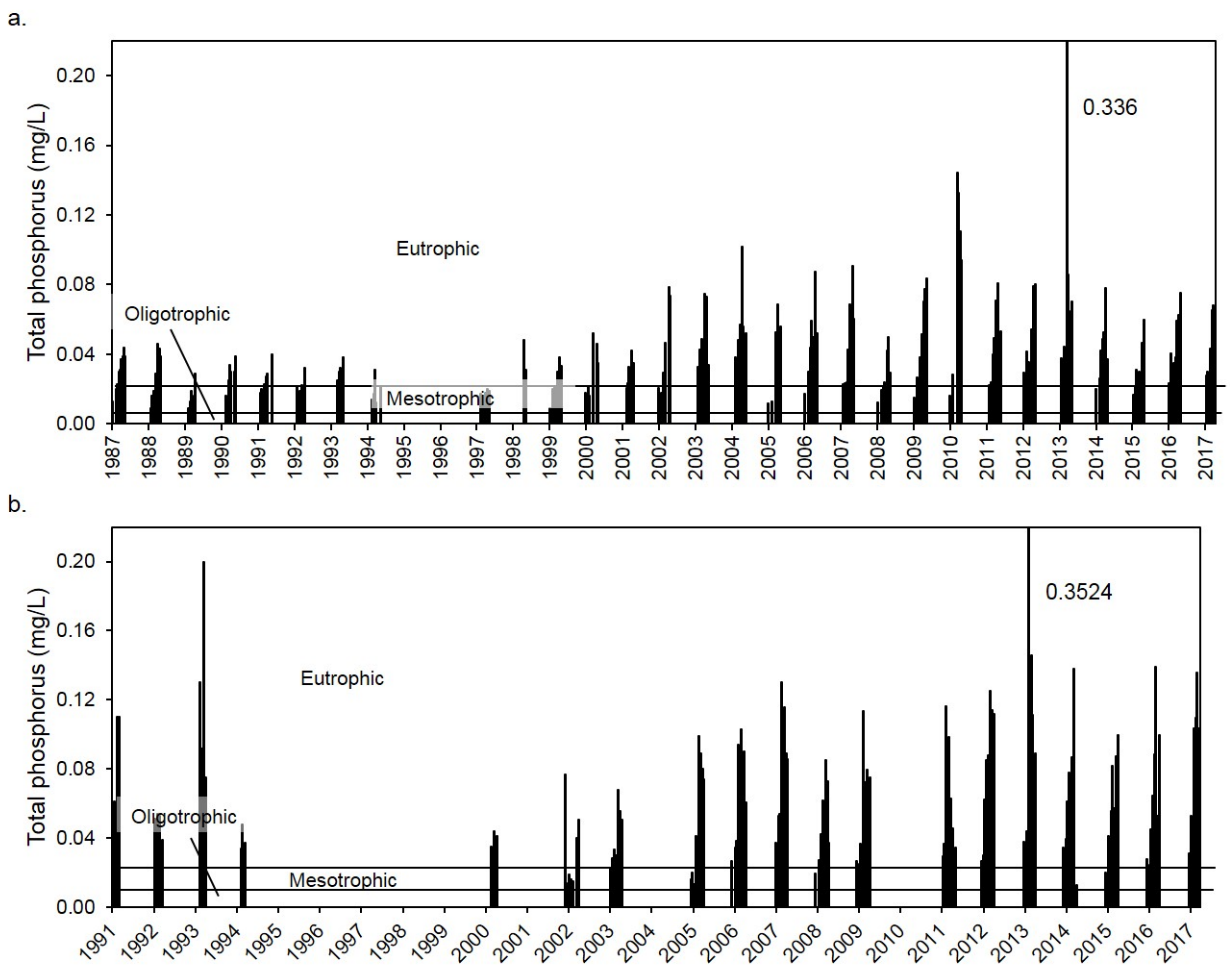

Figure 8. (a) Total phosphorus (mg/L) measured at the North sampling location in Chautauqua Lake from 1987 to 2017 (CSLAP and LCI). (b) Total phosphorus (mg/L) measured at the South sampling location in Chautauqua Lake from 1991 to 1994, 2000, and 2002 to 2017 (CSLAP and LCI).

Like phosphorus, total nitrogen (TN) concentrations in Chautauqua Lake are suggestive of eutrophic conditions (> 0.6 mg/L, Canfield et al. 1983) (**Figure 9**). Total nitrogen concentrations in both the North and South basins of the lake generally follow a seasonal pattern, with increased concentrations of TN mid-season. Long-term trends in annual average and maximum TN were not observed in either the North or South basins:

- North basin
    - Average annual TN – $p = 0.929$, $\tau = -0.022$
    - Maximum annual TN – $p = 0.531$, $\tau = 0.156$
- South basin
    - Average annual TN – $p = 0.325$, $\tau = -0.244$
    - Maximum annual TN – $p = 0.655$, $\tau = 0.111$

Note that the June 2013 maximum TN concentration in the South basin was almost four times higher than other yearly maximum values. The average TN, average TP, and maximum TP concentrations were also significantly higher in 2013 than other sampling years. The reason for this spike is unknown, but these results might not be representative of normal conditions in the lake at that time.

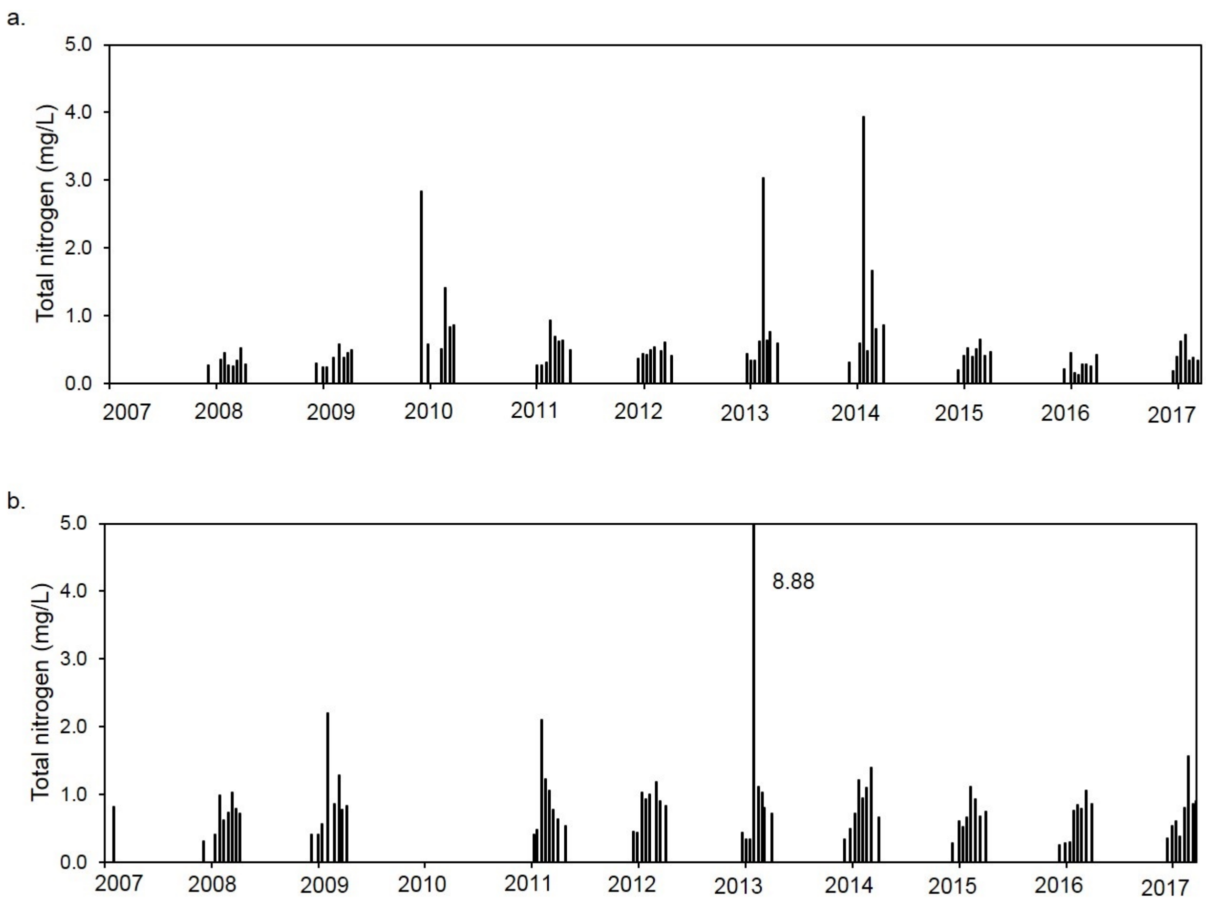

Figure 9. (a) Total nitrogen (mg/L) measured at the North sampling location in Chautauqua Lake from 2008 to 2017 (CSLAP and LCI). (b) Total nitrogen (mg/L) measured at the South sampling location in Chautauqua Lake from 1991 to 1994, 2000, and 2002 to 2017 (CSLAP and LCI).

The relative concentrations of nitrogen and phosphorus can influence algal community composition and the abundance of cyanobacteria. Ratios of TN to TP in lakes can be used as a suitable index to determine if algal growth is limited by the availability of nitrogen or phosphorus (Lv et al. 2011). The ratio of nitrogen to phosphorus (TN:TP) may determine whether HABs occur, with cyanobacteria blooms rare in lakes where mass based TN:TP ratios are greater than 29:1 (Filstrup et al. 2016, Smith 1983). Certain cyanobacteria taxa are capable of utilizing atmospheric dinitrogen (N_2), which is unavailable to other phytoplankton, providing a competitive advantage to N-fixing cyanobacteria when nitrogen becomes limiting.

Ratios (by mass) of TN:TP in the North basin of Chautauqua Lake averaged 11.5 (± 5.7 standard deviation), and TN:TP was on average 12.3 (± 4.0) in the South basin, over the span of available data and excluding outliers in the dataset (**Figure 10**, not that outliers identified in the figure were not included in TN:TP averages). These TN:TP values suggest that algal biomass (including cyanobacteria) is generally limited by nitrogen during the growing season (but see **Section 9**). Further, increased nitrogen availability during blooms can encourage increased toxicity (Gobler et al. 2016), however, Chautauqua Lake exhibits toxic blooms when inorganic nitrogen is relatively low. Certain cyanobacteria can thrive when nitrogen is limited because they have the ability to capture inorganic atmospheric nitrogen (Vitousek et al. 2002). Indeed, the cyanobacteria assemblage in Chautauqua Lake appears to consist of nitrogen fixing taxa (e.g., *Dolichospermum*, see **Section 7.3**). Thus, even though nitrogen may be limiting overall phytoplankton biomass in Chautauqua Lake, reducing phosphorus concentrations will likely result in decreased frequency of cyanobacteria blooms by limiting the N-fixation ability of certain cyanobacteria taxa.

Based on previous monitoring from 2008 to 2017, the TN:TP ratio showed the following trends, with statistically significant trends in **bold**:

North basin (2008-2017)

- Average TN:TP ratio - $p = 0.531$, $\tau = -0.156$
- Maximum TN:TP ratio - $p = 0.421$, $\tau = -0.200$
- Minimum TN:TP ratio - $p = 0.655$, $\tau = -0.111$

Additionally, maximum concentrations of NO_x (nitrate plus nitrite) (mg/L) in the North basin have significantly decreased over time from 1987 to 2017 ($p = 0.027$, $\tau = -0.497$). There was not a significant long-term trend in average annual NO_x concentrations over the same time period ($p = 0.093$, $\tau = -0.374$), though this trend could be result of declining detection limits over time. Ammonia concentrations (mg/L), another form of inorganic nitrogen, showed no long-term trends over time in the North basin (average ammonia – $p = 0.653$, $\tau = 0.083$; maximum ammonia – $p = 0.787$, $\tau = 0.050$).

South basin (2007-2017)

- **Average TN:TP ratio - $p = 0.016$, $\tau = -0.600$**
- Maximum TN:TP ratio - $p = 0.929$, $\tau = -0.022$
- **Minimum TN:TP ratio - $p = 0.003$, $\tau = -0.733$**

The decreasing trends in the South basin suggest conditions are more favorable to nitrogen-fixing cyanobacteria and HABs. However, forms of inorganic nitrogen (both NO_x and ammonia) in the South basin showed no long-term trends from 1991 to 2017 (p-values > 0.05). It should be noted that the number of NO_x samples from the South basin is comparatively low (n = 4) relative to the North basin (n = 13), making a meaningful trend analysis of NO_x in the South basin difficult to assess statistically.

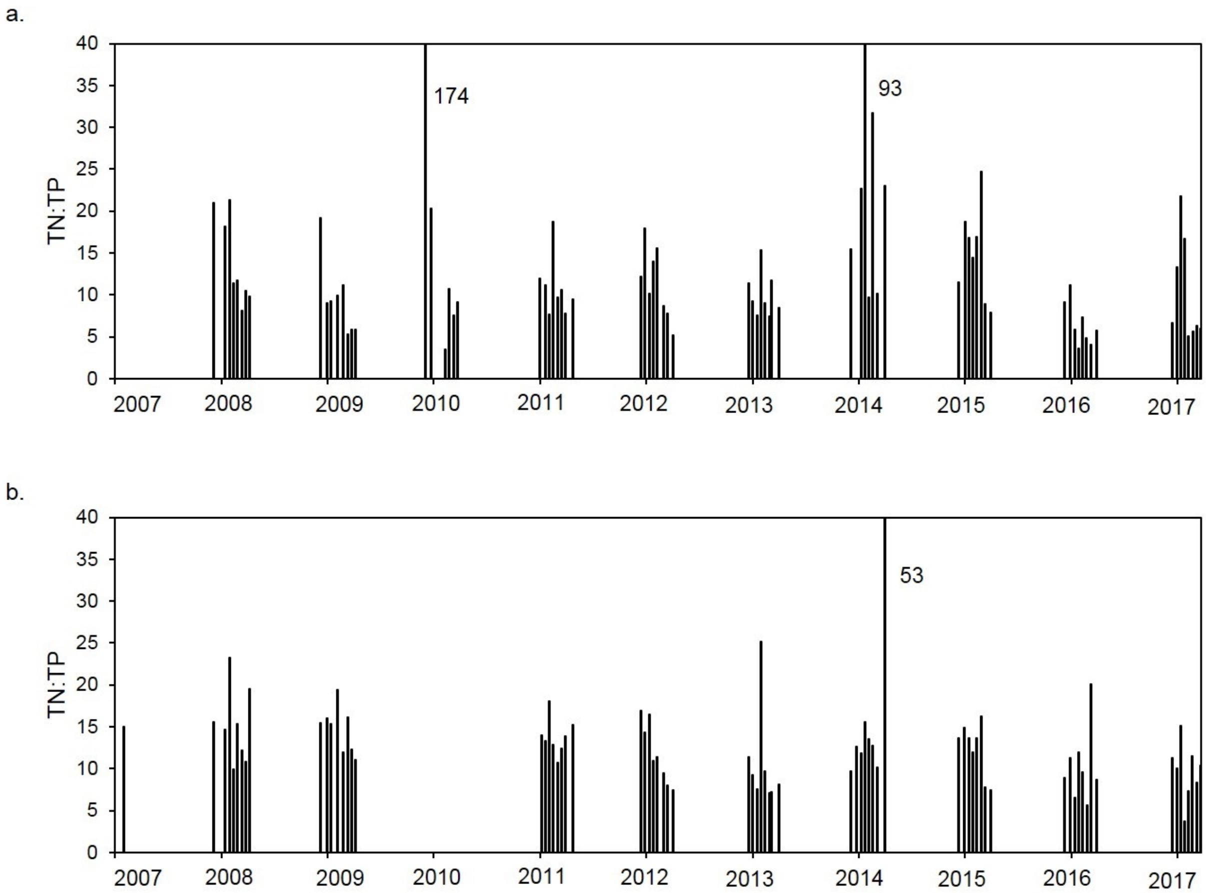

Figure 10. (a) Ratios of total nitrogen (TN) to total phosphorus (TP) (by mass) measured at the North sampling location in Chautauqua Lake from 2008 to 2017 (CSLAP and LCI). (b) Ratios of total nitrogen (TN) to total phosphorus (TP) (by mass) measured at the South sampling location in Chautauqua Lake from 1991 to 1994, 2000, and 2002 to 2017 (CSLAP and LCI).

6.3 Biological Conditions

Results from Past Studies

During the NYSCD's 1937 study, 40 fish species were identified as inhabiting Chautauqua Lake. Of these, bluegill sunfish, common sunfish, black crappie, and brook silversides were abundant. The remaining species were identified as "common", "fairly common", and "rare" (NYSCD 1937).

According to the *1970's Benchmark Studies*, the taxonomic diversity of invertebrate organisms in Chautauqua Lake declined compared to data from 35 years prior. The authors could not definitively conclude if the change was due to data collection differences or an actual decline. However, the report noted that the decline is likely real and should be further investigated using the data collected as a benchmark (Jamestown CC 1972).

Data from the USEPA's 1972 study indicate Chautauqua Lake was eutrophic. Of the 26 New York lakes sampled, 19 had lower mean chlorophyll-a levels than Chautauqua Lake (USEPA 1974).

SUNY Fredonia's 1988-1989 macrophyte survey results indicate nearshore biomass was similar in the North and South basins. Macrophyte biomass varied based on depth, with the greatest biomass occurring in the approximate 5-6.5-foot range. Biomass at the 9.8-foot range was only found in the North basin (Winter et al. 1990).

A recent survey conducted by Racine-Johnson Aquatic Ecologists (2017a) found a total of 21 aquatic plant species in Chautauqua Lake. Since monitoring efforts began in 2003, the number of species has declined from 32 species between 2003-2008. Of these, five invasive aquatic plants have been observed, including water chestnut (*Trapa natans*) which was only observed in the 2013 sampling season. Observation of aquatic insect herbivores indicated continued biological control of Eurasian watermilfoil (*Myriophyllum spicatum*) in 2016, although the distribution of Eurasian watermilfoil was greater in 2016 compared to 2015 (Racine-Johnson Aquatic Ecologists 2017a).

Current Study

Aquatic plants are visually assessed as part of CSLAP based on the perceived extent of weed growth in the lake. Their assessments indicate that aquatic plant coverage was lower than usual in 2014 and 2015, with less favorable assessments in the South basin (NYSDEC 2016). CSLAP plant evaluations are incomplete for very large lakes where visual assessments are limited to small parts of the lake.

Invasive species remain a concern in the lake; public bathing and recreational use are considered impaired by nutrients which lead to excessive plant growth (Chautauqua Lake Watershed WI/PWL 2014). Currently, Chautauqua Lake contains nine aquatic invasive species (NYSFOLA 2018):

- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Curly-leaf pondweed (*Potamogeton crispus*)
- Water chestnut (*Trapa natans*)
- Brittle naiad (*Najas major*)
- Zebra mussels (*Dreissenia polymorpha*)
- Goldfish (*Carassius auratus*)
- Common carp (*Cyprinus carpio*)
- Asian clam (*Corbicula fluminea*)
- Allegheny crayfish (*Orconectes obscurus*)

Certain invasive species may influence the frequency and duration of HABs. For instance, common carp can increase sediment suspension and associated nutrients in the water column based on their feeding behavior. This species feeds on benthic macroinvertebrates found within the sediment, with that sediment suspended during active feeding. The increased sediment being suspended in the water will include nutrients that may be utilized by cyanobacteria.

Eurasian watermilfoil is of major concern in Chautauqua Lake because the species often grows in large dense beds, outcompeting and crowding out native aquatic vegetation. The dense beds of this aquatic invasive species provide less suitable habitat for fish and other aquatic life and can impede recreational activities such as boating, fishing, and swimming. Eurasian watermilfoil may also act as a nutrient pump, by bringing nutrients up from the sediment and back into the water column as plant biomass during the growing season (Smith and Adams 1986). Some of these nutrients are then released into the water column during respiration and decay of plant material. While several studies from the scientific literature discuss the role of Eurasian milfoil as a potential nutrient pump, lake specific conditions can alter these dynamics including, local anoxic patches, trophic state, plant density, and plant decomposition rates (Carpenter 1983, Carpenter and Lodge 1986); further research is warranted to assess these variables in Chautauqua Lake. There has been ongoing research in the management and control of Eurasian watermilfoil over the past several years using biocontrols, and most recently an assessment to use herbicides (Chautauqua County 2017, Rupp Baase Pfalzgraf Cunningham 2018). There is some evidence that herbivorous insects, particularly the Chautauqua caddis (*Nectopsyche albida)* are feeding on Eurasian watermilfoil in several areas of the lake. The influence of Eurasian watermilfoil and other aquatic plants on HABs may be confounded by these herbivores, including caddisflies, aquatic weevils (*Euhrychiopsis lecontei*), and aquatic moths (*Acentria ephemerella*), and could be affected by the use of herbicides or other plant management actions.

Zebra mussels can influence phytoplankton composition by selectively feeding on phytoplankton, which can result in increased prevalence of cyanobacteria (Vanderploeg et al. 2010). Dreissenid mussels are often found in nearshore zones and coupled with their high filtration rates of algae and subsequent elimination of wastes, can concentrate nutrients in nearshore zones (Hecky et al. 2004). Shifts in nutrient concentrations to nearshore areas may result in greater incidence of shoreline HABs.

Chlorophyll-a is a main photosynthetic pigment of all algae, including cyanobacteria, and is often used as a proxy variable to estimate the amount of algae present. Concentrations of annual chlorophyll-a suggest that Chautauqua Lake is eutrophic (highly productive) (**Figure 11**). Chlorophyll-a concentrations generally follow a seasonal pattern, with increased concentrations during the mid- to late-growing season (**Figure 11**). There were no long-term trends in average ($p = 0.940$, $\tau = -0.010$) or maximum ($p = 0.320$, $\tau = 0.131$) chlorophyll-a concentrations in the North basin from 1987 to 2017. Additionally, there was not a trend in average chlorophyll-a in the South basin from 1991 to 2017 (p = 0.382, τ = 0.146), but a non-significant increasing trend in maximum chlorophyll-a over this same time period (p = 0.074, τ = 0.298).

Chlorophyll-a concentrations in Chautauqua Lake (**Figures 11a and 11b**) consistently exceed the 6.0 µg/L threshold for Class A lakes proposed by Callinan et al. (2013). Callinan et al. (2013) indicated that average annual chlorophyll-a concentrations above 6 µg/L would be sufficient to reach or exceed the existing USEPA maximum contamination level of 80 µg/L total trihalomethanes concentration for drinking water (USEPA 2006).

Note that the 2013 maximum chlorophyll-a concentration in the North basin was almost six times higher than other yearly maximum values. The 2009 maximum chlorophyll-a concentration in the South basin was almost twice the other yearly maximum values. The reason for these spikes is unknown, although chlorophyll-*a* spikes associated with blooms may indicate heterogenous conditions that are not representative of algae levels in the lake.

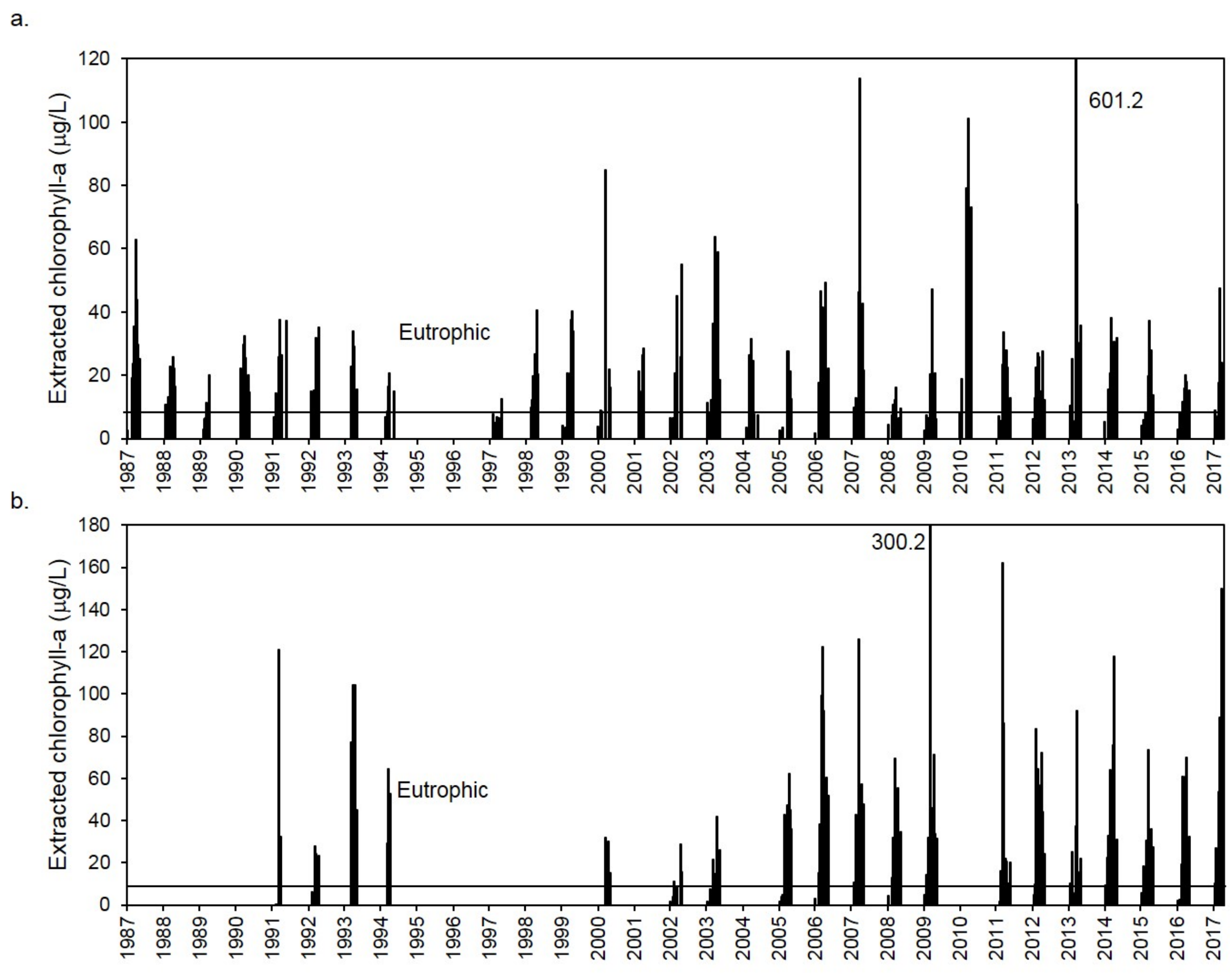

Figure 11. (a) Chlorophyll-a (µg/L) measured at the North sampling location in Chautauqua Lake from 1987 to 2017 (CSLAP and LCI). (b) Chlorophyll-a (µg/L) measured at the South sampling location in Chautauqua Lake from 1991 to 1994, 2000, and 2002 to 2017 (CSLAP and LCI).

6.4 Remote Sensing Estimates of Chlorophyll-a Concentrations

Chlorophyll-a concentrations were estimated for the entire lake using a remote sensing chlorophyll-a model developed by the University of Massachusetts for Lake Champlain (Trescott 2012). The analysis provides an estimate of the spatial distribution of chlorophyll-a on any particular day and is intended to supplement data collected via the field measurement programs. The model estimates of chlorophyll-a are based on the spectral properties of chlorophyll-a, and are thus a measure of green particles near the water surface. The chlorophyll-a model was developed based on data with concentrations less than 20 µg/L. The accuracy of the model for chlorophyll-a concentrations exceeding 20 µg/L has not been tested. At this time, the estimated chlorophyll-a concentrations are reported as a concentration index due to the limited number of field measurements to calibrate the model to the other NYS lakes; for more information, including limitations of the model, refer to **Appendix C.**

The remote sensing analysis was conducted using satellite imagery from NASA's Landsat 8 satellite. Seasonal imagery from May to October was acquired and processed for the past three years (2015-2017). Based on the available remote sensing images shown in **Figure 12**, the North basin tends to have lower chlorophyll-a concentration than the South basin (as supported by the CSLAP data). The highest chlorophyll-a concentrations are found to start from Long Point State Park (immediately north of the narrows) and extend to Jamestown (at the outlet of the lake). Chlorophyll-a tends to increase through the summer season and peak in September and October.

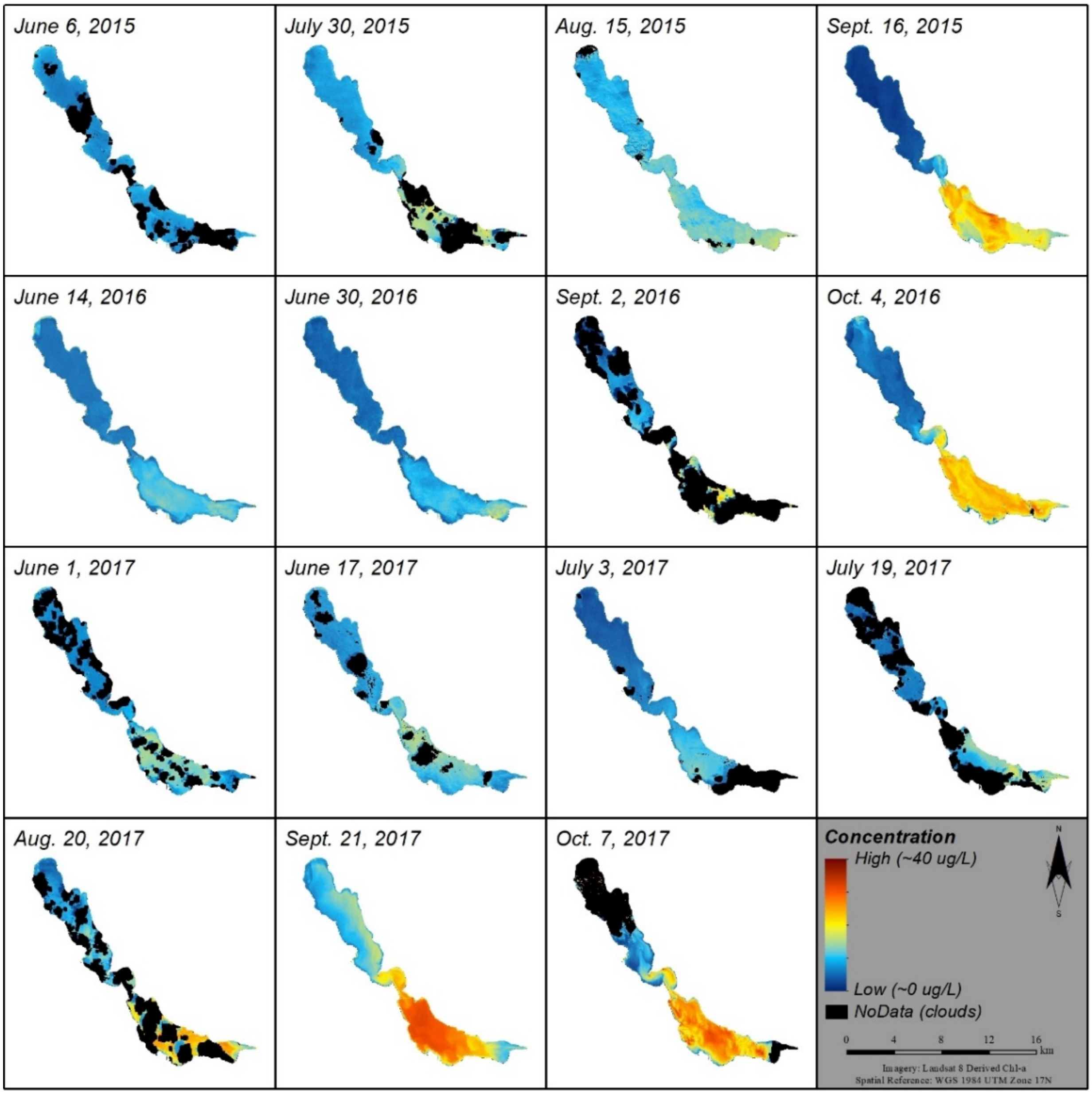

Figure 12. Estimated chlorophyll-a concentrations in Chautauqua Lake, 2015-2017.

The estimated chlorophyll-a concentrations from the remote sensing analysis were extracted at the CSLAP monitoring stations (North and South) to compare the estimates with the measured chlorophyll-a concentrations (see **Figure 13**). In general, there was relative agreement between the measured and estimated concentrations when there is coincident data. However, **Figure 13** indicates that the remote sensing did not capture some of the higher chlorophyll-a concentrations observed in the CSLAP measurements due to the timing of the satellite overpasses and cloud cover (no data) and due to the maximum reporting limits associated with the satellite data (20-30 µg/L).

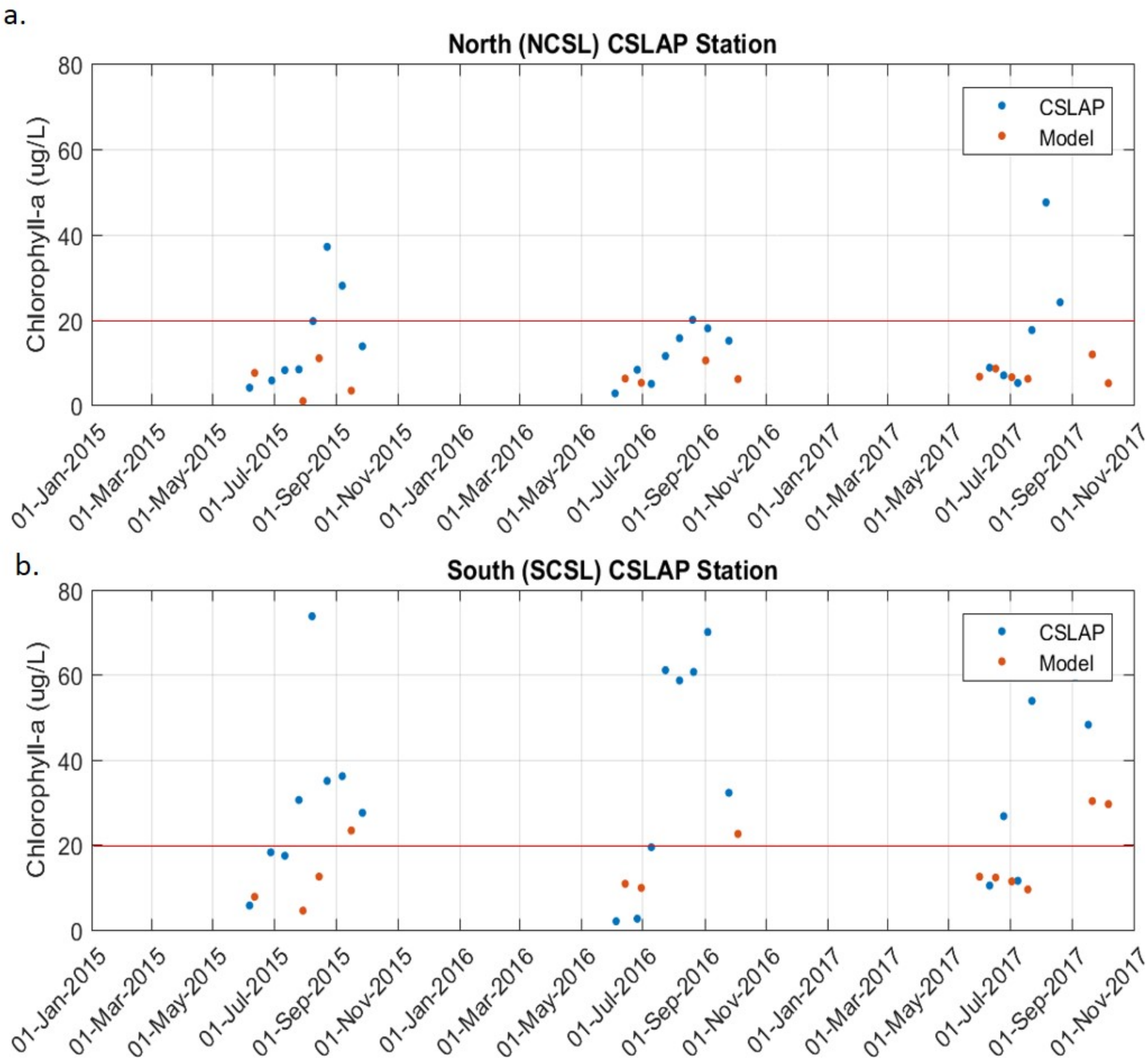

Figure 13. Measured (CSLAP, blue circles) and modeled (Landsat 8, orange circles) chlorophyll-a concentrations from the (a) North and (b) South basins of Chautauqua Lake, 2015 to 2017. The red lines represent the upper threshold of chlorophyll-a concentrations (20 μg/L) for which the remote sensing algorithm was tested in Lake Champlain (Trescott 2012).

7. Summary of HABs

New York State possesses one of, if not the most, comprehensive HABs monitoring and notification programs in the country. The NYSDEC and NYSDOH collaborate to document and communicate with New Yorkers regarding HABs. Within NYSDEC, staff in the Division of Water, Lake Monitoring and Assessment Section oversee HAB monitoring and surveillance activities, identify bloom status, communicate public health risks, and conduct outreach, education, and research regarding HABs. The NYSDEC HABs Program has adopted a combination of visual surveillance, algal concentration measurements, and toxin concentration to determine bloom status. This process is unique to New York State and has been used consistently since 2012.

The NYSDEC HABs Program has established four levels of bloom status:

- **No Bloom**: evaluation of a bloom report indicates low likelihood that a cyanobacteria bloom (HAB) is present
- **Suspicious Bloom**: NYSDEC staff determined that conditions fit the description of a HAB, based on visual observations and/or digital photographs. Laboratory analysis has not been done to confirm if this is a HAB. It is not known if there are toxins in the water.
- **Confirmed Bloom**: Water sampling results have confirmed the presence of a HAB which may produce toxins or other harmful compounds (BGA chlorophyll-a levels ≥ 25 µg/L and/or microscopic confirmation that majority of sample is cyanobacteria and present in bloom-like densities). For the purposes of evaluating HABs samples, chlorophyll-a is quantified with a Fluoroprobe (bbe Moldaenke) which can effectively differentiate relative contributions to total chlorophyll-a by phytoplankton taxonomic group (Kring et al. 2014). BGA chlorophyll-a concentrations (attributed to most types of cyanobacteria) are utilized by the NYSDEC HABs Program for determining bloom status. This method provides an accurate assessment of cyanobacteria density and can be accomplished much more quickly and cost-effectively than traditional cell counts.
- **Confirmed with High Toxins Bloom**: Water sampling results have confirmed that there are toxins present in sufficient quantities to potentially cause health effects if people and animals come in contact with the water through swimming or drinking (microcystin ≥ 20 µg/L (shoreline samples) or microcystin ≥ 10 µg/L (open water samples).

The spatial extent of HABs are categorized as follows:

- **Small Localized**: Bloom affects a small area of the waterbody, limited from one to several neighboring properties.
- **Large Localized**: Bloom affects many properties within an entire cove, along a large segment of the shoreline, or in a specific region of the waterbody.
- **Widespread/Lakewide**: Bloom affects the entire waterbody, a large portion of the lake, or most to all of the shoreline.
- **Open Water**: Sample was collected near the center of the lake and may indicate that the bloom is widespread and conditions may be worse along shorelines or within recreational areas.

7.1 Ambient Lake HABs History

Chautauqua Lake has received considerable attention by state agencies, non-governmental organizations, community interest groups, lake users, water suppliers, and other stakeholders because of the documented presence of HABs in the lake in recent years. HABs have been reported to the NYSDEC by many data providers including Chautauqua County DOH, NYSDOH, and members of the public. HABs in Chautauqua Lake occur predominantly along the shoreline in the lake's North and South basins. Chautauqua Lake is sampled bi-weekly by trained citizen volunteers who visually assess shoreline areas for the presence of cyanobacteria and collect surface water samples if a bloom is noted. In addition, several beaches and public areas overseen by the Chautauqua Institution and the Chautauqua Lake Association are sampled regularly during the summer. The frequency that samples surpassed NYSDEC bloom status thresholds is summarized in **Table 4**.

Between 2012 and 2017, a total of 298 HABs occurrences were reported based on visual reporting and/or surface water samples collected by the Chautauqua Lake Association or CSLAP volunteers. Results indicate that samples were determined to be Confirmed or Confirmed with High Toxins during 97 days of sampling, primarily between early July and mid-October. However, bloom frequency and duration clearly extended beyond these discrete sampled events and locations, even though bloom conditions were evaluated at high frequency (weekly) in many locations.

The South basin of Chautauqua Lake has had 76 Confirmed or Suspicious Blooms since 2013 (**Table 1** in **Appendix D**). Of these, 8 were reported as large localized or widespread in extent. The North basin has had 70 samples that were determined to be Confirmed or Suspicious Blooms, dating back to 2012. Of these samples, 2 were reported as large localized or widespread in extent (**Table 2** in **Appendix D**).

Table 4. Number of HABs notifications by bloom status.

Year	Suspicious	Confirmed	Confirmed w/ High Toxins
2012	4	0	3
2013	0	26	27
2014	0	63	5
2015	1	21	9
2016	4	45	7
2017	1	68	14

Chautauqua Lake spent 11 weeks on the NYSDEC's HABs notification page in 2012, 16 weeks in 2013, 15 weeks in 2014, 10 weeks in 2015, 16 weeks in 2016, and 18 weeks in 2017. At some point in each year from 2012-2017, samples were found to exceed the NYSDEC threshold for a Confirmed with High Toxin Bloom (NYSDEC 2018c).

7.2 Drinking Water and Swimming Beach HABs History

Drinking Water

Across New York, NYSDOH first sampled ambient water for toxin measurement in 2001, and raw and finished drinking water samples beginning in 2010. Two public water supplies were sampled in a 2012 pilot study that included both fixed interval and bloom-based event criteria. While microcystin has been detected in pre-treatment water occasionally, rarely have any detects been found in finished water. To date, no samples of finished water have exceeded the 0.3 µg/L microcystin health advisory limit (HAL). Many different water systems using different source waters have been sampled, and drinking water HABs toxin sampling has increased substantially since 2015 when the USEPA released the microcystin and cylindrospermopsin HALs. The information gained from this work and a review of the scientific literature was used to create the current NYSDOH HABs drinking water response protocol. This document contains background information on HABs and toxins, when and how water supplies should be sampled, drinking water treatment optimization, and steps to be taken if health advisories are exceeded (which has not yet occurred in New York State).

In 2018, the USEPA started monitoring for their Unregulated Contaminant Monitoring Rule 4 (UCMR 4), which includes several HAB toxins. In 2018, the USEPA will sample 32 public water systems in New York State. The UCMR 4 is expected to bring further attention to this issue, leading to a greater demand for monitoring at PWSs. To help with the increasing demand for laboratory analysis of microcystin, the NYSDOH ELAP is offering certification for laboratories performing HAB toxin analysis, starting in spring 2018. Public water supplies should only use ELAP-certified labs and consult with local health departments (with the support of NYSDOH) prior to beginning HAB toxin monitoring and response actions.

Chautauqua Lake is used by lake residents and visitors as a source of drinking water, and the evaluation of this use includes conditions of the lake water prior to treatment, as well as the quality of water distributed for use after treatment. Water supply use of both the North and South basins is designated as impaired by elevated nutrient and chlorophyll levels in the lake that result in the formation of disinfection by-products (DBPs) in finished potable water, which make treatment to meet drinking standards more difficult (Chautauqua Lake Watershed WI/PWL 2014). The Chautauqua Water District #2 reported levels of specific DBPs (trihalomethanes (THMs) and haloacetic acids) greater than regulatory limits during a portion of 2014 (Chautauqua Lake Watershed WI/PWL 2014).

The two public water supplies on Chautauqua Lake have been sampled intermittently in response to HAB blooms since 2011. In 2017, one of the water supplies exhibited finished drinking water with detectable microcystin at levels below the 0.3 µg/L action level, but a do not drink recommendation was issued out of an abundance of caution. Immediate follow-up sampling, public notification, and drinking water treatment optimization were performed; and microcystin levels were not detected in subsequent finished water samples. As noted in **Section 3.2** it is never advisable to draw drinking water from a surface source unless it has been treated by a public drinking water system, regardless of the presence of HABs (NSF P477; NYSDOH 2017).

Swimming

Swimming within both the North and South basins is identified as impaired by elevated nutrients (phosphorus), excessive algae, poor water clarity, and shoreline HABs. The Chautauqua County Department of Health and Human Services (CCDHHS) monitors permitted bathing beaches, and has frequently closed several beaches due to HABs, including Bemus Point Beach, Lakewood Village Beach, and four beaches at Chautauqua Institution (Chautauqua Lake Watershed WI/PWL 2014, Pignataro 2014). A summary of the observations and impacts of HABs on bathing beach recreational use at Chautauqua Lake from 2012 to 2017 is presented below based on beach closure data supplied by NYSDEC and NYSDOH.

- 2012- 3 closures, resulting in 25 lost beach days (Lakewood Village Beach, Mayville Lakeside Park Beach and YWCA).
- 2014 - 8 closures, resulting in 109 lost beach days (Bemus Point, Children's Beach, College Pier, Heinz Beach, Lakewood Village Beach, Long Point State Park, Mayville Lakeside Park Beach, and University Beach).
- 2015 - 3 closures, resulting in 11 lost beach days (Heinz, Long Point State Park, and University Beach).
- 2016 - 3 closures, resulting in 25.5 lost beach days (Lakewood Village Beach, Long Point State Park, and YWCA).
- 2017 - 5 closures, resulting in 116 lost beach days (Camp Onyahsa, JIM Boys Club, Lakewood Village Beach, Long Point State Park, and YWCA in Lakewood).

Bathing beaches are regulated by NYSDOH District Offices, County Health Departments and the New York City Department of Health and Mental Hygiene in accordance with the State Sanitary Code (SSC). The SSC contains qualitative water quality requirements for protection from HABs. NYSDOH developed an interactive intranet tool that provides guidance to County, City and State District DOH staff to standardize the process for identifying blooms, closing beaches, sampling, reopening beaches and reporting activities. The protocol uses a visual assessment to initiate beach closures as it affords a more rapid response than sampling and analysis. Beaches are reopened when a bloom dissipates (visually) and samples collected the following day confirm the bloom has dissipated and show toxin levels are below the latest guidance value for microcystins. Sample analysis is performed by local health departments, the Wadsworth Laboratory in Albany or academic institutions.

Table 5 provides a summary of the guidance criteria that the NYSDEC and NYSDOH use to advise local beach operators.

Table 5. HABs guidance criteria.			
NYSDEC Bloom Categories			
Confirmed	**Confirmed w/ high toxins**		**Suspicious**
	Open water	**Shoreline**	
[BGA Chlorophyll-a] >25 µg/L	[Microcystin] > 10 µg/L	[Microcystin] > 20 µg/L	Visual evidence w/out sampling results
NYSDOH Guidelines			
Closure		**Re-open**	
Visual evidence (sampling results not needed).		Bloom has dissipated (based on visual evidence); confirmatory samples 1 day after dissipation w/ microcystin < 10 µg/l or < 4 µg/l (USEPA 2016) in 2017.	

7.3 Other Bloom Documentation

Cyanobacteria Chlorophyll-a

BGA chlorophyll-a concentrations from samples determined to be Confirmed or Confirmed with High Toxin blooms ranged from 25.2 µg/L (August 2014) to 210,100 µg/L (September 2014; **Table 6**).

Cyanotoxins

Some cyanobacteria taxa also produce toxins (cyanotoxins) that can be harmful to people and pets. As a result, several different toxins are monitored by the NYSDEC. Microcystin is the most commonly detected cyanotoxin in New York State (NYSDEC 2017). The 20 µg/L microcystin "high toxin" threshold for shoreline blooms was, like the BGA chlorophyll-a threshold, established based on World Health Organization (WHO) criteria.

Microcystin concentrations were quantified from shoreline bloom samples, generally collected as a result of visual observation of scum accumulations. Microcystin was detected above the 20 µg/L threshold by laboratory analysis in 64 of 290 samples. Microcystin levels also exceeded the draft USEPA human health recreational swimming advisory threshold of 4 µg/L (USEPA 2016) during 106 out of 162 laboratory samples in which microcystin was detected. Sample results below this threshold value are consistent with what is currently prescribed by NYSDOH guidance to allow a regulated bathing beach to reopen. NYSDEC and NYSDOH believe that all cyanobacteria blooms should be avoided, even if measured microcystin levels are less than the recommended threshold level. Other toxins may be present, and illness is possible even in the absence of toxins.

Table 6. Measured toxin and cyanobacteria (BGA) chlorophyll-a concentrations for bloom events (2012-2017, CSLAP, Chautauqua Lake Association).						
	Microcystin (µg/L)			**Cyanobacteria (BGA) chl-a (µg/L)**		
Status	**Min**	**Max**	**# of samples**	**Min**	**Max**	**# of samples**
Confirmed	ND	1814.56	226	25.2	170056	226
Confirmed, High Toxins	20.7	17804.3	64	30.6	210100	64

Cyanobacteria Taxa

In the North basin, *Microcystis* was documented as comprising a substantial portion of the phytoplankton community in 61% of samples analyzed by qualitative microscopy (n = 132) (NYSDEC). In addition, *Dolichospermum* was present in 59% of samples analyzed. In the South basin, *Microcystis* comprised a large portion of the phytoplankton community in 82% of samples collected from confirmed or confirmed with high toxin reported HAB events (n = 149), while *Dolichospermum* and *Aphanizomenon* were documented in 57% and 50% of samples, respectively (NYSDEC). It should be noted that these do not represent a complete assessment of the phytoplankton or cyanobacteria community in the lake, but instead indicate the most abundant taxa found through a preliminary microscopic evaluation of these samples.

Microcystin, *Dolichospermum*, and *Aphanizomenon* have the ability to regulate their buoyancy (Mantzouki et al. 2016). This functional trait allows for these taxa to move up into the photic zone for photosynthesis, while also moving down into the water column to access available nutrients found near the metalimnion.

7.4 Use Impacts

Recreational use of Chautauqua Lake is considered to be impaired due to elevated nutrients (phosphorus), excessive algae, poor water clarity, and shorelines HABs (Chautauqua Lake Watershed WI/PWL 2014). This has resulted in beach closures, impacts to shoreline swimming, and poor aesthetic quality in areas affected by these blooms.

7.5 HABs and Remote Sensing

To investigate possible HABs triggers, the remote sensing results were plotted together with hourly rainfall, wind speed and direction, locations of recreational beaches, locations of wastewater treatment plants, and locations of the detected HABs recorded within three days of the remote sensing images. Hourly rainfall is plotted with hourly air temperature. The weekly average and long-term average (12 years) air temperature are shown to provide context. Hourly wind is presented using stick plots that provide direction and magnitude. Each arrow is pointing in the compass direction the wind is blowing towards; up is north. The magnitude is indicated by the length of the line; a scale line is provided for reference. A full set of these figures is provided in **Appendix C**. Select examples from the past three years are discussed below.

HABs were confirmed in Chautauqua Lake from July 1 to September 8, 2015. The remoting sensing data indicate that estimated chlorophyll-a concentrations were around 10-15 µg/L in both the North basin and South basin in June, July, and August. In September 2015, the estimated chlorophyll-a concentration in the North basin decreased while the concentration in the South basin increased to around 20-30 µg/L (**Figure 14**). The CSLAP data (**Figure 13**), suggests that the timing of the remote sensing image missed the high chlorophyll-a concentrations captured by the CSLAP data in July and August. In the week prior to the September 16, 2015 satellite image, air temperatures were slightly above seasonal and there were strong winds from the north.

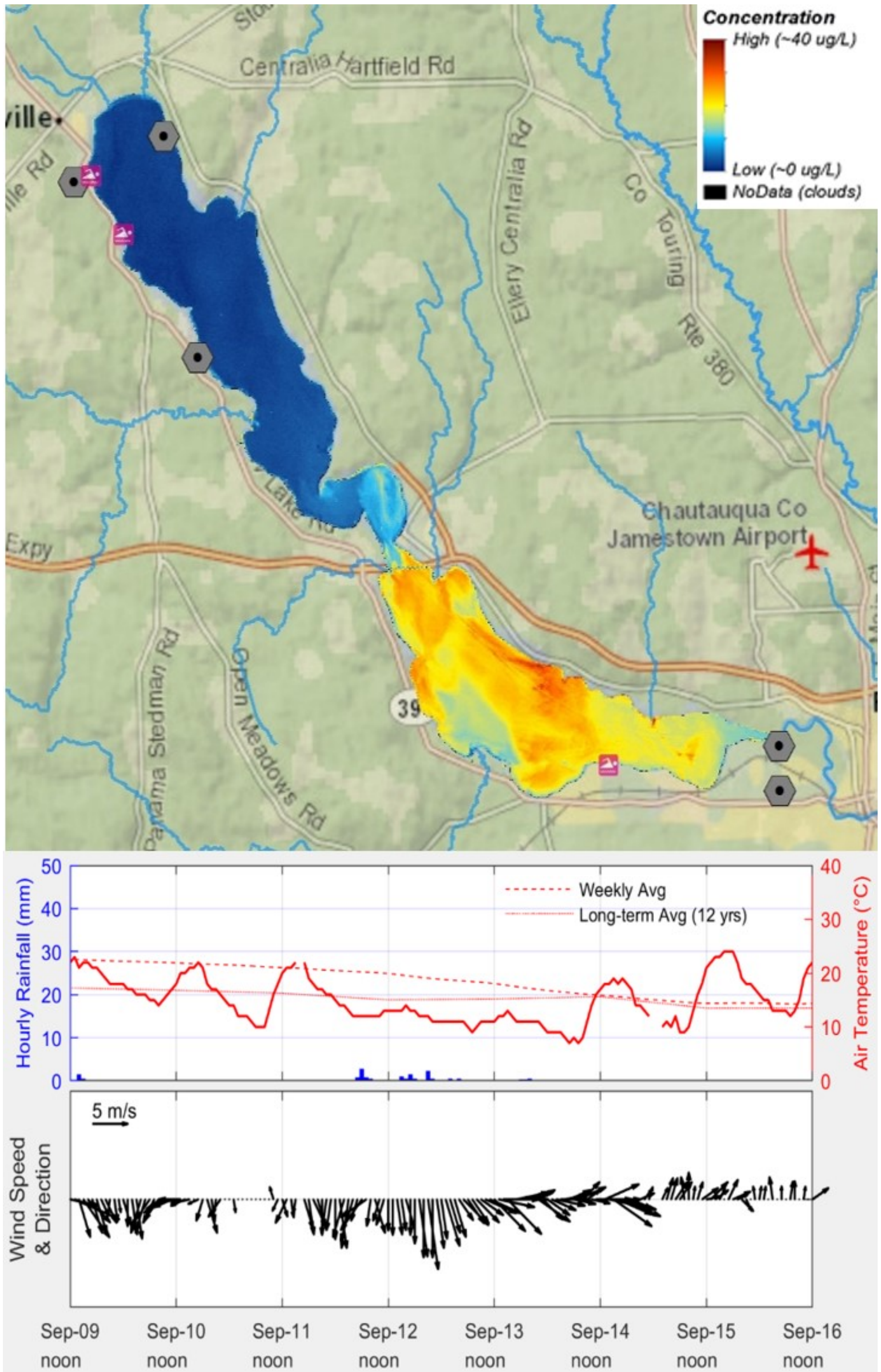

Figure 14. Estimated chlorophyll-a concentrations on September 16, 2015 and wind speed (m/s) and direction, hourly rainfall (mm), and air temperature (◦C) for Chautauqua Lake.

HABs were confirmed in Chautauqua Lake from July 11 to October 17, 2016. The remote sensing data indicate that estimated chlorophyll-a concentrations were around 10-15 µg/L in both the North and South basins in June. Unfortunately, the July and August imagery were not useable due to extensive cloud cover; this coincides with CSLAP chlorophyll-a concentrations in the South basin above 60 µg/L for an extended period (see **Figure 13**). The September 2016 imagery is mostly obscured by clouds; however, there is an increase evident in chlorophyll-a concentrations relative to June in the South basin. The estimated chlorophyll-a concentrations on October 4, 2016 were approximately 10 µg/L in the North basin and 20-30 µg/L in the South basin (**Figure 15**), consistent with the seasonal trend in chlorophyll-a concentrations observed in 2015. Due to the infrequency of the remote sensing images, triggers for the increase in chlorophyll-a concentrations in 2016 could not be identified.

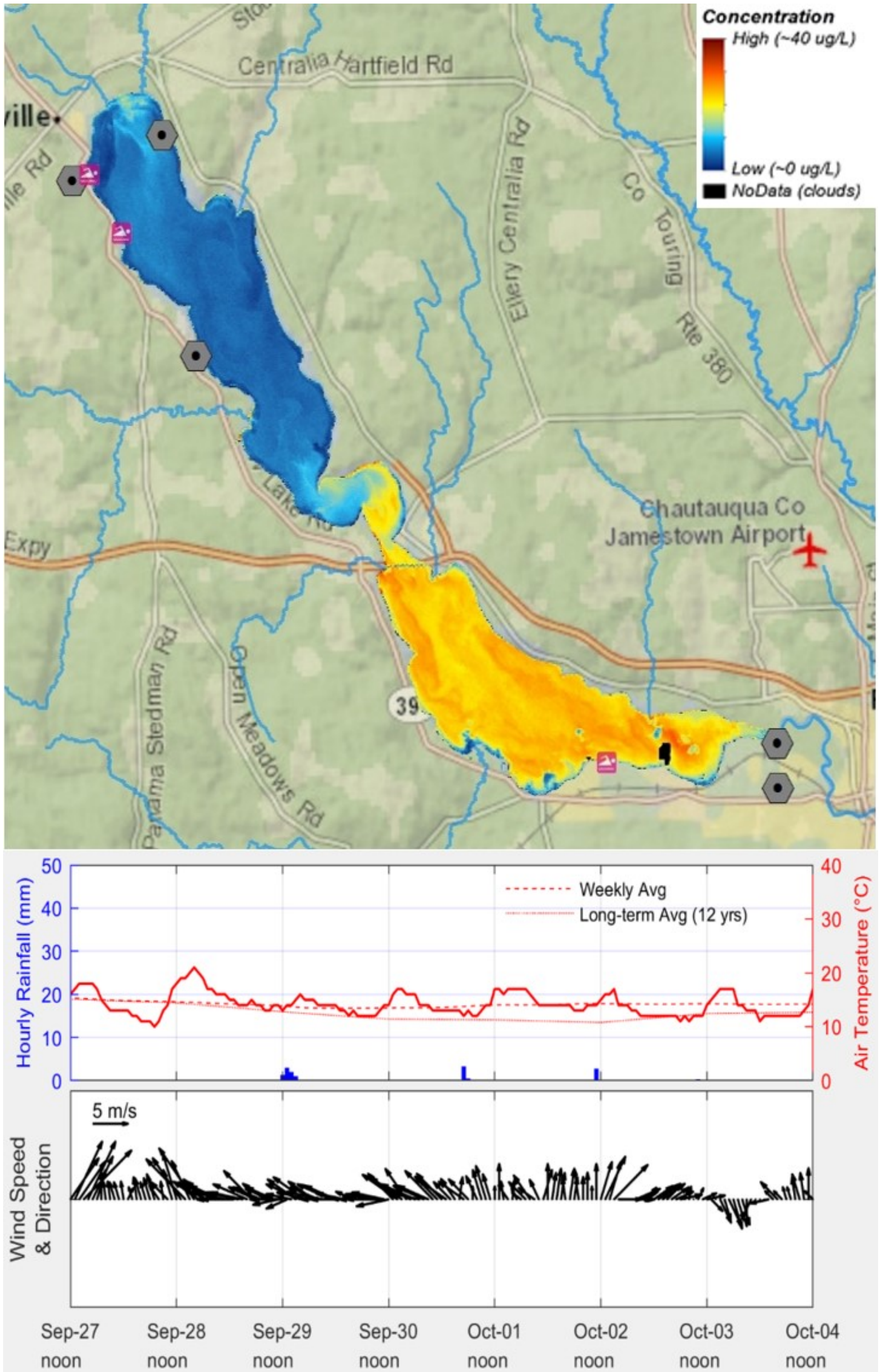

Figure 15. Estimated chlorophyll-a concentrations on October 4, 2016 and wind speed (m/s) and direction, hourly rainfall (mm), and air temperature (◦C) for Chautauqua Lake.

The percentage of the lake surface area with an estimated chlorophyll-a concentration greater than 10 µg/L and 25 µg/L is summarized in **Table 7** (North basin) and **Table 8** (South basin). Cyanobacteria cell counts and/or chlorophyll-a concentrations (e.g., BGA chlorophyll-a) less than 25 µg/L is NYSDEC's threshold for "no-bloom" (refer **to Section 7.2** for more information). However, the relationship between measured chlorophyll and satellite-estimated chlorophyll shown in **Appendix C** (**Figure C2**) suggests that some waterbodies may exhibit bloom conditions at satellite-estimated chlorophyll levels as low as 10 µg/L.

Table 7. Percent (%) of water surface area with an estimated chlorophyll-a concentration (µg/L) above and below 10 µg/L and 25 µg/L in the North basin of Chautauqua Lake (2015 to 2017).

Date	% of surface area less than		% of surface area greater than or equal		% No data
	10 µg/L	25 µg/L	10 µg/L	25 µg/L	
2015-06-12	64	71	6	0	29
2015-07-30	78	93	15	0	7
2015-08-15	40	94	54	0	6
2017-09-16	93	99	7	0	1
2016-06-14	94	99	6	0	1
2016-06-30	96	99	3	0	1
2016-09-02	33	40	7	0	60
2016-10-04	85	99	15	0	1
2017-06-01	42	46	4	0	54
2017-06-17	62	78	16	0	22
2017-07-03	93	95	3	0	5
2017-07-19	40	42	2	0	58
2017-08-20	33	52	19	0	48
2017-09-21	23	98	77	2	1
2017-10-07	23	42	20	1	57

Table 8. Percent (%) of water surface area with an estimated chlorophyll-a concentration (mg/L) above and below 10 µg/L and 25 µg/L in the South basin of Chautauqua Lake (2015 to 2017).					
Date	**% of surface area less than**		**% of surface area greater than or equal**		**% No data**
	10 µg/L	**25 µg/L**	**10 µg/L**	**25 µg/L**	
2015-06-12	43	49	5	0	51
2015-07-30	7	40	34	0	60
2015-08-15	2	96	94	0	4
2017-09-16	0	88	99	11	1
2016-06-14	23	99	76	0	0
2016-06-30	44	99	55	0	0
2016-09-02	4	18	14	0	82
2016-10-04	2	85	97	14	1
2017-06-01	19	68	49	0	32
2017-06-17	20	81	61	0	19
2017-07-03	15	59	44	0	41
2017-07-19	10	47	36	0	53
2017-08-20	4	35	37	6	59
2017-09-21	0	32	99	68	1
2017-10-07	2	46	90	46	8

8. Waterbody Assessment

The Waterbody Inventory/Priority Waterbodies List (WI/PWL) is an inventory of water quality assessments that characterize known/and or suspected water quality issues and determine the level of designated use support in a waterbody. It is instrumental in directing water quality management efforts to address water quality impacts and for tracking progress toward their resolution. In addition, the WI/PWL provides the foundation for the development of the state Section 303(d) List of Impaired Waters Requiring a Total Maximum Daily Load (TMDL).

The WI/PWL assessments reflect data and information drawn from numerous NYSDEC programs (e.g. CSLAP) as well as other federal, state and local government agencies, and citizen organizations. All data and information used in these assessments has been evaluated for adequacy and quality as per the NYSDEC Consolidated Assessment and Listing Methodology (CALM).

8.1 WI/PWL Assessment

The most recent (May 2018) WI/PWL update for Chautauqua Lake (**Appendix E**) reflects monitoring data collected in 2017. A specialized survey to measure chlorophyll in the lake was conducted under NYSDEC guidance. The data support previous assessments of the lake as an impaired waterbody due to primary and secondary contact recreation uses that are known to be impaired by nutrients (phosphorus) and excessive algae. The updated WI/PWL assessment incorporates an evaluation of sources from the TMDL completed for Chautauqua Lake. Within the North and South basins, phosphorus loads from sediment and internal loading are more than a quarter and a half, respectively, while other small loads come from agricultural activities, wastewater point sources, and septic systems. **Section 10.2** details additional nutrient sources to both the North and South basins.

Chautauqua Lake is included on the NYS Section 303(d) List of Impaired Waters Requiring a TMDL. Chautauqua Lake is categorized as USEPA's Integrated Reporting (IR) Category 4a waters where a TMDL has already been completed (a TMDL for phosphorus was completed in 2012) and as IR Category 4c waters where a TMDL is not appropriate because the sole impairment is the result of pollution, rather than a pollutant that can be allocated through a TMDL.

Table 9. WI/PWL severity use impact categorization (Source: NYSDEC 2009).

Impairment Classification	Description
Precluded	*Frequent/persistent* water quality, or quantity, conditions and/or associated habitat degradation prevents all aspects of a specific waterbody use.
Impaired	*Occasional* water quality, or quantity, conditions and/or habitat characteristics periodically prevent specific uses of the waterbody, or; Waterbody uses are not precluded, but some aspects of the use are *limited or restricted*, or; Waterbody uses are not precluded, but frequent/persistent water quality, or quantity, conditions and/or associated habitat degradation discourage the use of the waterbody, or; Support of the waterbody use *requires additional/advanced* measures or treatment.
Stressed	Waterbody uses are not significantly limited or restricted (i.e. uses are *Fully Supported*), but *occasional* water quality, or quantity, conditions and/or associated habitat degradation *periodically discourage* specific uses of the waterbody.
Threatened	Water quality supports waterbody uses and ecosystem exhibits no obvious signs of stress, however *existing or changing land use patterns* may result in restricted use or ecosystem disruption, or; *Data reveals decreases in water quality* or presence of toxics below the level of concern.

8.2 Source Water Protection Program (SWPP)

The NYSDOH Source Waters Assessment Program (SWAP) was completed in 2004 to compile, organize, and evaluate information regarding possible and actual threats to the quality of public water supply (PWS) sources based on information available at the time. Each assessment included a watershed delineation prioritizing the area closest to the PWS source, an inventory of potential contaminant sources based on land cover and the regulated potential pollutant source facilities present, a waterbody type sensitivity rating, and susceptibility ratings for contaminant categories. The information included in these analyses included: GIS analyses of land cover, types and location of facilities, discharge permits, Concentrated Animal Feeding Operations (CAFOs), NYSDEC WI/PWL listings, local health department drinking water history and concerns, and existing lake/watershed reports. A SWAP for the Chautauqua Lake public drinking supply sources was completed. Although the information provides a historical perspective, the drinking water systems and/or land uses may have changed. Chautauqua Lake public drinking supply sources need updated assessments to understand the current impacts to best protect water quality. NYSDEC and NYSDOH are working with stakeholders to build a sustainable statewide program to assist and encourage municipalities to develop and implement Source Water Protection Programs (SWPP) in their communities.

Evaluation of the water supply is done both prior to and after treatment by local water suppliers and public health agencies. The SWAP analysis in 2004 of Chautauqua Lake found an elevated susceptibility to contamination for drinking water. The amount of pasture in the assessment area results in a medium potential for protozoa contamination. The high density of sanitary wastewater discharges results in elevated susceptibility for numerous contaminant categories and is high enough to raise the potential for contamination (particularly for protozoa). Non-sanitary wastewater discharges may also contribute to contamination and there is susceptibility to contamination associated with discrete contaminant source facilities such as RCRA, TRI, IHWS, and landfills (Chautauqua Lake Watershed WI/PWL 2014).

Currently, the State is meeting with a working group of stakeholders to develop the SWPP structure and potential tools (e.g., templates, data sets, guidance and other resources) that will be pilot tested in municipalities. Following the pilot, the state will roll out the program and work with municipalities as they develop and implement their individual SWPP and associated implementation program. The goal of the SWPP is for municipalities to not merely assess threats to their public water supply but to take action at the local level to protect public drinking water.

8.3 CSLAP Scorecard

Results from CSLAP activities are forwarded to the New York State Federation of Lake Associations (NYSFOLA) and NYSDEC, and are combined into a scorecard detailing potential lake use impact levels and stresses. The scorecards represent a preliminary assessment of one source of data, in this case CSLAP. The WI/PWL updates include the evaluation of multiple data sources, including the CSLAP scorecard preliminary evaluations. Because the North and South basins of Chautauqua Lake behave as two distinct waterbodies, two 2017 CSLAP scorecards are provided. According to Chautauqua Lake’s 2017 scorecard (**Figure 16)**, algae blooms impact swimming in the North basin, and stress aesthetic conditions in the North and South basins. Algae levels impact potable water use and recreation in the North and South basins, and swimming in the South basin.

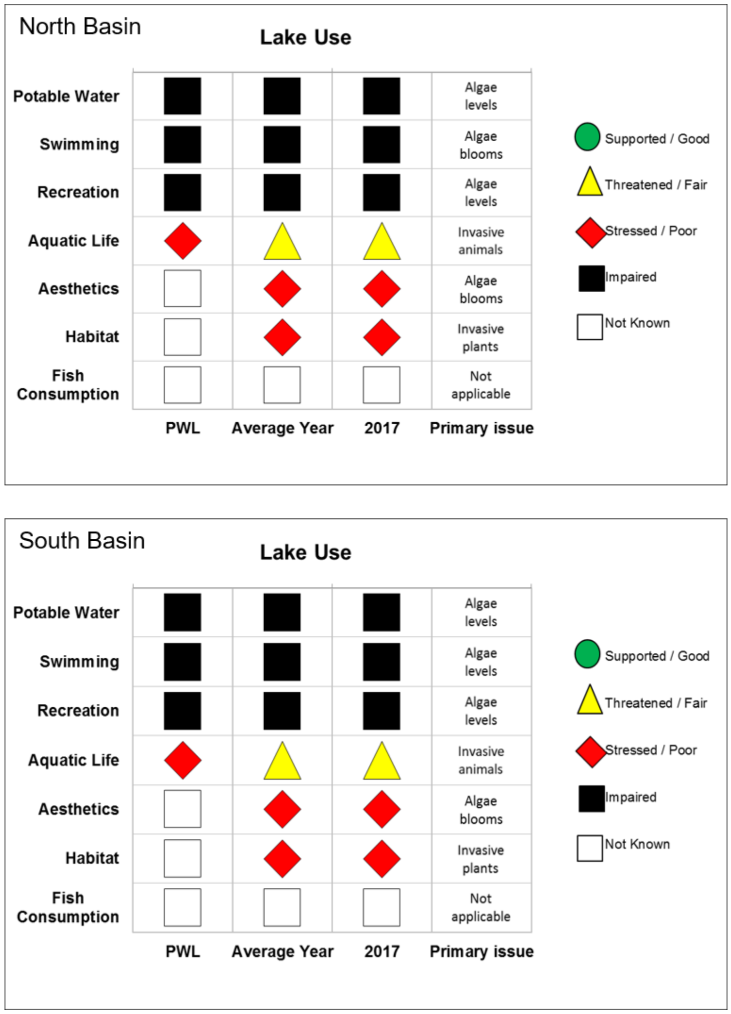

Figure 16. Chautauqua Lake 2017 CSLAP scorecard, North and South basins.

9. Conditions triggering HABs

Resilience is an important factor in determining an ecosystem's ability to respond to and overcome negative impacts (Zhou et al. 2010), including the occurrence and prevalence of HABs. Certain lakes may not experience HABs even though factors hypothesized to be "triggers" (e.g., elevated P concentrations) are realized (Mantzouki et al. 2016), and conversely, lakes that have historically been subject to HABs may still be negatively affected even after one or more triggers have been reduced. Thus, phytoplankton dynamics may cause the presence of HABs to lag behind associated triggers (Faassen et al. 2015). Further, unusual climatic events (*e.g.*, high TP input from spring runoff and hot calm weather in fall) may create unique conditions that contribute to a HAB despite implementation of management strategies to prevent them (Reichwaldt and Ghadouani 2012).

Ecosystems often exhibit a resistance to change that can delay outcomes associated with HABs management. This system resilience demands that prevention and management of these triggers be viewed long-term through a lens of both watershed and in-lake action. It may take significant time following implementation of recommended actions for the frequency, duration, and intensity of HABs to be reduced.

A dataset spanning 2012 to 2017 of 163 waterbodies in New York State has been compiled to help understand the potential triggers of HABs at the state-scale (CSLAP data). This dataset includes information on several factors that may be related to the occurrence of HABs, e.g., lake size and orientation (related to fetch length, or the horizontal distance influenced by wind); average total phosphorus and total nitrogen concentrations; average surface water temperatures; as well as the presence of invasive zebra and quagga mussels (i.e., dreissenid mussels). This data set has been analyzed systematically, using a statistical approach known as logistic regression, to identify the minimum number of factors that best explain the occurrences of HABs in NYS. A minimum number of factors are evaluated to provide the simplest possible explanation of HABs occurrences (presence or absence) and to provide a basis for potential targets for management. One potential challenge to note with this data set is that lakes may have unequal effort regarding HABs observations, which could confound understanding of underlying processes of HABs evaluated by the data analysis.

Across New York, four of the factors evaluated were sufficiently correlated with the occurrence of HABs, namely, average total phosphorus levels in a lake, the presence of dreissenid mussels, the maximum lake fetch length and the lake compass orientation of that maximum length. The data analysis shows that for every 0.01 mg/L increase in total phosphorus levels, the probability that a lake in New York will have a HAB in a given year increases by about 10% to 18% (this range represents the 95% confidence interval based on the parameter estimates of the statistical model). The other factors, while statistically significant, entailed a broad range of uncertainty given this initial analysis. The presence of dreissenid mussels is associated with an increase in the annual HAB probability of 18% to 66%. Lakes with long fetch lengths are associated with an increased occurrence of HABs; for every mile of increased fetch length, lakes are associated with up to a 20% increase in the annual probability of HABs. Lastly, lakes with a northwest orientation along their longest fetch length are 10% to 56% more likely to have a HAB in a given year. Each of these relationships are bounded, i.e., the frequency of blooms cannot exceed 100%, meaning that as the likelihood of blooms increases the marginal effect of these variables decreases. While this preliminary evaluation will be expanded as more data are collected on HABs throughout New York, these results are supported by prior literature. For example, phosphorus has long been known to be a limiting nutrient in freshwater systems and a key driver of HABs, however the potential role of nitrogen should not be overlooked as HABs mitigation strategies are contemplated (e.g., Conley et al. 2009). Similarly, dreissenid mussels favor HABs by increasing the bioavailability of phosphorus and selectively filtering organisms that may otherwise compete with cyanobacteria (Vanderploeg et al. 2001). The statistically-significant association of fetch length and northwest orientation with HABs may suggest that these conditions are particularly favorable to wind-driven accumulation of cyanobacteria and/or to wind-driven hydrodynamic mixing of lakes, leading to periodic pulses of nutrients. While each of these potential drivers of HABs deserves more evaluation, the role of lake fetch length and orientation are of interest and warrant additional study.

There is continuing interest in the possible role of nitrogen in the occurrence and toxicity of HABs (e.g., Conley et al. 2009), and preliminary analysis of this statewide data set suggests that elevated total N and total P concentrations are both statistically significant associates with the occurrence of toxic blooms. When total N and total P concentrations are not included in the statistical model, elevated inorganic nitrogen (NH4 and NOx) concentrations are also positively associated with toxic blooms. The significant association of inorganic N forms with toxic blooms may provide a more compelling association than total N, which may simply be a redundant measure of the biomass associated with toxins. It should be noted that while this analysis may provide some preliminary insight into state-scale patterns, it is simplistic in that it does not account for important local, lake-specific drivers of HABs such as temperature, wind, light intensity, and runoff events.

Chautauqua Lake exhibits several factors—elevated phosphorus concentrations, presence of dreissenid mussels, long fetch length—that render the lake susceptible to HABs. These conditions may be exacerbated by seasonal release of nutrients from bottom to surface waters under conditions of periodic anoxia.

To evaluate if lake-specific HABs triggers were important for Chautauqua Lake, in addition to those observed at the State scale, additional statistical analyses were performed with lake-specific data. All available HABs observations (bloom/no bloom) were aligned by date with water quality (e.g., TP and TN concentrations) and meteorological information (e.g., temperature, precipitation, and wind speed) from the Chautauqua County/Jamestown Airport. Estimated maximum wave heights were calculated from wind speed and direction data, fetch distances across the lake, and water depths along the fetch length. The fetches were measured in 10 degree increments along the compass rose, taking the longest distance across the lake. Using this data, an hourly wave hindcast covering the duration of the wind field measurements was generated (Donelan 1980).

As with the statewide data analysis, logistic regression was used to test whether meteorological variables could explain the occurrences of HABs. Because weather variables hypothesized to influence HABs can be correlated (e.g., maximum wind speed and wave height), the logistic regression was performed in two ways: (1) using the original meteorological data as explanatory variables and (2) by first performing a Principal Components Analysis (PCA) on the explanatory variables and using the PCA axes as explanatory variables in the logistic regression. Principal components analysis is helpful when evaluating data sets with correlated variables because it can recast the original data as an uncorrelated set of “axes” (*i.e*., linear equations) that are representative of the original input data. Data was available to perform the statistical analyses for both the North and South basins.

In the North basin, the data suggest that increased total phosphorus concentrations were significantly correlated with recorded HABs ($p = 0.038$, **Figure 17a**). While not significant, there was evidence that decreased maximum wave height in the preceding 10-days of a recorded HAB may additionally influenced blooms in the North basin of Chautauqua Lake ($p = 0.142$, **Figure 17b**).

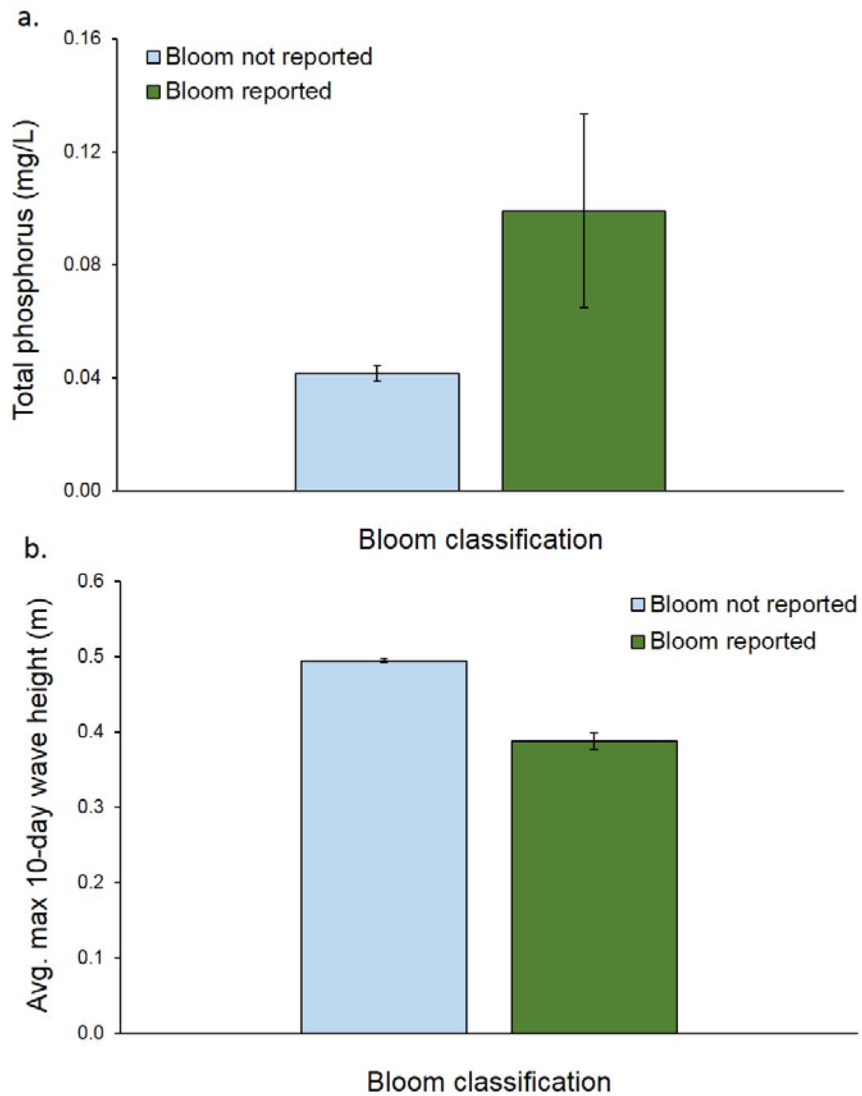

Figure 17. (a) Average total phosphorus (mg/L, ± standard error) concentrations during reported HAB blooms (green bar) and during sample when HAB not reported (blue bar) in the North basin. Increased TP was significantly correlated with recorded HABs. (b) Maximum wave height (m, ± standard error) in the preceding 10 days before a recorded HAB (green bar) and leading up to sampling when a HAB was not reported (green bar) in the North basin.

In the South basin, none of the water quality or meteorological variables were significantly correlated with HABs. However, a statistical model that included only Julian day (the null model) was the best model based on the Akaike information criteria (AIC), which is a measure of the relative quality of a statistical model. This result suggests that when elevated nutrients are present in a system (such as the South basin of Chautauqua Lake), seasonality is most important in explaining the presence of HABs compared to other variables hypothesized to be correlated with blooms (e.g., water quality and meteorological drivers).

Additional water quality data aligned with HABs observations (both presence and absence of blooms) could be used to further refine the above statistical analyses.

10. Sources of Pollutants triggering HABs

10.1 Land Uses

Chautauqua Lake has a watershed area of approximately 115,349 acres, with a watershed to lake ratio of approximately 8.6. As part of the 2012 TMDL study, land use percentage within the Chautauqua Lake drainage basin was estimated using digital aerial photography and geographic information system (GIS) datasets and includes the following land use types (**Table 10**):

Table 10. Land use percentages, North and South basins.

Land Type	North Basin (%)	South Basin (%)
Forests	62.1	63.3
Developed	3.5	5.8
Hay and Pasture	21.8	21.1
Row Crops	7.0	6.3
Open Water	0.1	0.0
Turf Grass	1.3	0.6
Quarry	0.0	0.1
Wetland	4.2	2.8

10.2 Nutrient Sources

Nutrients enter the lake via poorly bound phosphorus in lake sediments, overland flow, tributaries, wastewater treatment plant (WWTP) discharges, and other sources, where they become available for use by algae (including cyanobacteria) and aquatic plants, or are deposited and stored in lakebed sediments. Land use and pollutant loading estimates were generated using the ArcView Generalized Watershed Loading Function (AVGWLF) watershed model and are summarized in **Table 11** and **Figure 18**.

Table 11. Phosphorus loading percentages, North and South basins.		
Source Type	**North Basin (%)**	**South Basin (%)**
Groundwater	36.7	20.9
Developed Land	1.6	2.0
Turf Grass	1.3	0.0
Quarry	0.0	0.0
Forest	0.4	0.1
Wetland	0.1	0.0
Cropland	5.1	1.8
Hay and Pasture	6.5	1.3
Internal Loading	25.1	55.0
Point Source	19.6	1.9
Septic System	3.5	1.4
Load from North Basin	N/A	15.4

The loading associated with groundwater flow comes from several sources, including forest, developed land, and agriculture. Based on the TMDL completed in 2012, it is estimated that 11% of the total load from groundwater in both basins is attributed to natural background loading (i.e., from forest), with the remaining 11% and 35% from developed land and 78% and 54% from agricultural land in the North and South basins, respectively (Cadmus Group 2012).

The loading percentages are based upon data collected as part of the TMDL analysis, but does not take into consideration existing BMPs and other nutrient reduction measures implemented by the agricultural community, treatment plants, and other potential contributors of nutrients to the lake. Consequently, the land use percentages and loading estimates presented above for Chautauqua Lake should be interpreted with caution.

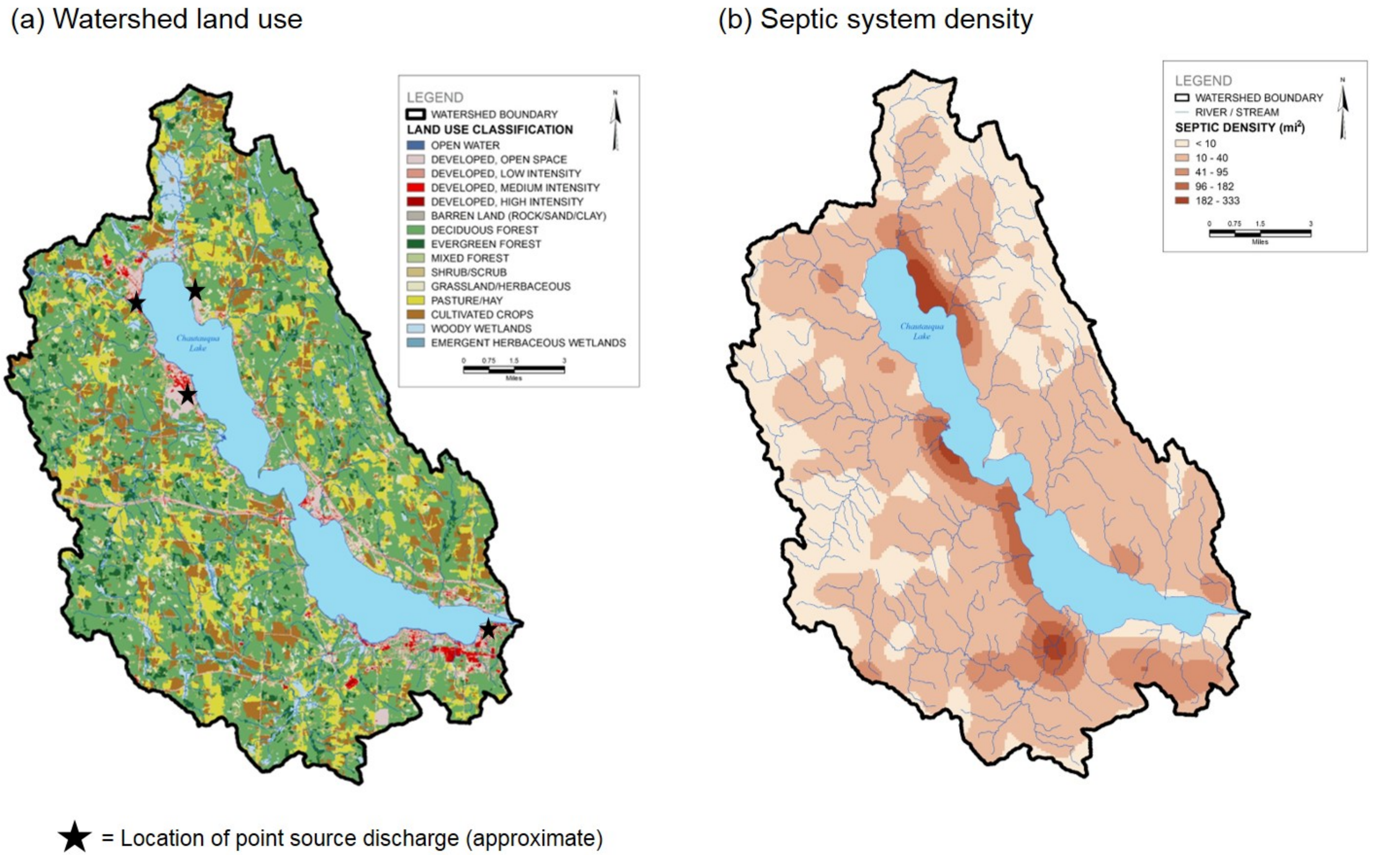

Figure 18. (a) Watershed land use and (b) septic system density for Chautauqua Lake The septic density zones are estimated from public records and may not reflect all areas accurately. For example, the Chautauqua Heights Sewer District falls within the estimate of high septic densities on the northeast side of the Lake.

Much of the point source loading is attributed to the 13 WWTPs that have effluent discharges located in the North basin and the nine WWTP effluent discharges located in the South basin (Cadmus Group 2012).

Figure 18b illustrates how the concentrated development in some portions of the watershed corresponds with the higher density of septic systems. One area of interest is in the south end of the lake in the Town of Ellicott where high densities of septic systems are adjacent to the lake and the lake outlet.

10.3 Internal Pollutant Sources

It is likely that internal loading is important in Chautauqua Lake due to the development of high phosphorus concentrations in the hypolimnion of the North basin (resulting from anoxia), which then mixes with the epilimnion especially later in the summer/fall during mixing events.

Dreissenid mussels (both zebra and quagga mussels) may contribute to internal cycling of bioavailable nutrients in freshwater systems that have been invaded (Turner 2010), however, the role of these invasive mussels has not been empirically quantified in Chautauqua Lake.

10.4 Summary of Priority Land Uses and Land Areas

As discussed in **Sections 10.2** and **10.3**, loading occurs predominately through internal release of legacy phosphorus from the lake sediment. The other primary contributors are groundwater inputs and point source discharge associated primarily with the WWTPs located within the lake watershed.

11. Lake Management / Water Quality Goals

The primary lake management/water quality goal for Chautauqua Lake is to implement proactive management to minimize HABs through nutrient input reduction to levels stipulated in the TMDL. Strategies aimed at the following should be implemented to the extent practicable to achieve this goal:

- Reduce TP concentrations in effluent from the four major WWTPs, as identified in the TMDL (Chautauqua Heights Sewer District, North Chautauqua Lake Sewer District, Chautauqua Utility District and South & Center Chautauqua Lake WWTP)
- Minimize the contribution of nutrients conveyed by stormwater runoff from agricultural land
- Minimize the concentration of nutrients conveyed by groundwater from septic systems
- Incorporate stormwater management facilities into developed land to minimize nutrient concentrations within runoff

- Maintain forest health and restore pit and mound topography, such that infiltration is maximized, runoff is minimized, and nutrient loading to the lake remains low relative to its extent of cover within the watershed
- Conserve remaining forests and wetlands and restore forests and wetlands to achieve a minimum of 70% natural forest cover in the watershed. This will reduce the probability of incremental urbanization substantially driving up nutrient loads to the lake
- Implement smart growth to promote re-development and infilling of existing urbanized areas and minimize the conversion of forest and farmland to residential, commercial, and transportation use
- Maintain compliance and enhance performance of point source discharge facilities

12. Summary of Management Actions to Date

The Chautauqua Lake TMDL (Cadmus Group 2012) proposed significant reductions in contributions from the sources listed in **Section 11**. To date, the following have been completed:

WWTPs

Waste load allocations for Chautauqua Heights Sewer District, North Chautauqua Lake Sewer District (NCLSD), Chautauqua Utility District, and South and Center Chautauqua Lake WWTP were adopted as part of the TMDL. The waste load allocations were then translated into the State Pollutant Discharge Elimination System (SPDES) program permit limits for each of the facilities as an interim phosphorus limit of 1.0 mg/L for a period of five years (Cadmus Group 2012). Final load limits will be implemented by June 2018, and are expressed as follows as 12 month rolling averages (OBG 2014):

- Chautauqua Heights Sewer District (CHSD): 36.1 lbs/yr; 375.6 lbs/yr aggregate when combined with NCLSD (SPDES Permit NY0269450)
- North Chautauqua Lake Sewer District (NCLSD): 339.5 lbs/yr; 375.6 lbs/yr aggregate when combined with CHSD (SPDES Permit NY0020826)
- Chautauqua Utility District (CUD): 492.8 lbs/yr (SPDES Permit NY0029769)
- South & Center Chautauqua Lake Sewer District (SSCLSD): 27.4 lbs/day (SPDES Permit NY0106895)

Wasteload allocation (WLA) offsets have also been offered to those facilities that provide sewer service to areas currently served by on-site septic systems or for accepting wastewater from any of the private, commercial and institutional (PCI) dischargers in the watershed (Cadmus Group 2012).

Agriculture

Manure from the one CAFO located within the watershed, as well as from others located just outside the watershed, must be applied in accordance with a

Comprehensive Nutrient Management Plan which limits the amount of phosphorus applied to the fields. This farm is regulated under the SPDES Environmental Conservation Law (ECL) Permit (GP-0-16-001) for CAFOs and is given a WLA of zero (0) since the production area is required to contain runoff from a 25-year, 24-hour rainfall event.

Chautauqua County Soil and Water Conservation District statistics show a large percentage of farms in the watershed are enrolled in the State Agricultural Environmental Management (AEM) program (see **Section 12.2**) (Cadmus Group 2012).

Septic systems

NYSDEC developed a statewide training program for onsite wastewater treatment system professionals to reduce loading associated with septic systems. The Onsite Wastewater Treatment Training Network (OTN) was formed and has been provided financial and staff support by the NYSDEC since its formation (Cadmus Group 2012).

For more information about NYSDEC's SPDES program and to view MSGP and Individual SPDES permits issued in the Chautauqua Lake watershed visit http://www.dec.ny.gov/permits/6054.html.

12.1 Local Management Actions

The 2010 *Chautauqua Lake Watershed Management Plan* was developed to ensure the continued sustainability of Chautauqua Lake and the surrounding region. The overall goals of the Watershed Management Plan include:

1. Improve water quality within the watershed by reducing inflow of nutrients and sedimentation
2. Protect and restore the natural function of the watershed's drainage system
3. Conserve the watershed's critical natural resources
4. Maintain and improve recreational opportunities
5. Inspire and educate watershed stakeholders
6. Implement sound land use practices and policies

To implement the Watershed Management Plan, an implementation team must be identified, a work plan prepared, a monitoring program and evaluation framework developed, and achievements and results communicated (Bergmann et al. 2010).

The 2012 *TMDL for Phosphorus in Chautauqua Lake* was developed due to Chautauqua Lake's high priority rating and listing on the NYSDEC's 2004 CWA Section 303(d) list of impaired waterbodies that do not meet water quality standards due to phosphorus impairments (Cadmus Group 2012). Because the TMDL was developed and is being implemented, the lake is no longer listed. **Section 12.6** provides more detail on the TMDL. It should be noted that while Chautauqua Lake is no longer listed on the CWA Section 303(d) based on the fact that a TMDL was developed in 2012 and is being implemented, both lake basins (South 0202-0020, North 0202-0072) are still listed as impaired in the NYS Waterbody/Priority Waterbodies List (WI/PWL) as recently as 2018 (See **Appendix E**).

The Local Waterfront Revitalization Program (LWRP) process involves the cooperation of State, County, local, and private agencies, along with an appointed LWRP local advisory committee. The local committee consists of local planning and municipal board members and residents. Goals of the LWRP include environmental protection, economic development, water resource protection, and public waterfront access improvement. The 2011 *Chautauqua Lake Local Waterfront Revitalization Program* has been adopted by nine municipalities around Chautauqua Lake, and is intended to provide a clear vision for waterfront development for Chautauqua Lake, formulate policies and projects to manage and guide waterfront development, and refine policies related to waterfront development (Chautauqua County 2011).

Recommendations to alleviate issues with Chautauqua Lake and its watershed are identified by the Chautauqua County Department of Planning and Economic Development (CCDPED) and the Citizens Advisory Committee (CAC) in *The Management of Chautauqua Lake and its Watershed* (2000) and include:

- Lake level management
- Elevated sedimentation
- Water and wastewater quality
- Aquatic vegetation management
- Development pressure
- Impacts to lake views and aesthetics
- Limited lake access
- The need for efficient administration

Recommendations were designed to be implemented by various levels of government, including local municipalities and the Chautauqua County SWCD (Bergmann et al. 2010).

12.2 Agricultural Environmental Management Program

The New York State Agricultural Environmental Management (AEM) Framework was created by the New York State Department of Agriculture and Markets (NYSDAM) and the State's Soil & Water Conservation Committee as a voluntary, incentive-based program that helps farmers make common-sense, cost-effective, and science-based decisions to meet business objectives while protecting and conserving New York State's natural resources. Soil and Water Conservation Districts (SWCDs) in agricultural counties lead the local AEM effort, including Chautauqua County within the Chautauqua Lake watershed.

The Chautauqua County SWCD, in partnership with the Natural Resources Conservation Service (NRCS), Cornell Cooperative Extension (CCE), Farm Service Agency (FSA), Chautauqua County Water Quality Task Force, Western New York Crop

Management Association, Chautauqua County Chapter of the New York Farm Bureau, Conewango Watershed Association, and Chautauqua County Department of Environmental Health Water Quality Control Commission (WQCC), developed an *Agricultural Environmental Management (AEM) Program Strategic Plan 2015-2020* (Chautauqua County SWCD 2015) to promote land stewardship to increase the quality of natural resources and production on agricultural lands within the County. The goal of this Plan is to protect and enhance the environment through the AEM process, while increasing the economic viability of Chautauqua County's agricultural industry.

Agriculture is the number one industry in Chautauqua County. According to the 2012 Agricultural Census, Chautauqua County has 1,067 farms with sales of $2,500 or more, ranking eleventh in the state for total value of agricultural products sold. These farms utilized 236,546 acres or 35% of the land mass in the county, and there was an average of 156 acres per farm. Details of Chautauqua County's agricultural practices include:

- Dairy production ranks 13th in New York State counties
- Grape acreage ranks number one in New York State with 20,557 acres
- 56,990 acres are in hay production
- 13,876 acres are in corn for silage
- 12,937 acres are in corn for grain
- 3,403 acres are in vegetable production.

Many AEM-sponsored activities have been undertaken within the Chautauqua Lake watershed to address important environmental challenges including improving water quality, categorized by tier (**Table 12**). Several non-regulated farms in the watershed have also invested on their own and are following Comprehensive Nutrient Management Plans (CNMPs) to manage phosphorus application. The tiered process is as follows (NYSSWCC 2018):

- **Tier 1** – Inventory current activities, future plans, and potential environmental concerns
- **Tier 2** – Document current land stewardship, assess and prioritize areas of concern
- **Tier 3** – Develop conservation plans addressing concerns and opportunities tailored to farm goals
    - **Tier 3A**: Component Conservation Plan
    - **Tier 3B**: Comprehensive Nutrient Management Plan (CNMP)
- **Tier 4** – Implement plans utilizing available financial, educational, and technical assistance
- **Tier 5** – Evaluate to ensure the protection of the environment and farm viability
    - **Tier 5A**: Update Tier 1 and 2
    - **Tier 5B**: Plan evaluation/update, BMP system evaluation

Table 12. Total number of AEM projects conducted in the Chautauqua Lake watershed (2011-2017).							
	Tier 1	**Tier 2**	**Tier 3A**	**Tier 3B**	**Tier 4**	**Tier 5A**	**Tier 5B**
Total Number of AEM Projects	10	5	11	3	1	1	27

Both basins of Chautauqua Lake were listed on the NYSDEC's 2004 Section 303(d) List for being impaired due to contributions from agricultural nutrients. However, because a TMDL for phosphorus has already been completed and is being implemented, the lake is no longer listed (Chautauqua Lake Watershed WI/PWL 2014). As noted in **Section 12.1**, while Chautauqua Lake is no longer listed on the CWA Section 303(d), both lake basins (South 0202-0020, North 0202-0072) are still listed as impaired in the NYS Waterbody/Priority Waterbodies List (WI/PWL) as recently as 2018 (see **Appendix E**). The larger streams in the watershed are also listed on the WI/PWL. Dewittville Creek, Goose Creek, Hartfield Creek, and Prendergast Creek are all listed as threatened due to nutrients from agricultural sources. Siltation has also been documented at the mouth of each creek. The Chautauqua Lake watershed was identified in the AEM Plan as the top priority for suspected sources of nutrient and sediment concerns identified in the AEM Plan include:

- Bunk silo leachate
- Barnyard management
- Cropland erosion
- Stream bank erosion

Objectives identified in the AEM Plan to address these sources include:

- Reduction of agricultural sources of nutrient and sediment loading
- Restoration of riparian buffers
- Increased public awareness of agriculture's contribution to maintaining a healthy watershed
- Improved grazing practices to enhance environmental quality and farm viability

12.3 Funded Projects

Funded projects include those facilitated by programs specifically targeting water quality improvement and the agricultural community in New York State, such as the Water Quality Improvement Program (WQIP) and the Agricultural Nonpoint Source Abatement and Control (ANSACP) program. These programs have committed more than $3.6M between 2011 and 2017 to support the implementation of BMPs within the Chautauqua Lake watershed. Examples of BMP systems implemented that contribute to an improvement in water quality include water control structures, stripcropping, diversions, riparian buffers, nutrient management planning, prescribed grazing, and wastewater and silage leachate treatment. Additional projects that have been funded include:

- Stream bank erosion control and other BMP projects have been funded through the County's 2% occupancy tax waterway enhancement fund.

- Chautauqua Lake Association’s mechanical harvesting program periodically removes aquatic vegetation.

12.4 NYSDEC Issued Permits

Article 17 of New York’s Environmental Conservation Law (ECL) entitled “Water Pollution Control" was enacted to protect and maintain the state’s surface water and groundwater resources. Under Article 17, the State Pollutant Discharge Elimination System (SPDES) program was authorized to maintain reasonable standards of purity for state waters. NYSDEC issues Multi-Sector General Permits (MSGPs) under the SPDES Program for stormwater discharges related to certain industrial activities. MSGPs have been issued for numerous active facilities in Chautauqua County (NYSDEC SPDES Permit Program, undated). Many of the facilities are within the Chautauqua Lake watershed, and therefore are likely to influence water quality conditions in Chautauqua Lake. According to the 2012 TMDL, there are 17 private, commercial, and institutional (PCI) dischargers in both the North and South basins in addition to the major SPDES discharger.

CAFO permits, issued under the SPDES Program, are required for animal feed programs that meet animal size (number of animal) thresholds. According to the 2012 TMDL, one CAFO is located in the watershed for the North basin.

In 2017, NYSDEC issued two new CAFO general permits which specifically prohibit liquid manure applications on saturated soils and also include additional restrictions for liquid manure applications on frozen, ice, and snow-covered soils. More information about the CAFO permits is on NYSDEC’s website (https://www.dec.ny.gov/permits/6285.html).

12.5 Research Activities

In addition to the monitoring activities discussed in **Section 5**, the CLA leads a yearly aquatic plant survey to assess the presence and growth of macrophytes within Chautauqua Lake. Two surveys were conducted in 2017: one in the summer and one in the fall (Racine-Johnson Aquatic Ecologists 2017b).

12.6 Clean Water Plans (TMDL, 9E, or Other Plans)

Clean water plans are a watershed-based approach to outline a strategy to improve or protect water quality. TMDLs and 9E Plans are examples of clean water plans; these plans document the pollution sources, pollutant reduction goals and recommend strategies/actions to improve water quality:

- A TMDL calculates the maximum amount of a single pollutant that a waterbody can receive and still meet water quality standards. TMDLs are developed by determining the amount that each source of a pollutant can discharge into the waterbody and the reductions from those sources needed to meet water quality standards. A TMDL is initiated by NYSDEC for waterbodies that are on the 303d impaired waters list with a known pollutant. Chautauqua Lake has a TMDL in place which is discussed in **Section 12.1**.

- 9E Watershed Plans are consistent with the USEPA's framework to develop watershed-based plans. USEPA's framework consists of nine key elements that are intended to identify the contributing causes and sources of nonpoint source pollution, involve key stakeholders in the planning process, and identify restoration and protection strategies that will address the water quality concerns. The nine minimum elements to be included in these plans include:

    1. Identify and quantify sources of pollution in watershed.
    2. Identify water quality target or goal and pollutant reductions needed to achieve goal.
    3. Identify the best management practices (BMPs) that will help to achieve reductions needed to meet water quality goal/target.
    4. Describe the financial and technical assistance needed to implement BMPs identified in Element C.
    5. Describe the outreach to stakeholders and how their input was incorporated and the role of stakeholders to implement the plan.
    6. Estimate a schedule to implement BMPs identified in plan.
    7. Describe the milestones and estimated time frames for the implementation of BMPs.
    8. Identify the criteria that will be used to assess water quality improvement as the plan is implemented.
    9. Describe the monitoring plan that will collect water quality data need to measure water quality improvement (criteria identified in Element H).

9E Plans are best suited for waterbodies where the pollutant of concern is well understood and nonpoint sources are likely a significant part of the pollutant load; the waterbody does not need to be on the 303d impaired waters list to initiate a 9E Plan.

12.7 Watershed Land Conservation Actions

Working collaboratively, the CWC and the NYSDEC have conserved over two miles of sensitive Chautauqua Lake and lake outlet shoreline over the past 40 years. In addition, CWC has conserved over 500 acres of wetlands and stream corridor forests in the watershed over three decades. These conservation projects have primarily targeted lakefront wetlands, stream mouths, and steep slopes. The NYSDEC’s first such project on the lake was the conservation of the Tom’s Point site. These projects were followed by the Cheney Farm, Stow Farm, and Whitney Bay lakeshores projects which involved CWC collaboration or pre-acquisition.

13. Proposed Harmful Algal Blooms (HABs) Actions

13.1 Overarching Considerations

When selecting projects intended to reduce the frequency and severity of HABs, lake and watershed managers may need to balance many factors. These include budget, available land area, landowner willingness, planning needs, community priorities or local initiatives, complementary projects or programs, water quality impact or other environmental benefit (e.g., fish/habitat restoration, flooding issues, open space).

Additional important considerations include (1) the types of nutrients, particularly phosphorus, involved in triggering HABs, (2) confounding factors including climate change, and (3) available funding sources (discussed in **Section 13.2**).

13.1.1 Phosphorus Forms

As described throughout this Action Plan, a primary factor contributing to HABs in the waterbody is excess nutrients, in particular, phosphorus. Total phosphorus (TP) is a common metric of water quality and is often the nutrient monitored for and targeted in watershed and lake management strategies to prevent or mitigate eutrophication (Cooke et al. 2005).

However, TP consists of different forms (Dodds 2003) that differ in their ability to support algal growth. There are two major categories of phosphorus: particulate and dissolved (or soluble). The dissolved forms of P are more readily bioavailable to phytoplankton than particulate forms (Auer et al. 1998, Effler et al. 2012, Auer et al. 2015, Prestigiacomo et al. 2016). Phosphorus bioavailability is a term that refers to the usability of specific forms of phosphorus by phytoplankton and algae for assimilation and growth (DePinto et al. 1981, Young et al. 1982).

Because of the importance of dissolved P forms affecting receiving waterbody quality, readers of the Action Plan should consider the source and form of P, in addition to project-specific stakeholder interest(s), when planning to select and implement the recommended actions, best management practices or management strategies in the Action Plan. Management of soluble P is an emerging research area; practices designed for conservation of soluble phosphorus are recommended in Sonzogni et al. 1982, Ritter and Shiromohammadi 2000, and Sharpley et al. 2006.

13.1.2 Climate Change

Climate change is also an important consideration when selecting implementation projects. There is still uncertainty in the understanding of BMP responses to climate change conditions that may influence best management practice efficiencies and effectiveness. More research is needed to understand which BMPs will retain their effectiveness at removing nutrient and sediment pollution under changing climate conditions, as well as which BMPs will be able to physically withstand changing conditions expected to occur because of climate change.

Where possible, selection of BMPs should be aligned with existing climate resiliency plans and strategies (e.g., floodplain management programs, fisheries/habitat restoration programs, or hazard mitigation programs). When selecting BMPs, it is also important to consider seasonal, inter-annual climate or weather conditions and how they may affect the performance of the BMPs. For example, restoration of wetlands and riparian forest buffers not only filter nutrient and sediment from overland surface flows, but also slow runoff and absorb excessive water during flood events, which are expected to increase in frequency due to climate change. These practices not only reduce disturbance of the riverine environment but also protect valuable agricultural lands from erosion and increase resiliency to droughts.

In New York State, ditches parallel nearly every mile of our roadways and in some watersheds, the length of these conduits is greater than the natural watercourses themselves. Although roadside ditches have long been used to enhance road drainage and safety, traditional management practices have been a significant, but unrecognized contributor to flooding and water pollution, with ditch management practices that often enhance rather than mitigate these problems. The primary objective has been to move water away from local road surfaces as quickly as possible, without evaluating local and downstream impacts. As a result, elevated discharges increase peak stream flows and exacerbate downstream flooding. The rapid, high volumes of flow also carry nutrient-laden sediment, salt and other road contaminants, and even elevated bacteria counts, thus contributing significantly to regional water quantity and quality concerns that can impact biological communities. All of these impacts will be exacerbated by the increased frequency of high intensity storms associated with climate change. For more information about road ditches, see **Appendix G**.

For more information about climate change visit DEC's website (https://www.dec.ny.gov/energy/44992.html) and the Chesapeake Bay Climate Resiliency Workgroup Planning Tools and Resources website (https://www.chesapeakebay.net/documents/Resilient_BMP_Tools_and_Resources_November_20172.pdf).

13.2 Priority Project Development and Funding Opportunities

The priority projects listed below have been developed by an interagency team and local steering committee that has worked cooperatively to identify, assess feasibility and costs, and prioritize both in-lake and watershed management strategies aimed at reducing HABs in Chautauqua Lake.

Steering committee members:

- Bill Boria, Chautauqua County Department of Health
- David McCoy, Chautauqua County Department of Planning & Economic Development
- George Borrello, Chautauqua County Executive's Office
- Pierre Chagnon, Chautauqua County Legislature

- Cassie Brower, Chautauqua County Soil and Water Conservation District (SWCD)
- John Shedd, Chautauqua Institution
- Erin Brickley, Chautauqua Lake and Watershed Management Alliance
- Douglas Conroe, Chautauqua Lake Association
- Tom Erlandson, Chautauqua Lake Partnership
- John Jablonski, Chautauqua Watershed Conservancy
- Patrick Jackson, Global Energy Management at Corning, Inc.
- Victor DiGiacomo, NYSDAM
- Jeff Konsella, NYSDEC
- Ken Kosinski, NYSDEC
- Courtney Wigdahl-Perry, SUNY Fredonia

These projects have been assigned priority rankings based on the potential for each individual action to achieve one of two primary objectives of this HABs Action Plan:

1. *In-lake management actions*: Minimize the internal stressors (e.g., nutrient concentrations, dissolved oxygen levels, temperature) that contribute to HABs within Chautauqua Lake.

2. *Watershed management actions:* Address watershed inputs that influence in-lake conditions that support HABs.

As described throughout this HABs Action Plan, the primary factors that often contribute to HABs and represent conditions within Chautauqua Lake and its watershed that can be controlled through management actions include:

- Internal loading of legacy phosphorus from in-lake sediments.

- Nonpoint source sediment and nutrient inputs from the contributing watershed (e.g., agricultural lands, forests, ditches and streambank erosion).

- Stormwater runoff and failing septic systems from developed areas.

The management actions identified below have been prioritized to address these sources. Projects were prioritized based on the following cost-benefit and project readiness criteria: local support or specific recommendation by steering committee members, eligibility under existing funding mechanisms, and expected water quality impacts as determined by the interagency team. Additionally, nutrient forms and the impacts of climate change were considered in this prioritization as described above.

The implementation of the actions outlined in this Plan is contingent on the submittal of applications (which may require, for example, landowner agreements, feasibility studies, funding match, or engineering plans), award of funding, and timeframe to complete implementation. Due to these contingencies, recommended projects are organized into broad implementation schedules: short-term (3 years), mid-term (3-5 years), and long-term (5-10 years).

Funding Programs

The recommended actions outlined in this Section may be eligible for funding from the many state, federal and local/regional programs that help finance implementation of projects in New York State (see https://on.ny.gov/HABsAction). The New York State Water Quality Rapid Response Team stands ready to assist all partners in securing funding. Some of the funding opportunities available include:

The New York State Environmental Protection Fund (EPF) was created by state legislation in 1993 and is financed primarily through a dedicated portion of real estate transfer taxes. The EPF is a source of funding for capital projects that protect the environment and enhance communities. Several NYS agencies administer the funds and award grants, including NYSDAM, NYSDEC, and Department of State. The following two grant programs are supported by the EPF to award funding to implement projects to address nonpoint source pollution:

The Agricultural Nonpoint Source Abatement and Control Program (ANSACP), administered by the NYSDAM and the Soil and Water Conservation Committee, is a competitive financial assistance program for projects led by the Soil and Water Conservation Districts that involves planning, designing, and implementing priority BMPs. It also provides cost-share funding to farmers to implement BMPs. For more information visit https://www.nys-soilandwater.org/aem/nonpoint.html.

The Water Quality Improvement Program (WQIP), administered by the NYSDEC Division of Water, is a competitive reimbursement program for projects that reduce impacted runoff, improve water quality, and restore habitat. Eligible applicants include municipalities, municipal corporations, and Soil and Water Conservation Districts.

The Environmental Facilities Corporation (EFC) is a public benefit corporation which provides financial and technical assistance, primarily to municipalities through low-cost financing for water quality infrastructure projects. EFC's core funding programs are the Clean Water State Revolving Fund and the Drinking Water State Revolving Fund. EFC administers both loan and grant programs, including the Green Innovation Grant Program (GIGP), Engineering Planning Grant Program (EPG), Water Infrastructure Improvement Act (WIIA), and the Septic System Replacement Program. For more information about the programs and application process visit https://www.efc.ny.gov/.

Wastewater Infrastructure Engineering Planning Grant is available to municipalities with median household income equal to or less than $65,000 according to the United States Census 2015 American Community Survey or equal to or less than $85,000 for Long Island, NYC and Mid-Hudson Regional Economic Development Council (REDC) regions. Priority is usually given to smaller grants to support initial engineering reports and plans for wastewater treatment repairs and upgrades that are necessary for municipalities to successfully submit a complete application for grants and low interest financing.

Clean Water Infrastructure Act (CWIA) Septic Program funds county-sponsored and administered household septic repair grants. This program entails repair and/or replacement of failing household septic systems in hot-spot areas of priority watersheds. Grants are channeled through participating counties.

CWIA Inter-Municipal Grant Program funds municipalities, municipal corporations, as well as soil and water conservation districts for wastewater treatment plant construction, retrofit of outdated stormwater management facilities, as well as installation of municipal sanitary sewer infrastructure.

CWIA Source Water Protection Land Acquisition Grant Program funds municipalities, municipal corporations, soil and water conservation districts, as well as not-for-profits (e.g., land trusts) for land acquisition projects providing source water protection. This program is administered as an important new part of the Water Quality Improvement Project program.

Consolidated Animal Feeding Operation Waste Storage and Transfer Program Grants fund soil and water conservation districts to implement comprehensive nutrient management plans through the completion of agricultural waste storage and transfer systems on larger livestock farms.

Water Infrastructure Improvement Act Grants funds municipalities to perform capital projects to upgrade or repair wastewater treatments plants and to abate combined sewer overflows, including projects to install heightened nutrient treatment systems.

Green Innovation Grant Program provides municipalities, state agencies, private entities, as well as soil and water conservation districts with funds to install transformative green stormwater infrastructure.

Readers of this Action Plan interested in submitting funding applications are encouraged to reference this Action Plan and complementary planning documents (i.e., TMDLs or Nine Element [9E] Plans) as supporting evidence of the potential for their proposed projects to improve water quality. However, applicants must thoroughly review each funding program's eligibility, match, and documentation requirements before submitting applications to maximize their potential for securing funding.

There may be recommended actions that are not eligible for funding through existing programs, however, there may be opportunities to implement actions through watershed programs (https://www.dec.ny.gov/chemical/110140.html) or other mechanisms.

13.3 Chautauqua Lake Priority Projects

13.3.1 Priority 1 Projects

Priority 1 projects are considered necessary to manage water quality and reduce HABs in Chautauqua Lake, and implementation should be evaluated to begin as soon as possible.

Short-term (3 years)

1. Increase funding to relevant county agencies (e.g., SWCD, County DOH) and local non-profits to implement BMP work, increase education/outreach, perform site inspections for municipalities, and conduct upland water management (stormwater/green and gray infrastructure) projects on both public and private lands. This project could include:
    a. Addition of staff member(s), including those that are Certified Professional in Erosion and Sediment Control (CPESC), to provide technical assistance.
    b. Assist the County Health Department with inspections of septic systems, including expanded data collection and integration into the County's GIS interface for public use. This program can also be applied to private water wells, including shallow wells near the lake and private drinking water intakes from the lake.
    c. Assist homeowners with corrective measures for septic systems to include a reimbursement/cost sharing program for inspections, pump-outs, and system updates.
    d. Evaluate agricultural producers in the watershed to identify potential BMPs that could be implemented to reduce nutrient loadings.
2. Implement the South and Center Chautauqua Lake Sewer District expansion project to reduce nutrient loadings to the lake.
3. Increase SWCD staffing (e.g., planners, engineers, technical staff) through appropriations to focus capacity to plan and implement runoff reduction BMPs on croplands and non-agricultural lands to reduce stormwater and nutrient runoff and soil erosion within the watershed. These projects could include:
    a. Establish vegetated riparian buffers to inhibit or reduce nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams.
    b. Rehabilitate degraded vegetated buffers to improve riparian habitat function.
    c. Conserve wetlands, floodplains, and drainage corridors.

d. Reconnect tributaries to their floodplains and/or create wetlands.

e. Plant trees and shrubs along the lake shoreline and along tributaries (e.g., Trees for Tribs program) to stabilize riparian habitat.

f. Install stream stabilization facilities (e.g., log or stone revetments or vanes, vegetated riparian buffers) on select tributaries where bed and bank erosion is contributing significant sediment nutrient loads.

g. Use techniques on agricultural fields such as field leveling and water and sediment control basins (WASCoBs) to promote stormwater retention and minimize concentrated runoff (e.g., rills, gullies).

h. Stabilize agricultural drainage swales through establishment of vegetation and/or installation of check dams.

i. Install control facilities at the outlets of drainage swales (prior to entering the lake or tributaries) to promote sediment and nutrient capture.

4. Purchase additional equipment (i.e., skimmer collector conveyorized work barge) to harvest, store, transport, and dispose of nuisance and undesirable aquatic vegetation and implement a harvesting program according to an approved plan. This program would be targeted at collecting macrophytes during the summer and fall seasons with acquisition of the proposed equipment. It is anticipated that removal of the macrophytes may reduce the localized quiescent conditions that may facilitate accumulations of HABs. This program is envisioned to be led by stakeholders including, but not limited to, Chautauqua County SWCD.

5. Work with local municipal Department of Public Works (DPW) staff throughout the watershed to implement a roadside ditch program. Best management practices could include:

   a. Installing check dams or other facilities to reduce flow velocities, minimize erosion, and promote sedimentation.

   b. Timing cleanout to minimize vegetative loss.

   c. Properly sizing culverts and channels to avoid headcuts and other erosion.

   d. Hydroseeding disturbed areas to assist in ditch bank stabilization.

   e. Retrofitting existing drainage ditches to bio-swales (i.e., wet swales) consistent with the design criteria in the New York State Stormwater Management Design Manual where feasible.

   f. Identifying and implementing improvement projects at sites where ditches can be disconnected from direct connections to surface waters, sheet flow can be restored downgradient from roads, and retention basins, infiltration

BMPs and constructed wetlands, etc. can be engineered into the system for total discharge volume reduction and water quality improvement.

6. Purchase and deploy an additional sampling buoy in the South basin that is consistent with the existing buoy currently utilized by the Chautauqua Aquatic Monitoring Project (ChAMP) conducted by SUNY Fredonia in the North basin. This buoy could provide additional data on in-lake water quality that could be networked through the Global Lakes Ecological Observatory (GLEON) network to enable further analysis of trends and HABs.
7. Complete a landscape assessment within the watershed to identify nutrient sources and recommend BMPs to minimize nutrient export. Available tools (*e.g.*, the NYSDEC's Statewide Riparian Opportunity Assessment, Chesapeake Precision Conservation modeling) can be used before field assessment to identify areas where land management actions could contribute to improved water quality in Chautauqua Lake. This project is envisioned to be a collaborative effort among Chautauqua County SWCD and local organizations. Areas could include:
    a. Unstable hillsides and stream banks where stabilization measures could be applied to reduce erosion and sedimentation.
    b. Degraded or impacted wetlands and floodplains where restoration and enhancement efforts could be applied with a focus on minimizing downstream sediment flux.
    c. Areas with landscape conditions amenable to wetland creation.

Mid-term (3 to 5 years)

1. Continue to create Comprehensive Nutrient Management Plans (CNMPs) for non-Concentrated Animal Feeding Operation (CAFO) farms to reduce sediment and nutrient runoff on crop farms. This could include an evaluation and tracking system that includes GIS to map which farms have CNMPs and which active farms would benefit most from developing a CNMP. This project would be led by the Chautauqua County SWCD.
2. Provide public outreach and education to homeowners and lake-shore residents about watershed management and nonpoint source pollution, including encouraging proper lawn management to minimize watershed impacts. The program could build on the Chautauqua Watershed Conservancy's "Don't Feed the Weeds!" campaign that was launched in 2007 to build awareness and understanding of the interconnectedness of watershed land use on waterways and use this awareness to promote best land management practices that preserve and enhance the water quality, scenic beauty and ecological health of the lakes, streams and watersheds of the Chautauqua region. This project is

envisioned to be a collaborative effort among local municipalities, non-profit organizations, and Chautauqua County SWCD.

3. Develop and implement a tributary and sub-watershed water quality monitoring program to identify significant sub-watershed sources of nutrients. Priority sub-watersheds can then be identified for treatment to address the largest sources of nutrient input from these surface water sources. Once projects are implemented in the identified sub-watersheds, on-going monitoring can track the impacts of BMPs and other watershed treatment practices. This project is envisioned to be a collaborative effort among Chautauqua County SWCD and local organizations.

4. Utilize existing programs and develop and implement new programs to acquire conservation easements and fee simple title on sensitive sites and BMP-installed sites including, but not limited to those described above; utilize and/or develop funding sources to provide for long-term monitoring, stewardship, and maintenance of these sites through easements or outright purchase.

Long-term (5 to 10 years)

1. Acquire and conserve lands within the watershed to reduce existing or future land use impacts on water quality. Potential parcels may include areas in sensitive riparian settings, and/or that offer protection of extensive natural areas providing water quality benefits.

2. Develop a 9E Plan to better inform the in-lake and watershed dynamics that contribute to Chautauqua Lake water quality.

3. Use the Chesapeake Precision Conservation Analysis tools or similar tools to transform raw light detection and ranging (LiDAR) remote sensing data into a format that local stakeholders and conservation organizations can utilize to better understand in-lake dynamics.

4. Conduct additional in-lake monitoring to help determine the stresses that lead to potential HABs in Chautauqua Lake and to assess improvements associated with management actions. Collectively, these data can be used to enhance capabilities for predicting future HABs occurrences.
    a. Develop a HAB monitoring network. Monitoring should be focused on areas of the lake where prevailing wind and wave action contributes to the accumulation of BGA, specifically, the southern portion of the lake.

    b. Maintain and enhance community and/or volunteer monitoring efforts of water quality conditions in the lake, particularly during the growing season and fall turnover.

    c. Collect depth profiles of DO and phosphorus in both basins of Chautauqua Lake to advance the understanding of internal phosphorus loading.

d. Identify certified laboratories that water samples can be sent locally to streamline the testing process and response.

e. Align in-lake water quality data collection efforts with overpasses of NASA's Landsat 8 satellite (**Table 13**), to the extent possible. This alignment will allow for the effective use of satellite imagery when characterizing lake conditions based on corresponding field data.

Table 13. Landsat 8 overpasses of Chautauqua Lake for May through October 2018.

Month	Dates	
May	May 3	May 19
June	June 4	June 20
July	July 6	July 22
August	August 7	August 23
September	September 8	September 24
October	October 10	October 26

5. Complete a feasibility study, including bench testing, to facilitate the application of nutrient inactivants in the North basin of Chautauqua Lake for inactivation of internal phosphorus sources. Data will be collected to calculate proposed nutrient inactivant application rates and to assess potential impacts of the treatment. The target of the treatment would be on deep portions of the lake that are stratified with hypoxic and anoxic zones that allow for the release of sediment-bound phosphorus.

   a. If this feasibility study indicated that the application of nutrient inactivants would be an appropriate mitigation action to address internal nutrient loading, a mitigation project could then be completed on select portions of the lake. This project would need to include the following prior to field implementation:

      i. Preparation of supplemental environmental impact statement (EIS) to comply with the State Environmental Quality Review Act, if needed.
      ii. Apply for and receive regulatory approvals from the NYSDEC, USACE, and other agencies.
      iii. Note that New York State is developing an approach for safely and legally using nutrient inactivants, and until that process is completed, the use of any inactivants in Chautauqua Lake is prohibited.

6. The public water systems, with support from the DEC and DOH, should pursue engineering studies to evaluate the potential efficacy of adding additional treatment. If these studies show that adding treatment is appropriate and feasible, then the water systems should then work with DOH and EFC to pursue

funding opportunities through programs such as the Drinking Water State Revolving Fund (DWSRF) and Water Infrastructure Improvement Act (WIIA), as well as engage their local elected officials for support.

13.3.2 Priority 2 Projects

Priority 2 projects are considered necessary, but may not have a similar immediate need as Priority 1 projects.

Short-term (3 years)

1. When blooms occur, collect water samples from the lake and send them to the laboratory at SUNY Environmental Science and Forestry or other State certified laboratories to analyze the samples for algal presence, harmful conditions and toxicity. The data will then be compared with known previous years' data to determine if any trends exist.

Mid-term (3 to 5 years)

1. Evaluate the presence of forest pests that affect hemlock (*Tsuga spp.*), ash (*Fraxinus spp.*), spruce (*Picea spp.*), and other tree species that are currently integral to watershed stabilization. Implement pro-active pest prevention and/or management to reduce the impacts of the pests. Recommended strategies may be led by, but not limited to, Chautauqua County SWCD, and include:
    a. Work with Cornell Cooperative Extension on establishing hemlock hedges within biological control field stations.
    b. Use systemic insecticides (imidacloprid and dinotefuran) and/or introduce natural enemies such as the predatory beetle *Laricobius nigrinus* that controls the hemlock wooly adelgid (*Adelges tsugae*), a destructive invasive pest of the eastern hemlock, in hemlock-dominated forest/woodlands.
2. Provide funding and/or staff to help municipalities complete the feasibility studies necessary for Green Infrastructure Practices/Stormwater Retrofits Program.

Long-term (5 to 10 years)

1. Replace shoreline structures such as sheet pile, concrete, wood or large armor stone walls with natural shoreline features (bed and bank) that increase the value of aquatic habitat and dissipate wave energy, thereby reducing in-lake erosion. Replacement structures should be installed above the mean high-water elevation, behind, or on the same footprint as the existing structure and include shoreline tree and shrub plantings that create a riparian buffer. This project would be done collaboratively amongst the Chautauqua County SWCD and local municipalities.

13.4 Additional Management Actions

In addition to the priority actions identified above by the steering committee, the following watershed management actions could be considered:

Short-term

1. Emphasize phosphorus source control in stormwater planning, targeting areas with potentially high levels of phosphorus runoff, Emphasis should be placed on locations within the Chautauqua Lake watershed that have a combination of relatively high percentages of impervious cover, small lot sizes, and/or compacted soils.
2. Evaluate locations where animal wastes are concentrated (*e.g.*, pet stores and animal care/boarding facilities) for illicit connections and exposure to stormwater, and provide them with tailored outreach materials.
3. Evaluate locations where yard or food wastes are stored (*e.g.*, “dumpsters” serving restaurants and grocery stores, yard waste composting and disposal areas) for illicit connections and exposure to stormwater and provide them with tailored outreach materials.
4. Work to implement the Agricultural Environmental Management (AEM) Plan and identify best applications of funds through available grant programs.
5. Stop or reduce applying herbicides to rights-of-way and stream banks at road crossings.

Mid-term

1. Construct wetlands or enhance/restore existing wetlands within the watershed to reduce nutrient loads. **Figure 19** shows the locations within the Chautauqua Lake watershed that have either hydric, very poor, or poorly drained soils, but are not currently mapped wetland habitats according to the National Wetland Inventory (NWI) database. These locations should be targeted for proposed new wetlands as they are more likely to support wetland hydrology and vegetation.

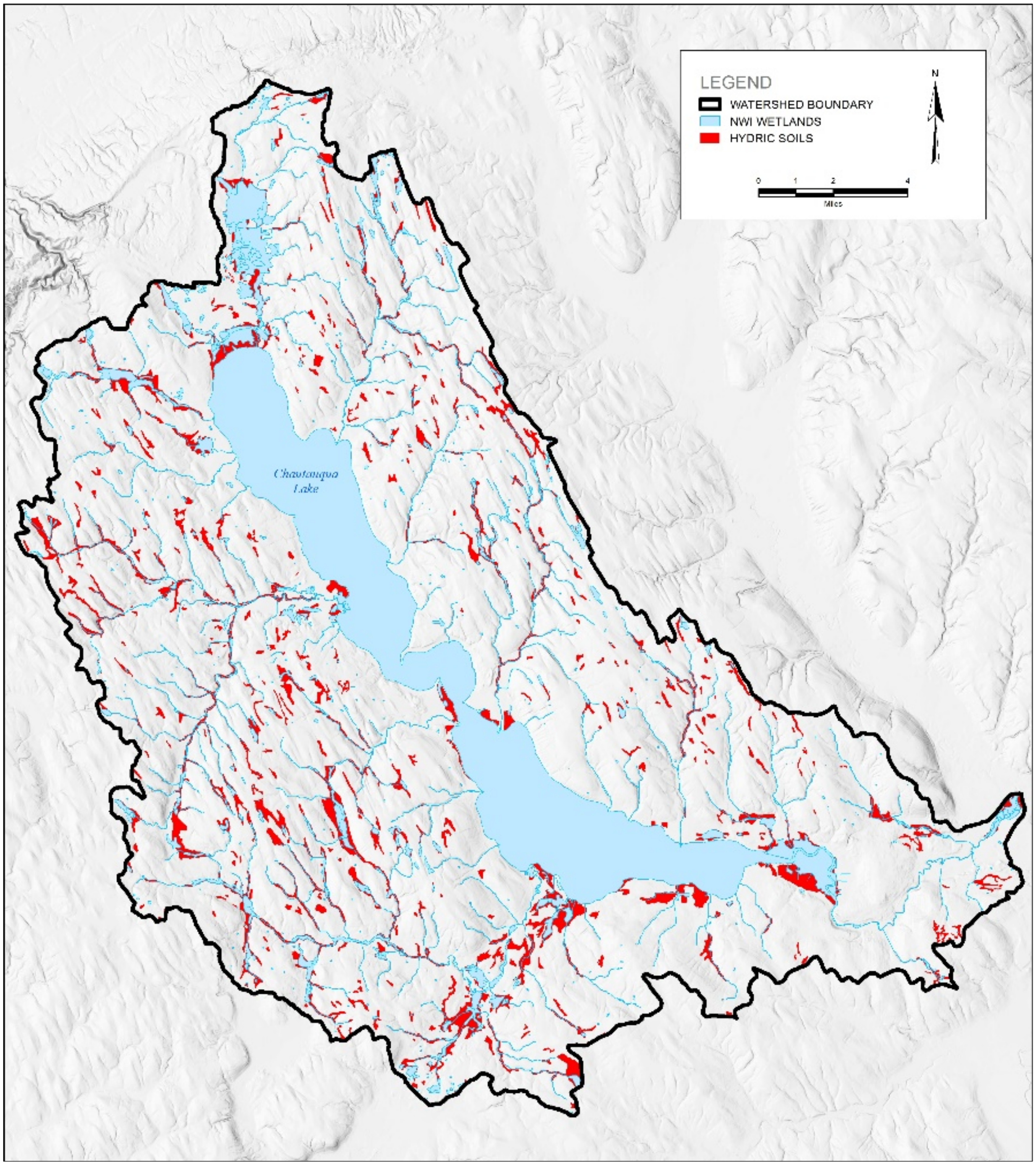

Figure 19. Locations (depicted in red) of either hydric, very poor, or poorly drained soils in the Chautauqua Lake watershed, which are not mapped as wetlands per the National Wetland Inventory (NWI).

13.5 Monitoring Actions

To help determine the stresses that lead to potential HABs in Chautauqua Lake and to assess improvements associated with management actions, the following monitoring actions are recommended for evaluation:

Short-term

1. Expand CSLAP sampling locations to nearshore zones. Current sample locations are offshore and may not provide the most useful data and information for identifying area-specific triggers for HABs in the lake. Water sample analyses should include at a minimum: total phosphorus, total dissolved phosphorus, total nitrogen, temperature, pH and alkalinity.
2. Collect additional dissolved oxygen data and develop depth profiles for each sub-basin within Chautauqua Lake.

Long-term

1. Develop and maintain long term monitoring (decadal) programs in-lake and in the watershed to provide valuable data in the assessment of future water quality and trends.

13.6 Research Actions

The NYSDEC should continue to coordinate with local organizations and research groups to maximize the efficacy of research efforts with the shared goal of maintaining the water quality within Chautauqua Lake. Specifically, the role of nitrogen concentrations in the production of toxins by cyanobacteria should be studied and management actions targeted at optimizing the nutrient levels to minimize the production of toxins associated with HABs.

The NYSDEC should support research to better understand how to target dissolved phosphorus with traditional and innovative nonpoint source best management practices. This applied research would guide selection of appropriate BMPs to target dissolved phosphorus in the future.

The NYSDEC should support research to understand and identify which best management practices will retain their effectiveness at removing nutrient and sediment pollution under changing climate conditions, as well as which BMPs will be able to physically withstand changing conditions expected to occur as a result of climate change. This applied research would guide selection of appropriate BMPs in the future and determination of the likely future effectiveness of existing BMPs.

The NYSDEC should support research to investigate the role of climate change on lake metabolism, primary production, nutrient cycling, and carbon chemistry.

The NYSDEC should encourage and support research into management options for dreissenids and better understanding of their natural population cycles.

13.7 Coordination Actions

The following actions are opportunities for stakeholders, general public, steering committee members, federal, state, and local partners to collaborate, improve project or program integration, enhance communication and increase implementation. The actions are intended to increase collaboration and cooperation in the overall advancement of this HABs Action Plan. These actions will likely change or expand as the Action Plan is implemented and/or research is completed, or when opportunities for coordination are identified.

Short-term

1. Promote the implementation of the watershed-scale BMPs for curtailing runoff from farm fields and other agricultural areas (detailed in the Chautauqua AEM Plan), developed land, and forested land.
2. Encourage public participation in initiatives for reducing phosphorus and documenting/tracking BGA, such as volunteer monitoring networks and/or increasing awareness of procedures to report HABs to NYSDEC.
3. Improve coordination between NYSDEC and owners of highway infrastructure (state, county, municipal) to address road ditch management; including, identify practices, areas of collaboration with other stakeholder groups, and evaluation of current maintenance practices.
4. Continue to support and provide targeted training (e.g., ditch management, emergency stream intervention, sediment and erosion controls, prescribed grazing, conservation skills, etc.) to municipal decision makers, SWCDs, and personnel in order to underscore the importance of water quality protection as well as associated tools and strategies.

Long-term

1. Pursue and identify cooperative landowners to facilitate acquisitions of conservation easements to implement watershed protection strategies, harnessing available funding opportunities related to land acquisition for water quality protection.
2. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.
3. Coordinate with NYS Department of Health to support the local health departments to implement onsite septic replacement and inspection activities.
4. Identify areas to improve efficiency of existing funding programs that will benefit the application and contracting process. For example, develop technical resources to assist with application process and BMP selection, identify financial resources needed by applicants for engineering and feasibility studies.

5. Support evaluation of watershed rules and regulations.

13.8 Long-term Use of Action Plan

This Action Plan is intended to be an adaptive document that may require updates and amendments, or evaluation as projects are implemented, research is completed, new conservation practices are developed, implementation projects are updated, or priority areas within the watershed are better understood.

Local support and implementation of each plan's recommended actions are crucial to successfully preventing and combatting HABs. The New York State Water Quality Rapid Response Team has established a one-stop shop funding portal and stands ready to assist all localities in securing funding and expeditiously implementing priority projects.

Communities and watershed organizations are encouraged to review the plan for their lake, particularly the proposed actions, and work with state and local partners to implement those recommendations. Individuals can get involved with local groups and encourage their communities or organizations to take action.

Steering committee members are encouraged to coordinate with their partners to submit funding applications to complete implementation projects. For more information on these funding opportunities, please visit https://on.ny.gov/HABsAction.

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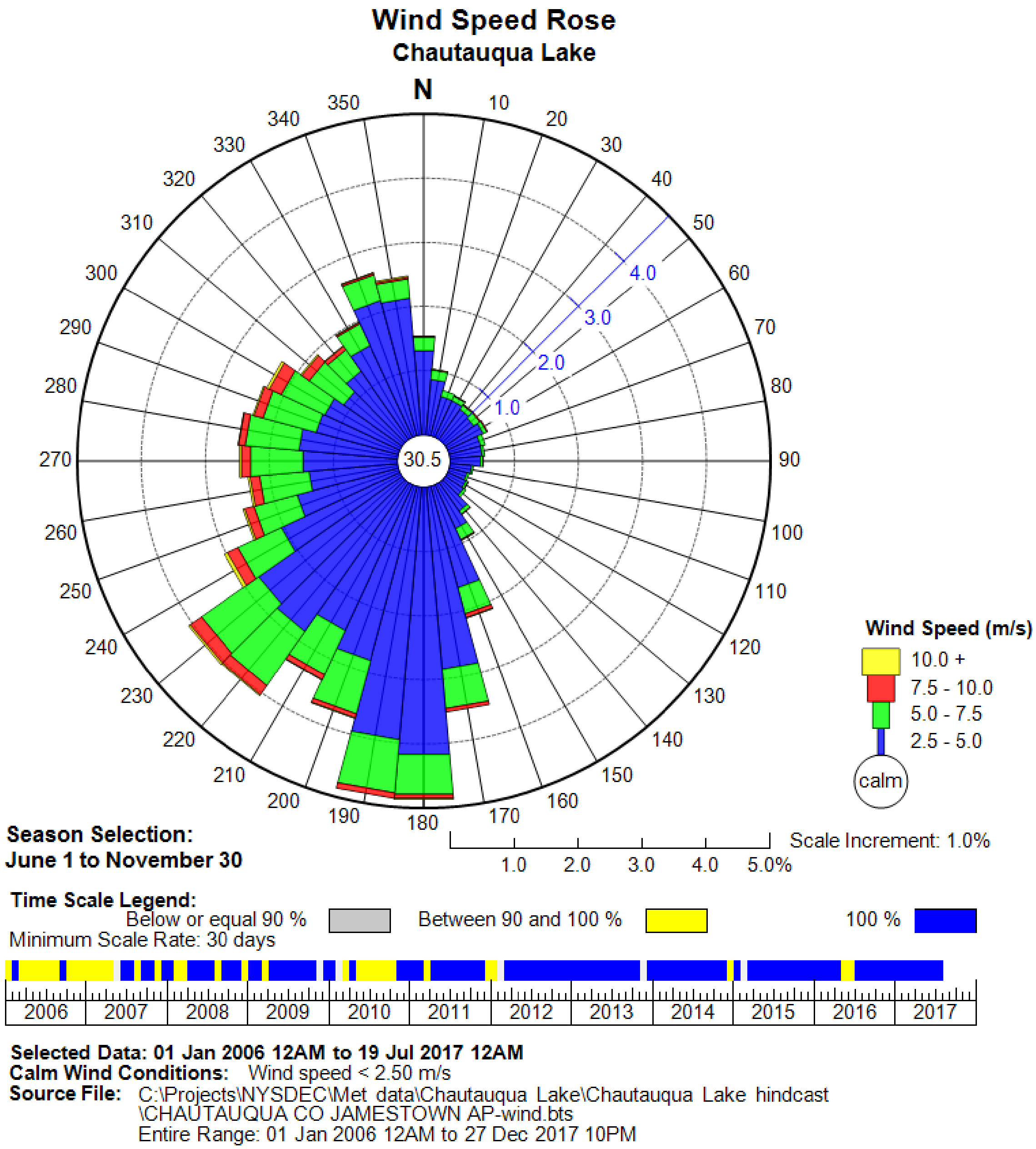
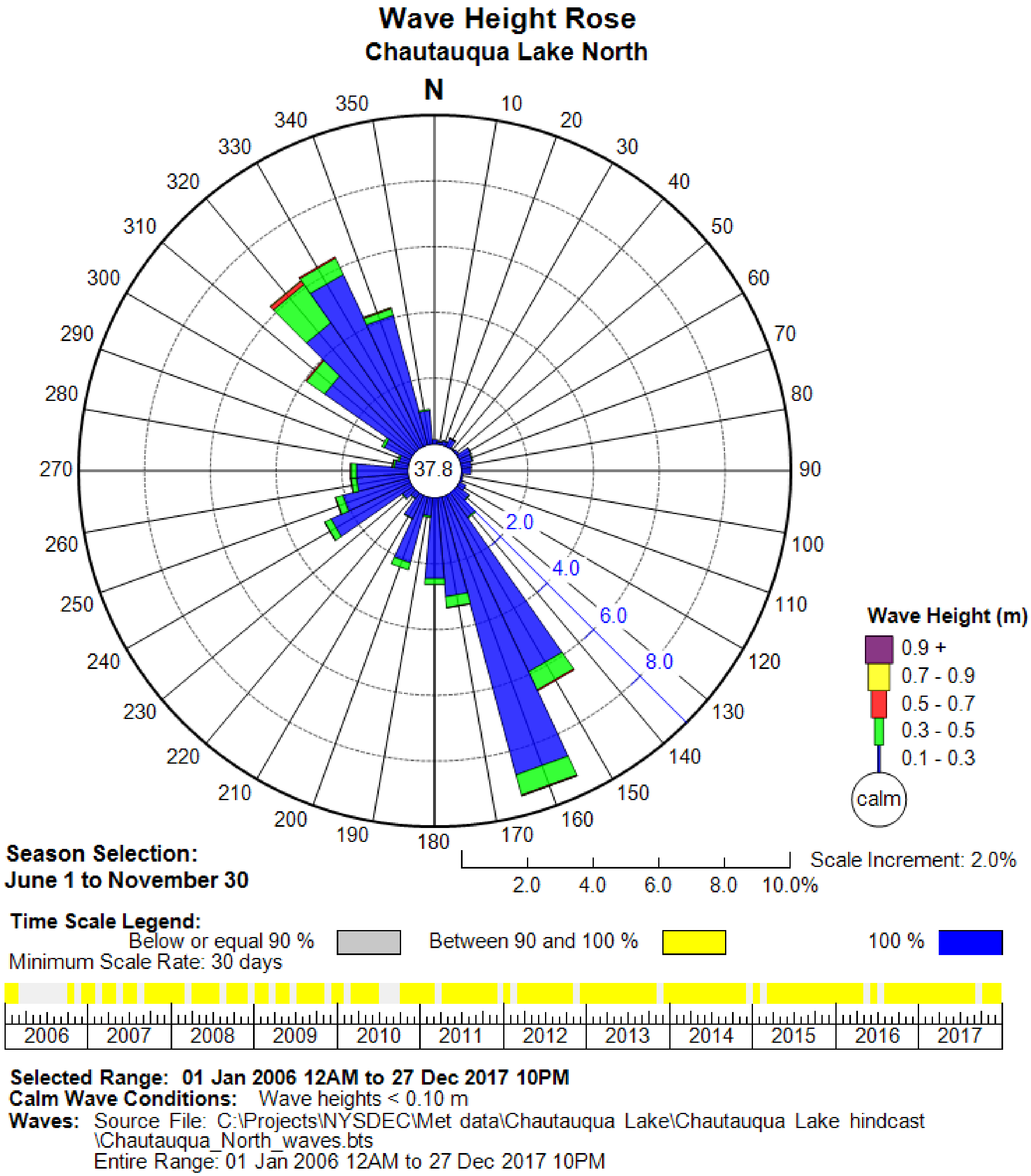
Appendix A. Wind and Wave Patterns

Wind Speed



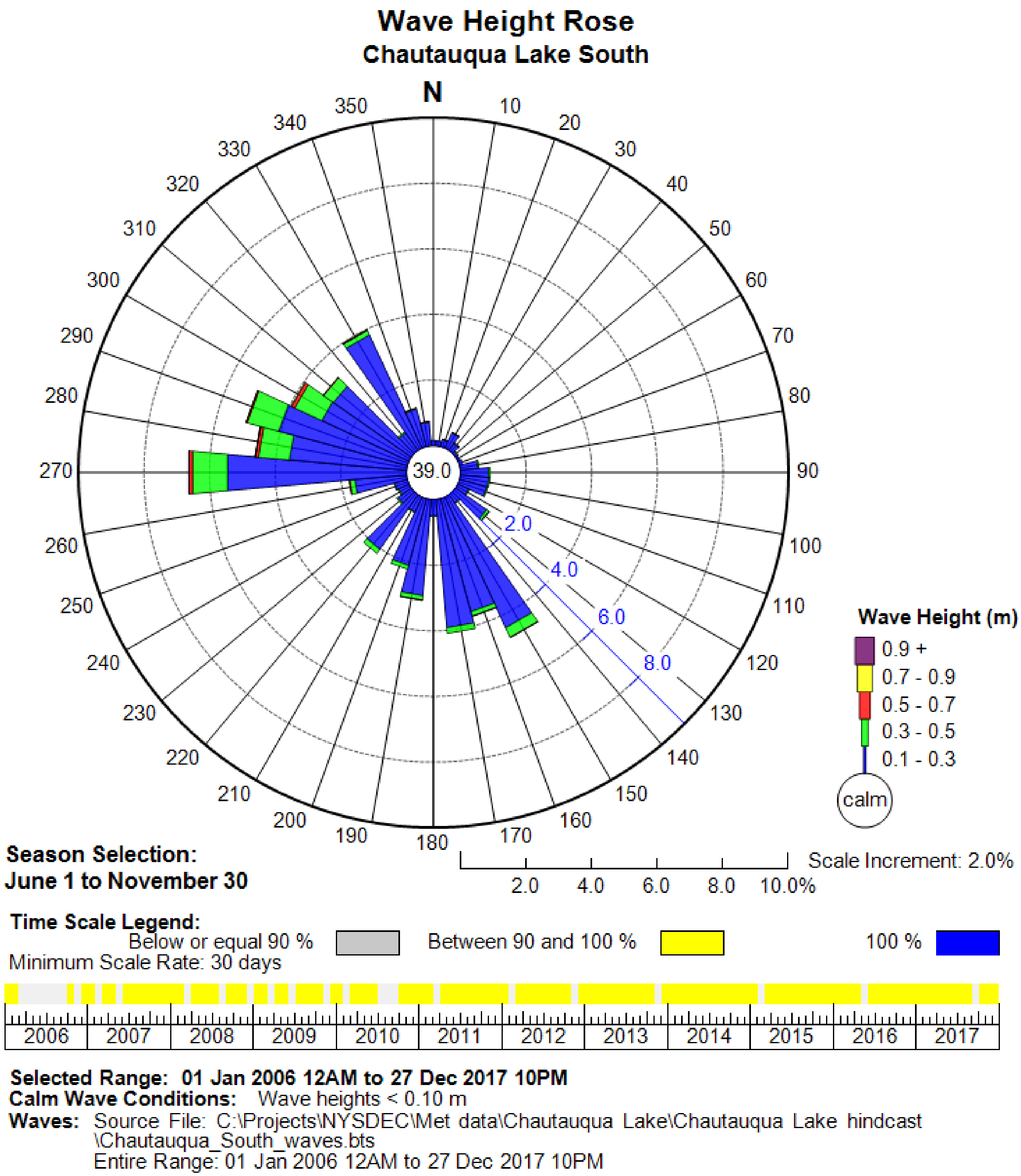
Wind speed patterns for Chautauqua Lake from 2006 to 2017 during the growing season (June through November) suggest that stronger winds were generally out of the south/southwest and northwest.

Wave Height – North



Estimated wave height patterns in Chautauqua Lake North basin from 2006 through 2017 during the growing season (June through November) indicate greater wave heights in the northwest and southeastern portions of the North basin.

Wave Height – South



Estimated wave height patterns in Chautauqua Lake South basin from 2006 to 2017 during the growing season (June through November) indicate greater wave heights in the western and southeastern portion of the South basin.

Appendix B. Waterbody Classifications

Class N: Enjoyment of water in its natural condition and where compatible, as source of water for drinking or culinary purposes, bathing, fishing and fish propagation, recreation and any other usages except for the discharge of sewage, industrial wastes or other wastes or any sewage or waste effluent not having filtration resulting from at least 200 feet of lateral travel through unconsolidated earth. These waters should contain no deleterious substances, hydrocarbons or substances that would contribute to eutrophication, nor shall they receive surface runoff containing any such substance.

Class $AA_{special}$: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival, and shall contain no floating solids, settleable solids, oils, sludge deposits, toxic wastes, deleterious substances, colored or other wastes or heated liquids attributable to sewage, industrial wastes or other wastes. There shall be no discharge or disposal of sewage, industrial wastes or other wastes into these waters. These waters shall contain no phosphorus and nitrogen in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.

Class $A_{special}$: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These international boundary waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class AA: Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These waters, if subjected to approved disinfection treatment, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes

Class A:	Source of water supply for drinking, culinary or food processing purposes; primary and secondary contact recreation; and fishing. These waters shall be suitable for fish propagation and survival. These waters, if subjected to approved treatment equal to coagulation, sedimentation, filtration and disinfection, with additional treatment if necessary to remove naturally present impurities, will meet New York State Department of Health drinking water standards and will be considered safe and satisfactory for drinking water purposes
Class B:	The best usage is for primary and secondary contact recreation and fishing. These waters shall be suitable for fish propagation and survival
Class C:	The best usage is for fishing, and fish propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
Class D:	The best usage is for fishing. Due to such natural conditions as intermittency of flow, water conditions not conducive to propagation of game fishery, or stream bed conditions, the waters will not support fish propagation. These waters shall be suitable for fish survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
Class (T):	Designated for trout survival, defined by the Environmental Conservation Law Article 11 (NYS, 1984b) as brook trout, brown trout, red throat trout, rainbow trout, and splake.
Class (TS):	Designated for trout spawning waters. Any water quality standard, guidance value, or thermal criterion that specifically refers to trout, trout spawning, trout waters, or trout spawning waters applies.

Appendix C. Remote Sensing Methodology

Relative chlorophyll-a concentrations were estimated for eight water bodies using remote sensing methods. The analysis involved processing the spectral wavelengths of satellite imagery to estimate the amount of chlorophyll-a at the water surface. The analysis is based on the ratios of reflected and absorbed light for discrete spectral bands (i.e., blue, green, and red) and is thus a measure of green particles near the water surface.

The analysis was completed for seven water bodies, with dimension larger than 1 km in both length and width. These include: Conesus Lake, Honeoye Lake, Chautauqua Lake, Owasco Lake, Lake Champlain, Lake George, and Cayuga Lake.

The remote sensing analysis provides an overview of the spatial distribution and relative concentration of chlorophyll-a on specific dates. Imagery was acquired for the past three summer seasons (2015-2017) to gain a better understanding of the development of chlorophyll-a concentrations over the summer and potential Harmful Algal Bloom (HAB) triggers. This information may be used to:

- Understand the spatial extent, temporal coverage, and magnitude of historical HAB events;
- Identify regions of each lake susceptible to HABs due to the location of point source inputs, prevailing winds, etc.;
- Identify conditions which may trigger a HAB (e.g. rainfall, temperature, solar radiation, wind, water chemistry, etc.);
- Guide monitoring plans such as location and frequency of in-situ measurements;
- Guide the development of water quality assessment programs, for which HAB extent, intensity, and duration are relevant;
- Guide management plans such as prioritizing remedial actions, locating new facilities (e.g. water intakes, parks, beaches, residential development, etc.) and targeting in-lake management efforts.

At this time, the estimated chlorophyll-a concentrations are reported as a concentration index due to the limited number of in-situ measurements (+/- 1 day of the satellite images) to calibrate the method. Chlorophyll-a concentrations can be quantified using this method, but more in-situ data is required from New York State lakes to calibrate/validate the method. Once the calibration/validation is completed, the quantified chlorophyll-a concentrations would give an improved understanding of the spatial and temporal dynamics of chlorophyll-a concentrations.

Analysis could be conducted to estimate cyanobacteria in addition to chlorophyll-a. However, there are a lot less cyanobacteria measured data than chlorophyll-a. As more measured cyanobacteria concentration data becomes available, remote sensing analysis of cyanobacteria could be investigated.

Overview of the Method

Chlorophyll-a concentrations were estimated using a remote sensing algorithm/model developed by the University of Massachusetts (Trescott 2012) for Lake Champlain. The model was calibrated and cross-validated using four years of in-situ chlorophyll-a measurements from fifteen locations on the lake. The samples were collected from the water surface to a depth equal to twice the Secchi depth.

Chlorophyll-a has a maximum spectral reflectance in the green wavelength (~560 nm) and absorbance peaks in the blue and red wavelengths (~450 nm & ~680 nm). There is an additional secondary reflectance peak in the near infrared spectrum at ~700 nm that was not incorporated in the University of Massachusetts study[1]. The model was then calibrated and cross-validated to field data collected within one day of the satellite overpasses using only images with clear skies. This was done to minimize the uncertainty and complexity with atmospheric correction for the satellite imagery. The chlorophyll-a model developed for Lake Champlain using Landsat 7 color bands is shown in Eq. 1.

$$Chla = -46.51 + 105.30\left(\frac{RB_{green}}{RB_{blue}}\right) - 40.39\left(\frac{RB_{red}}{RB_{blue}}\right) \qquad [Eq. 1]$$

The model has a coefficient of determination (R^2) of 0.78, which indicates that 78% of the variation in measured chlorophyll-a can be explained by Eq. 1. The relationship between measured and modeled chlorophyll-a concentrations for Lake Champlain is shown in **Figure C1**.

[1] The accuracy of the model could potentially be improved by incorporating data from the near infrared band.

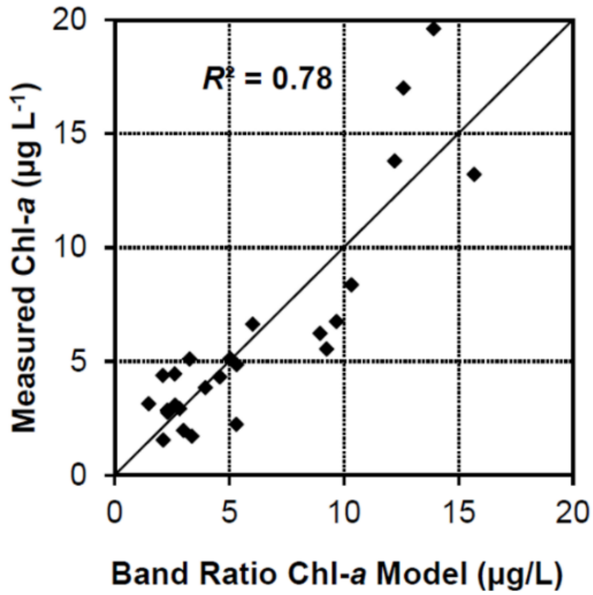


Figure C1. Measured and modeled chlorophyll-a concentrations for Lake Champlain, from Trescott 2012.

Application of the Method

Landsat 8 was launched in February 2013 and provides increased spectral and radiometric resolution compared to Landsat 7. In this study, Landsat 8 imagery were downloaded from the USGS website, Earth Explorer, for the months of May through October 2015 to 2017. These scenes were visually examined for extensive cloud cover and haze over the project lakes, discarding those that had 100% cloud coverage[2]. The selected images were processed to Top of Atmosphere (TOA) reflectance as per the Landsat 8 Data Users Handbook (USGS 2016). TOA reflectance reduces the variability between satellite scenes captured at different dates by normalizing the solar irradiance.

The TOA corrected images were processed using the chlorophyll-a model (Eq. 1) developed for Lake Champlain using Landsat 7 imagery (Trescott 2012). The blue, green, and red spectral bands are very similar for Landsat 7 and Landsat 8 and the model was used without adjustment.

The Landsat 8 Quality Assessment Band was used to remove areas designated as cloud or haze. However, this method is not able to remove the shadows of clouds that are seen in some of the images. Modeled chlorophyll-a concentrations may be lower in areas adjacent to cloud or haze due to less reflected lighted being received by the satellite sensors. The shadowed areas can be identified by their proximity, size, and shape relative areas of no data (clouds).

The modeled chlorophyll-a concentrations were clipped to the lake shorelines using a 100-m buffer of the National Hydrography Dataset (NHD) lake polygons. This step was

[2] NASA's quality assurance band algorithm was used to mask out clouds and cirrus (black/no data patches on figures).

used to exclude pixels that may overlap between land and water and possibly contain shoreline and shallow submerged aquatic vegetation. Landsat 8 spectral imagery is provided at a 30-m resolution.

A comparison of measured and modeled chlorophyll-a concentrations for five of the study lakes for 2016 and 2017 is shown in **Figure C2**. Based on the 22 field measurements that occurred within one day of the satellite imagery, the model appears to under estimate chlorophyll-a concentrations in some situations.

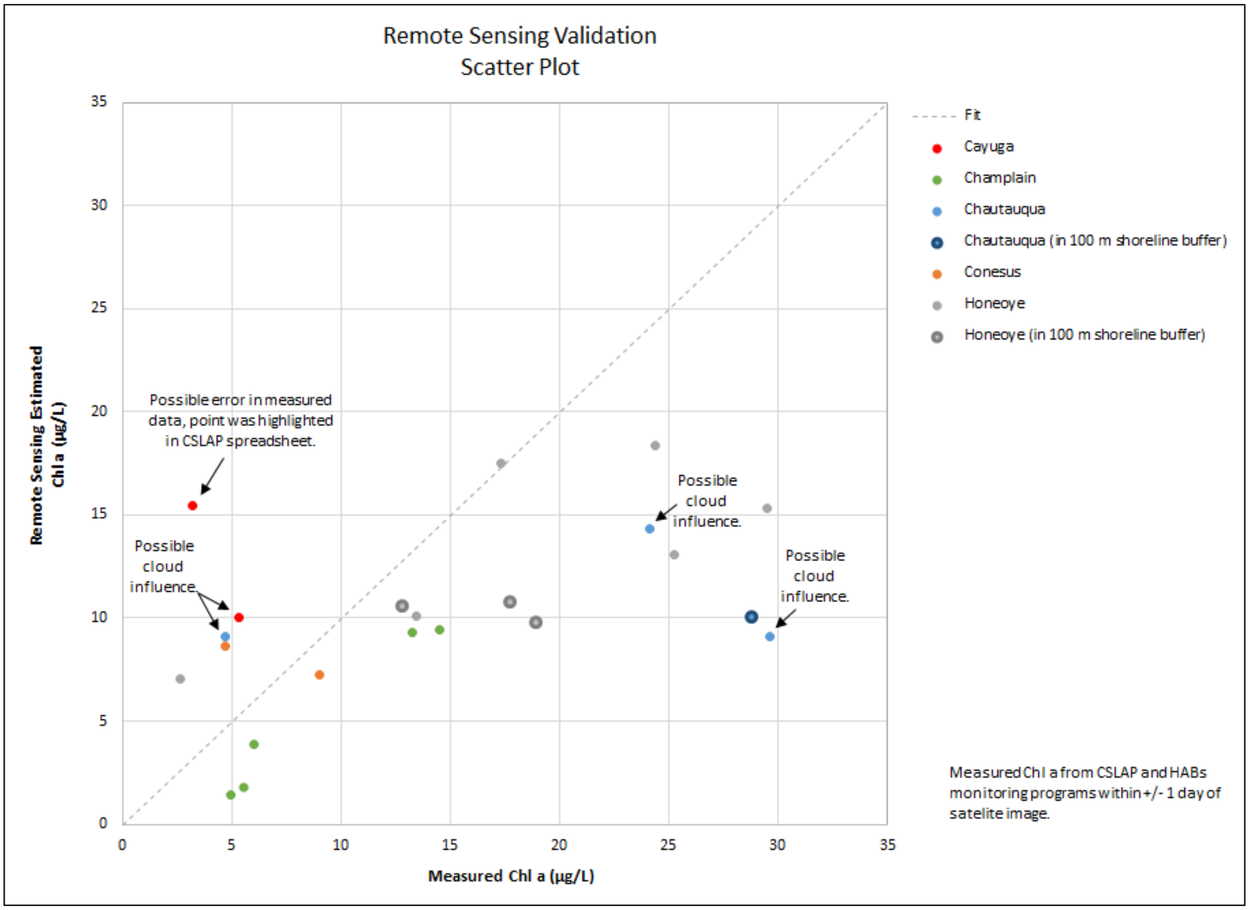


Figure C2. Measured and modeled chlorophyll-a concentrations for Cayuga Lake, Lake Champlain, Chautauqua Lake, Conesus Lake, and Honeoye Lake (2016-2017 data).

Limitations of the Method

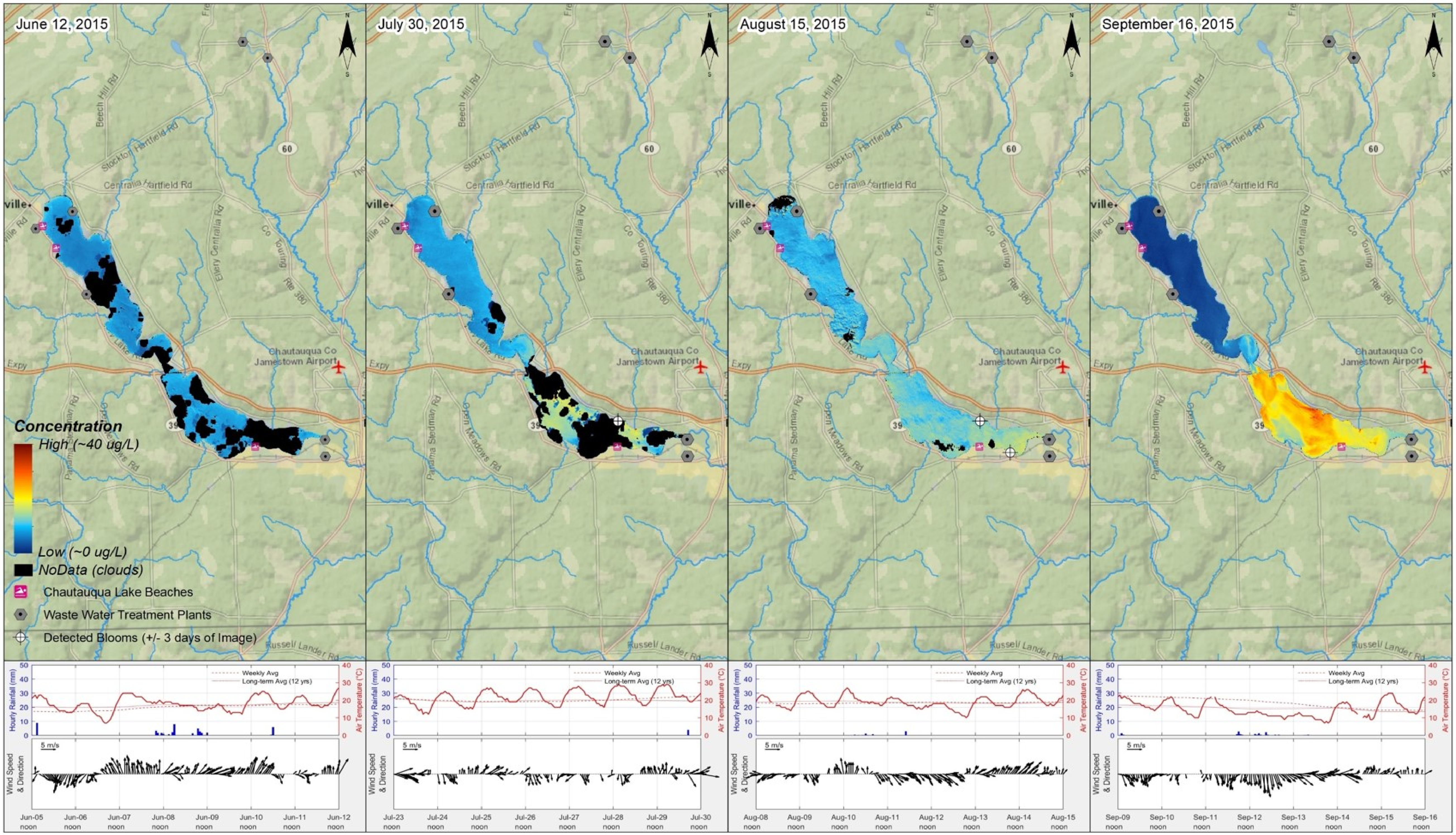
The remote sensing chlorophyll-a model was developed for Lake Champlain using four years of coincident in-situ chlorophyll-a measurements and Landsat 7 imagery. The model was calibrated and cross-validated using samples that were collected within one day of the satellite overpasses and imagery that was free of cloud and haze. The maximum in-situ chlorophyll-a concentration was 20 µg/L.

The method was applied to eight freshwater lakes in New York State (including Lake Champlain). These lakes have excess phosphorus loading from sources similar to Lake

Champlain, including agricultural runoff and septic systems. The method is expected to be most accurate under clear sky conditions and chlorophyll-a concentrations less than 20 µg/L (until validated for higher concentrations).

Further development and application of the method to New York State lakes should consider the following:

- The model estimates chlorophyll-a concentrations rather than HABs species directly. Remote sensing studies tend to use abnormally high chlorophyll-a concentrations as a first step in detecting possible HABs (Trescott 2012; USGS 2016).
- The model was developed for Lake Champlain and hasn't been fully validated for other New York State lakes. In the future, field sampling should be conducted on the dates of the Landsat 8 satellite overpasses for the lakes of interest.
- Different algae species may be present in the Lake Champlain calibration dataset than in the other New York State lakes. The model may be less accurate for the other lakes if different algae species are present.
- The model was calibrated using chlorophyll-a measurements taken within one day of the satellite overpasses as wind and precipitation are expected to change the composition of the algal blooms (Trescott 2012). Measurements greater than one day could potentially be used to validate the model for other lakes if winds were calm and there was no rain over the extended period.
- The model was developed using cloud and haze-free imagery. Estimated chlorophyll-a concentrations are expected to be less accurate when clouds and haze are present.
- The model was calibrated to depth-integrated chlorophyll-a measurements (from twice the Secchi depth to the water surface). Estimated chlorophyll-a concentrations are expected to compare better with measurements taken over the depth of light transmission (i.e. Secchi depth) than measurements taken from a predefined depth (e.g. CSLAP grab samples are collected at a water depth of 1.5 m).
- Estimated chlorophyll-a concentrations are expected to be less accurate in shallow water where light may be absorbed and reflected by submerged aquatic vegetation and the lake bed.
- The influence from turbidity caused by inorganic suspended solids on the modeled chlorophyll-a concentrations was not thoroughly investigated. However, it is unlikely to affect the results since there are distinct differences in the reflection pattern of chlorophyll-a versus inorganic turbidity (Karabult and Ceylan 2005).
- The estimated chlorophyll-a concentration from the nearest remote sensing pixel was used in the validation plot (**Figure C2**) because many of the measurements were near the shoreline. A 5-by-5 pixel averaging window was used previously for Lake Champlain (Trescott 2012) to filter the satellite noise and patchiness in the algae.



1:250,000

0 2 4 6 Miles

0 2 4 6 8 10 Kilometers

Plots

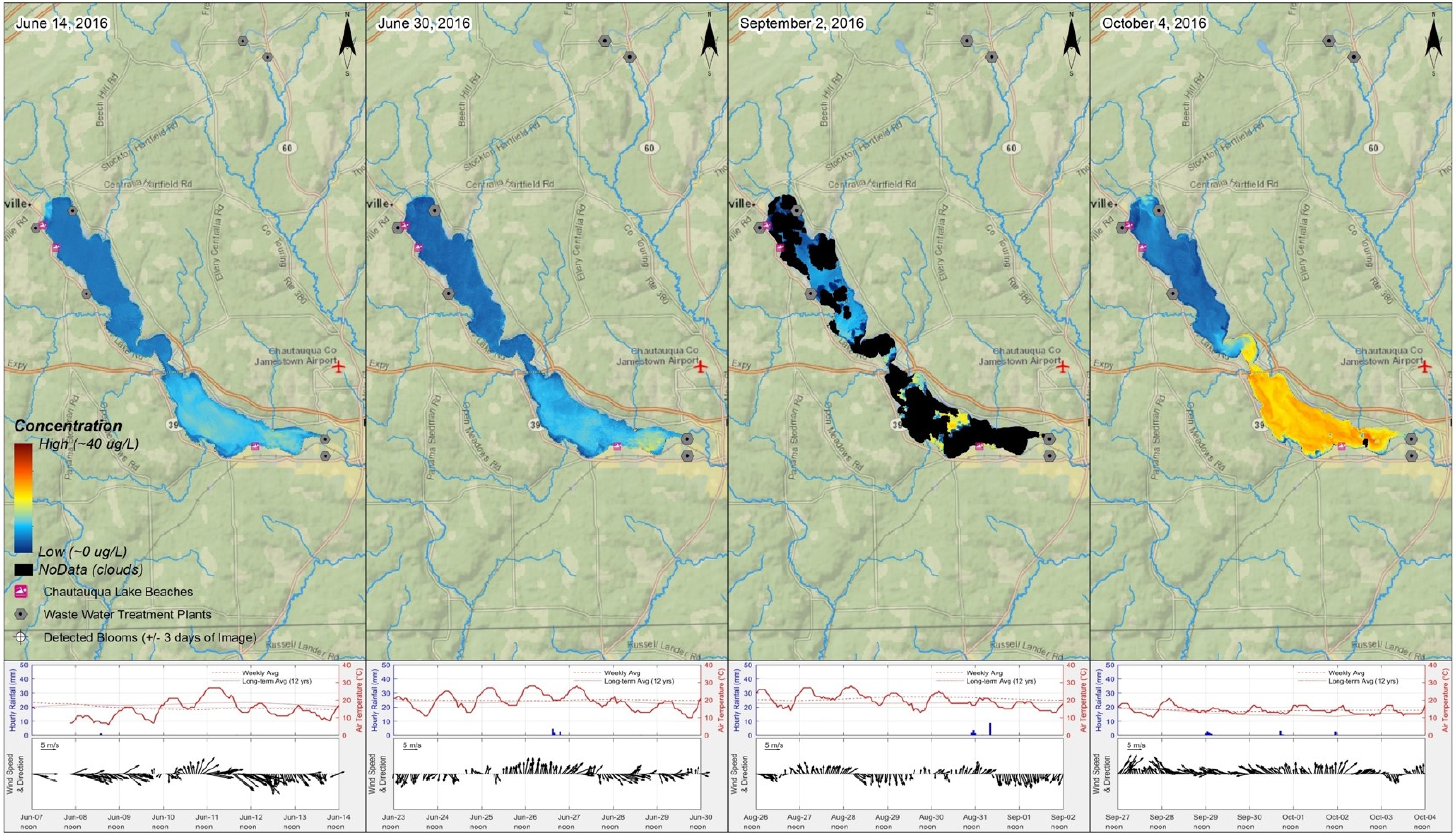
Plots show meteorological data 7 days prior to the satellite passing over the lake.

Satellite Derived Chlorophyll a

Chl-a Data is Derived from NASA's LandSat 8 Satellite
Data Gaps are Caused by Haze and Clouds

Disclaimer
These maps represent an estimate of chlorophyll-a concentration and are meant for discussion purposes to aid in management decisions and planning.

Basemap: National Geographic World Imagery Layer.
Spatial Reference: WGS 1984 UTM Zone 17N



1:250,000

0 2 4 6 Miles

0 2 4 6 8 10 Kilometers

Plots

Plots show meteorological data 7 days prior to the satellite passing over the lake.

Satellite Derived Chlorophyll a

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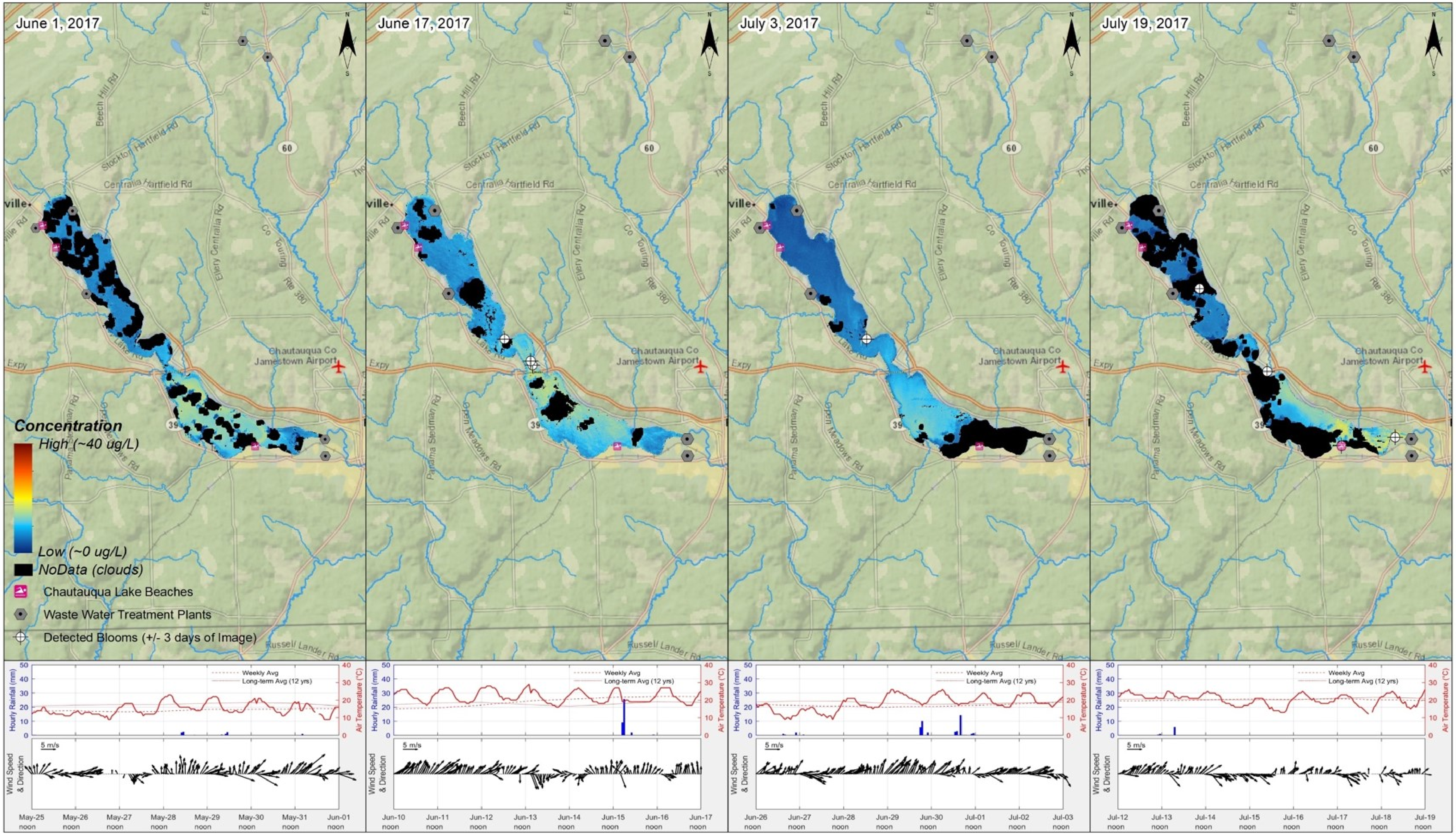
These maps represent an estimate of chlorophyll-a concentration and are meant for discussion purposes to aid in management decisions and planning.

Basemap: National Geographic World Imagery Layer.
Spatial Reference: WGS 1984 UTM Zone 17N



1:250,000

0 2 4 6 Miles

0 2 4 6 8 10 Kilometers

Plots

Plots show meteorological data 7 days prior to the satellite passing over the lake.

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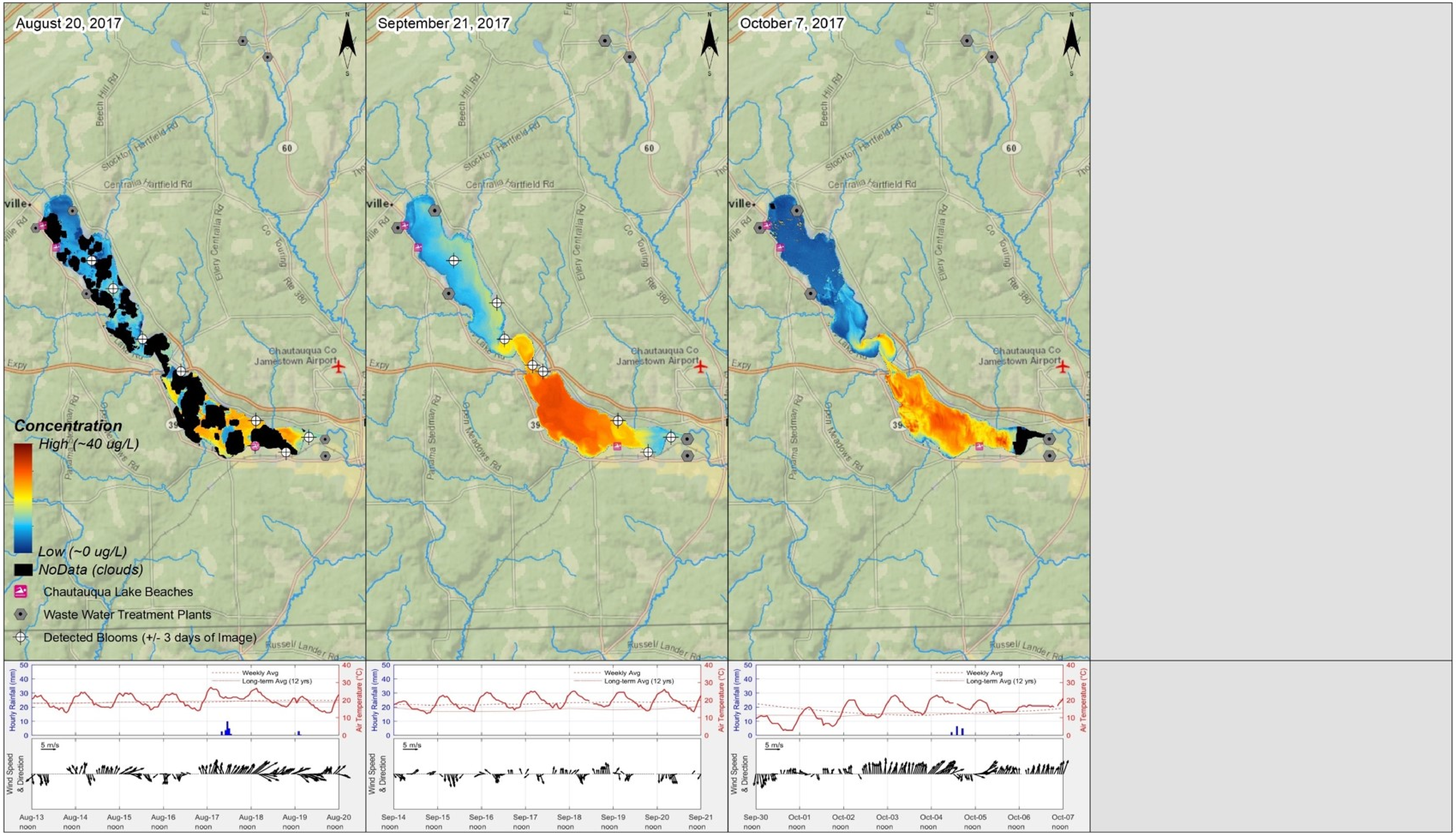
Spatial Reference: WGS 1984 UTM Zone 17N



1:250,000

0 2 4 6 Miles

0 2 4 6 8 10 Kilometers

Plots

Plots show meteorological data 7 days prior to the satellite passing over the lake.

Satellite Derived Chlorophyll a

Chl-a Data is Derived from NASA's LandSat 8 Satellite

Data Gaps are Caused by Haze and Clouds

Disclaimer

These maps represent an estimate of chlorophyll-a concentration and are meant for discussion purposes to aid in management decisions and planning.

Basemap: National Geographic World Imagery Layer.
Spatial Reference: WGS 1984 UTM Zone 17N

Appendix D. HABs History

Table 1. History of HABs in Chautauqua Lake, 2013-2017, South Basin.										
Date	**Bloom extent**	**HAB Status**	**Bloom location**	**Chl-a (µg/L)**	**Daily avg. air temp (ºC)**	**Water Temp (ºC)**	**Daily rainfall (mm)**	**10-day total rainfall (mm)**	**Max daily wind speed (m/s)**	**Water Quality Data**
7/15/2013	NR	C	Shore	272.16	24.3	NA	0	23.5	4.1	NA
8/3/2013	NR	C	Shore	1346.3	18.3	NA	0.8	3.9	6.2	NA
8/5/2013	NR	C	Shore	10186.0	14.6	NA	0	3.9	4.6	NA
8/12/2013	NR	C	Shore	170.4	16.8	NA	0.5	9.2	4.1	NA
8/21/2013*	NR	C/HT	Shore	128.61-12167.0	19.7	NA	0	19.8	3.6	NA
8/25/2013*	NR	C/HT	Shore	42.5-66.6	18.2	NA	0	0	5.7	Available
8/26/2013	NR	C	Shore	66.1	20.8	NA	4.9	4.9	6.7	NA
8/28/2013	NR	C	Shore	3545	21.2	NA	6.1	12.6	4.1	NA
8/29/2013*	NR	C/HT	Shore	73.1-213.9	22.1	NA	0	12.6	4.1	NA
9/2/2013*	NR	C/HT	Shore	85.4-2460.0	20.2	NA	5.1	19.3	5.7	Available
9/3/2013	NR	C	Shore	29.4	14.2	NA	1.1	20.4	5.7	NA
9/25/2013	NR	C/HT	Shore	169.2	10.9	NA	0	30.2	4.1	NA
9/28/2013	NR	C/HT	Shore	39.9	14.5	NA	0	26.7	4.6	Available
6/30/2014	NR	C	Shore	111.0	22.2	NA	0.3	0.6	6.2	NA
7/20/2014	LL	C	Shore	4316.25	18	NA	2.6	40.8	4.1	Available
7/21/2014*	NR	C	Shore	81.6-20893.8	20.2	NA	0	40.8	4.6	NA
8/3/2014*	NR	C	Shore	47.2-5239.0	17.7	NA	2.2	56.8	3.1	Available
8/4/2014	NR	C	Shore	53.1	18.5	NA	0	56.8	4.1	NA
8/6/2014	NR	C	Shore	241.1	17.5	NA	0.5	73	5.1	NA
8/10/2014	NR	C	Shore	81.3	18.9	NA	0	37.8	3.6	NA
8/11/2014	NR	C	Shore	158.8	20.1	NA	0	37.8	7.2	NA
8/17/2014	LL	C	Shore	44.37	16.4	NA	6.6	38.5	5.1	Available
8/18/2014	NR	C	Shore	54.2	15.8	NA	0	38.5	3.6	NA
8/21/2014	NR	C	Shore	250.0	20.1	NA	0	40.3	6.2	NA
8/24/2014	NR	C	Shore	48.8	18.7	NA	0	8.4	4.1	NA
8/27/2014	NR	C	Shore	2005.5	21.4	NA	0	1.8	6.7	NA
9/1/2014*	WL, LL	C/HT	Shore	1305.5-6935.0	21	NA	0	53.9	5.1	Available
9/2/2014*	NR	C/HT	Shore	98717.5-210100.0	21	NA	18.8	72.7	6.7	NA
9/22/2014	NR	C	Shore	103.6	9.3	NA	1.1	15.7	9.8	NA

7/27/2015	NR	C	Shore	58.38	21.7	NA	0	0	4.1	NA
8/4/2015	NR	C	Shore	74.33	19	NA	0	3.8	6.7	NA
8/6/2015*	NR	C	Shore	101.38-1102.5	15.5	NA	0	3.8	4.6	NA
8/10/2015*	NR	C	Shore	40.88-261.22	20.4	NA	0.5	0.5	5.7	NA
8/17/2015*	NR	C/HT	Shore	58.59-67.98	22.2	NA	0	6.8	3.6	NA
8/23/2015	LL	C	Shore	448.75	17.7	24	0	23.8	4.6	Available
8/26/2015	NR	C/HT	Shore	226.04	13.8	NA	2.1	26.2	6.7	NA
8/28/2015	NR	C/HT	Shore	5228.75	14.7	NA	0	22.3	4.1	NA
8/31/2015*	NR	C/HT	Shore	62.17-8817.5	21.3	NA	0	2.4	6.7	NA
9/2/2015*	NR	C/HT	Shore	38.49-271.75	21.6	NA	0	2.4	4.6	NA
9/7/2015	LL	C/HT	Shore	241.05	23	19	0	2.5	6.2	Available
9/8/2015*	NR	C/HT	Shore	72.39-1539.5	23.6	NA	0	2.5	5.1	NA
7/11/2016*	NR	C	Shore	89.72-393.36	19.5	NA	0	23.3	4.6	NA
7/25/2016*	NR	C	Shore	47.77-57.4	22.5	NA	9.7	16.3	6.7	NA
7/27/2016*	NR	C	Shore	202.25-3217.0	21.3	NA	0	16.3	4.6	NA
8/1/2016*	NR	C	Shore	44.58-127.77	20.5	NA	0	20.3	5.1	NA
8/8/2016*	NR	C	Shore	60.42-147.49	19.8	NA	0	13.4	4.6	NA
8/11/2016*	NR	C	RT	32.5-84.95	22.7	NA	12.7	53.8	6.7	NA
8/15/2016*	NR	C/HT	Shore	37.76-93087.5	20.5	NA	0	61.3	4.1	NA
8/23/2016*	NR	C/HT	RT	50.97-1359.8	16.8	NA	0	52.6	4.6	NA
8/29/2016*	NR	C	Shore	32.5-11710.0	21.5	NA	0	21.9	5.1	NA
9/6/2016*	NR	C/HT	Shore	62.02-1538.75	20.8	NA	0	16.2	4.6	NA
10/17/2016*	NR	C	Shore	60.12-3729.0	17.6	NA	1.4	16.7	6.2	NA
6/19/2017	NR	C	Shore	1001.67	16.1	NA	5.3	82.7	8.8	NA
7/14/2017	NR	C	Shore	26437.5	22.4	NA	0	30.7	6.2	NA
7/17/2017	NR	C	Shore	57.3	20.3	NA	0	30.7	7.2	NA
7/19/2017*	NR, LL	C	Shore	147.3-1874.5	21.6	NA	0	14.9	6.2	NA
7/23/2017	LL	C	Shore	17587.5	21	28	2	2	6.7	Available
7/24/2017	NR	C	Shore	52.8	19.7	NA	0	2	8.2	NA
7/27/2017	WL	C	Shore	32350.0	19.5	NA	0	3.1	4.6	NA
7/31/2017*	NR	C/HT	Shore	94.8-1914.0	20.9	NA	0	3.1	6.2	NA
8/6/2017	WL	C	Shore	103.5	15.3	25	0	0	5.7	Available
8/7/2017*	NR	C/HT	Shore	70.9-13625.0	17.6	NA	0	0	5.7	NA
8/12/2017	NR	C	Shore	22543.8	18.5	NA	0	1	7.2	NA
8/14/2017*	NR	C	Shore	206.3-579.0	18.5	NA	0	1	4.1	NA
8/21/2017*	NR	C	Shore	42.4-3451.0	21.3	NA	5.6	31.5	4.6	NA
8/28/2017*	NR	C	Shore	32.2-3922.8	16.6	NA	0	29.8	7.2	NA
9/5/2017*	NR	C	Shore	35.6-190.3	17.3	NA	16.3	49.1	7.7	NA

9/11/20017*	NR	C	Shore	34.6-44.9	19.2	NA	0	51.4	3.6	NA
9/18/2017*	NR	C	Shore	81.81-3893.5	19.8	NA	0	46.1	4.1	NA
10/14/2017*	NR	C/HT	Shore	141.54-134.5	15.5	NA	3.8	62.5	5.1	NA
10/16/2017	NR	C	Shore	30.25	7.7	NA	0.3	55.3	9.3	NA

NOTES:
* = multiple samples collected on day
NA = Not Available
Bloom extent: LL = large localized, WL = widespread/lakewide, NR = not reported
HAB Status: S = suspicious, C = Confirmed, C/HT = Confirmed with High Toxins
Location: Shore = shoreline, OW = open water, RT = Report of bloom (usually not sampled)
Chlorophyll-a concentrations quantified with fluoroprobe

Table 2. History of HABs in Chautauqua Lake, 2012-2017, North Basin.

Date	Bloom extent	HAB Status	Bloom location	Chl-a (µg/L)	Daily avg. air temp (ºC)	Water Temp (ºC)	Daily rainfall (mm)	10-day total rainfall (mm)	Max daily wind speed (m/s)	Water Quality Data
8/13/2012	NR	C/HT	Shore	3324.0	17.7	NA	0	14.1	4.1	NA
9/7/2012	NR	C/HT	Shore	16285.0	20.2	NA	0	10.5	5.7	NA
9/30/2012	NR	C/HT	Shore	1123.0	10.1	NA	0	21.7	5.1	Available
6/26/2013	NR	C	Shore	140.8	19.8	NA	0.8	0.8	5.7	NA
7/15/2013*	NR	C/HT	Shore	1982.0-19405.0	24.3	NA	0	23.5	4.1	NA
7/16/2013*	NR	C	Shore	1026.0-3106.0	24.6	NA	0	23.5	4.6	NA
8/3/2013	NR	C	Shore	460.0	18.3	NA	0..8	3.9	6.2	NA
8/5/2013	NR	C	Shore	1443.0	14.6	NA	0	3.9	4.6	NA
8/8/2013*	NR	C	Shore	41.1-333.8	20.8	NA	7.9	10.2	4.6	NA
8/9/2013*	NR	C	Shore	329.2-31035.0	20.2	NA	0	10.2	4.1	NA
8/11/2013*	NR	C/HT	Shore	693.3-38427.5	16.9	NA	0	8.7	4.1	NA
8/26/2013*	NR	C/HT	Shore	65.9-124.5	20.8	NA	4.9	4.9	6.7	NA
8/29/2013*	NR	C/HT	Shore	42.8-465.0	22.1	NA	0	12.6	4.1	NA
9/2/2013	NR	C/HT	Shore	47.6	20.2	NA	5.1	19.3	5.7	NA
9/4/2013*	NR	C/HT	Shore	34.1-979.3	15.4	NA	0	20.4	7.7	NA
9/5/2013*	NR	C/HT	Shore	45.6-100.5	15.6	NA	0.8	16.3	6.7	NA
9/10/2013*	NR	C/HT	Shore	59.5-84.0	21.4	NA	0	18.7	7.7	NA
9/18/2013	NR	C/HT	Shore	55.6	12.5	NA	0	13.3	4.1	NA
9/25/2013	NR	C/HT	Shore	54.7	10.9	NA	0	30.2	4.1	NA
10/15/2013	NR	C/HT	Shore	64.8	10.7	NA	0	26.8	5.1	NA
11/2/2013	NR	C	Shore	1763.5	7	NA	2.7	35.6	6.2	NA

11/4/2013	NR	C	Shore	270.5	-1.2	NA	0	24.5	4.1	NA
11/11/2013	NR	C	Shore	13607.5	2.5	NA	0	9.9	9.3	NA
7/21/2014	NR	C	Shore	65.9	20.2	NA	0	40.8	4.6	NA
7/29/2014*	NR	C	Shore	39.1-1199.8	13.9	NA	0	20.8	5.1	NA
8/3/2014*	NR	C	Shore	71.68-159.31	17.7	NA	2.2	56.8	3.1	Available
8/4/2014*	NR	C	Shore	29.4-96.6	18.5	NA	0	56.8	4.1	NA
8/6/2014*	NR	C	Shore	31.2-194.8	17.5	NA	0.5	73	5.1	NA
8/11/2014*	NR	C	Shore	37.5-281.1	20.1	NA	0	37.8	7.2	NA
8/18/2014*	NR	C	Shore	53.2-170056.3	15.8	NA	0	38.5	3.6	NA
8/21/2014*	NR	C	Shore	29.0-635.0	20.1	NA	0	40.3	6.2	NA
8/24/2014	NR	C	Shore	185.8	18.7	NA	0	8.4	4.1	NA
8/27/2014*	NR	C/HT	Shore	246.2-3139.0	21.4	NA	0	1.8	6.7	NA
9/1/2014	NR	C	Shore	129.64	21	20	0	53.9	5.1	Available
9/2/2014*	NR	C	Shore	56.4-39200.0	21	NA	18.8	72.7	6.7	NA
9/7/2014	NR	C	Shore	7911.0	13.5	NA	0	77.7	4.1	NA
9/8/2014	NR	C	Shore	36.6	15	NA	0	77.7	7.2	NA
9/22/2014	NR	C	Shore	144.4	9.3	NA	1.1	15.7	9.8	NA
9/27/2014	NR	C/HT	Shore	4641.25	14.3	NA	0	8.8	3.1	NA
7/1/2015	NR	C	Shore	167.5	16.9	NA	33.7	93.7	7.7	NA
7/6/2015	NR	S	Shore	7.99	20.4	NA	0	79.4	4.1	NA
8/4/20015	NR	C	Shore	6.78	19	NA	0	3.8	6.7	NA
8/10/2015	NR	C	Shore	24.85	20.4	NA	0.5	0.5	5.7	NA
8/31/2015*	NR	C	Shore	66.72-170.5	21.3	NA	0	2.4	6.7	NA
8/11/2016*	NR	C	RT	518.75-57262.5	22.7	NA	12.7	53.8	6.7	NA
8/15/2016*	NR	C	Shore	160.95-299.0	20.5	NA	0	61.3	4.1	NA
8/23/2016*	NR	C/HT	RT	1172.25-2295.5	16.8	NA	0	52.6	4.6	NA
8/29/2016	NR	C	Shore	299.0	21.5	NA	0	21.9	5.1	NA
9/6/2016*	NR	C	Shore	52.25-160.5	20.8	NA	0	16.2	4.6	NA
9/26/2016*	NR	C/HT	Shore	61.72-157.54	13.1	NA	3.1	53.1	5.7	NA
10/17/2016	NR	C/HT	Shore	51656.25	17.6	NA	1.4	16.7	6.2	NA
6/19/2017*	NR	C	Shore	58.46-62.43	16.1	NA	5.3	82.7	8.8	NA
7/3/2017	NR	C	Shore	28.84	19.6	NA	0	63	6.7	NA
7/13/2017	LL	C	Shore	833.5	22.3	NA	7.3	30.7	6.2	NA
7/19/2017	NR	C	Shore	2416.3	21.6	NA	0	14.9	6.2	NA
8/2/2017	NR	C	Shore	98.8	23.1	NA	0	1.1	4.6	NA
8/7/2017*	NR	C	Shore	60.1-603.3	17.6	NA	0	0	5.7	NA
8/14/2017*	NR	C	Shore	78.2-855.3	18.5	NA	0	1	4.1	NA
8/20/2017*	WL	C	Shore	29.6-6686.0	18.4	22	0	26.9	4.6	Available

8/21/2017	NR	C	Shore	52.6	21.3	NA	5.6	31.5	4.6	NA
8/28/2017*	NR	C/HT	Shore	41.6-3364.0	16.6	NA	0	29.8	7.2	NA
9/5/2017*	NR	C/HT	Shore	140.5-1804.8	17.3	NA	16.3	49.1	7.7	NA
9/11/2017*	NR	C/HT	Shore	4812.5-15175.0	19.2	NA	0	51.4	3.6	NA
9/17/2017	NR	C	Shore	34.96	19.7	19	0	58.6	3.1	Available
9/18/2017*	NR	C	Shore	394.5-4134.5	19.8	NA	0	46.1	4.1	NA
10/14/2017*	NR	C/HT	Shore	93.25-195.75	15.5	NA	3.8	62.5	5.1	NA
10/30/2017*	NR	C	Shore	35.35-64.25	3.9	NA	0	0	9.8	NA

NOTES:
* = multiple samples collected on day
NA = Not Available
Bloom extent: LL = large localized, WL = widespread/lakewide, NR = not reported
HAB Status: S = suspicious, C = Confirmed, C/HT = Confirmed with High Toxins
Location: Shore = shoreline, OW = open water, RT = Report of bloom (usually not sampled)
Chlorophyll-a concentrations quantified with fluoroprobe

Appendix E. WI/PWL Summary

Chautauqua Lake, North (0202-0072) Impaired

Waterbody Location Information

Revised: 05/01/2018

Water Index No:	Pa-63-13- 4-P122 (portion 2)	**Water Class:**	A
Hydro Unit Code:	Chautauqua Lake (0501000202)	**Drainage Basin:**	Allegheny River
Water Type/Size:	Lake/Reservoir 7082.7 Acres	**Reg/County:**	9/Chautauqua (7)
Description:	portion of lake, north of Bemus Point		

Water Quality Problem/Issue Information

Uses Evaluated	**Severity**	**Confidence**
Water Supply	Impaired	Known
Public Bathing	Impaired	Known
Recreation	Impaired	Known
Aquatic Life	Stressed	Suspected
Fish Consumption	Unassessed	-
Conditions Evaluated		
Habitat/Hydrology	Fair	
Aesthetics	Poor	

Type of Pollutant(s) (CAPS indicate Major Pollutants/Sources that contribute to an Impaired/Precluded Uses)

Known: ALGAL/PLANT GROWTH, NUTRIENTS (PHOSPHORUS)
Suspected: ---
Unconfirmed: Metals (arsenic)

Source(s) of Pollutant(s)

Known: Agriculture, Hab/Hyd Mod, Internal Loading, Municipal Discharges,
Suspected: On-Site/Septic Syst
Unconfirmed: ---

Management Information

Management Status: Strategy Implementation Scheduled or Underway
Lead Agency/Office: DOW/Reg9
IR/305(b) Code: Impaired Water, TMDL Completed (IR Category 4a)
Impaired Water, Pollution not a Pollutant (IR Category 4c)

Further Details

Overview

Chautauqua Lake, North is assessed as an impaired waterbody due to primary and secondary contact recreation uses that are known to be impaired by nutrients (phosphorus), excessive algae, and excessive plant growth. The most significant sources of nutrient loading to the lake include internal loads – the result of years of nutrient loading that resides in lake sediments – and nutrients transported to the lake via groundwater inflow. Other sources include wastewater point sources, agricultural sources and onsite septic systems.

Use Assessment

This portion of the Lake is a Class A waterbody, required to support and protect the best uses as a water supply source for drinking, culinary or foood processing purposes, primary and secondary contact recreation and fishing.

Evaluation of the use of Chautauqua Lake, North for public water supply includes conditions of the lake water prior to treatment, not the quality of water distributed for use after treatment. Monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. Water supply use in the waterbody is considered to be impaired by elevated nutrient and chlorophyll levels in the lake that result in the formation of disinfection by-products (DBPs) in finished potable water and make treatment to meet drinking water standards more difficult. DBPs are formed when disinfectants such as chlorine used in water treatment plants react with natural organic matter (i.e., decaying vegetation) present in the source water. Prolonged exposure to DBPs may increase the risk of certain health effects. The Chautauqua Water District #2 has reported levels of specific DBPs – THMs and haloacetic acids – in excess of regulatory limits during a portion of the year. (DEC/DOW, BWAM and NYSDOH, Public Water Supply, December 2014)

Primary and secondary contact reacreational uses are considered to be impaired by elevated nutrients (phosphorus), excessive algae, and poor water clarity. These uses are also impaired by the frequent closure of several beaches (more than 10 days of beach closures in 2017 and more than 100 days in 2014) by the county health department due to harmful algal blooms (HABs), and by persistent HABs with elevated toxin levels along the shoreline. Secondary contact recreation (boating, fishing) is also affected by excessive aquatic vegetation and the presence of invasive plant growth (Eurasian watermilfoil, curly leafed pondweed, water chestnut, and brittle naiad). Aesthetic conditions of the lake are considered to be poor due to excessive algae, shoreline algal blooms and excessive aquatic vegetation. (DEC/DOW, BWAM/CSLAP, July 2013)

There are no known restrictions to fishing use. Concerns have been noted regarding hypolimnetic oxygen depletion impacts on aquatic life support, however tiger muskie and walleye have been stocked by NYSDEC, and the lake provides a good smallmouth bass and largemouth bass fishery. While it is likely that zebra mussels affect phytoplankton (algae and cyanobacteria) dynamics in the lake, the effect of these invasive mussels on other aquatic life is not known. Asian clam, common carp, gold fish, and Allegheny crayfish are invasive species also found in the lake, potentially threatening aquatic life (DEC/DFWMR, Region 9, January 2007; DEC/DOW, BWAM/LMAS, April 2018)

Fish Consumption use is considered to be unassessed. There are no health advisories limiting the consumption of fish from this waterbody (beyond the general advice for all waters). However due to the uncertainty as to whether the lack of a waterbody-specific health advisory is based on actual sampling, fish consumption use is noted as unassessed. (NYS DOH Health Advisories and DEC/DOW, BWAM, April 2018)

Water Quality Information

Water quality monitoring of Chautauqua Lake has been conducted by multiple agencies, researchers, and academic institutions. The north basin of Chautauqua Lake has been sampled as part of the NYSDEC Citizens Statewide Lake Assessment Program (CSLAP) from 1987 through 2017. CSLAP data indicate that the lake continues to be best characterized as eutrophic, or highly productive. Phosphorus levels, though generally lower than in the South Basin, still consistently exceed the state guidance values of 20 µg/l, and chlorophyll a levels are also very high for much of the summer season.

Lake clarity is rarely restricted, with water transparency most often above minimally recommended levels for swimming beaches to protect swimmers safety. Readings of pH occasionally exceed the state water quality standards for protection of aquatic life, most likely in response to elevated algae levels. (NYS DEC/DOW, BWAM/CSLAP, April 2018)

The NYSDEC HABs Notification program confirmed the presence of HABs in Chautauqua Lake during the recreational seasons of 2012 through 2017, with widespread blooms commonly reported in both lake basins in each year. In 2017, Chautauqua Lake was on the HABs Notification List for 18 weeks. The blooms observed in 2017 were localized and did become widespread at certain times. Elevated levels of *Microcystin* were found in each year from at least 2012 to 2017. (NYS DEC/DOW, BWAM/LMAS, April 2018)

The public beaches throughout the lake are regularly monitored and evaluated by the Chautauqua County Department of Health. Aquatic plant surveys are regularly conducted by Racine-Johnson Aquatic Ecologists.

Source Assessment

Nutrient (phosphorus) sources to the lake were identified in the 2012 Chautauqua Lake Phosphorus TMDL. The TMDL indicates that wastewater point sources, agricultural activities, and onsite wastewater treatment (septic) systems are more significant sources of the phosphorus load than is the case in the south basin. Internal loading of nutrients is also significantly less in the north basin. Groundwater inflow load is similar for both basins, but makes up a greater percentage (one-third) of the load in the north basin. (NYS DEC/DOW, BWRM, TMDL for Phosphorus in Chautauqua Lake, November 2012)

Management Actions

This waterbody is considered a highly-valued water resource due to its drinking water supply classification and as a multi–use waterbody. On December 21, 2017, New York State Governor Andrew Cuomo announced a $65 million initiative to combat harmful algal blooms in Upstate New York. Chautauqua Lake was identified for inclusion in this initiative as it is vulnerable to HABs. (NYS DEC/DOW, BWRM, April 2018).

Recommendations for specific sources of nutrients loads to the Lake are outlined in the Chautauqua Lake Phosphorus TMDL. In addition, Chautauqua County prepared an extensive *State of the Lake Report* in May 2000 and followed it up with a *Lake Management Report* later that year. These reports outline a range of options and recommendations to address sources of water quality impacts to the lake. These include management of aquatic vegetation through in lake measures (harvesting, herbicide use), the need to maintain wastewater treatment (on site septics and sewered areas) to protect the uses of the lake, and erosion controls to address wet weather/stormwater runoff that contributes silt/sediment and nutrients to the lake. These reports also recognize the need to address development pressures in the basin that will also impact water quality in the lake. (NYS DEC/DOW, BWRM, TMDL for Phosphorus in Chautauqua Lake, November 2012 and Chautauqua Lake Entering the 21st Century: State of the Lake Report, Chautauqua County Department of Planning and Development, May 2000 and The Management of Chautauqua Lake and its Watershed, Chautauqua County, November 2000).

Section 303(d) Listing

The northern portion of Chautauqua Lake is not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. Although it is assessed as an impaired water, it is categorized as an IR Category 4a water that is not listed due to the completion of the phosphorus TMDL in 2012. The segment is also categorized as an IR Category 4c water due to impairments caused by algal and weed growth. (NYS DEC/DOW, BWAM/WQAS, April 2018)

Segment Description

This segment includes the total area of the north basin of the lake. The north basin includes waters of the lake north of Bemus Point.

Chautauqua Lake, South (0202-0020) — Impaired

Waterbody Location Information

Revised: 05/01/2018

Water Index No:	Pa-63-13- 4-P122 (portion 1)	**Water Class:**	A
Hydro Unit Code:	Chautauqua Lake (0501000202)	**Drainage Basin:**	Allegheny River
Water Type/Size:	Lake/Reservoir 6081.2 Acres	**Reg/County:**	9/Chautauqua (7)
Description:	portion of lake, south of Bemus Point		

Water Quality Problem/Issue Information

Uses Evaluated	**Severity**	**Confidence**
Water Supply	Impaired	Known
Public Bathing	Impaired	Known
Recreation	Impaired	Known
Aquatic Life	Stressed	Suspected
Fish Consumption	Unassessed	-
Conditions Evaluated		
Habitat/Hydrology	Fair	
Aesthetics	Poor	

Type of Pollutant(s) (CAPS indicate Major Pollutants/Sources that contribute to an Impaired/Precluded Uses)

Known: ALGAL/PLANT GROWTH, NUTRIENTS (PHOSPHORUS), PROBLEM SPECIES, Nutrients (nitrogen)
Suspected: ---
Unconfirmed: Metals (Arsenic)

Source(s) of Pollutant(s)

Known: AGRICULTURE, HAB/HYD MOD, Internal Loading
Suspected: On-Site/Septic Syst, Municipal Discharges
Unconfirmed: ---

Management Information

Management Status: Strategy Implementation Scheduled or Underway
Lead Agency/Office: DOW/Reg9
IR/305(b) Code: Impaired Water, TMDL Completed (IR Category 4a, 4c)

Further Details

Overview

Chautauqua Lake, South is assessed as an impaired waterbody due to primary and secondary contact recreation uses that are known to be impaired by nutrients (phosphorus), excessive algae, and excessive plant growth. The most significant sources of nutrient loading to the lake include internal loads – the result of years of nutrient loading that resides in lake sediments – and nutrients transported to the lake via groundwater inflow. Other sources include wastewater point sources that for the most part originate in the North Basin of the Lake, agricultural sources and onsite septic systems.

Use Assessment

This portion of the Lake is a Class A waterbody, required to support and protect the best uses as a water supply source for drinking, culinary or foood processing purposes, primary and secondary contact recreation, and fishing.

Evaluation of potable water use includes conditions of the lake water prior to treatment, as well as the quality of water distributed for use after treatment. Monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. Water supply use in the waterbody is considered to be impaired by elevated nutrient and chlorophyll levels in the lake that may result in the formation of disinfection by-products (DBPs) in finished potable water and make treatment to meet drinking water standards more difficult. DBPs are formed when disinfectants such as chlorine used in water treatment plants react with natural organic matter (i.e., decaying vegetation) present in the source water. Prolonged exposure to DBPs may increase the risk of certain health effects. There are currently no public water supplies drawing water from this portion of the Lake. However the Chautauqua Water District #2 reported levels of specific DBPs – THMs and haloacetic acids – in excess of regulatory limits during a portion of the year and it is reasonable to assume similar conditions would occur in the South Basin of the Lake. (NYS DEC/DOW, BWAM and NYSDOH, Public Water Supply, December 2014)

Primary and secondary contact reacreational uses are considered to be impaired by elevated nutrients (phosphorus), excessive algae, and poor water clarity. These uses are also impaired by the frequent closure of several beaches by the county health department (more than 100 days of beach closures in 2017 in the south basin) due to harmful algal blooms. Non-contact recreation (boating, fishing) is also affected by excessive aquatic vegetation and the presence of invasive plant growth (Eurasian watermilfoil, curly leafed pondweed). Aesthetic conditions of the lake are considered to be poor due to excessive algae, shoreline algal blooms and excessive aquatic vegetation. (NYS DEC/DOW, BWAM/CSLAP, July 2013)

There are no known restrictions to aquatic life. Concerns have been noted regarding hypolimnetic oxygen depletion impacts on aquatic life support, however tiger muskie and walleye have been stocked by NYSDEC, and the lake provides a good smallmouth bass and largemouth bass fishery. While it is likely that zebra mussels affect phytoplankton (algae and cyanobacteria) dynamics in the lake, the effect of these invasive mussels on other aquatic life is not known. Asian clam, common carp, gold fish, and Allegheny crayfish are invasive species also found in the lake, potentially threatening aquatic life (NYS DEC/DFWMR, Region 9, January 2007; NYS DEC/DOW, BWAM/LMAS, April 2018)

Fish Consumption use is considered to be unassessed. There are no health advisories limiting the consumption of fish from this waterbody (beyond the general advice for all waters). However due to the uncertainty as to whether the lack of a waterbody-specific health advisory is based on actual sampling, fish consumption use is noted as unassessed. (NYS DOH Health Advisories and NYS DEC/DOW, BWAM, April 2018)

Water quality monitoring by NYSDEC lakes programs focuses primarily on the support of general recreation and aquatic life. Samples to evaluate the bacteriological condition and bathing use of the lake, or to evaluate contamination from organic compounds, metals or other inorganic pollutants are not usually collected as part of these monitoring programs. Monitoring to assess public bathing use and assessments of restrictions on fish consumption are generally the responsibility of state and/or local health departments.

Water Quality Information

Water quality monitoring of Chautauqua Lake has been conducted by multiple agencies, researchers, and academic institutions. The south basin of Chautauqua Lake has been sampled as part of the NYSDEC Citizens Statewide Lake Assessment Program (CSLAP) from 1991 through 2017. CSLAP data indicate that the lake continues to be best characterized as eutrophic, or highly productive. Phosphorus levels in the lake consistently exceed the state guidance values of 20 µg/l, and chlorophyll a levels are also very high for much of the summer season. Lake clarity is frequently restricted, with water transparency most often at or below minimally recommended levels for swimming beaches to protect swimmers safety. Readings of pH occasionally exceed the state water quality standards for protection of aquatic life, most likely in response to elevated algae levels. (NYS DEC/DOW, BWAM/CSLAP, April 2018)

The NYSDEC HABs Notification program confirmed the presence of HABs in Chautauqua Lake during the recreational seasons of 2012 through 2017, with widespread blooms commonly reported in both lake basins in each year. In 2017, Chautauqua Lake was on the HABS Notification List for 18 weeks. The blooms observed in 2017 were localized and did become widespread at certain times. Elevated levels of *Microcystin* were found in each year from at least 2012 to 2017. (NYS DEC/DOW, BWAM/LMAS, April 2018)

The public beaches throughout the lake are regularly monitored and evaluated by the Chautauqua County Department of Health. Aquatic plant surveys are regularly conducted by Racine-Johnson Aquatic Ecologists.

Source Assessment

Nutrient (phosphorus) sources to the lake have been identified in the 2012 Chautauqua Lake Phosphorus TMDL. The TMDL indicates that more than half of the phosphorus load is from internal loading. Excess phosphorus that enters the Lake but cannot be assimilated is deposited in lake sediments. Under certain conditions (resuspension, sediment anoxia) this internal load is released into the water. Other significant sources of phosphorus load include groundwater inflow and load from the North Basin of the Lake. Small loads come from agricultural activities, wastewater point sources, and onsite wastewater treatment (septic) systems. (NYS DEC/DOW, BWRM, TMDL for Phosphorus in Chautauqua Lake, November 2012)

Management Actions

This waterbody is considered a highly-valued water resource due to its drinking water supply classification and as a multi–use waterbody. On December 21, 2017, New York State Governor Andrew Cuomo announced a $65 million initiative to combat harmful algal blooms in Upstate New York. Chautauqua Lake was identified for inclusion in this initiative as it is vulnerable to HABs. (NYS DEC/DOW, BWRM, April 2018).

Recommendations for specific sources of nutrients loads to the Lake are outlined in the Chautauqua Lake Phosphorus TMDL. In addition, Chautauqua County prepared an extensive *State of the Lake Report* in May 2000 and followed it up with a *Lake Management Report* later that year. These reports outline a range of options and recommendations to address sources of water quality impacts to the lake. These include management of aquatic vegetation though both in lake measures (harvesting, herbicide use), the need to maintain wastewater treatment (on site septics and sewered areas) to protect the uses of the lake, and erosion controls to address wet weather/stormwater runoff that contributes silt/sediment and nutrients to the lake. These reports also recognize the need to address development pressures in the basin that will also impact water quality in the lake. (NYS DEC/DOW, BWRM, TMDL for Phosphorus in Chautauqua Lake, November 2012 and Chautauqua Lake Entering the 21st Century: State of the Lake Report, Chautauqua County Department of Planning and Development, May 2000 and The Management of Chautauqua Lake and its Watershed, Chautauqua County, November 2000).

Section 303(d) Listing

The southern portion of Chautauqua Lake is not included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. Although it is assessed as an impaired water, it is categorized as an IR Category 4a water that is not listed due to the completion of the phosphorus TMDL in 2012. The segment is also categorized as an IR Category 4c water due to impairments caused by algal and weed growth and aquatic invasive species. (NYS DEC/DOW, BWAM/WQAS, April 2018)

Segment Description

This segment includes the total area of the South Basin of the Lake. The South Basin includes waters of the Lake south of Bemus Point.

Appendix F. NYSDEC Water Quality Monitoring Programs

Additional information at http://www.dec.ny.gov/chemical/81576.html.

Appendix G. Road Ditches

In New York State, ditches parallel nearly every mile of our roadways and in some watersheds, the length of these conduits is greater than the natural watercourses themselves. Although roadside ditches have long been used to enhance road drainage and safety, traditional management practices have been a significant, but unrecognized contributor to flooding and water pollution, with ditch management practices that often enhance rather than mitigate these problems. The primary objective has been to move water away from local road surfaces as quickly as possible, without evaluating local and downstream impacts. As a result, elevated discharges increase peak stream flows and exacerbate downstream flooding. The rapid, high volumes of flow also carry nutrient-laden sediment, salt and other road contaminants, and even elevated bacteria counts, thus contributing significantly to regional water quantity and quality concerns that can impact biological communities. All of these impacts will be exacerbated by the increased frequency of high intensity storms associated with climate change. Continued widespread use of outdated road maintenance practices reflects a break-down in communications among scientists, highway managers, and other relevant stakeholders, as well as tightening budgets and local pressures to maintain traditional road management services. Although road ditches can have a significant impact on water quality, discharges of nutrients and sediment from roadways can be mitigated with sound management practices.

Road Ditch Impacts

Roadside ditch management represents a critical, but overlooked opportunity to help meet watershed and clean water goals in the Chautauqua Lake watershed by properly addressing the nonpoint sources of nutrients and sediment entering the New York waters from roadside ditches. The three main impacts of roadside ditch networks are: (1) hydrological modification, (2) water quality degradation, and (3) biological impairment.

Mitigation Strategies to Reduce Impacts

Traditional stormwater management focused on scraping or armoring ditches to collect and rapidly transport water downstream. The recommended mitigation strategies described below focus on diffusing runoff to enhance sheet flow, slowing velocities, and increasing infiltration and groundwater recharge. This approach reduces the rapid transfer of rainwater out of catchments and helps to restore natural hydrologic conditions and to reduce pollution while accommodating road safety concerns.

These strategies can be divided into three broad, but overlapping categories:

1. **Practices designed to hold or redirect stormwater runoff to minimize downstream flooding.**
    - Redirect the discharges to infiltration or detention ponds.
    - Restore or establish an intervening wetland between the ditch and the stream.

- Divert concentrated flow into manmade depressions oriented perpendicular to flow using level lip spreader systems.
- Modify the road design to distribute runoff along a ditch, rather than a concentrated direct outflow.

2. **Practices designed to slow down outflow and filter out contaminants.**
    - Reshape ditches to shallow, trapezoidal, or rounded profiles to reduce concentrated, incisive flow and the potential for erosion.
    - Optimize vegetative cover, including hydroseeding and a regular mowing program, instead of mechanical scraping. Where scraping is necessary, managers should schedule roadside ditch maintenance during late spring or early summer when hydroseeding will be more successful.
    - Build check dams, or a series of riprap bars oriented across the channel perpendicular to flow, to reduce channel flow rates and induce sediment deposition while enhancing ground water recharge.
    - Reestablish natural filters, such as bio-swales, compound or “two-stage” channels, and level lip spreaders.
3. **Practices to improve habitat.**
    - Construct wetlands for the greatest potential to expand habitat.
    - Reduce runoff volumes to promote stable aquatic habitat.

The Upper Susquehanna Coalition (USC) is developing a technical guidance document in the form of a Ditch Maintenance Program Guide that can be used by any local highway department. The guide will include an assessment program to determine if the ditch needs maintenance and what is necessary to stabilize the ditch. It will also contain a group of acceptable and proven management guidelines and practices for ditch stabilization. In addition, the USC is developing a broad-based education and outreach program to increase awareness and provide guidance to stakeholder groups. This program will take advantage of existing education programs, such as the NY’s Emergency Stream Intervention (ESI) Training program, USC, Cornell University and the Cornell Local Roads program. This new program will be adaptable in all watersheds.