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

HARMFUL ALGAL BLOOM ACTION PLAN OWASCO LAKE

North end Owasco Lake algae bloom (*Source:* Owasco Watershed Lake Association)

www.dec.ny.gov

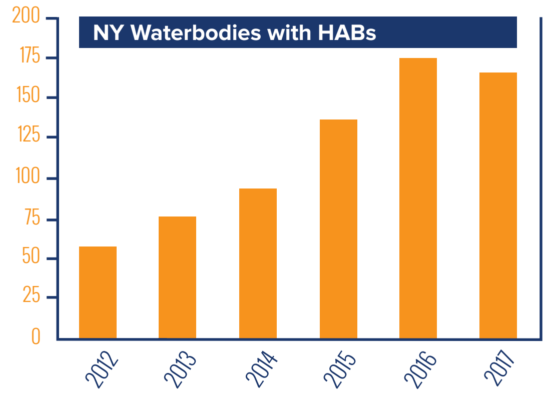
EXECUTIVE SUMMARY

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

OWASCO LAKE

Cayuga County

Owasco Lake, a 6,640-acre lake that is one of the Finger Lakes in central New York, is one of the 12 priority lakes impacted by HABs. The lake is used for swimming, fishing and boating. In addition, Owasco Lake is the primary drinking water source for the City of Auburn, Town of Owasco and many lakefront property owners.

Owasco Lake was designated as an "impaired waterbody" due to the lake's susceptibility to HABs from nutrient inputs from agricultural use of much of the surrounding area, septics, waterfowl and other sources; and the potential for increased disinfection byproducts (DBPs) in drinking water corresponding to increases in organic matter (e.g., algae) and increases in water treatment.

The significant sources of phosphorus loading in the lake are:

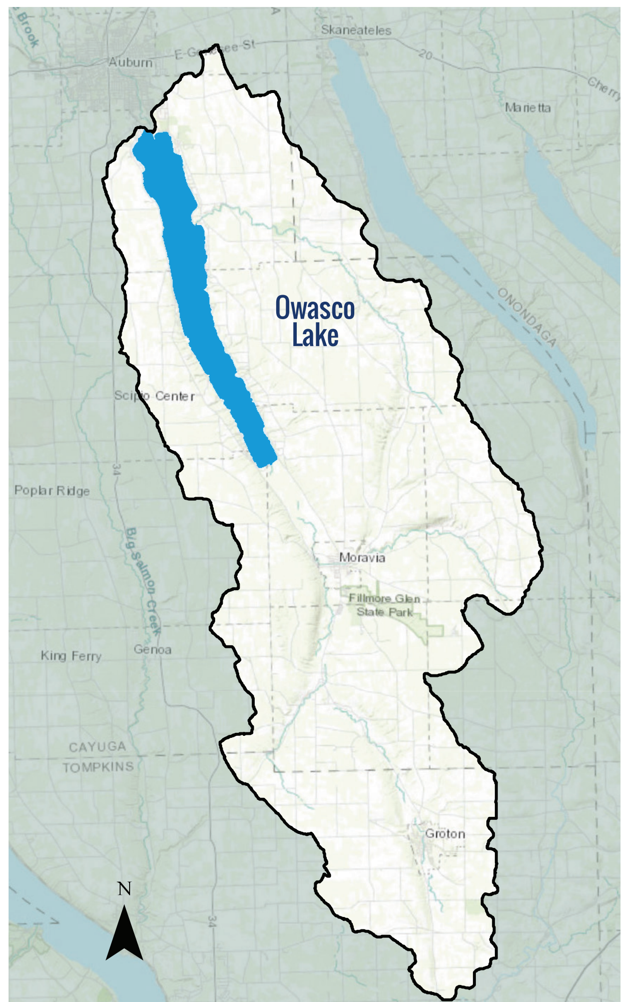
- Non-point source sediment and nutrient inputs from the contributing watershed (e.g., agricultural lands, forest, ditches and streambank erosion); and
- Stormwater runoff and failing septic systems.

There were 84 confirmed HABs occurrences in the lake from 2013 through 2017, including 55 confirmed HABs with high toxins. HABs resulted in 61 lost beach days between 2014 and 2017.

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 Owasco Lake, including the following:

- Build the capacity of soil and water conservation districts (SWCDs) in the Owasco Lake watershed to further implement Agricultural Environmental Management (AEM); enhance outreach to row crop farms; support farmers to enhance manure and livestock management; conduct a pilot program for emerging Best Management Practices (BMPs); and implement sediment control measures;
- Implement runoff reduction BMPs, roadside ditch and culvert improvement projects; stabilize selected tributaries; establish vegetated riparian buffers and plant trees and shrubs on available lands; and acquire and conserve lands and wetlands in the watershed;
- Complete a feasibility study to upgrade municipal sewer infrastructure; and
- Conduct a study of a possible extension and/or additional public water intake into a deeper water location.



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.

OWASCO 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 Owasco 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 Owasco 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.

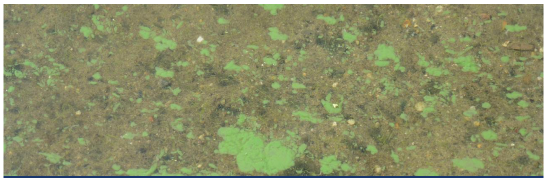
Research, Surveillance, and Monitoring:

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:

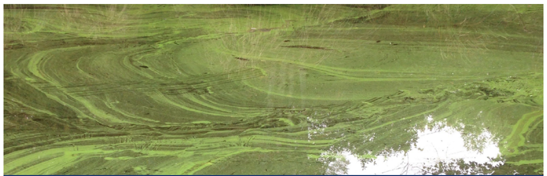
State laws and programs help control pollution and reduce nutrients from entering surface waters. State funding is available for municipalities, soil and water conservation districts, and non-profit organizations to implement projects that reduce nutrient runoff.

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 cascade of public health, economic, and ecological benefits including potable drinking water, tourism, water-based recreation, and ecosystem services. Harmful algal blooms (HABs), have become increasingly prevalent in recent years and have impacted the values and services that these resources provide.

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

- Describe the 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, both in Owasco Lake and in other lakes of similar morphology, hydrology, and background water quality.

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 HAB 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. Owasco Lake, with its recreational opportunities, aesthetic beauty, and importance as a long-standing source of drinking water, and documented HAB occurrences in recent years, 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:

- Members of the public interested in background information about the development and implications of harmful algal blooms and the NYSDEC HABs program
- 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 NYSDEC HABs monitoring and surveillance program
- Local and regional agencies and organizations involved in the oversight and management of Owasco Lake (e.g., Cayuga County, Tompkins County, and Onondaga County Soil & Water Conservation District [SWCD], Cayuga and Tompkins County Departments of Health [DOHs], The Finger Lakes Land Trust [FLLT])
- Owasco Watershed Lake Association (OWLA)
- The Owasco Lake Watershed Management Council and other Owasco Lake watershed conservation and oversight organizations
- The City of Auburn and Town of Owasco as the main public water purveyors
- Lake residents, managers, consultants, and others that are directly involved in the management of HABs in Owasco Lake
- Academic and other researchers interested in the water quality of Owasco Lake and/or Harmful Algal Blooms

Analyses conducted within this Action Plan provide insight of the processes within Owasco Lake that potentially influence the formation of HABs there, and their spatial extents, durations, and intensities. Implementation of the mitigation actions recommended in this HABs Action Plan are expected to reduce the spatial and temporal extents of blooms in Owasco 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 adequate nutrient (e.g., phosphorus) availability, warm temperatures, and calm winds, 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 Owasco Lake and has produced this HABs Action Plan to identify the primary factors triggering HAB events, and to facilitate decision-making to minimize the frequency, intensity, and duration of HABs, as well as the effects that HABs can have on both the users of the lake and its resident biological communities.

2. Lake Background

2.1 Geographic Location

Owasco Lake, meaning "the crossing" (OLMPSC and CCWQMA 2000), is located in central New York and is the sixth largest of the Finger Lakes by water volume and by surface area (**Figure 1**). The City of Auburn, which is situated on the northern end of the lake, is the largest population center along the lake with approximately 27,000 residents. Melrose Park, a suburb of Auburn, directly abuts the lake to the north and northeast. Other villages and towns include Fleming, Scipio, Scipio Center, and Ashland, which lie west of the lake, the town of Moravia and hamlet of Cascade, located near the lake's south end, and Owasco, Niles, and Austin, located east of the lake (**Figure 2**). The entirety of Owasco Lake and its surrounding communities are within the Cayuga County limits.

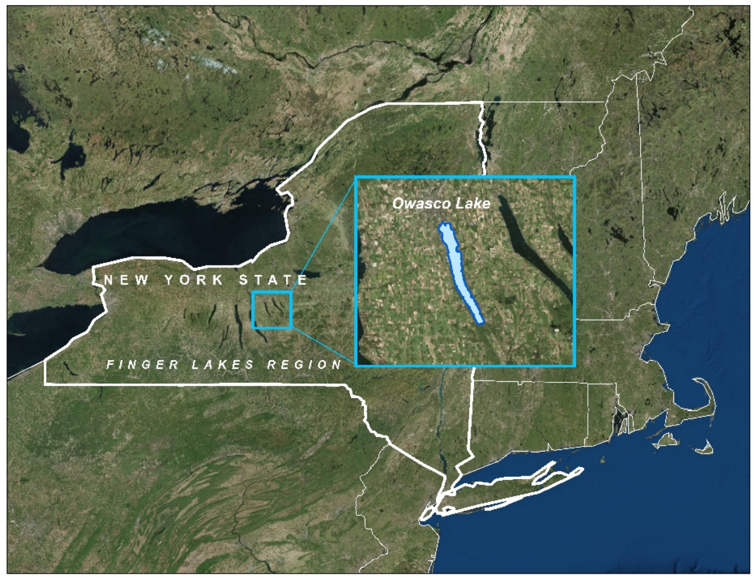

Figure 1. Location of Owasco Lake within New York State.

2.2 Basin Location

Owasco Lake is located within the Oswego River Drainage Basin, specifically the Finger Lakes Drainage Basin. The Oswego/Finger Lakes Watershed is one of the largest in New York State, comprising 8,896 miles of rivers and streams and 189,722 acres of ponds, lakes, and reservoirs (NYSDEC 2018a). The watershed comprises 470 square km (170 square miles) of land and water features in Cayuga County, 85 square km (33 square miles) in Tompkins County, and 13 square km (5 square miles) in Onondaga County (OLWIP 2016a).

2.3 Morphology

Owasco Lake is 17.9 km (11.1 miles) long with a south to north orientation, a maximum width of 2.1 km (1.3 miles) and approximately 43.4 km (27 miles) of shoreline. It has a surface area of 26.9 square km (10.4 square miles), and an elevation of 217 meters (712 feet) above mean sea level (NYSDEC 2018a). Owasco Lake has a volume of approximately 212 billion gallons, a maximum depth of 54 meters (177 feet) and an average depth of 29.5 meters (97 feet). Cliffs predominate the eastern and western shorelines in the southern two-thirds of the lake. The deepest waters in Owasco Lake are located approximately mid-lake from north to south, offshore of the town of Scipio on the west and the town of Niles and village of Austin on the east. Due to its steeply sloping, "U"-shaped basin, the lake has a small littoral zone (nearshore zone of full sunlight penetration) that is largely confined to the shallower northern and southern ends of the lake. The lake contains one island, Deauville Island, part of Emerson Park, located in the far northern portion of the lake.

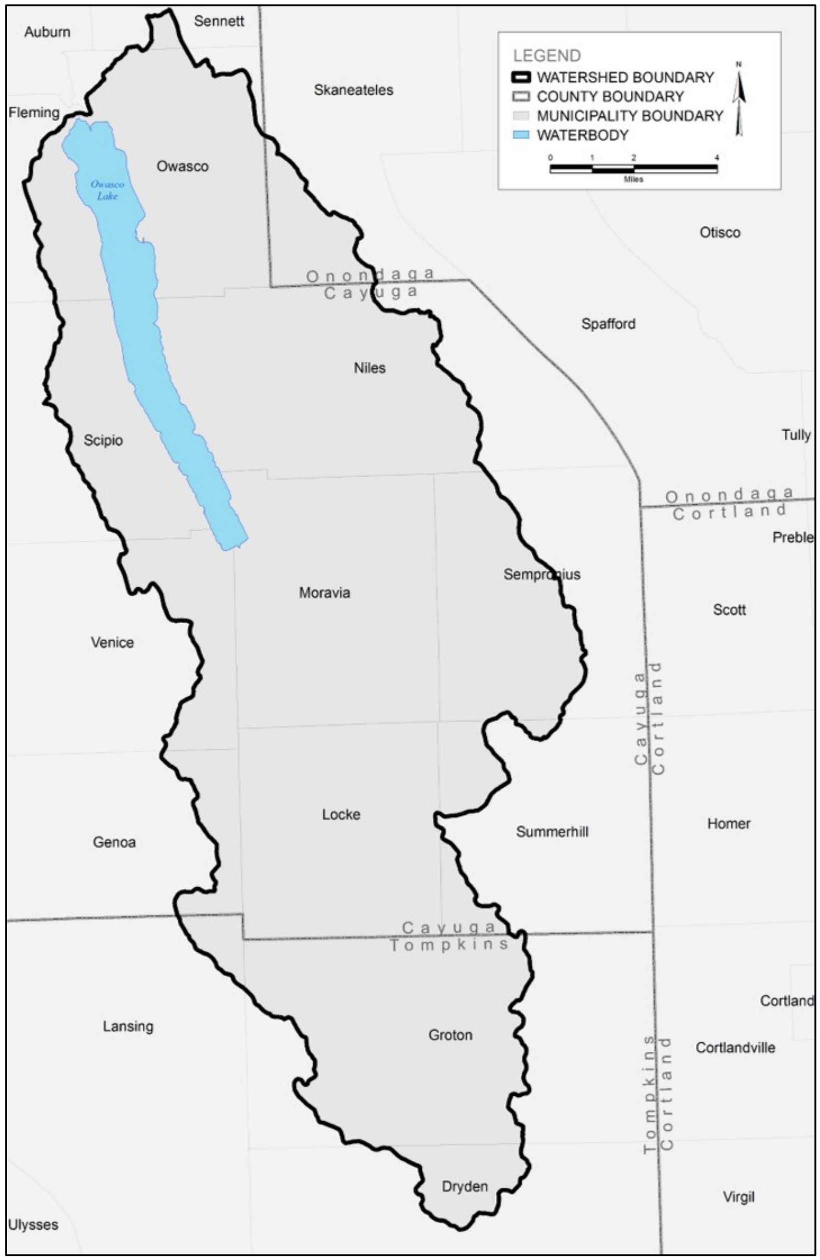

Figure 2. Political boundaries within the Owasco Lake watershed.

The wind rose in **Appendix A**, which depicts wind patterns from 2010 to 2017 during the months of June through November, suggests that the prevailing regional wind directions were out of the west, as recorded at the Syracuse Hancock International Airport, north of the City of Syracuse. However local observations suggest that these regional winds may be funneled from south to north through the lake valley. Given these wind patterns, buoyant cyanobacteria may accumulate in the eastern and northern portions of the lake, potentially impacting bathing beaches and recreational uses in these areas. Wind data from a buoy maintained by the Finger Lakes Institute supports this observation of southerly winds.

2.4 Hydrology

The Owasco Lake watershed area is approximately 470 square km (181 square miles), resulting in a large drainage basin to surface ratio (17:1; Callinan 2001). This large ratio results in higher nutrient loads (NYSDEC 2018b) that can contribute to the formation of HABs. In addition, the large ratio contributes to the lake's relatively short hydraulic retention time (i.e., mean time of water spends in a lake) of 3-4 years (OLWIP 2016a) compared to many of the other Finger Lakes. There are several major tributaries including the Owasco Inlet, Dutch Hollow Brook, Veness Brook, and Sucker Brook, as well as over fifty small and intermittent tributaries, many less than one mile in length (OLMPSC and CCWQMA 2000). Owasco Inlet, the primary tributary, originates in Tompkins County and flows northward for 24 miles before entering the lake at its southern end, approximately 0.5 miles east of the hamlet of Cascade and 3.8 miles northwest of the town of Moravia. Prior to discharging to the lake, the Owasco Inlet flows through a large wetland complex at the Owasco Flats Nature Preserve, which serves as a flood storage area during high intensity rainfall events. Outflow from Owasco Lake is conveyed to the Owasco Outlet, located at the lake’s north end, which then flows to the Owasco River and then to the Seneca River north of Port Byron.

2.5 Lake Origin

The Finger Lakes, including Owasco Lake, were formed more than 2 million years ago during the Pleistocene Epoch. Glacial scouring carved deep slices into the land through the area, moving land and rocks southward. As the ice gradually melted and the glaciers receded, valleys of water dammed by unconsolidated glacial debris were left, which are now the Finger Lakes (Murdock 2010). The bottom substrates of Owasco Lake consist primarily of sand and cobble deposited from glacial scouring (OLMPSC and CCWQMA 2000).

3. Designated Uses

3.1 Water Quality Classification – Lake and Major Tributaries

Owasco Lake is a Class AA(T) waterbody according to the New York Codes, Rules, and Regulations (6 NYCRR 898.4). Class AA waterbodies are best utilized for drinking water, culinary or food processing purposes, primary and secondary contact recreation, and fishing. Class AA waters, if subjected to approved disinfection treatment, with additional treatment if necessary, will meet New York State Department of Health (NYSDOH) drinking water standards (6 CRR NY 701.5). The “T” designation indicates the lake must meet all water quality standards established for trout survival.

The Owasco Inlet accounts for approximately 62% of all surface water from the watershed flowing into the lake (CCDPED and EcoLogic 2016) and is a Class C(T) watercourse. This classification indicates Owasco Inlet is best used for fishing, fish propagation and survival, primary and secondary contact recreation, and is a designated trout watercourse. Although Class C waterbodies may be suitable for recreational uses, other factors may prevent this use. Dutch Hollow Brook enters Owasco Lake from the east approximately 2.4 miles northwest of the town of Owasco, is classified as C(TS), and contributes 15% of the surface water to the lake (CCDPED and EcoLogic 2016). The “TS” designation signifies that Dutch Hollow Brook is a trout spawning watercourse. Sucker Brook, a Class C water, discharges to the lake from the northeast within the town of Auburn. Veness Brook also is a C-classified stream that flows into the lake from the west near the village of Fleming. Sucker Brook and Veness Brook collectively account for 6% of surface water inputs to the lake (CCDPED and EcoLogic 2016).

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

3.2 Potable Water Uses

Owasco Lake is the primary source of drinking water for the City of Auburn, Town of Owasco, and for many lakefront property owners (OLMPSC and CCWQMA 2000). The City of Auburn serves Aurelius water districts 1, 2, and 3, Sennett consolidated water districts, and Throop water district 1. The Town of Owasco serves Fleming water district 1. The total permitted water withdrawal for the Finger Lakes is approximately 190 million gallons per day (MGD); Owasco Lake has the third highest permitted withdrawal for an individual lake of the 11 Finger Lakes (Halfman 2017). More than 70% of Cayuga County’s population obtain their drinking water from Owasco Lake. In 1996, over 3 billion gallons of water were withdrawn from the lake to serve 58,000 county users (OLMPSC and CCWQMA 2000); while in 2014 the number of county users was reported to be 44,000 (CCDPED and EcoLogic 2015b). Lake water is also withdrawn by the Owasco Country Club for irrigation of its golf course (OLMPSC and CCWQMA 2000).

For the city of Auburn and surrounding communities, up to 15 MGD of water is permitted to be withdrawn from the lake via a single 30-inch diameter cast-iron intake pipe that extends approximately 1,875 feet into the lake at a depth of 33-35 feet, depending on the lake water level. Water is then pre-treated, filtered, and disinfected prior to distribution. In 2016, approximately 4.2 MGD on average was withdrawn with the highest daily withdrawal of 6.1 MGD (City of Auburn 2016). The town of Owasco draws 0.3 MGD of water through a single 10-inch cast iron pipe line that extends approximately 450 feet into the lake. The filtered and treated water is then supplied to 3,100 town residents. As of 2000, approximately 260 seasonal or year-round lakefront residences who do not receive public or well water draw their potable water from the lake (OLMPSC and CCWQMA 2000).

The formation of HABs and associated cyanotoxins in Owasco Lake in recent years represents a potential threat to potable water purveyors and users of lake-derived drinking water such as those in the communities described above. Additional discussion of potential HABs-associated impacts to potable water use is provided in **Section 7.2**.

The US 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 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 exceed 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 of the extensive sampling performed in New York State. New York State HAB response activities have focused on the blooms themselves and microcystin, given that it is the most commonly detected HAB toxin.

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

Only one public beach is present on Owasco Lake, at Emerson Park in Auburn, which also represents the only public access point on the lake. The beach contains a swimming area that is tended by lifeguards generally from Memorial Day weekend through Labor Day (NYFalls.com 2018). Other (private) beach/lakefront areas where swimming could occur at Owasco Lake include those at the Owasco Yacht Club, Camp Y-Owasco, Camp Columbus, Camp Rotary, and Casowasco Camp & Retreat Center. All bathing beach locations, including those designated as private, are regulated by the NYSDOH and may be subject to beach closures due to HABs.

3.4 Recreation Uses

As discussed in **Section 3.3**, Emerson Park, a county park located at the lake's northern end, is the only public access point and features a beach, marina equipped with 35 boat slips and pontoon rentals, and two boat launch ramps. In addition to swimming, boating, and fishing, Emerson Park provides opportunities for picnicking, playgrounds, disc golf, concerts, and theatre, among other attractions (Cayuga County

Government 2018a). The South Shore Marina, located in Moravia at the south end of the lake, is outfitted with 30 boat slips and two launch ramps, and offers kayak and canoe rentals. Another popular recreational area is Island Park, located immediately west of Emerson Park. The Owasco Country Club is located in Auburn at the lake's northern end, east of Emerson Park. Members enjoy golfing at the club's 9-hole golf course, tennis, and dining and relaxing at the clubhouse.

The Owasco Yacht Club, founded in 1892 and located along the northeastern shoreline, south of Martin's Point, is a nine-acre, private club that includes member- and guest-only amenities such as a lifeguard-tended swimming area, clubhouse, shaded picnic areas, and club-owned watercraft. Sailing program events are open to all club members. Children enjoy sliding boards, swings, sand box, tetherball, climbing ropes, and climbing wall and slide at the club's playground. A club policy is that the swimming area is closed immediately upon detection of a HAB (Owasco Yacht Club 2018).

3.5 Fish Consumption/Fishing Uses

Owasco Lake supports an assemblage of both coldwater and warmwater fish species. More than 49 species have been reported as inhabiting Owasco Lake or its tributaries (CCDPED and EcoLogic 2015b). several of which are important recreationally and may be taken for consumption. Sought after species include, but are not limited to:

Coldwater

- Atlantic salmon (*Salmo salar*)
- Lake trout (*Salvelinus namaycush*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Brown trout (*Salmo trutta*)

Warmwater

- Largemouth bass (*Micropterus salmoides*)
- Smallmouth bass (*Micropterus dolomieu*)
- Walleye (*Sander vitreus*)
- Northern pike (*Esox lucius*)
- Yellow perch (*Perca flavescens*)
- Brown bullhead (*Ameiurus nebulosus*)
- Yellow bullhead (*Ameiurus natalis*)
- Panfish, including bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), rock bass (*Ambloplites rupestris*), and black crappie (*Pomoxis nigromaculatus*)

Owasco Lake is stocked annually with approximately 10,500 lake trout, 10,000 brown trout, and 5,000 rainbow trout (NYSDEC 2018b). In 2018, the lake will be stocked with 8,700 brown trout and 4,440 rainbow trout; the stocking of 3,100 brown trout in Owasco Inlet is also planned for 2018 (NYSDEC 2018c). New York State fishing regulations are applicable to Owasco Lake, with special minimum size and take provisions for Atlantic salmon, lake trout, brown trout, and rainbow trout for the lake and its tributaries (eRegulations 2017).

No fish consumption advisories specific to Owasco Lake have been issued by the NYSDOH. In the absence of a specific advisory, the NYSDOH recommends limiting fish consumption to four, half-pound meals per month (NYSDOH 2018a). People are generally advised not to consume fish taken from HAB-impacted waters; however, such temporary conditions do not equate to an impact to fish consumption use (NYSDEC 2016).

3.6 Aquatic Life Uses

Owasco Lake is designated as a Class AA(T) water, suitable for fish propagation and survival, and supporting trout populations. Walleye were stocked in the lake from 1996 to 2006, but as part of salmonid stock assessment management actions and to support maintenance of aquatic life uses in the lake, walleye stocking was discontinued due to reductions in trout populations (CCDPED and EcoLogic 2015b; NYSDEC 2018b).

Water quality monitoring conducted by NYSDEC focuses primarily on support of aquatic life and general recreation. No impairment of aquatic life uses in the lake has been identified (CCDPED and EcoLogic 2015b). The aquatic life use in Owasco Inlet is stressed. The source of impacts to aquatic life in the Owasco Inlet is nutrient (phosphorus) enrichment from agricultural, municipal wastewater, and other nonpoint sources (NYSDEC 2016). In addition, the presence of several invasive animals, including Asian clam, scud, and zebra mussels, along with alewives, may stress aquatic life uses.

Careful management of the sport fishery in Owasco Lake, coupled with the absence of observable impairment to the aquatic life use in the lake, suggests that the fish species assemblage and its potential cascading regulating effects on lower trophic levels (e.g., zooplankton) is not a driver for HABs formations in Owasco Lake. However, the presence of alewife (*Alosa pseudoharengus*), an invasive alosine in the lake that forages selectively on larger prey organisms, may exert “top-down” effects on the plankton community, leading to smaller individuals of zooplankton that are less efficient grazers of phytoplankton, which can contribute to HABs. This trophic interaction is discussed further in **Section 6.3**.

3.7 Other Uses

Many taxa of wildlife, both birds and mammals, rely on Owasco Lake and its shoreline as high-quality foraging, roosting, and nesting habitat. While resident birds stay in the area year-round, the majority are found seasonally during breeding and migration seasons. Many species of waterfowl, game birds, marsh and shore birds, raptors, woodpeckers, and songbirds likely utilize the Owasco Inlet, Owasco Flats Nature Preserve, and associated lake habitat. The diverse bird community is reflective of the mosaic of habitats and richness of transition zones between fern and willow marsh, flood plain forest, woodlands, and open fields. The Owasco Flats are part of the Greater Summerhill Important Bird Area (IBA), which possesses valuable habitat for rare and endangered bird species whose habitats are in decline (FLLT 2018a).

Mammals that depend on the lake for foraging and den habitat include muskrat, mink, beaver, and river otter. Other mammalian species expected to utilize Owasco Lake include small mammals, such as American marten, fisher, long-tailed weasel, and striped skunk; and large mammals, including black bear, bobcat, coyote, red fox, gray fox, and white-tailed deer.

4. User and Stakeholder Groups

Owasco Lake is used (**Section 3.4**) by all age groups, including fulltime and seasonal homeowners of lakeside properties, homeowner guests, day or extended stay recreationists, private clubs, and tourists. Access to the lake is available to the public only in Auburn at the northern portion of the lake, which offers a public park, marina, and beach and associated swimming area. Shoreline residents and their guests may also access the lake directly via private docks, piers, and boat launches.

As described in **Section 3.2**, Owasco Lake provides drinking water for potable use to approximately 44,000 households, including Auburn, the largest City abutting the lake. HABs, which have been reported by lake residents since at least 2012 (OWLA 2013) and documented by the NYDOH since 2010 (see **Section 7**), jeopardize the integrity and quality of drinking water, causing concern and enhanced vigilance among communities supplied with potable water from the lake.

Owasco Lake or watershed stakeholder groups include the following:

- The Owasco Lake Watershed Management Council (OLWMC) is an intermunicipal watershed advisory body whose mission is to coordinate actions for protecting and restoring the health of the lake and its watershed, with a specific focus on protection of public drinking water and recreation. The OLWMC monitors the health of the lake, supports watershed research, implements projects through partnerships with NYSDEC, the Finger Lakes Institute, and OWLA, directs an inspection program to curtail activities detrimental to watershed water quality, and educates the public on responsible care and protection of the watershed (Cayuga County Government 2018b).
    - The Owasco Lake Watershed Inspection Program (OLWIP) is coordinated by OLWMC and based in Auburn. The OLWIP was established in August of 2007 through an agreement with the City of Auburn, Town of Owasco, Cayuga County agencies, and other Owasco Lake advocates. The OLWIP protects water quality in Owasco Lake through regular inspections of the lake, its watercourses, and its watershed for compliance with watershed regulations, and provides educational outreach to the watershed

community to foster lake stewardship (OLWIP 2016b). Protection measures include focused monitoring, reporting, volunteer training, and community education of HABs through teamed efforts with NYSDEC, OWLA, and the Cayuga County Department of Health (CCDOH) (OLWIP 2016c). Prior to 2018, OWLIP provided local coordination for the shoreline HAB surveillance program conducted jointly by OWLIP, NYSDEC, OWLA, and the Cayuga County Department of Health.

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- The Owasco Watershed Lake Association (OWLA) is a citizen-focused, not-for-profit corporation established to educate the public on the appreciation, wise use, environmental management, and preservation of the lake and its watershed. OWLA's mission is to "…*actively engage in an ongoing process for coordinating, documenting, and tracking all of the strategies and activities that are designed to restore our watershed and improve water quality for both drinking and full recreational use of Owasco Lake and its watershed.*" (OWLA 2016). OWLA generates a dynamic annual watershed management plan that includes a process for updating throughout the year. The plan incorporates inputs from community partners, with desired outcomes that include but are not limited to:
  - Improved water quality in the lake to support full recreational use
  - Reduction of nuisance weed growth and suppression of invasive aquatic species
  - Reduction of phosphorus levels in the lake
  - Public policy, legislation and land use regulations that protect environmentally sensitive areas, including wetlands, natural riparian habitats, and waterways

- Finger Lakes-Lake Ontario Watershed Protection Alliance (FLLOWPA) stems from conservation efforts dating back to the mid-1980s, and facilitates processes that encourage partnerships and action plans to protect and enhance water quality through the sharing of information, data, resources, and approaches (FLLOWPA 2018).

- The Finger Lakes Land Trust (FLLT) is a small non-profit organization founded in 1989, and is comprised of members, landowners, and volunteers whose mission is "*...to conserve forever the lands and waters of the Finger Lakes region, ensuring scenic vistas, local foods, clean water, and wild places for everyone.*" In February 2018, the FLLT, as part of its Owasco Lakeshore Protection Project, reported its protection of 1,100 feet of Owasco Lake shoreline through the acquisition of 74 acres in the town of Owasco. The property comprises forested bluffs, meadows, hay fields, brushland, and gorge habitat. The FLLT intends to manage the site as a public conservation area and will restore wetlands to filter overland runoff to the lake and construct a hiking trail that traverses a variety of lakeside habitats, while also providing access to scenic views of the lake (FLLT 2018b).
- The Finger Lakes Regional Water Alliance (FLRWA) was formed in 2010 and is a collaboration between nine lake and watershed organizations representing the Finger Lakes whose mission is to preserve and protect the region's watersheds (FLRWA 2018).

5. Monitoring Efforts

5.1 Lake Monitoring Activities

Monitoring efforts on Owasco Lake have been conducted as part of the Citizen's Statewide Lake Assessment Program (CSLAP) on a single site from 1989-1994 and then again on two sites in 2017. The 2017 northern site was close to the location of the single CSLAP sampling site established from 1989 to 1994, as noted in **Figure 3**. Water quality parameters monitored as part of CSLAP generally include:

- Water temperature
- Water clarity (Secchi depth)
- Total phosphorus (TP)
- Total nitrogen (TN)
- Chlorophyll a
- pH
- Specific conductivity
- Color

In response to public concerns about HABs on Owasco Lake and a lack of a routine HABs monitoring program on the lake, the NYSDEC developed HABs and water quality monitoring plans for the lake in late 2014. Continuing into 2015, bloom detection and monitoring programs were enhanced. This included routine surveillance and periodic HABs monitoring along portions of the shoreline by the OLWIP, responses to public HABs reports, limited nutrient sampling within blooms, and bloom reporting and outreach. Partners within this HABs effort include the NYSDEC, NYSDOH, CCDOH, OWLA, OLWIP, OWLA volunteers, and SUNY ESF. The objectives of the 2017 HABs surveillance program are as follows:

- Document and report HABs to the public to protect public health and build public awareness about safety concerns regarding exposure to HABs
- Provide regulatory agencies (NYSDOH and NYSDEC) with comprehensive information to inform decisions about drinking water concerns and beach closures or advisories and on-the-ground investigations, provide context to evaluate public complaints and a basis for more detailed water quality monitoring and clean water plan preparation.

This surveillance, monitoring and public outreach program will continue into at least 2018, although program administration may change in the future.

Other data collections conducted in Owasco Lake include the NYSDEC Lake Classification and Inventory (LCI) Monitoring Program (2005 and 2012), NYSDEC Disinfection by-products (DBPs) Study in 2004 (Callinan et al. 2013), Finger Lakes Synoptic Water Quality Investigation (SWQI, 1996, 1997 and 1999), the Finger Lakes Institute's Finger Lakes Survey (FLI/FLS 2005-2017, Halfman 2017, described below), monitoring conducted by Upstate Freshwater Institute (UFI) in 2005 to 2008, and monitoring in 1986 by Effler et al. (1988). Owasco Lake has been extensively studied in recent years by Upstate Freshwater Institute and OWLA, with a focus on nearshore conditions evaluated with discrete sampling and water quality buoys, and through mid-lake rapid profiling. In addition to these monitoring efforts, water quality conditions were evaluated in the Finger Lakes during the 1910s (Birge and Juday 1914) and 1960s and 1970s (Bloomfield 1978).

Water quality summary reports are being developed for each Finger Lake and for the entire Finger Lakes region, including comparisons to historical NYSDEC data.

The DBPs study was conducted in 2004 in response to the US Environmental Protection Agency (USEPA) initiation of a National Nutrient Criteria Strategy (USEPA 1998) that called on states to establish a numeric nutrient criteria (NNC). A total of 21 lakes, including Owasco Lake, were included in the NYSDEC DBPs study, which focused on lakes designated potable water supplies. Nutrient enrichment in lakes used as potable water supplies are associated with increases in human health-risk factors such as increased generation of DBPs and production of cyanotoxins by certain species of cyanobacteria (Callinan et al. 2013). Sampling efforts focused on total phosphorus, chlorophyll-a, dissolved organic carbon (DOC), and the total trihalomethanes formation potential (THMFP - a measure of potential DBPs).

The NYSDEC Finger Lakes study in the late 1990s was an attempt to replicate comparative investigations of the Finger Lakes not conducted systematically on all eleven Lakes since at least 1970. This study included sediment coring and monthly water quality monitoring from 1996 to 1999 on at least one sample site per lake, as well as comparisons of water quality data to historical NYS sampling results.

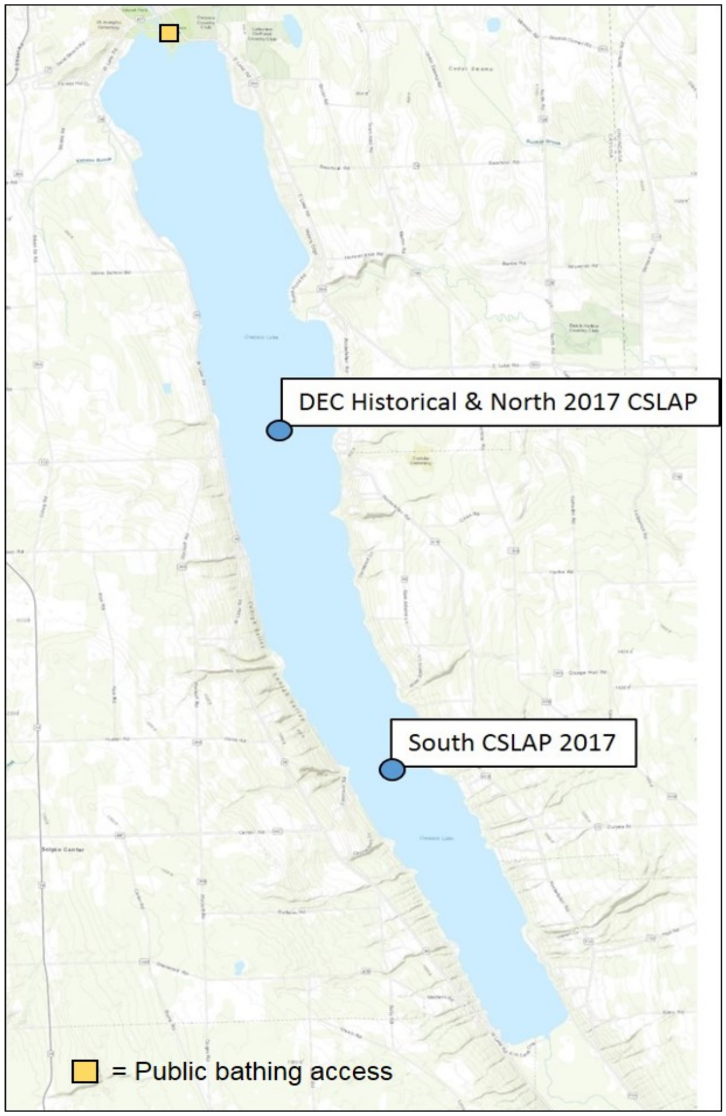

Figure 3. Map of Owasco Lake with CSLAP and LCI sampling locations.

The NYSDEC collects data as part of the LCI program to support water quality assessments and management activities, including identifying and responding to HABs. The LCI data set for Owasco Lake includes monthly samples collected in 2005 and 2012 from May to September. Data collected during the LCI for Owasco Lake included monthly profiles of water quality parameters from just below the water surface, including:

- Surface water temperature
- Dissolved oxygen
- pH
- Specific conductivity
- Oxidation reduction potential
- Phosphorus (total)
- Nitrogen (total, dissolved total, and nitrogen oxides)
- Chlorophyll a
- Calcium

The eight easternmost Finger Lakes have been sampled by Hobart William Smith College and the Finger Lakes Institute since 2005. This work involves monthly sampling from May through September sampling at least two sites per lake for several water quality indicators, plankton tows, and depth profiles. This program did not operate under a Quality Assurance Project Plan (QAPP) or laboratory certification under the NYS Department of Health (DOH) Environmental Laboratory Approval Program (ELAP), so these data cannot be used for this NYSDEC water quality assessment. Hobart William Smith has also installed a YSI/Xylem pontoon buoy platform with cellular modem communications and meteorological sensors, at a md-lake location, just south of Burtis Point, in about 50 meters of water. More information about the near-real time reporting of select water quality indicators from this system can be found at http://fli-data.hws.edu/buoy/owasco/conditions.php.

5.2 Tributary Monitoring Activities

The OWLA has conducted a volunteer monitoring program since 1999, during which water samples were collected from multiple locations around Owasco Lake and from several tributaries to test for fecal coliform bacteria. Funding for the program is through Cayuga County and OWLA and is administered by the Cayuga County Department of Planning and Economic Development (CCDPED and EcoLogic 2015b). Streams in the monitoring program include Dutch Hollow Brook (stream mouth), Sucker Brook, and the Owasco Inlet at Rounds Lane and Long Hill Road.

The NYSDEC Biomonitoring Unit conducted sampling events on the Owasco Inlet in 2001, 2006, 2007, and 2011. Monitoring was conducted to determine the impacts of nutrient limitations controls implemented at the Groton WWTP between 2006 and 2009. The 2006 sampling event reflects conditions prior to the nutrient controls at the WWTP. In addition to monitoring conducted by the NYSDEC, phosphorus, nitrogen and suspended solids have been monitored by the Finger Lakes Institute from 2006 to 2017 (Halfman et al. 2016). Sampling efforts were focused along Dutch Hollow Brook and the Owasco Inlet. Cornell University, from 2015 to present, has been performing sampling at various locations in the Owasco Basin to support the development of a watershed model for the development of a Nine Elements Plan. The NYSDEC Finger Lakes Hub has also been performing tributary sampling of the four largest tributaries to Owasco Lake in the late winter and early spring of 2018 for nutrients, suspended solids, physical parameters, and discharge to characterize inputs to Owasco Lake during the non-growing season.

6. Water Quality Conditions

General long-term trends in water quality were assessed using available data collected at all locations (**Figure 3**) combined through CSLAP (1989-1994, 2017), LCI (2004 and 2012), the DBPs study (2005) and SWQI (1996, 1997, and 1999). Trends were evaluated using a nonparametric correlation coefficient (Kendall's tau, τ) to determine if time trends were statistically significant (assumed for p-values less than 0.05). Water quality data used in this analysis were generally limited to those that were collected under a State-approved Quality Assurance Project Plan (QAPP) and analyzed at an

Environmental Laboratory Accredited Program (ELAP) certified laboratory. Water clarity, measured as Secchi depth, is presented with NYSDEC and FLI data. 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 1 provides a regional summary of surface total phosphorus (TP) concentrations from Owasco Lake in 2017 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**).

The 2017 TP concentration in Owasco Lake was much lower than other (much smaller and shallower) lakes in the Finger Lakes region, but similar to other Finger Lakes (**Table 1**). TP concentration, on average, was slightly higher at the North station than the South Station. Additionally, the average TP concentration for both stations in Owasco Lake is typically less than New York State water quality guidance value of 0.02 mg/L of TP for lakes. Thus, targeted TP concentrations for Owasco Lake likely need to be lake specific and below the Statewide threshold of 0.02 mg/L, when considering future management actions to limit the frequency and duration of HABs.

Table 1. Regional summary of surface total phosphorus (TP) concentrations (mg/L, ± standard error) for New York State lakes (2012-2017, CSLAP and LCI), and the average TP concentration (± standard error) in Owasco Lake in 2017.

Region	Number of Lakes	Average TP (mg/L)	Average TP Owasco Lake (mg/L) North, 2017	Average TP Owasco Lake (mg/L) South, 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 Lakes region	45	0.077 (± 0.022)	-	-
Finger Lakes	11	0.015 (± 0.003)	0.015 (± 0.002)	0.013 (± 0.0007)-
Western NY	47	0.045 (± 0.008)	-	-

Owasco Lake is typically considered mesotrophic (moderate productivity), with nutrient levels typical of other New York state lakes exhibiting only a moderate susceptibility to HABs. However, the lake has persistently demonstrated a high frequency of extensive shoreline blooms. A summary of HABs in the lake is provided in **Section 7**. The presence of HABs in the lake over the past decade have raised concerns about long-term water quality and public health. Lake water clarity (based on Secchi depth), TP, and chlorophyll-a concentrations are used to assess trophic state using New York State criteria – in 2017, these indicators reflected continued mesotrophic conditions (**Table 2**).

Table 2. New York State criteria for trophic classifications (NYSFOLA 2009) compared to average values in 2017 for Owasco Lake North and South locations (± standard error).					
Parameter	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Owasco Lake North**	**Owasco Lake South**
Transparency (m)	>5	2-5	<2	3.3 (± 0.5)	3.4 (± 0.3)
TP (mg/L)	<0.010	0.010-0.020	>0.020	0.015 (± 0.002)	0.013 (± 0.0007)
Chlorophyll-a (µg/L)	<2	2-8	>8	5.1 (± 0.7)	5.7 (± 2.4)

6.1 Physical Conditions

Water clarity can be related to the amount of suspended material in the water column including sediment, algae and cyanobacteria. Water clarity data, as represented by Secchi depth, collected in Owasco Lake between 1989 and 2017 were typically greater than 2 m and less than 5 m (**Figure 4b**). A significant increasing trend was observed in water clarity from 1989 to 2017 in Owasco Lake (p = 0.035, τ = 0.309), based on available data from NYSDEC and FLI. Maximum water clarity from 2004 to 2017 was greater than 5 m for at least part of the growing season (although annual averages were less than 5 m). Increased average water clarity in more recent years may be associated with the introduction of the invasive dreissenid mussels in the early 1990s. Similarly, minimum water clarity measurements have demonstrated an increasing trend (p = 0.120, τ = 0.336) between 1989 to 2017, although this trend was not statistically significant. Note that Secchi disk measurements generally exceed New York State Sanitary Code requirements for siting new bathing beaches (1.2-meter, or 4 ft., minimum, NYSDOH 2018b). However, such trophic indicators should continue to be monitored for any changes.

In 2017, average annual water clarity was indicative of mesotrophic conditions, although seasonal variation was evident (**Figure 4a**). From mid-June to mid-July water clarity decreased throughout the lake at the North location. Decreased water clarity in late-June to mid-July are likely related to high amounts of precipitation during this period. Rain events impact water clarity by increasing the amount of suspended material in the water column and indirectly by stimulating algal growth. Starting in late August, water clarity increased until October when sampling ended. Water clarity at the South station was typically higher than at the North station, except for samples collected in late September and October. Sediment loads entering the lake from the southern inlet often plunge to the metalimnion (deeper water) and has additionally been observed to be associated with the eastern shoreline early in the season (Dave Matthews, personal communication). Therefore, the water clarity measurements at the CSLAP open water sampling location may not capture the incoming sediment load, and its influence on water clarity, at the South station.

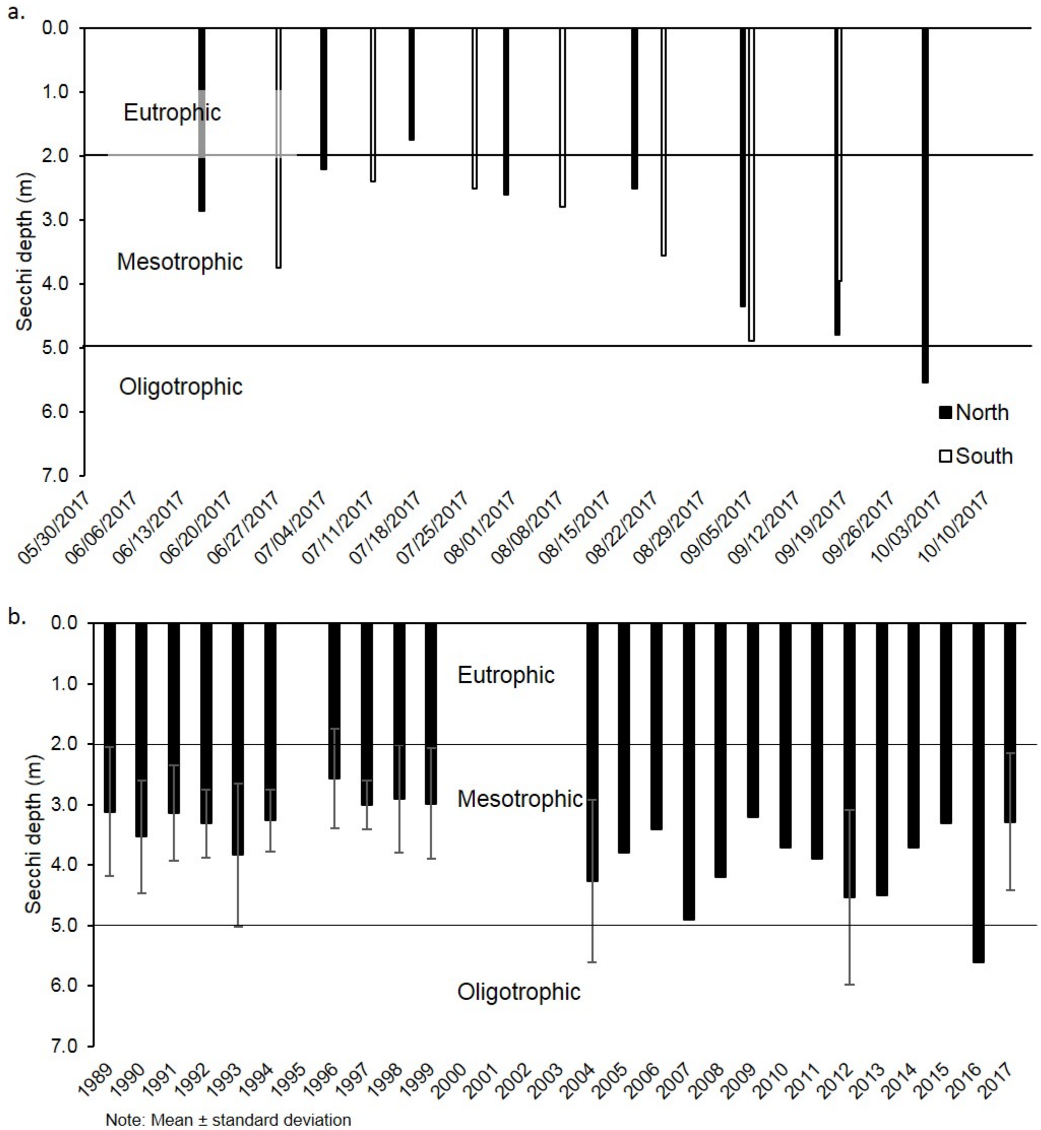

Figure 4. (a) Water clarity, measured as Secchi depth (m), in 2017 from the North (black bars) and South (white bars) sampling locations. (b) Annual average water clarity from all sample locations in Owasco Lake from 1989 to 2017 (NYSDEC and FLI; note NYSDEC and FLI values were averaged when data was available for a given year).

Understanding interannual (between years) and seasonal (within a year) temperature changes within a waterbody 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). Maximum summer water temperatures ranged between 23.0 °C (73.4°F, 1989,1990 and 1994) and 25.2 °C (77.4°F, 2012) (**Figure 5b**). Although no trend (p = 0.805, τ = -0.071) was observed for average temperatures from 1989 to

2017, a non-significant increasing trend (p = 0.066, τ = 0.564) in maximum temperature was evident in the data. Note that this increasing maximum temperature trend may be biased due to increased sampling frequency in more recent years. Typical seasonal trends in water temperature were observed, with temperatures increasing in the spring and early summer before decreasing in late summer and early fall. Recent CSLAP (2017) and LCI (2012) water temperature data are consistent with temperature data collected between 2005 to 2016 (Halfman 2017) and in the 1970's (Bloomfield 1978), when maximum temperatures were observed between 26.0 °C (78.8 °F) and 24.4 °C (76.0 °F).

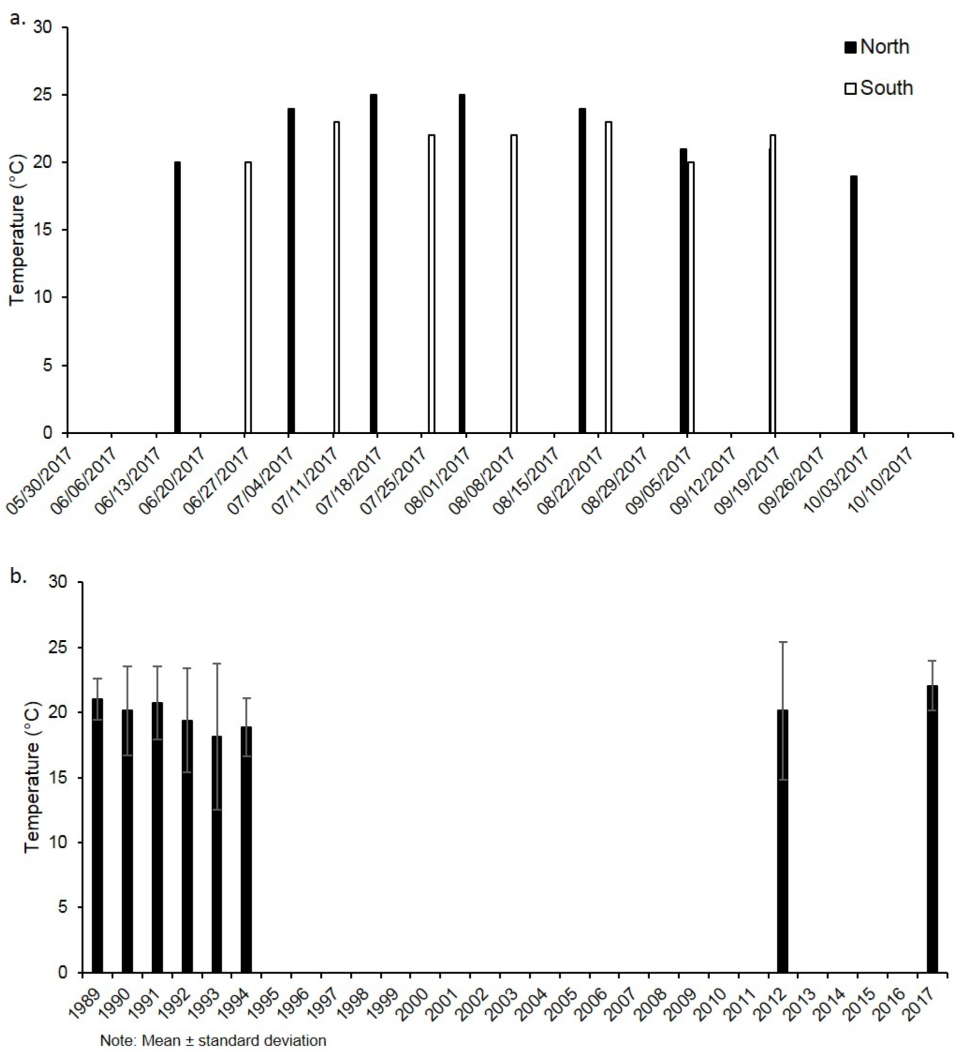

Figure 5. (a) Surface water temperature (°C) in 2017 from the North (black bars) and South (white bars) sampling locations. (b) Annual average surface water temperature from all sample locations in Owasco Lake from 1989 to 2017.

Water temperature depth profiles (**Figure 6**) from 2017 (FLI) indicate that Owasco Lake stratifies strongly during summer. The epilimnion, the warmer surface water, varied from approximately 10 to 20 m thick during sampling events. The metalimnion, the layer of temperature change between the warm epilimnion and colder hypolimnion (bottom layer), was observed between 10 and 20 m. Temperature depth profiles were consistent with profiles conducted in the 1970's (epilimnion depth 11.2 m, Bloomfield 1978) and 1910's (epilimnion depth 12 m, Birge and Juday 1914) during the growing season.

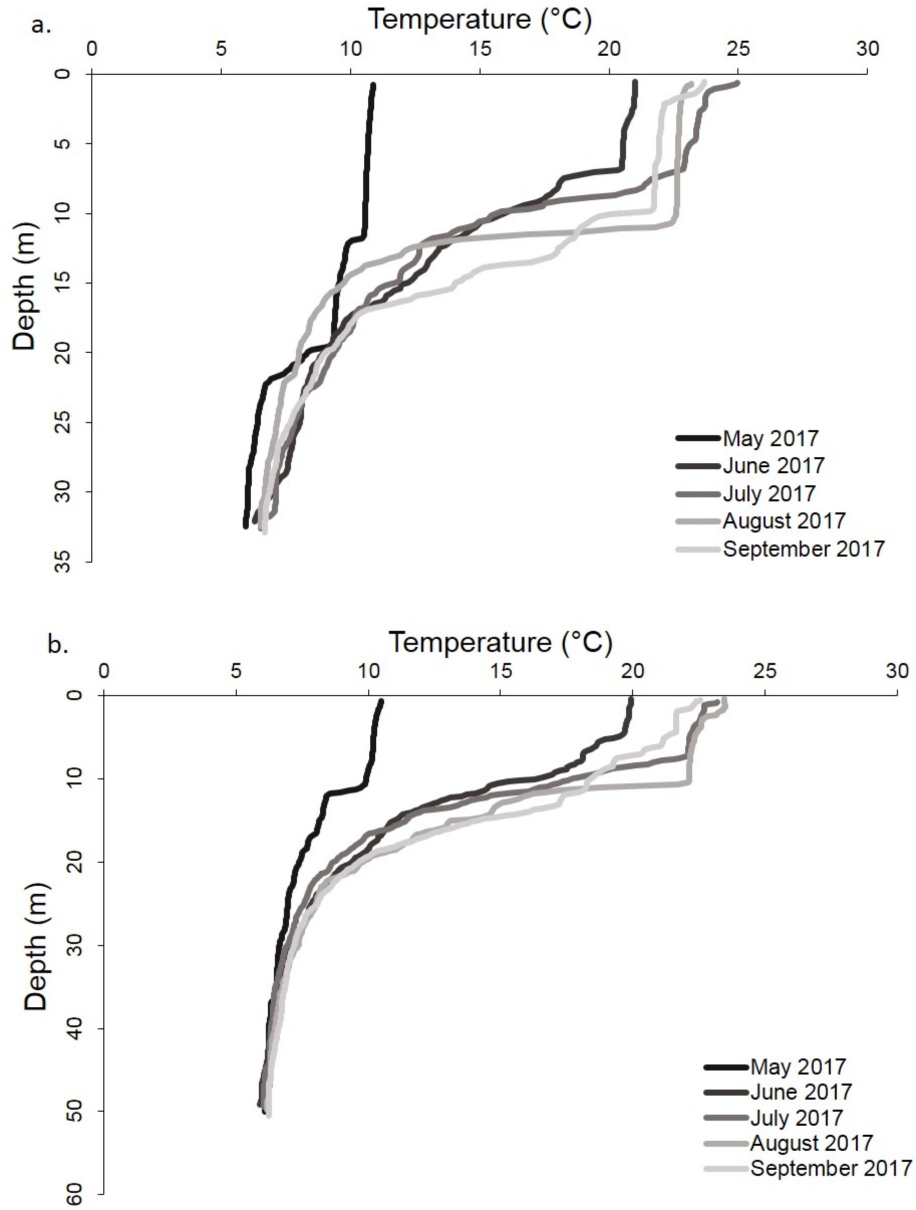

Figure 6. Water temperature profiles in Owasco Lake from May to September 2017, collected from (a) 42° 52.4'' N, 76° 31.35'' W and (b) 42° 49.15'' N, 76° 30.45'' W. Data provided by John Halfman, Hobart and William Smith Colleges.

6.2 Chemical Conditions

Dissolved oxygen (DO) depth profiles (**Figure 7**) from 2014 (the latest year with validated data, FLI) from May to August and October indicate a decrease in DO in the metalimnion later in the growing season (July, August, and October) in both the north and south areas of Owasco Lake. This decrease in DO is typically due to decomposition of settling phytoplankton coupled with limited DO inputs. Depth profiles indicate relatively uniform DO concentrations from the surface to a depth of ~ 10 m, indicating a relatively stable epilimnion. A DO depth profile from August 13, 1910 indicated that Owasco Lake had relatively consistent DO concentrations from the surface to the bottom (50 m), although, a slight decrease was observed in the metalimnion or thermocline followed by an increase in dissolved oxygen levels (Birge and Juday 1914). Progressively more severe DO depletion in the metalimnion from 1910, 1942 (Oglesby et al.1973), and 1986 (Effler et al. 1988) to the present is likely a result of long-term eutrophication (increasing productivity) of Owasco Lake or increased oxygen demand at these depths. Note that DO concentrations did not reach anoxic (no oxygen) conditions at depth in 2014, and this pattern of oxygenated water at depth is typical for Owasco Lake in previous years (Halfman 2017). Thus, internal loading in Owasco Lake associated with anoxic (lack of oxygen) nutrient release from bottom sediments is assumed to be negligible based on available data.

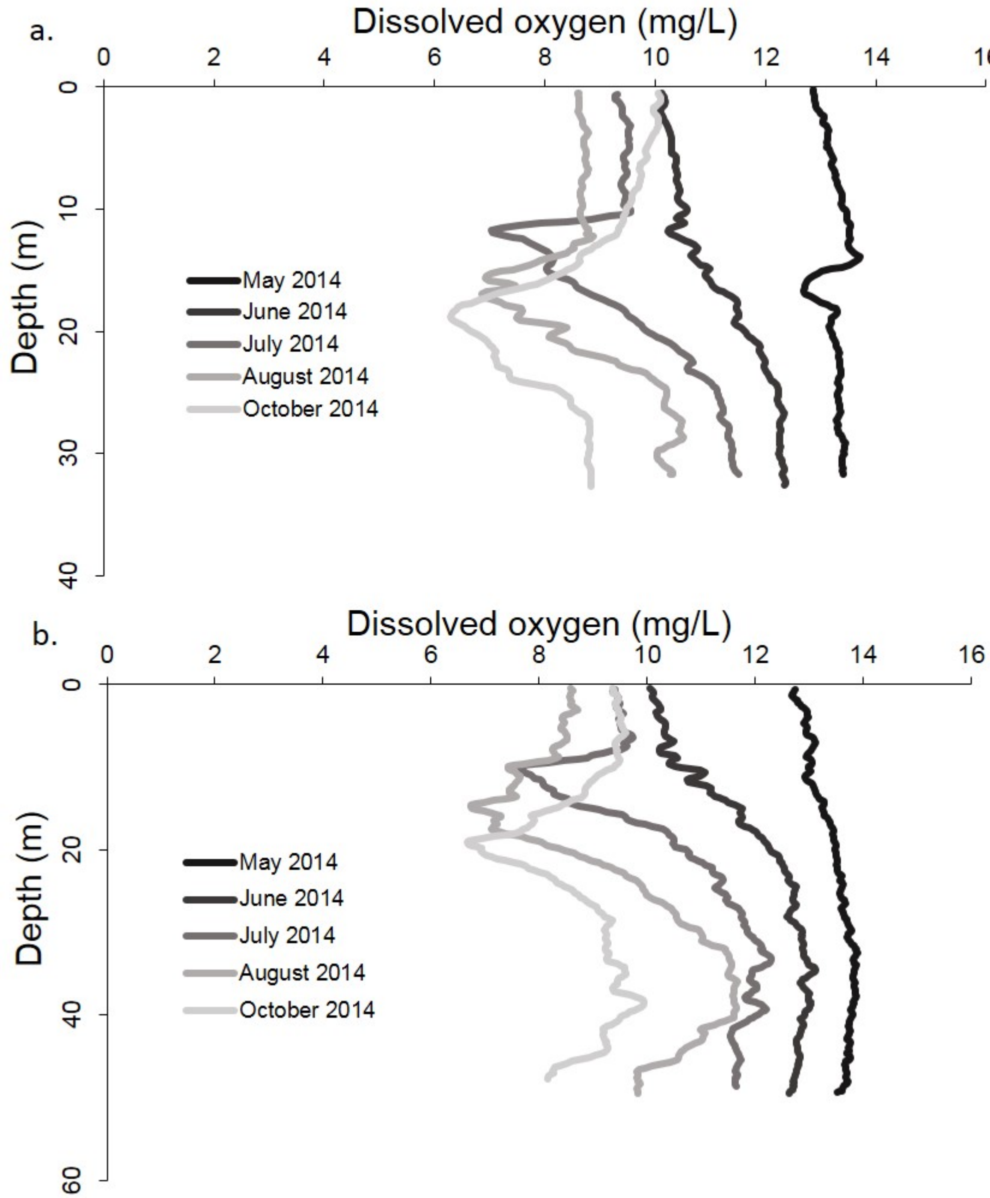

Figure 7. Dissolved oxygen profiles in Owasco Lake from July to October 2015, collected from (a) 42° 52.4'' N, 76° 31.35'' W and (b) 42° 49.15'' N, 76° 30.45'' W. Data provided by John Halfman, Hobart and William Smith Colleges.

Total phosphorus (TP) concentration in Owasco Lake from 1989 to 2017 (**Figure 8b**) were on average indicative of mesotrophic (moderate productivity) conditions, although, during a few years (1990, 1994, 1996, and 2005) average TP concentrations were indicative of oligotrophic (low productivity) conditions. Average TP concentrations from 1997 to 2017 were generally higher than those observed from 1989 to 1996, except for 2005, which was represented by a single measurement. Trend analyses indicated a general increase in average (p = 0.071, τ = 0.363) TP concentrations from 1989 to

2017; however, this increasing non-significant trend is likely driven by higher TP concentrations in a single year, 2012. Average concentrations of TP from 1971 to 1973 were approximately 0.012 mg/L (Bloomfield 1978) and were approximately 0.012 mg/L in the late 1990s (Callinan 2001), which is consistent with concentrations observed between 1989 and 2017.

In 2017 (**Figure 8a**), average TP concentrations were indicative of mesotrophic conditions. From mid-June to mid-July, TP increased throughout the lake and reached their highest 2017 concentration at the Northern location in mid-July. Increased TP concentrations in late-June to mid-July are likely related to high amounts of precipitation during this period. Starting in late August, TP decreased until October when sampling ended. TP concentrations at the Southern station were typically lower than at the Northern station.

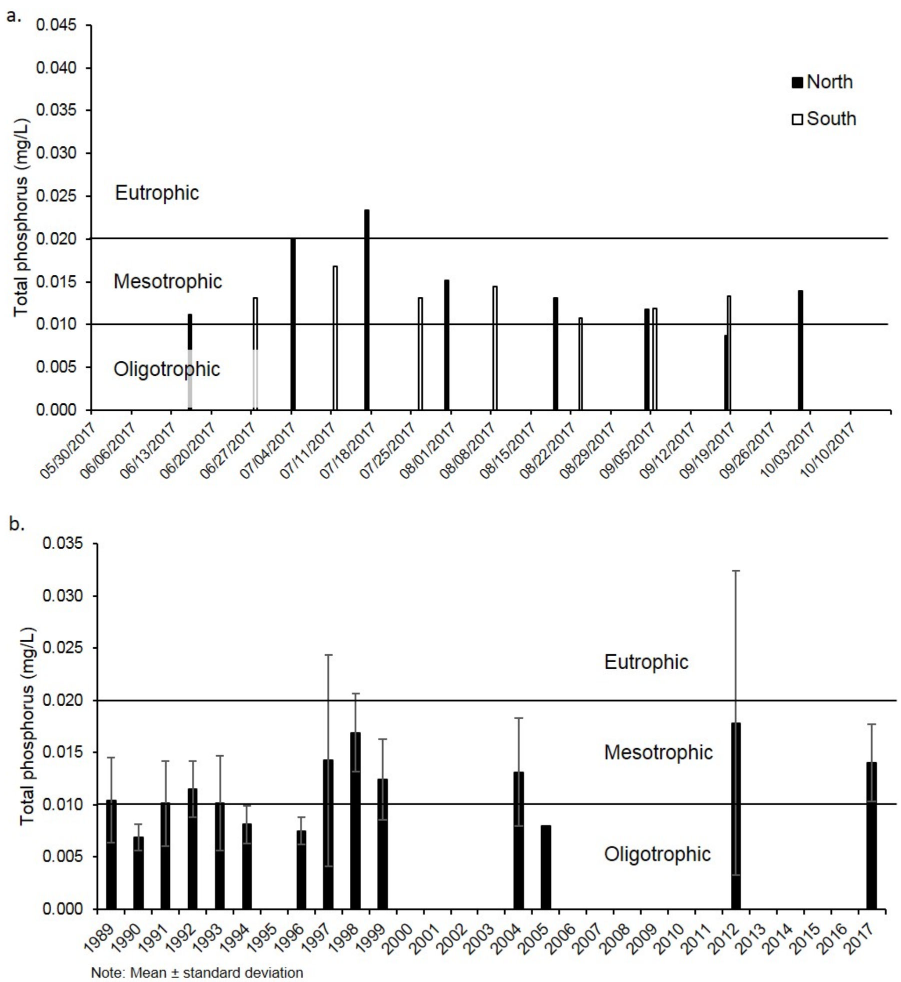

Figure 8. (a) Total phosphorus (TP) concentrations (mg/L) in 2017 from the North (black bars) and South (white bars) sampling locations (CSLAP). (b) Annual average TP concentrations from all sample locations in Owasco Lake from 1989 to 2017 (CSLAP; LCI).

Average annual total nitrogen (TN) was above or near 0.8 mg/L, except for in 2012 when average TN was approximately 0.4 mg/L. Depleted TN concentrations in 2012 are likely a result of particularly dry weather in 2012 (because precipitation is a major contributor of nitrogen to lakes (Bloomfield 1978)). No trend in average TN concentrations between 1996 and 2017 was observed (p = 0.453, τ = -0.238) (**Figure 9b**). In 2017, TN concentrations were slightly higher from late-June to late-July (**Figure 9a**). Concentrations from the North station were typically higher than the South station. Trend analysis of nitrate concentrations during the growing season from 1989-1999 (CSLAP and LCI) indicated a significant decreasing trend (p = 0.025, τ = -0.556) in average and a non-significant decreasing trend (p = 0.106, τ = -0.405) in maximum nitrate concentrations. In contrast, a non-significant increasing trend (p = 0.091, τ = 0.600) in average and a significant increasing trend (p = 0.015, τ = 0.861) in maximum ammonium concentrations between 1996 to 2017 were observed.

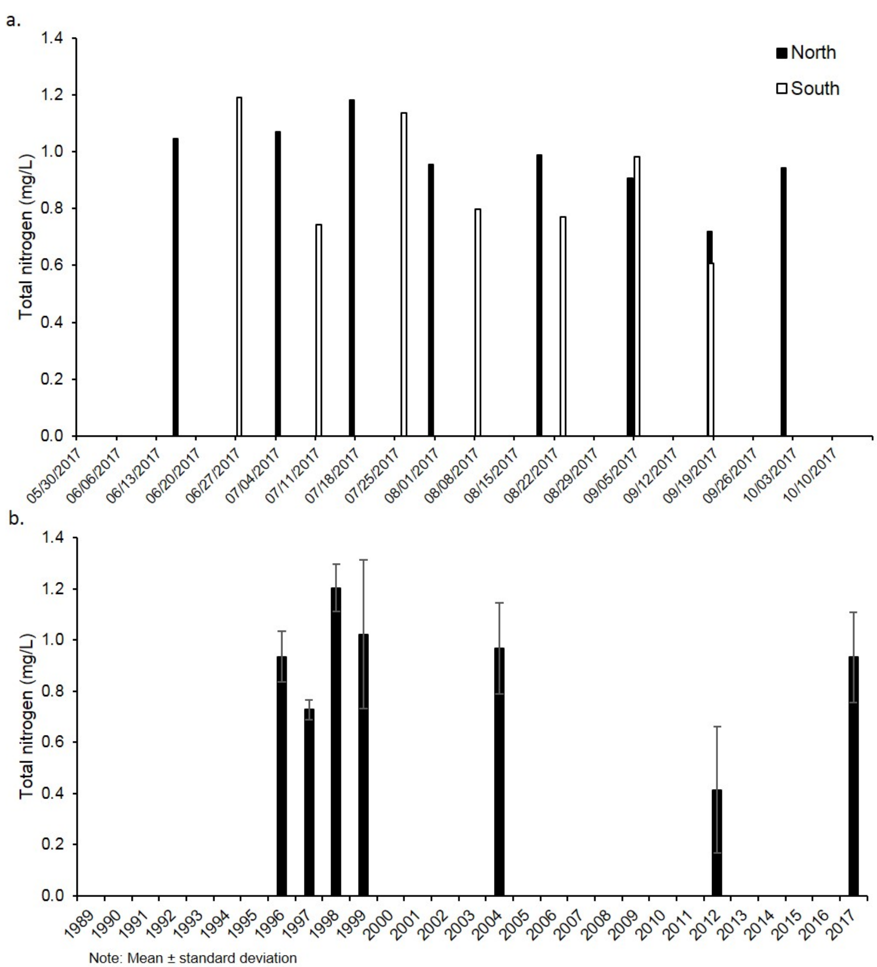

Figure 9. (a) Total nitrogen (TN) concentrations (mg/L) in 2017 from the North (black bars) and South (white bars). (b) Annual average TN concentrations from all sample locations in Owasco Lake from 1996 to 2017.

The relative concentrations of nitrogen and phosphorus can influence algal community composition and the abundance of cyanobacteria. Ratios of total nitrogen (TN) to total phosphorus (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 or not 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. Total nitrogen to total phosphorus ratios (TN:TP, 1996 to 2017, **Figure 10b**) indicate that nitrogen is not limiting to algal growth in Owasco Lake. Average annual mass-based TN:TP ratios ranged from 26.8 (2012) to 127.7 (1996). There was no long-term trend in TN:TP ratios from 1996 to 2017 (p = 0.293, τ = -0.333).

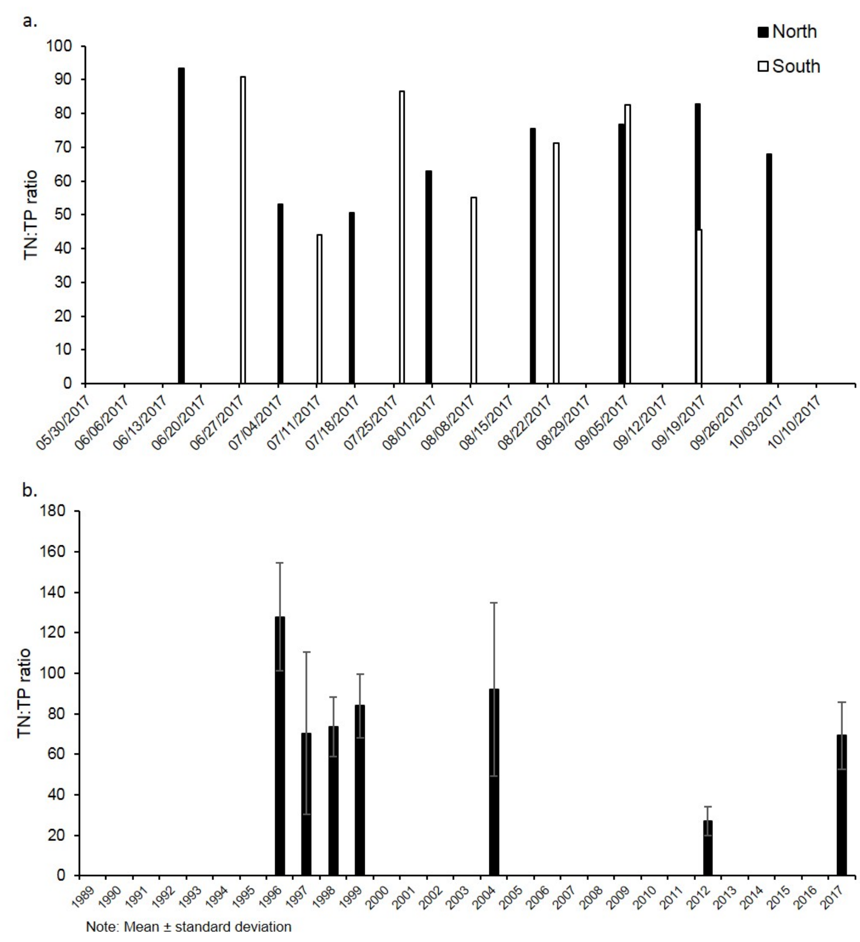

Figure 10. (a) Ratios of total nitrogen (TN) to total phosphorus (TP) in 2017 from the North (black bars) and South (white bars) sampling locations. (b) Annual average TN:TP ratios from all sample locations in Owasco Lake from 1989 to 2017.

6.3 Biological Conditions

Owasco Lake has eleven known aquatic invasive species (Cayuga County Government 2018b):

- Eurasian watermilfoil, *Myriophyllum spicatum*
- Curly-leaf pondweed, *Potamogeton crispus*
- Waterfleas, *Bythotrephes* and *Cercopagis*
- Chinese mystery snail, *Cipangopaludina chinensis*
- Zebra mussel, *Dreissena polymorpha*
- Quagga mussel, *Dreissena bugensis*
- Asian clam, *Corbicula fluminea*
- Alewife, *Alosa pseudoharengus*
- Common carp, *Cyprinus carpio*
- European rudd*, Scardinius erythrophthalmus*

Certain invasive species may influence the frequency and duration of HABs. For instance, cyprinid fish species – common carp and European rudd – can increase sediment suspension and associated nutrients in the water column based on their feeding behavior. These species feed on benthic macroinvertebrates found within the sediment, with that sediment suspended during active feeding. The increased sediment suspended in the water will include nutrients that may be utilized by blue green algae.

Alewife may additionally contribute to increased prevalence of HABs. Specifically, alewife consumption of large zooplankton may increase abundance of phytoplankton and cyanobacteria because fewer zooplankton are present to control algae abundance. In addition to a general decrease in zooplankton abundance, the smaller zooplankton, which are less likely to be consumed by alewife, are less efficient at grazing on phytoplankton (Brooks and Dodson 1965). The decline in large zooplankton, such as *Daphnia,* in lakes through predation has been speculated to increase cyanobacteria dominance in summer months (Couture and Watzin 2008). Studies conducted by FLI annually since 2005 have included plankton samples and reported the zooplankton community dominated by small organisms, specifically, *Polyarthra* and *Vorticella* with some copepods, nauplii, and the invasive *Cercopagus* (Halfman et al. 2016)

Eurasian watermilfoil and curly-leaf pondweed are of major concern in Owasco Lake because these species often grow in large dense beds, outcompeting and crowding out native aquatic vegetation. The dense beds of these aquatic invasive species provide less suitable habitat for fish and other aquatic life and can impede recreational activities such as boating, fishing, and swimming. These invasive aquatic macrophytes 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 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 the variables on Owasco Lake.

Dreissenid mussels (zebra and quagga mussels) can influence phytoplankton composition by selectively filter feeding phytoplankton, which can result in increased prevalence of cyanobacteria (Vanderploeg et al. 2001). Zebra 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). Shifting nutrient concentrations to nearshore areas may result in greater incidence of shoreline HABs. Additionally, quagga mussels can colonize a wide range of substrates (e.g., soft sediment as opposed to hard substrates), and at varying depths, and thus likely have a greater localized spatial influence on nutrient availability in waterbodies in which they have invaded (Turner 2010). In addition, Asian clams were first discovered in Owasco Lake in 2010; this species also has high filtration rates and can concentrate nutrients in nearshore zones where they are found (NYSISI 2018).

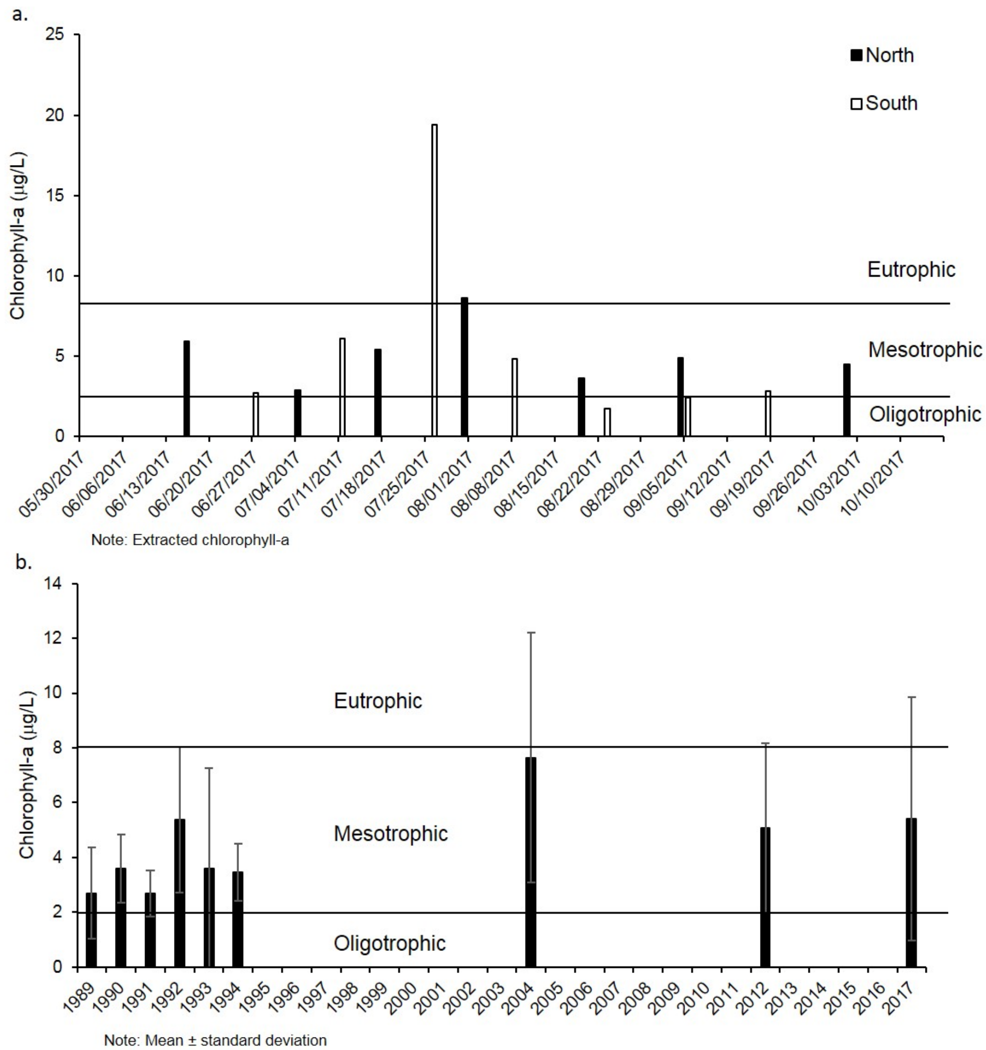

Figure 11. (a) Chlorophyll-a concentrations (µg/L) in 2017 from the North (black bars) and South (white bars) sampling locations. (b) Annual average chlorophyll-a concentrations from all sample locations in Owasco Lake from 1989 to 2017.

Annual average chlorophyll-a concentrations (**Figure 11b**) in Owasco Lake ranged between 2.7 (1989) and 7.6 (2004) µg/L. Trend analyses indicated a non-significant increase in annual average chlorophyll-a concentrations (p = 0.095, τ = 0.444) from 1989 to 2017. Additionally, maximum annual chlorophyll-a over this same time period showed a significant increasing trend (p = 0.037 τ = 0.556). In 2017, chlorophyll-a concentrations increased from late June to late July before concentrations decreased through October. In 2017 (**Figure 11a**), a large increase in chlorophyll-a concentrations was observed at the South location on July 25, which may have been a result of nutrient loading from recent intense rain events. Note, however, that a corresponding decrease in Secchi depth was not observed in conjunction with increased chlorophyll-a during the July 25th sampling event

Summer average chlorophyll-a concentrations in Owasco Lake (**Figure 11b**) typically reached levels near or above the 4.0 μg/L threshold for Class AA and the 6.0 μg/L threshold for Class A lakes proposed by Callinan et al. (2013). Callinan et al. (2013) indicated that average chlorophyll-a concentrations above 4 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).

6.4 Other Conditions

The OWLA bacteriological volunteer monitoring program, OLWMC, and Cayuga County have collected water samples from multiple locations around Owasco Lake and from several tributaries. Bacteria counts in lake and stream samples that exceed NYSDOH limits have decreased since 2010, although, part of the changes are a result of variability due to non-uniform distribution of bacteria and changes in the laboratory used for the analyses. Agriculture was identified as the intermediate source of fecal coliform at Emerson Park and a major source to tributaries. Wildlife, particularly waterfowl, were identified as a major source of fecal coliform to Emerson Park and the tributaries, while pet and human sources were minor at all sampling sites (NYSDEC 2016).

Sampling conducted by the NYSDEC Stream Biomonitoring Unit in the Owasco Inlet between 2006 and 2011 indicated that water quality improved slightly due to nutrient controls implemented at the Groton WWTP from 2006 to 2009. A measurable improvement in the macroinvertebrate community downstream of the Groton WWTP suggests an improvement in phosphorus conditions (lower concentrations).

6.5 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 a particular day and is intended to supplement 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**, chlorophyll-a concentrations tend to be higher in the north portion of the lake (near Emerson, Island Park, Poplar Cove and in the bay south of Buck Point) and at the south end near the Owasco Inlet. It should be noted that these areas also feature water depths of less than 25 ft. In these shallow areas, the remote sensing might also be picking up suspended algae, algal mats, submerged aquatic vegetation, and the lake bed. Despite these interferences it may be that the north end of the lake is confined by Owasco Outlet, where chlorophyll-a concentrations may accumulate in the water column. The south end, receives flow from Owasco Inlet which may be a source of chlorophyll-a concentrations following rainfall events.

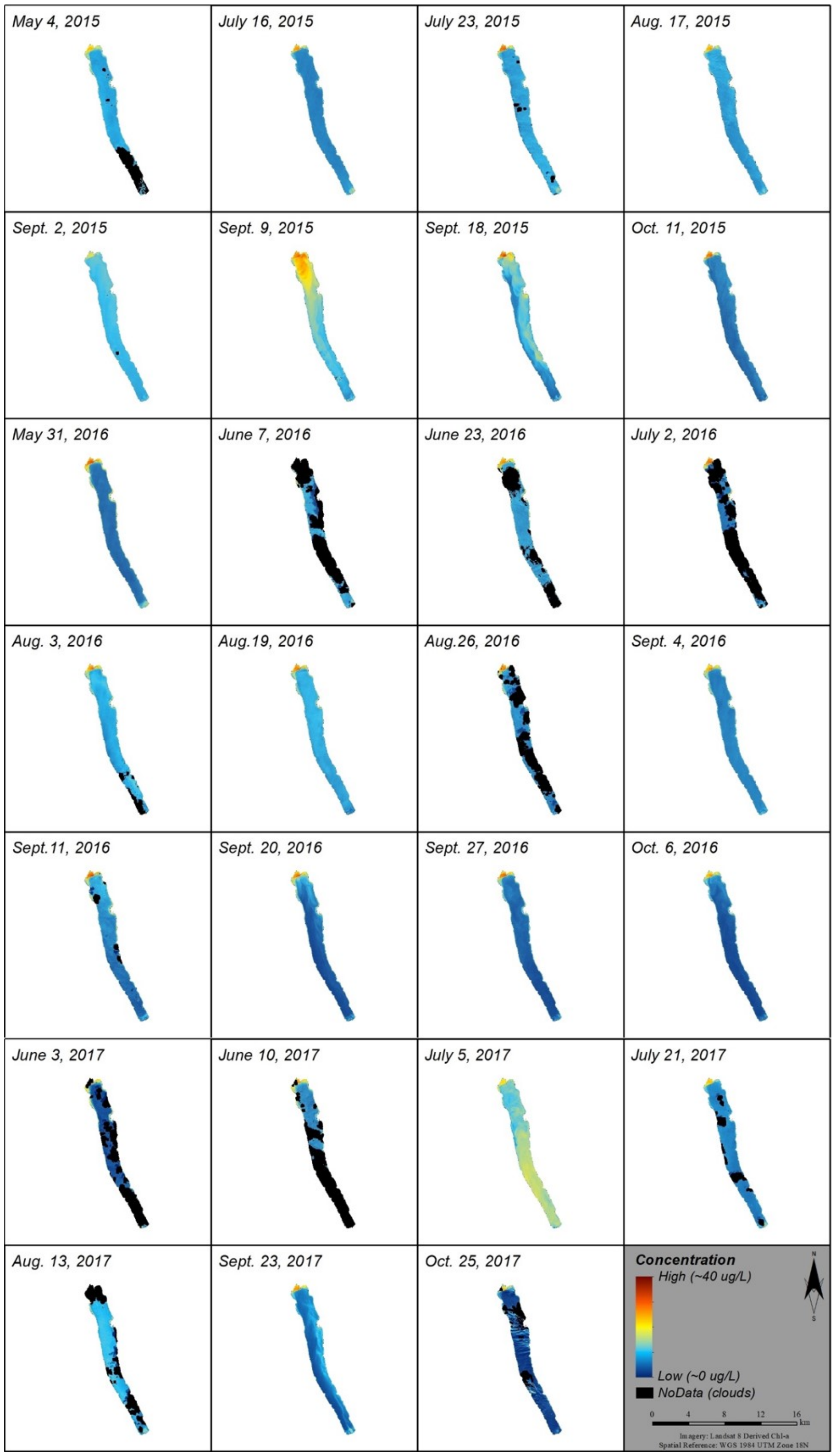

Figure 12. Estimated chlorophyll-a concentrations in Owasco Lake, 2015 to 2017.

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 (**Figure 13**). The figure indicates that there is relative agreement between the measured and estimated concentrations when there is coincident data. CSLAP was not conducted on the lake in 2015 and 2016, however the remote sensing estimates provide some insight into these time periods where in-lake monitoring data were not collected through CSLAP. From the results, the estimated chlorophyll-a concentrations were higher in 2017 compared to 2015 and 2016.

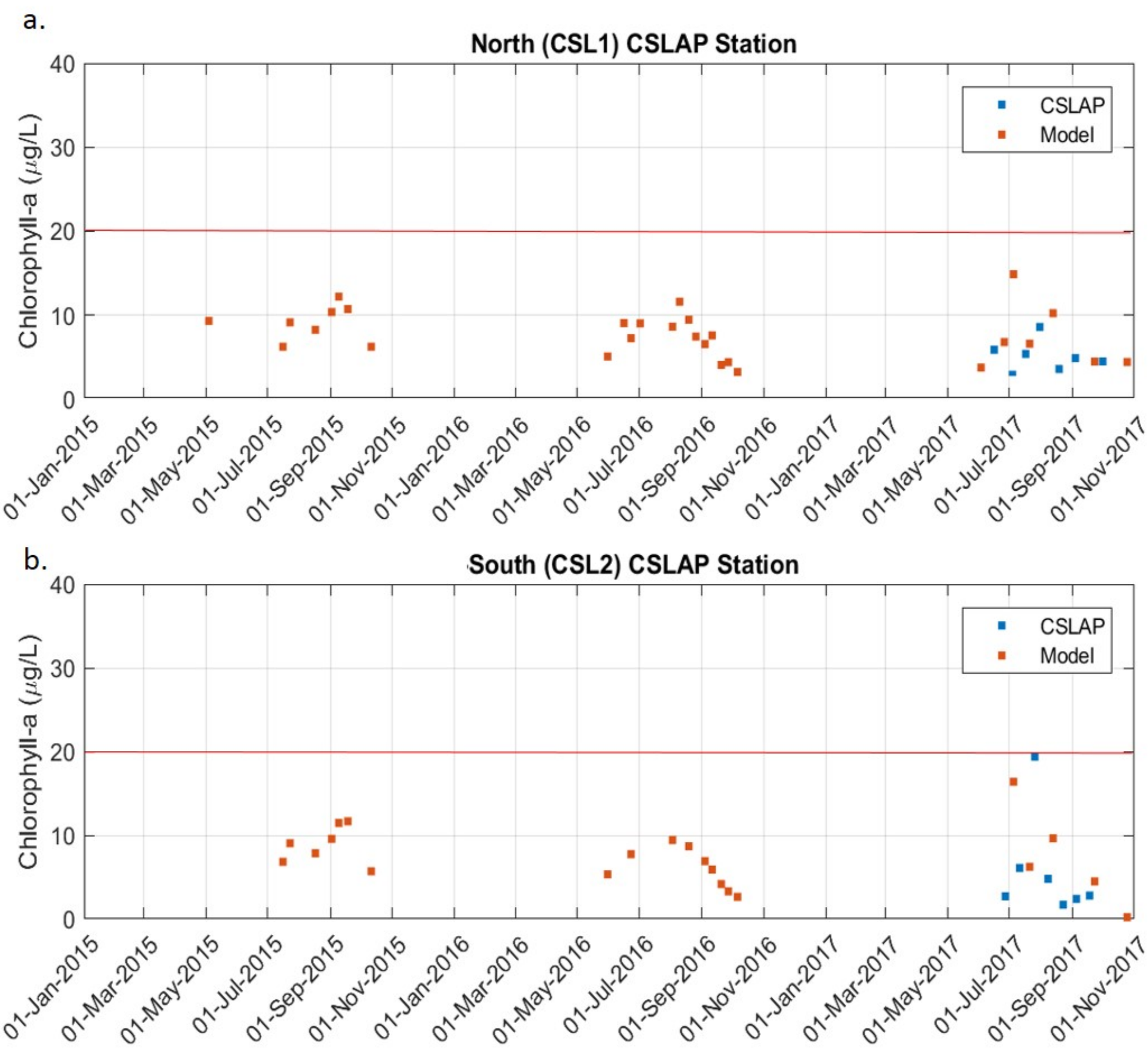

Figure 13. Measured (CSLAP, blue squares) and modeled (Landsat 8, orange squares) chlorophyll-a concentrations in Owasco Lake from 2015 to 2017. The red lines represent the upper threshold of chlorophyll-a concentrations (20 μg/L) for which the remote sensing algorithm was tested in Lake Champlain (Trescott 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 extensively to document and communicate HABs to the citizens of New York State. 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 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 a HABs sample, 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 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

Owasco Lake, along with some of the other Finger Lakes, 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 CCDOH/NYSDOH, OWLA, OLWIP, and members of the public. HABs in Owasco Lake occur predominantly in the lake's north end. In 2016 and 2017, most of the HABs sampling on Owasco Lake was conducted by staff of the OLWIP and trained volunteer monitors that agree to survey a zone of lakeshore weekly. This surveillance and monitoring network involves trained OWLA volunteers conducting weekly surveys of 24 shoreline zones every Monday from early July through early October. When blooms were observed, volunteers collected samples and provided them to OLWIP to be transported to SUNY ESF for analysis. This information helps the NYSDEC to be able to rapidly communicate bloom location to regional stakeholders. When lake observations of potential HABs are collected, they are compiled and assigned a bloom status, per NYSDEC's *Harmful Algal Blooms Program Guide* (NYSDEC 2017) and as described above. These conditions are reported to local stakeholders by NYSDEC, and also further reported on the OLWIP website, at least prior to 2018.

As presented in **Section 6.1**, nutrient concentrations and total chlorophyll-a concentrations in Owasco Lake have been indicative of mesotrophic conditions. Such conditions are conducive to the formation of HABs when accompanied by other potential triggers or exacerbating factors (e.g., high water temperature, calm winds, and the presence of dreissenid mussels).

Between 2013 and 2017, a total of 84 HAB occurrences were reported based on water quality sampling and/or visual reporting by the CCDOH, OWLA, and OLWIP. Confirmed or Confirmed with High Toxins HABs were reported during 34 days of sampling, occurring primarily between late July and early September, although bloom frequency and duration clearly extended beyond these sampled events. The 34 sampling days of Confirmed and Confirmed with High Toxin HABs were reported as occurring within the following months and years:

- 2013: 1 (October)
- 2014: 3 (September)
- 2015: 10 (July-October)
- 2016: 10 (July-October)
- 2017: 10 (July-September)

A photograph of a confirmed HAB that occurred in the northern portion of Owasco Lake offshore of Emerson Park in September 2017 is provided as **Figure 14**.

Figure 14. Photograph of a 2017 HAB in Owasco Lake (Source: OLWIP).

Most HABs documented by the NYSDEC between 2013 and 2017 were identified as shoreline blooms, ranging in extent from small localized to large localized to widespread/lakewide. A total of 55 of the 84 HABs reports were determined to be Confirmed with High Toxins Blooms (see **Section 7.3**).

Cyanobacteria HABs were most commonly associated with the northern and northeastern shorelines of Owasco Lake (along Emerson Park and the Owasco Yacht Club), and although all were identified as shoreline blooms, several extended well into the open waters of the lake. Because sampling is often limited to the shoreline, particularly as part of the volunteer monitoring program, the sampling effort does not necessarily reflect the true extent of the blooms. And as noted above, blooms were frequently present between discrete sampling events, so the duration of these blooms cannot be easily evaluated. The lakewide extent of blooms, particularly in the open water, cannot be easily evaluated through shoreline HAB surveillance and monitoring activities. Northern shoreline blooms resulted in beach closures at multiple locations (see **Section 7.2**).

In addition to confirmed blooms, visual observations and/or photographs indicated seven Suspicious Blooms in 2013, 2014, and 2017. These observations were reported by the CCDOH, NYSDOH, and general lake users as occurring predominantly in the lake's north end. These Suspicious Blooms resulted in beach closures at three distinct locations in 2017. Beach closures attributable to HABs are discussed in further detail in **Section 7.2**. The NYSDOH also has data documenting HABs in 2010 and 2012.

Table 3. History of HABs in Owasco Lake, 2013-2017.										
Date	Bloom extent	HAB Status	Chl-a (μg/L)**		Daily avg. air temp (°C)	Water temp (°C)	Daily rainfall (mm)	10-day total rainfall (mm)	Max daily wind speed (m/s)	Water quality data
			Min	Max						
8/25/2013	SL	S.	NA	NA	19.5	NA	0	9.9	7.2	NA
10/3/2013	NR	C/HT	52.0	52.0	15.7	NA	0	0	3.1	NA
8/22/2014	LL	S	NA	NA	20.5	NA	8.3	61.3	5.7	NA
8/25/2014	LL	S	NA	NA	21.9	NA	0	33.9	2.6	NA
9/1/2014	NR	C	1130.0	1130.0	24.4	NA	0	6.3	3.6	NA
9/18/2014	NR	C/HT	119.3	119.3	12.8	NA	0	22.4	5.7	NA
9/25/2014	NR	C/HT	244.5	244.5	16	NA	0	11.8	4.1	NA
10/12/2014	LL	S	NA	NA	8	NA	0	26.9	3.6	NA
7/9/2015	SL	C	38.78	38.78	18	NA	7.4	93.6	3.1	NA
9/2/2015*	SL	C/HT	71.39	984.0	22.3	NA	0	2.9	4.1	NA
9/3/2015*	LL	C/HT	190.02	252.25	23.7	NA	0	2.6	5.7	NA
9/4/2015*	SL;LL	C/HT	2382	4651	22.9	NA	0	2.6	4.6	NA
9/16/2015	LL	C/HT	678.75	678.75	20	NA	0	32.5	2.6	NA
9/17/2015*	SL;LL	C/HT	88.77	943.75	21.2	NA	0	32.5	2.6	NA
9/25/2015	NR	C/HT	207.49	207.49	17.1	NA	0	9.2	5.1	NA
10/4/2015	LL	C/HT	3477.5	3477.5	12.2	NA	0	65.4	5.7	NA
10/5/2015*	LL	C/HT	96.25	2522.5	10.9	NA	0	65.4	4.1	NA
7/27/2016*	LL	C	NA	NA	23.3	NA	0	33.4	4.6	NA
7/28/2016	LL	C	1245.25	1245.25	25	NA	0	32.9	4.6	NA
7/29/2106	LL	C/HT	8432.25	8432.25	23.9	NA	0	32.9	6.2	NA
8/1/2016*	SL;LL	C;C/HT	737.75	17144.5	21.8	NA	14.3	48	4.6	NA
8/27/2016	LL	C	297.39	297.39	22.6	NA	0	17	4.6	NA
9/6/2016*	NR;LL	C	69.04	212.48	20.8	NA	0	0	4.6	NA
9/9/2016*	LL	C;C/HT	277.32	10047.5	25	NA	4.1	38.9	4.6	NA
9/15/2016	SL	C/HT	4509.25	4509.25	13.8	NA	0	42.2	3.6	NA
9/19/2016*	LL;W/L	C/HT	183	8239.25	21	NA	16.8	54.5	3.6	NA
10/3/2016*	SL;LL;W/L	C/HT	418	8877	15.5	NA	10	23.1	4.6	NA
7/19/2017	NR	S	NA	NA	23.1	NA	0	26.4	4.6	NA
7/27/2017	SL	C	8274	8274	20.3	NA	12	29.1	4.1	NA
7/28/2017	SL	C	7618.8	7618.8	19.8	NA	0	29.1	6.7	NA
7/30/2017	NR	C	1975.3	1975.3	19.1	NA	0	28.3	5.1	NA
7/31/2017*	NR	C; S	688.8	3385.8	22.1	25	0	28.3	5.1	Yes
8/2/2017	NR	S	NA	NA	23.9	NA	0	28.3	4.1	NA
9/11/2017*	NR	C/HT	334.3	727	13.7	NA	0	29.7	3.6	NA
9/12/2017*	NR	C/HT	1036.5	2301.3	16	NA	0	29.7	3.6	NA
9/18/2017	NR	C/HT	45618.75	45618.75	21.8	21	0	1	3.6	Yes
9/19/2017*	NR	C/HT	1304	21162.5	21.1	NA	0	1	3.6	NA
9/25/2017*	NR	C/HT	1364	4525	23.3	NA	0	0	3.6	NA
9/29/2017*	NR	C/HT	1175	1648.75	12.9	NA	0	0.2	4.6	NA

Note – all locations were shoreline
Abbreviations:
* = multiple samples collected on day
NA = Not Available
Bloom extent: SL= small localized, LL = large localized, WL = widespread/lakewide, NR = not reported
HAB Status: S = Suspicious, C = Confirmed, C/HT = Confirmed with High Toxins
**Chlorophyll-a concentrations quantified with fluoroprobe

7.2 Drinking Water and Swimming Beach HABs History

Drinking Water

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 were 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 Environmental Laboratory Approval Program (ELAP) is offering certification for laboratories performing HAB toxin analysis, starting in spring 2018, and 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.

Because Owasco Lake is a source of drinking water for several lakeside communities, there is a concern that cyanotoxins could be withdrawn through the lake's intakes and incorporated into the City of Auburn and Town of Owasco water supply systems. As discussed in **Section 8.1**, the public water supply use of Owasco Lake is currently impaired due to: 1) the lake's susceptibility to HABs from high nutrient inputs from agricultural use of much of the surrounding area, septics, waterfowl and other sources, and 2) the potential for increased in DBPs in drinking water corresponding to increases in organic matter (e.g., algae) and increases in water treatment. The public water supplies were first sampled for microcystin based on bloom concerns in 2011. Sampling on multiple dates between September and October 2016 indicated that the finished drinking water contained microcystin concentrations up to 0.22 µg/L. The presence of detectable microcystin in treated drinking water, however, was short lived and measured concentrations never exceeded the USEPA's Health Advisories for microcystin in drinking water of 0.3 µg/L for pre-school (< 6 years) children and 1.6 µg/L for school-age children and adults (USEPA 2015). The state and county health departments worked together to optimize treatment and communicated these results and their implications to public. This incident led to the state funding the addition of activated carbon treatment at both treatment plans, and extensive sampling during 2017 indicated this treatment is working properly. (City of Auburn 2016; Town of Owasco 2016). 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

Beach closures in Owasco Lake were historically attributable to elevated coliform levels, however, the increasing prevalence of HABs in the lake, particularly along its northern shorelines, has resulted in more frequent beach closures associated with cyanobacteria blooms. Public bathing and recreation (see **Section 3.4**) at Owasco Lake are considered impaired based on several indicators of eutrophication in the lake, including excess algae and HABs (NYSDEC 2016). This includes documentation of blooms through the NYSDEC HABs surveillance and notification program established on Owasco Lake through a partnership between NYSDEC, the Owasco Lake Watershed Inspection Program, and the Owasco Watershed Lake Association. Routine HAB surveillance and monitoring confirmed frequent high toxin blooms in multiple locations in the lake.

The presence and intensity of HABs at some lakes may be facilitated by wind, either via its absence or by directional currents that are strong enough to influence cyanobacterial transport and concentrations. As discussed in **Section 2.3**, wind-driven accumulation of HABs at Owasco Lake during blooms, particularly along the north-eastern shoreline, has implications for public health, including private swimming at camp-run recreation centers and other private swimming areas.

A summary of the observations and impacts of HABs on bathing beach recreational use at Owasco Lake from 2014 to 2017 is presented below based on beach closure data supplied by NYSDOH (**Figure 15**).

- 2014: 14 lost beach days (4 at Owasco Yacht Club, 10 at Emerson Park)
- 2015: 12 lost beach days (Owasco Yacht Club, and Camp Y-Owasco)
- 2016: 8 lost beach days (Owasco Yacht Club)
- 2017: 27.5 lost beach days (13.5 at Owasco Yacht Club, 4 at Emerson Park, 5 at Camp Y-Owasco, and 5 at Camp Columbus).

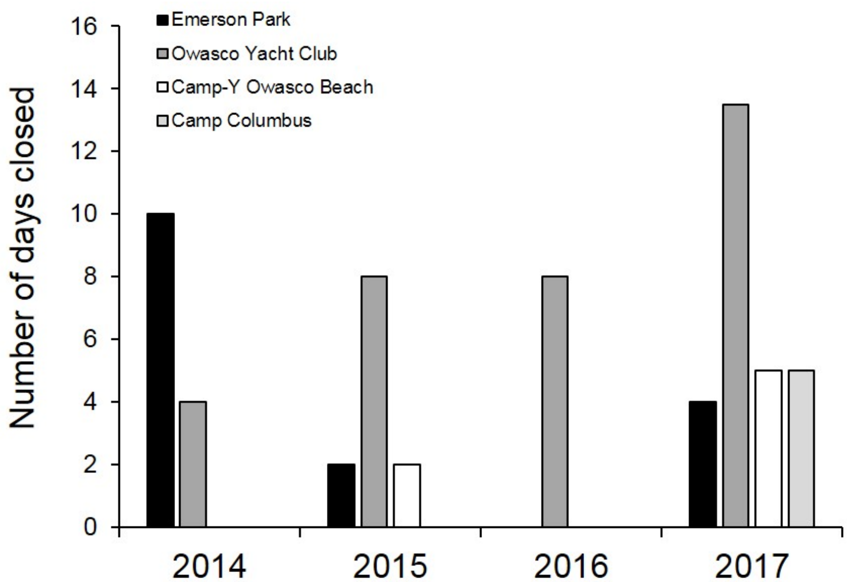

Figure 15. Number of beach days lost due to beach closures associated with HABs in Owasco Lake from 2014 to 2017.

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

Table 4. HABs guidance criteria.			
NYSDEC Bloom Status Categories			
Confirmed	**Confirmed w/ high toxins**		**Suspicious**
	Open water	**Shoreline**	
[BGA Chl-a] >25 µg/L	[Microcystin] > 10 µg/L	[Microcystin] > 20 µg/L	Visual evidence of cyanobacteria HAB 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 < 4µg/l (USEPA 2016) starting in 2017	

7.3 Other Bloom Documentation

Cyanobacteria Chlorophyll-a

Cyanobacteria cell counts and/or chlorophyll-a (BGA) concentrations can be used to trigger HABs alert and advisory systems. BGA chlorophyll-a concentrations were quantified at a laboratory at SUNY ESF with a FluoroProbe (bbe Moldaenke) for all samples collected from 2013 to 2017. The skim sampling strategy used for this work likely documents the worst-case conditions of shoreline blooms, and therefore may not be representative of conditions in that location or at that time. Confirmed bloom BGA chlorophyll-a concentrations ranged from 31.0 µg/L (July 2015) to 45,462 µg/L (September 2017; **Table 5**).

Cyanotoxins

Some cyanobacteria taxa also produce toxins (cyanotoxins) that are harmful to people and pets. As a result, several different toxins are monitored during blooms. 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 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 laboratory detection limits in 71 of the 89 samples submitted for microcystin analysis, ranging in concentration from 0.6 µg/L (September 2017) to 2,438 µg/L (September 2016; **Table 5**). The 20 µg/L microcystin threshold was exceeded in 56 of the 89 samples and identified by NYSDEC as a Confirmed with High Toxin Bloom (**Table 5**). Microcystin levels also exceeded the draft human health recreational swimming advisory threshold of 4 µg/L (USEPA 2016) during 64 of the 71 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. The 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 5. Measured toxin and cyanobacteria (BGA) chlorophyll-a concentrations (µg/L) for bloom events (2013-2017, Owasco Lake HAB surveillance network, CSLAP, and public reports).

Status	Microcystin (µg/L)			Cyanobacteria (BGA) chl-a (µg/L)		
	Min	Max	# of samples	Min	Max	# of samples
Confirmed	ND	17.9	18	31.0	9603	18
Confirmed, High Toxins	29.5	2438	56	39.9	45462	59

Cyanobacteria Taxa

Although several genera of cyanobacteria were identified in samples collected during blooms in 2013 to 2017, *Dolichospermum*, a filamentous, nitrogen-fixing genus and *Microcystis*, a common unicellular, buoyancy-regulating genus, were most common and most abundant in microscopic evaluation of samples collected during blooms, particularly during late summer and fall. Several species of *Dolichospermum* and *Microcystis* are capable of producing microcystin, which as discussed above was reported at high levels in water samples during some HABs. *Dolichospermum* may have a competitive advantage in nitrogen-limited lakes given its ability to fix nitrogen; however, its presence at high densities during HABs in late summer-fall is likely not attributable to its nitrogen-fixing ability given that Owasco Lake is phosphorus-limited. *Microcystis* may have the capacity to selectively outcompete other algae in lakes such as Owasco Lake, as its ability to regulate its buoyancy provides an edge in relatively warm, stratified systems that experience infrequent wind-driven mixing during the growing season.

7.4 Use Impacts

Prompted by the detection of cyanobacteria in both withdrawn raw water and treated drinking water, both the City of Auburn and the Town of Owasco have installed activated carbon treatment systems as a proactive measure to filter cyanobacteria and remove cyanotoxins from drinking water drawn from Owasco Lake, and to address taste and odor complaints likely associated with excessive algae levels (NYSDEC 2016). As described in **Section 7.2**, microcystin was detected on several occasions in finished drinking water from the City of Auburn and Town of Owasco municipal water supply in September and October 2016, but at levels below the HAL.

7.5 HABs and Remote Sensing

Remote sensing images 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 (8 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.

In 2015, Landsat 8 images were available from May to October, with the exception of June. There was a noticeable lake-wide increase in chlorophyll-a concentrations in September 2015 with the highest concentrations observed on September 9, 2015 as shown in **Figure 16**. HAB reports were confirmed on September 2, 3, 4, 16, 17 and 25. The corresponding location for all recorded HABs in **Figure 16** is a lake marker and is not representative of the location of these HABs. During the period of high chlorophyll-a concentration in September 2015 there were dry, hot and calm weather conditions. From September 12 to 14, 2015 there was a storm event that brought high winds, rainfall and a decrease in air temperature. This may have helped to decrease chlorophyll-a concentration observed on September 18, 2015.

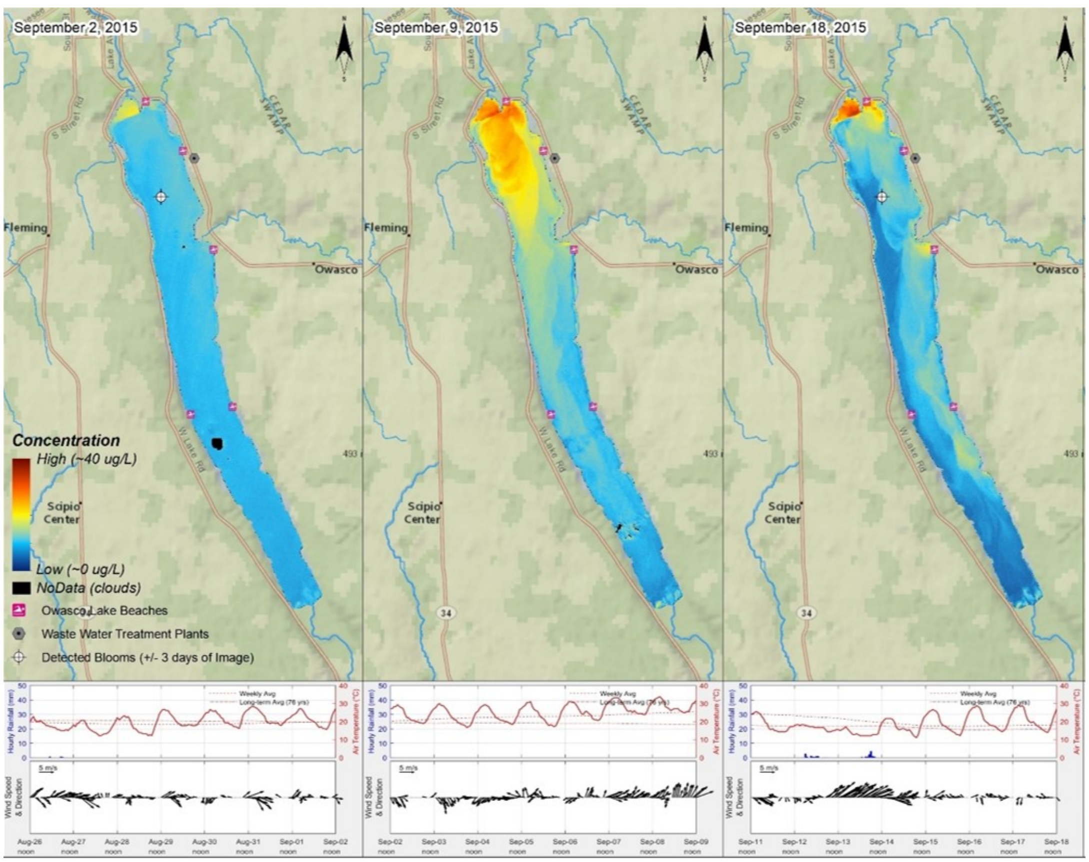

Figure 16. Modeled chlorophyll-a concentrations in Owasco Lake, September 2015.

In 2016, Landsat 8 images were available from May to October, with the exception of July. There was a noticeable lake-wide increase in chlorophyll-a concentrations starting in June 2016 and persisting until late September 2016 as shown in the figures provided in **Appendix C**. On August 1st, 2016 HABs were reported at five different locations; a remote sensing image was available on August 3rd, 2016 (**Figure 17**). On July 31st there was a large rainfall event recorded at both the Ithaca Airport (located south of Owasco Lake) and Syracuse Hancock International Airport (located northeast of Owasco Lake). Before and after the rainfall event, air temperatures were above normal. The combination of the rainfall and warm temperatures may have contributed to the HABs observed on September 1st, 2016. By September 3, 2016 (the date of the remote sensing image) the winds had picked up starting the day before at both regional airports, therefore the estimated chlorophyll-a concentrations observed in the remote sensing image on August 3rd may not be representative of concentrations during the HABs event on August 1st, 2016.

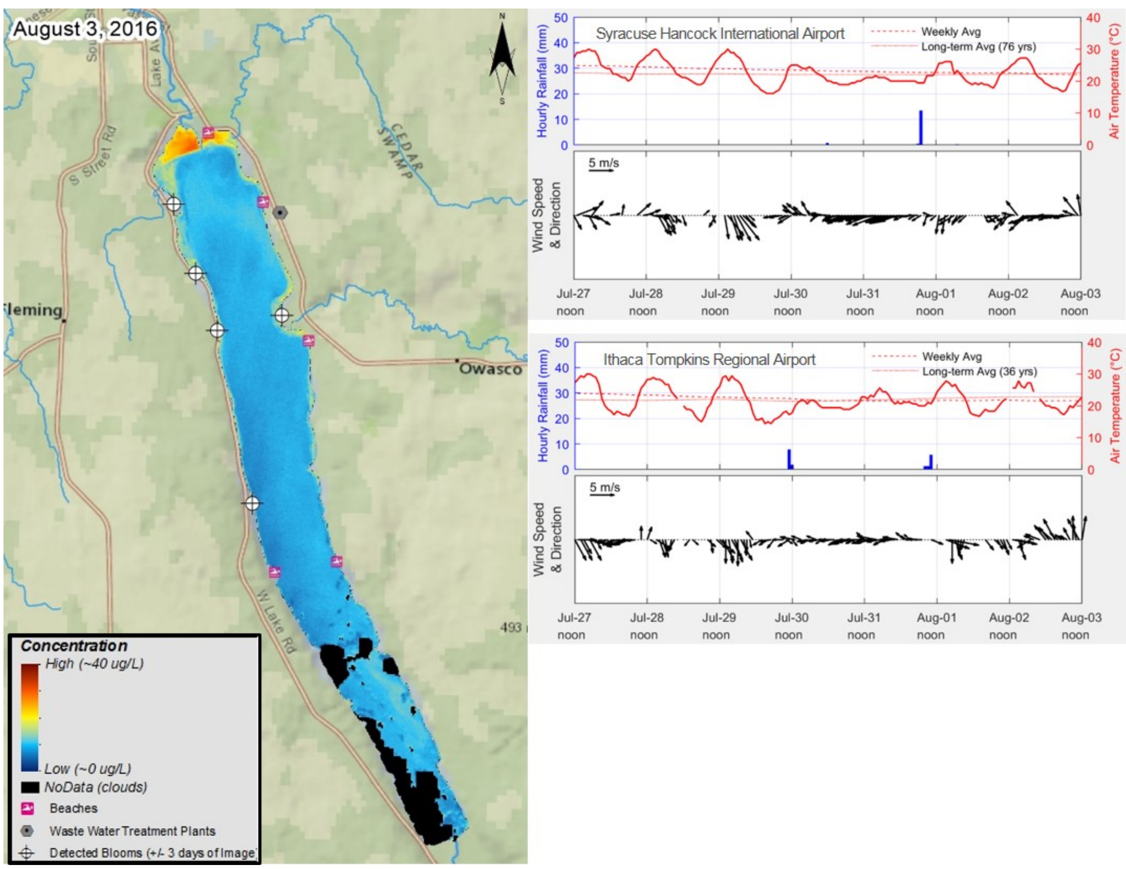

Figure 17. Modeled chlorophyll-a concentrations in Owasco Lake on August 3, 2016.

On September 19, 2016 HABs were reported in nine locations in the north half of Owasco Lake. On September 17 and 18th there were rainfall events at both regional airports. In addition, winds were calm and air temperature were above average on this day. The remote sensing image on September 20, 2016 shows high chlorophyll-a concentrations around the shoreline coinciding with HABs reports (**Figure 18**).

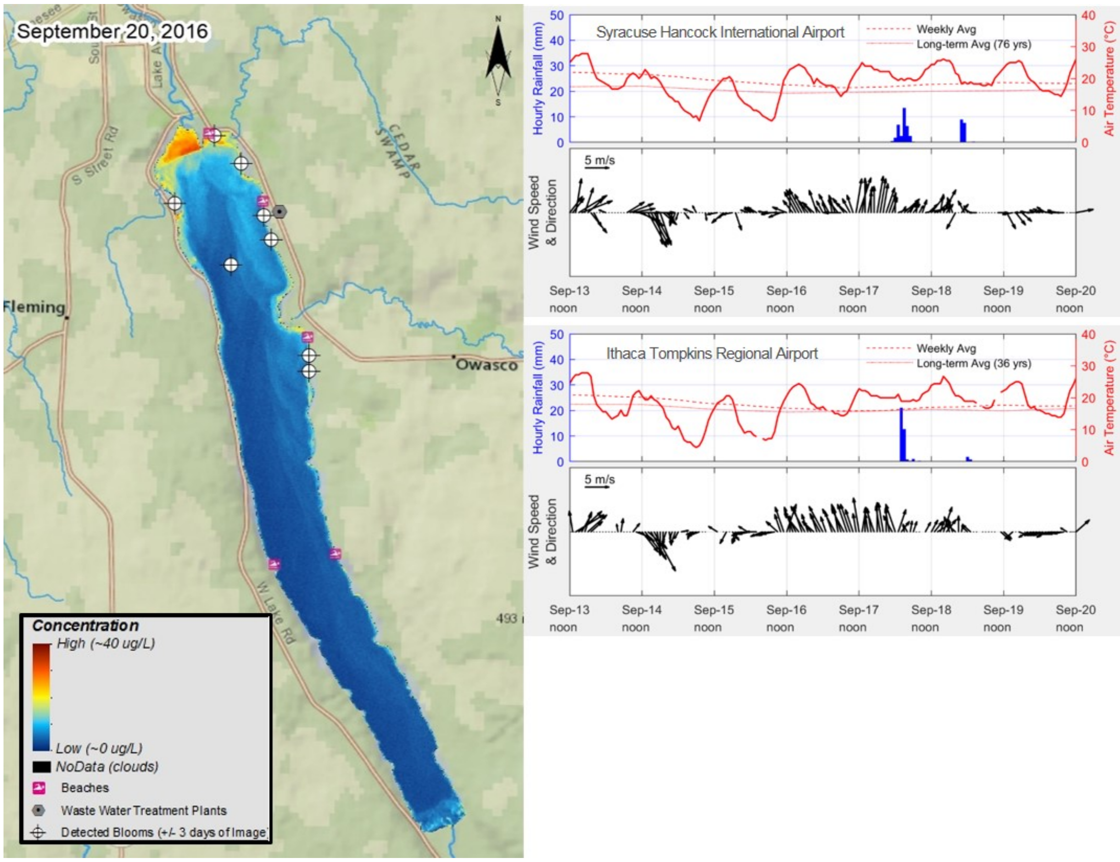

Figure 18. Modeled chlorophyll-a concentrations in Owasco Lake on September 20, 2016.

In 2017, Landsat 8 images were available from July to September. There was a noticeable lake-wide increase in chlorophyll-a concentrations on July 5, 2017 with the plume concentrated in the south portion of the lake (**Figure 19**). Leading up to this day, there was rainfall on June 29th through to July 1st, 2017 at both regional airports. Then starting two days before the image, winds were from the north, which may explain the higher chlorophyll-a concentrations on July 5th, 2017 south portion of Owasco Lake. On the day of the image, winds were calm and air temperature was above normal.

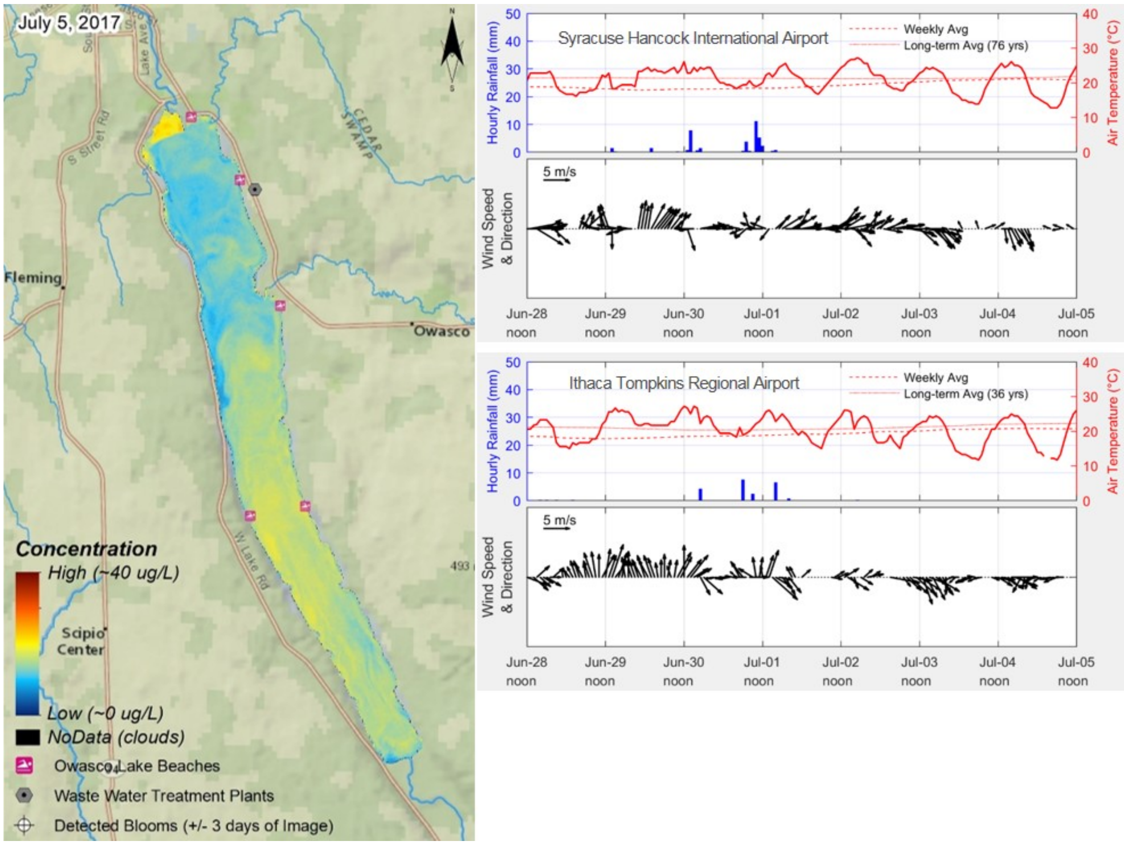

Figure 19. Modeled chlorophyll-a concentrations in Owasco Lake on July 5, 2017.

The percentage of the Owasco Lake surface area with an estimated chlorophyll-a concentration greater than 10 µg/L and 25 µg/L is summarized in **Table 6**. Cyanobacteria cell counts and/or chlorophyll-a concentrations (e.g., BGA chlorophyll-a) less than 25 µg/L is NYSDEC's criteria 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 6. Percent (%) of water surface area with an estimated chlorophyll-a concentration (µg/L) above and below 10 µg/L and 25 µg/L in Owasco 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	
2015-05-04	57	76	19	0	24
2015-05-29	2	5	2	0	95
2015-06-05	0	0	0	0	100
2015-07-16	91	99	9	1	1
2015-07-23	76	95	19	1	4
2015-08-17	84	98	14	0	1
2015-09-02	21	99	78	0	1
2015-09-09	12	96	87	3	1
2015-09-18	40	98	59	1	1
2015-09-25	2	24	22	0	76
2015-10-11	93	98	6	1	1
2016-05-31	86	98	13	1	1
2016-06-07	27	34	7	0	66
2016-06-16	26	28	2	0	72
2016-06-23	49	61	12	1	39
2016-07-02	24	28	5	1	71
2016-08-03	56	89	34	1	10
2016-08-10	0	27	27	0	73
2016-08-19	67	98	32	1	1
2016-08-26	39	45	7	1	54
2016-09-04	89	99	11	0	1
2016-09-11	79	93	15	1	6
2016-09-20	87	98	12	1	1
2016-09-27	91	98	9	1	1
2016-10-06	92	99	8	0	1
2017-05-09	2	3	1	0	96
2017-06-03	41	47	7	0	52
2017-06-10	30	37	7	0	63
2017-06-26	13	14	1	0	86
2017-07-05	1	99	98	0	1
2017-07-21	76	83	7	0	17
2017-08-06	19	26	6	0	74
2017-08-13	23	66	43	0	34
2017-08-29	0	0	0	0	100
2017-09-23	86	99	13	1	1
2017-10-25	74	79	5	0	21

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 TMDL.

The WIP/WL 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 current WI/PWL assessment for Owasco Lake (**Table 7**, **Appendix D**) reflects monitoring data collected in 2014 through 2017. Owasco Lake is required to support its best uses as a drinking water supply source, primary and secondary contact recreation uses, and fishing use.

Owasco Lake is currently assessed as an impaired waterbody due to primary contact recreation use that is impaired by pathogens from wildlife sources and due to the temporary/occasional closures of public beaches for swimming. Drinking water supply use is threatened due to elevated chlorophyll-a levels that create the potential for the formation of disinfection by-products in finished potable water. In addition, primary secondary contact recreation use is stressed due to the temporary/occasional closures of public beaches for swimming associated with HABs. Point sources such as wastewater treatment facilities and nonpoint sources such as a runoff from agriculture (both animal and crop), onsite/septic systems, soil erosion, and streambank erosion have been identified as the known sources of nutrient and sediment loads to the lake.

The 2018 update of the WI/PWL suggests removing Owasco Lake from Part 3b of the NYS Section 303(d) List, based on the NYSDEC CALM, as HABs are not a pollutant and cannot be regulated with a TMDL. Owasco Lake is also categorized as an Integrated Reporting (IR) Category 4c waterbody 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 7. 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 (SWAP)

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 Owasco 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. Owasco 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.

The SWAP for Owasco Lake in 2005 concluded that the water supply was moderately susceptible to contamination from pesticides and other contaminants due to the high level of row crop agriculture and the number of point sources or permitted municipal wastewater discharges in the watershed.

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. The 2017 scorecard for Owasco Lake suggests that algae blooms impact swimming and other recreational activities, and stress the aesthetic conditions of the Lake at the North and South sampling locations (**Figure 20**).

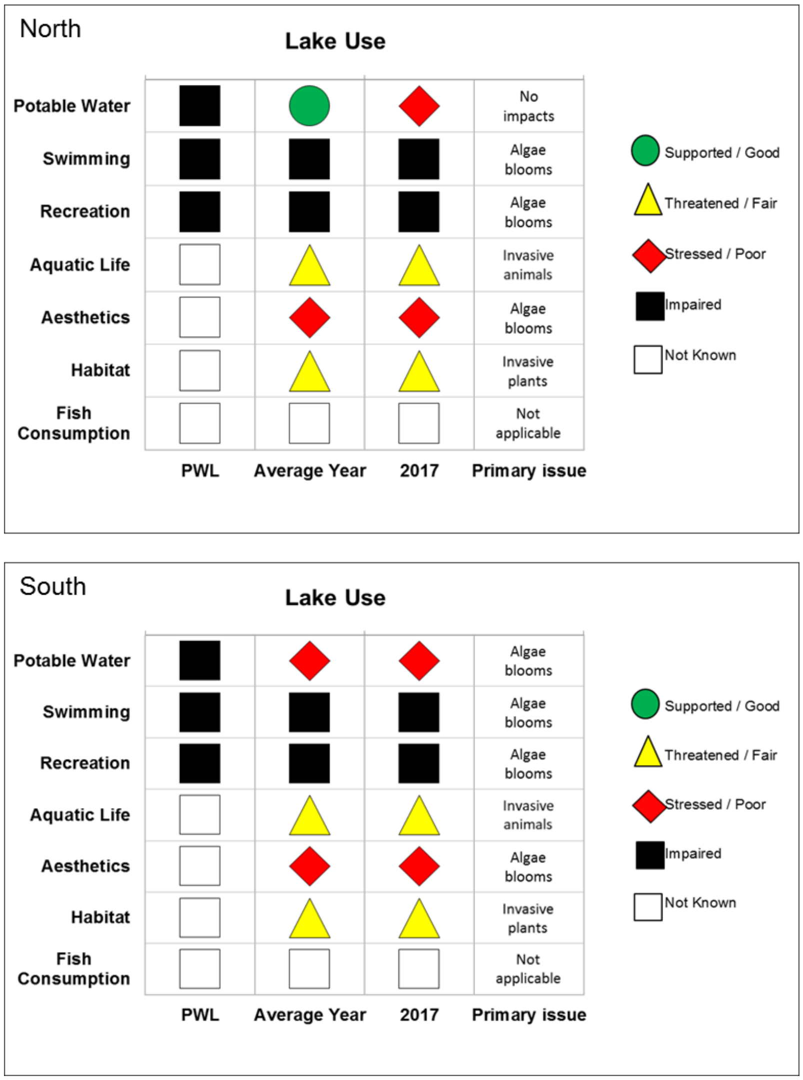

Figure 20. Owasco Lake 2017 CSLAP scorecard.

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 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 deserve 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 is does not account for important local, lake-specific drivers of HABs such as temperature, wind, light intensity, and runoff events.

To evaluate if lake-specific HABs triggers, in addition to those observed at the state scale, were important at Owasco Lake, additional statistical analyses were performed with data spanning from 2013 to 2017. All available HABs observations (bloom/no bloom) were aligned by date with meteorological information (e.g., temperature, precipitation, and wind speed) from the Syracuse Hancock airport station. A wave hindcast for Owasco Lake was performed by using measured wind data from the airport, fetch distances across the lake, and water depths along the fetches. 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 prepared using the wave hindcasting technique by Donelan (1980). Water quality variables were not assessed in this HABs trigger analysis because water quality measurements from samples analyzed by state certified laboratories only aligned with HABs observations in 2017.

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.

Logistic regression indicated that decreased maximum wave heights the day of a reported bloom were correlated with HAB observations in Owasco Lake ($p < 0.001$, **Figure 21**). Decreased wave heights, or calm surface water conditions, the day of a bloom may be related to the dominant cyanobacteria taxa found in Owasco Lake. In particular, *Microcystis*, which can regulate buoyancy, was documented in 79% (n = 72) of qualitative microscopy samples collected from Owasco Lake. Calm surface water conditions may permit *Microcystis* to move up into the photic zone to efficiently capture light for photosynthesis, providing a competitive advantage of other algae. In addition, decreased average daily rainfall in the days leading up to a reported HAB were significantly correlated with HAB observations ($p = 0.002$).

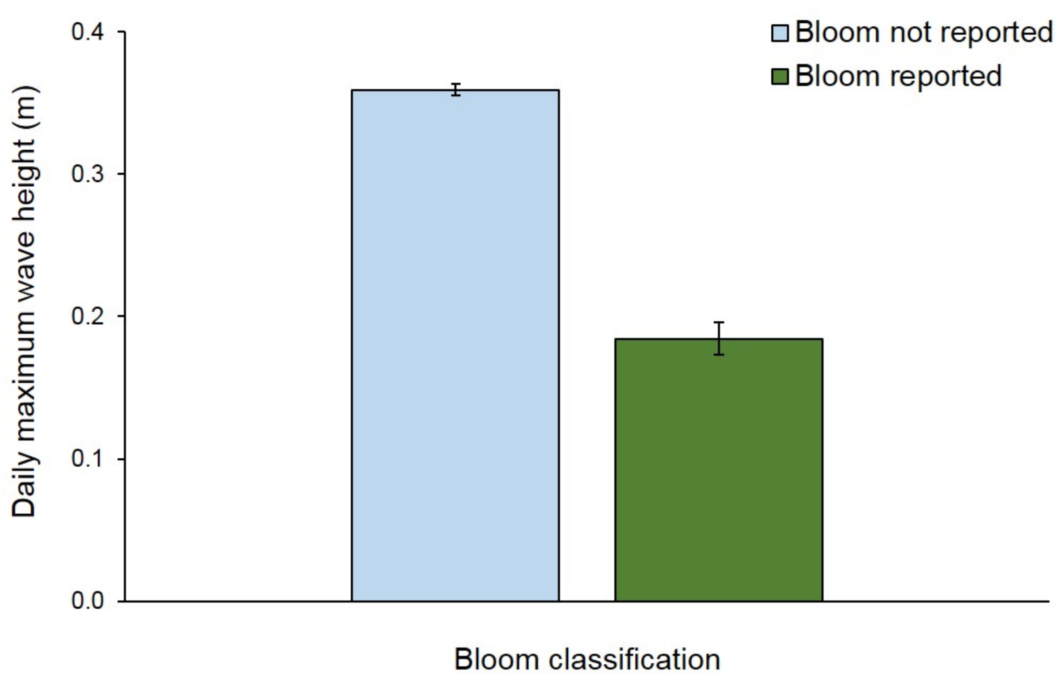

Figure 21. Average wave heights (m, ± standard error) the day of recorded blooms (green bar) and no recorded blooms (blue bars) in Owasco Lake.

To fully understand the likely triggers of HABs in Owasco Lake, additional water quality monitoring and associated HABs observations should be collected. Nutrient and water chemistry information aligned with HABs observations (both presence and absence) in subsequent years will complement the meteorological analyses.

10. Sources of Pollutants triggering HABs

NYSDEC's Loading Estimator of Nutrient Sources (LENS) screening tool was used to estimate land use proportions and identify potential nutrient pollutant sources in the Owasco Lake watershed (NYSDEC, undated). Based on the LENS model analysis, the greatest source of phosphorus loading to Owasco Lake is estimated to be from nonpoint source runoff (see **Section 10.2**, below).

10.1 Land Uses

Based on the LENS analysis, the watershed comprises the following land use types (**Figure 22**):

- Natural areas = 42%
- Developed land = 5%
- Agriculture = 49%
- Open water = 5%

If the open water is excluded from the Owasco Lake land use breakdown, approximately 44% of the watershed consists of natural areas, while approximately 52% of the watershed is agricultural. As depicted in **Figure 23a**, much of the forested land use within the Owasco Lake watershed is found in the Southern extent.

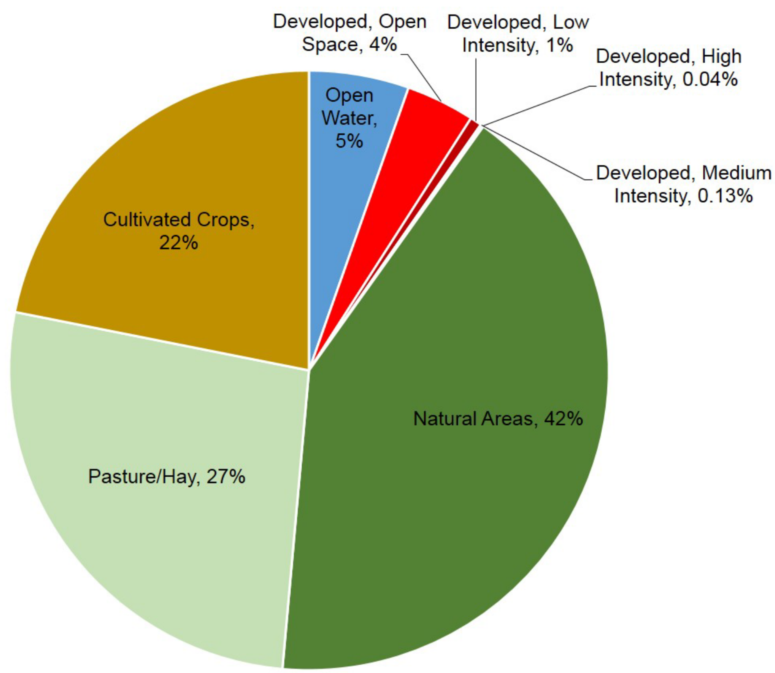

Figure 22. Land use categories and percentages for the Owasco Lake watershed. Natural areas include forests, shrublands, grasslands, and wetlands.

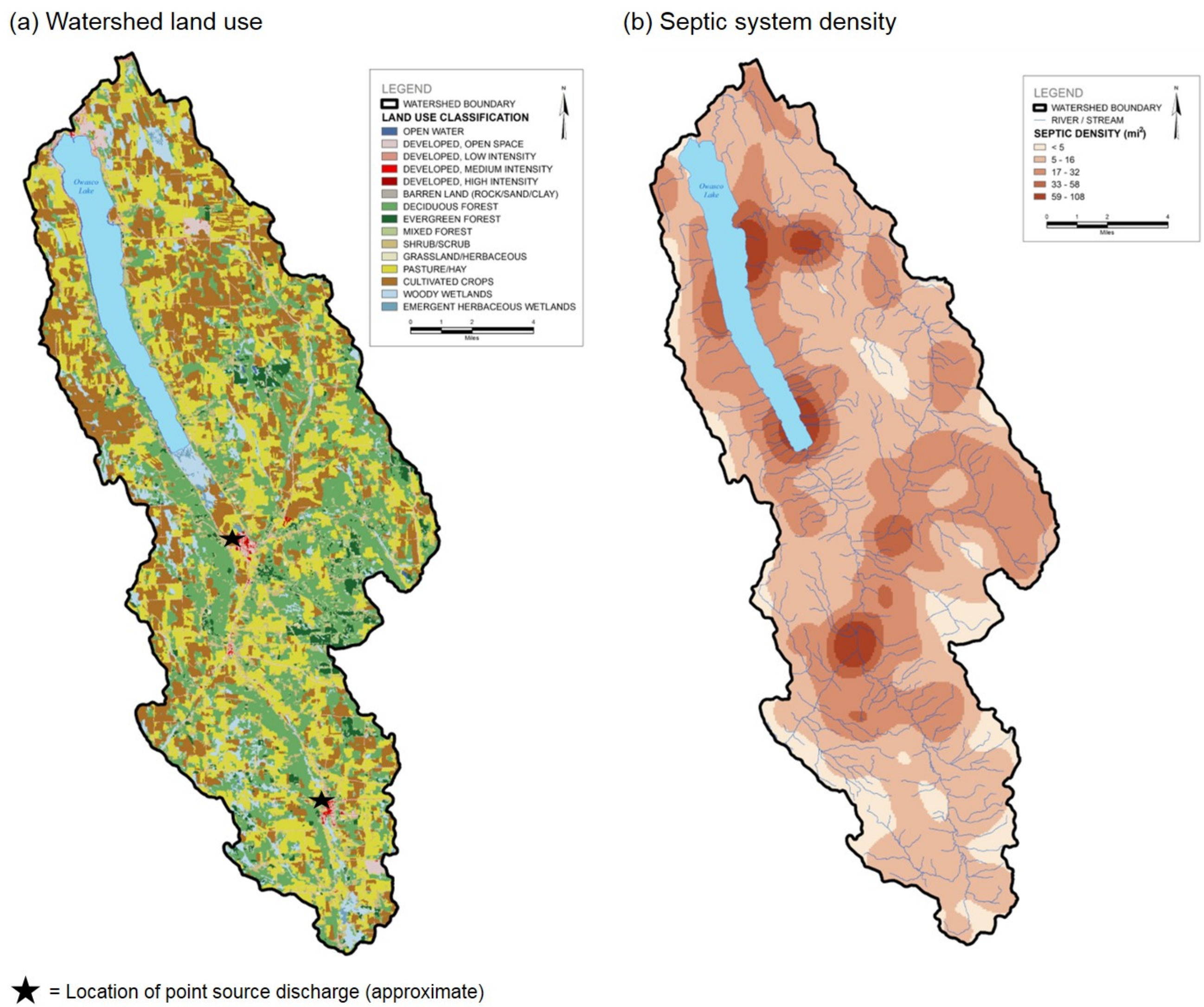

Figure 23. (a) Owasco Lake watershed land use and (b) septic system density.

10.2 External Pollutant Sources

NYSDEC's LENS tool is a simple watershed model that uses average, assumed meteorological conditions, estimated average annual loading rates from nonpoint sectors based on accepted literature values, and estimates of point source contribution. It employs the most recent data for the National Land Cover Dataset, septic density information collected by NYS Office of Real Property and Tax, and State Pollution Discharge Elimination System (SPDES) permit, and discharge monitoring report information. LENS is a screening tool, used by the NYSDEC, intended to assess the relative load contributions by watershed source to help determine the most appropriate watershed management approach (i.e., a TMDL or 9E plan; https://www.dec.ny.gov/docs/water_pdf/dowvision.pdf) and, for purposes of this Action Plan, support prioritization of water quality improvement projects and allocation of associated resources to mitigate HABs (presented in Section 13).

LENS is not designed to be a comprehensive watershed model or analysis and does not include all data requirements for a Total Maximum Daily Load (TMDL) or Nine Element (9E) Plan. Although LENS output has shown to be consistent with more comprehensive watershed analyses in New York State, there is uncertainty in the watershed loading estimates presented in this Action Plan. For example, LENS does not it take into consideration: (1) other potential contributors of nutrients to the lake such as groundwater, consistently underperforming septic systems, and streambank erosion (2) internal sources of nutrients (e.g., sediments, dreissenid mussels), (3) existing best management practices (BMPs) and other nutrient reduction measures being implemented by the municipalities, agricultural community, Soil and Water Conservation Districts, and other stakeholders.

Therefore, LENS results presented and discussed here and in subsequent sections should be considered a ***preliminary approximation*** of external nutrient sources to the lake. Precise quantification of nutrient sources from the watershed are needed and should be determined through: (1) a detailed inventory of nutrient sources – ***from all suspected sectors*** within the watershed, (2) complete a detailed analysis of nutrient load and budget that includes critical factors not accounted in LENS, (3) the development of a robust land-side nutrient loading model, and (4) completion or update of a NYSDEC approved clean water plan.

This Action Plan should be considered the first step of an adaptive management approach to HABs in Owasco Lake. Any completed TMDL or 9E plan developed for Owasco Lake will supplement the loading assessment included in this report. At that time, this Action Plan can be updated to reflect current and better understanding of Owasco Lake.

The LENS model analysis for Owasco Lake indicates that annual total phosphorus loading primarily occurs from nonpoint sources (95%), with the remaining 5% from point sources. Pollutant load estimates generated from the LENS analysis (NYSDEC, undated) include:

- Septic load = 2%
- Agricultural = 83%
- Natural areas = 7%
- Developed land = 3%

While the developed land estimate is relatively low (3%) is should be noted that in nonpoint source dominated watersheds (such as that of Owasco Lake), the management of storm water is important because loading varies over time and is usually a result of differences in hydrology (i.e., precipitation and runoff) throughout the year and most of the annual nutrient load occurs at periods of high flow; however, any nutrient inputs can be important, especially if they occur at a time and location when the lake is susceptible to blooms.

Septic density surrounding Owasco Lake is relatively low, although there are some areas within the watershed that have relatively higher septic system densities (**Figure 23b).** One area of interest is focused around the Town of Moravia, where high densities of septic systems are adjacent to the Owasco Lake Inlet (CCDPED and EcoLogic 2015b). It should also be noted that some sources of nutrients, such as wastewater inputs, might be higher at times of the year- mid to late summer- when water temperatures are highest and runoff is lower. This may represent a higher seasonal load that represent an elevated risk for blooms.

10.3 Internal Pollutant Sources

As described in **Section 6.2**, internal loading of phosphorus, associated with anoxic release of nutrients, is likely minimal due to oxygenated conditions in the bottom waters of Owasco Lake. However, the role of dreissenid mussels in mobilizing bioavailable nutrients that may stimulate algal growth may be an important element of nutrient dynamics, and has not been directly quantified in Owasco Lake. Documenting the contribution of dreissenid mussels to the overall phosphorus budget for the lake could provide increased understanding of nutrient cycling for Owasco Lake.

10.4 Summary of Priority Land Uses and Land Areas

As discussed in **Section 10.2**, nonpoint sources dominate TP loading to Owasco Lake. Of these nonpoint sources, 83% is estimated to originate from agricultural land use within the Owasco Lake watershed and therefore should be a focus of nutrient reduction strategies (**Section 13**).

11. Lake Management / Water Quality Goals

The overarching goal of this Owasco Lake Harmful Algal Bloom Action Plan is to minimize the spatial and temporal extent of HABs in Owasco Lake though well planned, targeted nutrient reduction watershed strategies from all contributing sectors. The findings and recommendations of this HAB Action Plan are generally consistent with the recommendations listed in the Owasco Lake Watershed Management and Waterfront Revitalization Plan (CCDPED and EcoLogic 2016) and can be used as a template upon which to base the forthcoming Owasco Lake 9E Plan (Section 12.5). Given the surrounding land use and associated loading estimates, management actions for Owasco Lake should prioritize reducing contributions of nutrients delivered to the lake from agricultural areas. Phosphorus loads from agricultural areas should be minimized to the extent practicable through the strategic application of BMPs in sub-watersheds, guided by local expertise or though detailed water quality monitoring data. Preliminary strategies and actions aimed at achieving Owasco Lake management objectives for HABs are presented in **Section 13.**

12. Summary of Management Actions to Date

12.1 Local Management Actions

Owasco Lake Watershed Management Program

Numerous local management actions have been implemented by local communities throughout the Owasco Lake watershed. The *State of the Owasco Lake Watershed* report, produced by the Owasco Lake Management Plan Steering Committee and the Cayuga County Water Quality Management Agency in 2000, and the *Owasco Lake Watershed Management Plan*, published in 2001 by the Cayuga County Soil and Water Conservation District, were developed to guide management actions within the watershed. Local management actions implemented within the Owasco Lake watershed since the development of these reports include the following, based on the *Owasco Lake Watershed Management and Waterfront Revitalization Plan: Watershed and Waterbody Inventory Report* (CCDPED and EcoLogic 2015a) and the *Owasco Lake Watershed Management and Waterfront Revitalization Plan* (CCDPED and EcoLogic 2016):

- Agricultural BMPs and Agricultural Environmental Management (AEM).
- Incorporation of water quality previsions into local municipality zoning codes.
- Streambank and roadside ditch remediation.
- Water and sewer infrastructure improvements.
- Invasive species monitoring and prevention.

Water and sewer infrastructure improvements

Nutrient concentrations and biomonitoring efforts (see **Section 6.4**) have indicated that the nutrient control enhancements to the Groton WWTP may have improved water quality in the Owasco Inlet (Halfman et al. 2016). The Groton WWTP was established in 1963 and only provided primary water treatment. Since then, the WWTP was updated in 1976 to provide secondary treatment to waste water and a $4.1 million renovation was completed in 2010 to bring the plant up to date with modern sewage treatment methods (Village of Groton 2015). Upgrades include two new Sequencing Batch Reactor units and effluent disinfection using chloride and subsequent dichlorination.

Improvements to the Groton WWTP have reduced the average discharge of phosphorus from greater than 6 pounds per day (ppd) (2001 – 2005) to an average of 1.6 ppd (2009 – 2014), which is below the SPDES limit for the facility of 2.1 ppd. The Groton WWTP and the Moravia WWTP both currently operate below their permitted discharges.

Streambank Repairs and Stabilization

Surveys to identify regions where bank repairs and stabilization are needed to reduce the erosion and transport of sediments have been conducted in several tributaries to Owasco Lake including:

- Dutch Hollow Brook
- Veness Brook
- Sucker Brook
- Owasco Inlet

Several of these identified segments have been restored and stabilized and additional funding is being sought to restore additional segments. In addition to on the ground stream surveys, the CCPED developed a detailed map of watershed tributary basin to identify areas that are prone to becoming saturated during precipitation events and generate runoff. The map was developed using soil characteristics and topography to rank the watershed tributary basins (CCPED and EcoLogic 2016).

Invasive species monitoring and prevention

The Cayuga County WQMA has developed a task force to monitor Asian clam densities in Owasco Lake as well as to develop an effective public informational campaign and investigate effective means of control (Cayuga County Government 2011).

12.2 Funded Projects

Roadside conveyance ditches represent a recognized source of sediment and nutrient loading to Owasco Lake and its tributaries. Stabilization of these ditches is a goal of the Owasco Lake Watershed Inspection Program which has identified more than 35 linear miles of ditch features requiring improvement since 2014 (OLWIP 2016d). The New York State Consolidated Funding Application (CFA) and the Local Waterfront Revitalization Program has provided funding to support ditch stabilization efforts throughout the watershed. The project aims to stabilize nearly 100 miles of roadside ditches within approximately five years.

Additional funding is provided through 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 Program (ANSACP) program. These programs have supported the implementation of more than thirty BMPs within the Owasco Lake watershed. Examples of BMP systems implemented include waste storage, subsurface drainage, watering facilities, roof runoff control, prescribed grazing, nutrient management, and water and sediment control basins.

The New York State AEM program also supports farmers in their site-specific efforts to protect water quality and conserve natural resources, while enhancing farm viability (NYSSWCC 2018). AEM uses a five-tiered framework to categorize on-farm activities that have been prioritized by a committee of resource professionals and stakeholders. The following lists important elements associated with each tier:

- **Tier 1** – Infrastructure, land use, and livestock inventory, farmer interview, environmental concern identification
- **Tier 2** – Environmental assessment, document environmental stewardship, further farmer education, farm prioritization
- **Tier 3** – Conservation planning addressing business objectives, watershed concerns, resources, and environmental risk
    - **Tier 3A**: Component Conservation Plan
    - **Tier 3B**: Comprehensive Nutrient Management Plan (CNMP)
- **Tier 4** – Implementation of priority BMPs identified in the conservation plans
- **Tier 5** – Evaluate effectiveness of conservation plans and BMPs, monitoring and maintenance, and adaptive management
    - **Tier 5A**: Update Tier 1 and 2
    - **Tier 5B**: Plan evaluation/update, BMP system evaluation

Many AEM-sponsored activities have been undertaken within the Owasco Lake watershed to address important environmental challenges including improving water quality (**Table 8**).

Table 8. Total number of AEM projects conducted in the Owasco Lake watershed (2011-2017).

	Tier 1	Tier 2	Tier 3A	Tier 3B	Tier 4	Tier 5A	Tier 5B
Total Number of AEM Projects	31	31	24	7	11	13	9

The 9E plan (**Section 12.5**) currently in development for Owasco Lake will provide additional guidance to the AEM process.

12.3 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 SPDES program was authorized to maintain reasonable standards of purity for state waters through the issuing of permits for discharges to waterbodies. NYSDEC provides on-line information for the SPDES

Permit Program for all nine regions in the state. The Owasco Lake watershed is located within NYSDEC Region 7.

Based on the SPDES Individual Permit records available for Cayuga and Tomkins County, NYSDEC has issued a total of 18 SPDES Individual Permits within the Towns of the Owasco Lake watershed. Of the 18 permits, six are available for viewing. Only three issued to the Village of Moravia WWTP, the Village of Groton Sewage Treatment Plant and the Owasco Water Works (discharges to groundwater) were determined to be associated with direct discharges of waters or materials to the Owasco Lake watershed (NYSDEC 2018d). Of the remaining 12 permits that are not available for viewing, 11 are within the Owasco Lake watershed. For more information about NYSDEC's SPDES program and to view MSGP, CAFO and Individual SPDES issued in the Owasco Lake watershed visit http://www.dec.ny.gov/permits/6054.html.

NYSDEC also issues Multi-Sector General Permits (MSGPs) under the SPDES Program for stormwater discharges related to certain industrial activities. MSGPs have been issued for 15 active facilities in Cayuga and Tompkins County to Towns within the Owasco Lake watershed (NYSDEC 2018d). Only one of these facilities are within the watershed, Groton Ready Mix, and discharges into a tributary to the Owasco Lake Inlet. In addition, two Municipal Separate Storm Sewer Systems (MS4s) discharge into the Owasco Lake watershed. These MS4s are operated by the towns of Lansing and Dryden, which potentially reduce the contribution of phosphorus to Owasco Lake through collection and subsequent contribution of stormwater from roadways and other impervious surfaces that discharge to tributaries and then to the lake.

CAFO permits, issued under the SPDES Program, are required for animal feed programs that meet animal size (number of animal) thresholds. Of the approximately 200 farms (Wright and Haight 2011) located in the Owasco Lake watershed, the majority were family owned small dairy farms that did not meet the animal size threshold requiring CAFO permitting. Sixteen large farms that meet the CAFO threshold were identified as fully or partially within the Owasco Lake watershed (NYSDEC 2018d). CAFO permitted farms are required to have a nutrient management plan developed by a certified agricultural planner filed with the NYSDEC.

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).

12.4 Research Activities

The LCI, CSLAP, Finger Lakes SWQI, and the Finger Lakes Water Hub early-year sampling are the primary research activities conducted by the NYSDEC on Owasco Lake to monitor water quality conditions. In addition to these efforts undertaken by the

NYSDEC, the Finger Lakes Institute has monitored water quality in Owasco Lake, as well as other Finger Lakes, since 2005 (Halfman 2017).

Finger Lakes Water Hub early-year sampling

Initial review of Finger Lakes water quality datasets in early 2017 showed that almost no data had been gathered on the state of the lakes in wintertime (November to April). Additional data collection during the winter months may provide additional information on overall water quality and potential for HABs formation during the growing season.

Staff from NYSDEC's Finger Lakes Water Hub, a Region 7-based group focused on HABs and other water quality threats in the Finger Lakes Region, collected water quality samples in February and April 2018 on all eleven Finger Lakes. These sampling efforts were undertaken to characterize important indicators of lake health during winter-early spring and to provide early-year information that can be used for HABs management planning. Temperature, conductivity, pH, dissolved oxygen, and chlorophyll were measured from the surface to the bottom of the lake using a multi-probe; Secchi depth also was recorded. Water samples were collected from just below the surface (1.5-meter depth) and at 2/3 of the total depth at one CSLAP site on each lake for analysis of the standard CSLAP parameters (e.g., TP, TN, NOx, ammonia, chloride, calcium, and chlorophyll-a). Samples were either collected from a boat or through the ice. For lakes with surface ice, samples were collected through a hole created by hand-auguring through up to 12 inches of ice. In addition to monitoring water quality, samples also were collected for researchers at SUNY ESF for analysis of algal toxins, zooplankton and phytoplankton, and lake sediments.

While data analysis is ongoing, highlights of observations in the field include: inverse stratification (warmer at the bottom than the top) in the ice-covered lakes, while those remaining ice-free were isothermal (all the same temperature) and well mixed; dissolved oxygen was lower, although not hypoxic, in the lower third of Honeoye and Canadice lakes than the surface during ice cover, whereas the remaining lakes were well oxygenated, even those under ice; and water clarity was generally high with Secchi Disk depths greater than 15m in both Skaneateles and Seneca lakes (both are generally less than 10 m during the growing season).

Additional research conducted on management efforts to improve water quality on Owasco Lake have included:

- Monitoring of the Owasco Inlet to assess the improvements to water quality after renovations and updates to the Groton WWTP (see **Section 5.2**).
- Assessment of the impacts of the Benson Brook watershed BMPs (see **Section 6.4**).

NYSDEC should support research to better understand how to target dissolved phosphorus with traditional and innovative nonpoint source best management practices.

12.5 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. A 9E Plan is an example of a clean water plan which documents pollution sources, pollutant reduction goals and recommend strategies/actions to improve water quality:

- 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:

  A. Identify and quantify sources of pollution in watershed.
  B. Identify water quality target or goal and pollutant reductions needed to achieve goal.
  C. Identify the best management practices (BMPs) that will help to achieve reductions needed to meet water quality goal/target.
  D. Describe the financial and technical assistance needed to implement BMPs identified in Element C.
  E. Describe the outreach to stakeholders and how their input was incorporated and the role of stakeholders to implement the plan.
  F. Estimate a schedule to implement BMPs identified in plan.
  G. Describe the milestones and estimated time frames for the implementation of BMPs.
  H. Identify the criteria that will be used to assess water quality improvement as the plan is implemented.
  I. 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.

Cayuga County is currently developing a 9E Watershed Plan for the Owasco Lake basin. A watershed model (Soil and Water Assessment Tool) is being developed by Cornell University to identify sources nutrients and quantify magnitudes of inputs to the lake in an effort to ultimately reduce external nutrient loading to minimize the extent of HABs in Owasco Lake. This effort was initiated in late 2016 following the detection of cyanotoxins in the drinking water from the Auburn and Owasco treatment plants. Cayuga County anticipates completion of the Owasco Lake 9E Plan in July 2019.

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 F**.

For more information about climate change visit NYSDEC'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 Owasco Lake.

Steering committee members:

- Steve Lynch, Cayuga County Department of Planning and Economic Development/Owasco Lake Watershed Management Council
- Kathleen Cuddy, Cayuga County Health Department
- Doug Kierst, Cayuga County Soil and Water Conservation District (SWCD)
- Seth Jensen, City of Auburn

- Zack Odell, Finger Lakes Land Trust
- John Halfman, Hobart and William Smith Colleges/Finger Lakes Institute
- PJ Emerick, NYSDAM
- Karen Stainbrook, NYSDEC
- Matt Kazmierski, NYSDEC
- Tony Prestigiacomo, NYSDEC
- John Strepelis, NYSDOH
- Mark Burger, Onondaga County SWCD
- Andrew Snell, Owasco Lake Inspection Program
- Ken Kudla, Owasco Lake Watershed Association
- Greg Rejman, Sunnyside Farm
- Liz Cameron, Tompkins County Health Department
- Jon Negley, Tompkins County SWCD
- Ed Wagner, Town of Owasco

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 Owasco 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 controllable factors that contribute to HABs in Owasco Lake include:

- 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 the 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 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 Owasco Lake Priority Projects

13.3.1 Priority 1 Projects

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

Short-term (3 years)

1. Maximize coordination and equitable allocation of resources through the Owasco Lake Watershed Management Council (OLWMC) in order to leverage available staffing to complete the projects listed herein.
2. Increase SWCD staffing through appropriations to focus capacity to plan and implement projects (e.g., planners, engineers, technical staff) to mitigate soil erosion and reduce nutrient pollution in subwatersheds through all counties that drain to Owasco Lake.
3. Implement various erosion and sediment control and land conservation projects on available land to reduce erosion and nutrient-laden runoff. These would be implemented by local SWCDs, municipalities, and non-profit organizations, and include:
    a. Implementation of cover crops on cropland that is prone to erosion and nutrient runoff when left unprotected. Cover crops are a specific type of vegetative cover that is carefully planted on a field that would otherwise be left bare after a cash crop is harvested. A cover crop diffuses heavy rainfall, protecting the soil surface from erosion. In addition, a cover crop allows for living roots to be present throughout much of the year adding rich organic matter to the soil and trapping nutrients that would otherwise be prone to runoff if the soil is left bare after harvest.
        i. Utilize a cost-share program where the State provides financial and technical support to farmers to plant cover crops on agricultural fields to reduce soil erosion and nutrient runoff.
    b. Implementation of a cost-share program where the State provides financial and technical support to farmers for manure storage, transfer, and application to maximize nutrient uptake.
    c. Establishment of vegetated riparian buffers to inhibit or reduce nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams.
    d. Rehabilitation of degraded vegetated buffers to improve riparian habitat function on tributaries to Owasco Lake.
4. Establish a program to work with crop farmers that accept manure from Concentrated Animal Feeding Operations (CAFOs) to properly store and apply the material to maximize nutrient uptake.
5. Implement Agricultural Environmental Management (AEM) Tier 3A Resource Management Plans to reduce sediment and nutrient runoff on crop and alternative farms and AEM Tier 3A Nutrient Management Plans (NMPs) for non-CAFO beef/dairy operations.

6. Implement a livestock exclusion program to minimize soil erosion and nutrient loading to aquatic habitat caused by livestock access to tributaries to Owasco Lake, including:
    a. Installation of fencing on stable portions of the stream banks at the maximum distance possible given the site conditions and no less than minimum required by funding source.
    b. Installation of livestock watering stations outside the limits of riparian areas.
    c. Installation of stable stream crossings to minimize livestock impacts.
    d. Establish vegetated riparian buffers within the fenced exclusion limits to inhibit or restrict nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams.
    e. Rehabilitate degraded vegetated buffers within the fenced exclusion limits to improve riparian habitat function.
7. Perform a pilot study to evaluate the phosphorus removal efficiency of stormwater management techniques (e.g., iron-enhanced sand filter, i.e., Minnesota Filter) in locations such as the discharge of agricultural swales and tile lines.

Mid-term (3 to 5 years)

1. Purchase equipment to implement erosion and sediment control measures on agricultural lands and their existing highway ditch maintenance program, including:
    a. Compost blowers to amend soils and stabilize critical areas
    b. Specialized seeders for cover crop applications, including independent Highboy seeders or high horsepower tractors for tow behind models
    c. Straw mulcher
    d. Hydroseeder
2. Implement runoff reduction BMPs on agricultural and non-agricultural lands to reduce nutrient runoff and soil erosion in the watershed. These BMPs would be implemented by, but are not limited to, local SWCDs, and include:
    a. Use of field erosion control systems (grassed waterways, shaping and grading, and water and sediment control basins (WASCoBs)) to promote stormwater retention and minimize concentrated runoff (e.g., rills, gullies).
    b. Stabilization of drainage swales through establishment of vegetation and/or installation of check dams.

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

d. Implementation of runoff reduction BMPs for farmsteads: roof runoff management, barnyards, laneways/access roads, and bunk silos.

3. Purchase wood waste recycling equipment to convert municipal and culvert debris into useful material that can be used, for example, in erosion and sediment control.
4. Complete a feasibility study to upgrade municipal sewer infrastructure to service residences and reduce septic system input to Owasco Lake in that area.
   a. Replace municipal storm sewer lines in the Town of Locke where residential septic systems are found to be connected.
   b. Replace substandard septic systems.
   c. Evaluate the applicability of and potentially install cluster septic systems that provide on-site wastewater treatment to multiple residences.
5. Acquire and/or conserve lands within the watershed to protect and maintain existing buffers before increased subdivision and land conversion impacts these functioning systems.
6. Implement manure management techniques, including manure storage and transfer lines to implement AEM Tier 3B Comprehensive Nutrient Management Plans designed to recycle manure and other farm nutrients to maximize soil health and crop uptake while minimizing runoff to Owasco Lake.

Long-term (5 to 10 years)

1. Acquire and/or conserve lands within the watershed to reduce existing or future land use impacts on water quality, and could include:
   a. Establish vegetated riparian buffers along the Owasco Lake shoreline and along tributaries (e.g., Trees for Tribs program), to stabilize riparian habitat and to reduce solar heat load.
   b. Establish vegetated riparian buffers on streams at the maximum distance allowable given the site conditions and no less than the minimum required by funding source.
2. Conduct a study of a possible extension and/or additional public water intake into a deeper water location to limit the potential for algal toxin entering the intake and affecting the City of Auburn and Town of Owasco public drinking water supplies.

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. Implement roadside ditch and culvert improvement projects on currently failing ditch systems to reduce and capture sediment. Best management practices could include:
    a. Properly sizing culverts and channels to avoid headcuts and other erosion.
    b. Installation of check dams or other facilities to reduce flow velocities, minimize erosion, and promote sedimentation.
    c. Timing of cleanout to minimize soil erosion.
    d. Use of erosion control practices to assist in ditch bank stabilization.
2. Establish a program to monitor, inspect, and sample existing septic systems within the Owasco Lake watershed to maximize the functional capacity of these systems and minimize nutrient contribution.
3. Map field drainage tile lines (underground pipes that drain and convey excess soil and water for crop cultivation), where practical, to build a database, conduct a pilot program to test for nutrients, and implement BMPs for tile drain water retention and treatment (such as constructed wetlands and detention basins). This project may be led by, but not limited to, local SWCDs, non-profit organizations, and municipalities.

Mid-term (3 to 5 years)

1. Increase staff responsible for education, outreach, and implementation programs regarding stormwater management (including Municipal Separate Storm Sewer System (MS4) programs) and agricultural BMPs.
2. 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 and nutrient loads.

Long-term (5 to 10 years)

1. Clear the existing blockage within the sluiceway and engineer a permanent system to pump water continuously through the sluiceway to the outlet to improve circulation and reduce stagnation in the Northern end of Owasco Lake.
2. Map and perform a hydraulic evaluation of the existing stormwater drainage system within the watershed to identify facilities that require upgrade or replacement.

13.4 Additional Watershed 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. Install filter socks to reduce sediment and nutrient runoff in the following locations:
    a. Construction sites for perimeter control
    b. Streambank stabilization projects
    c. The discharge end of tile drains
    d. Within roadside ditches to serve as check dams.

2. Complete a pilot program to evaluate the effectiveness of placing aerators under homeowner docks on reducing HABs.

Mid-term

1. Conduct research and management on forested portions of the watershed (e.g., Owasco Inlet, Dutch Hollow Brook) to identify and control invasive pests (e.g., hemlock wooly adelgid, emerald ash borer) as a proactive means to minimize impacts, including:
    a. Remove downed trees and replace with species that are less susceptible to pests.
    b. Work with Cornell Cooperative Extension on establishing hemlock hedges within biological control field stations.
    c. Use systemic insecticides (imidacloprid and dinotefuran) and introduce natural enemies such as the predatory beetle *Laricobius nigrinus* that controls HWA in areas dominated by hemlock.

2. Evaluate existing Department of Public Works (DPW) yards within the watershed to identify potential issues with site runoff. Based on these issues, secure funds to install BMPs to improve stormwater management at these facilities.

Long-term

1. Complete a feasibility study to build a causeway in Owasco Lake off the Owasco Inlet, similar to the one in Otisco Lake, that would act as a forebay to promote sediment and nutrient fallout before entering the main portion of the Lake.

2. Fund the OLWMC to complete the following water quality improvement projects:

    a. Install floating treatment islands at the outlets of the two largest tributaries to the lake to reduce nutrient concentrations.

    b. Spot-dredge portions of the Owasco Lake Inlet to remove detritus and silt.

c. Install emergent wetland plants in targeted areas to promote sedimentation and nutrient uptake.

3. Consider installing cementitious fabrics or articulated stone mats to line ditches on steep State, County, and Town roads and install stilling basins at discharge ends to catch sediment.

4. Stormwater management plans (SWMPs) should emphasize phosphorus source control, targeting areas with high levels of phosphorus runoff. Emphasis should be placed on locations within the Owasco Lake watershed that have a combination of relatively high percentages of impervious cover, small lot sizes, and/or compacted soils.

5. Construct wetlands or enhance/restore existing wetlands within the watershed to reduce nutrient and sediment loads. **Figure 24** shows the locations within the Owasco 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 could be targeted for proposed new wetlands as they are more likely to support wetland hydrology and vegetation. Such work should be closely monitored to evaluate nutrient transformations to better understand wetland functions and values in watershed nutrient reduction.

6. Purchase the former RPM Ecosystems property in Dryden and create a regional nursery/greenhouse that can be used to raise conservation plantings for use throughout the watershed. A tree planting program can then be established where fresh tree and shrub stock could be used for:

   d. Creating vegetated buffers along the lake shoreline and along tributaries (e.g., Trees for Tribs program) to stabilize riparian habitat.

   e. Landscape plantings in urban areas.

   f. Plantings associated with green infrastructure projects.

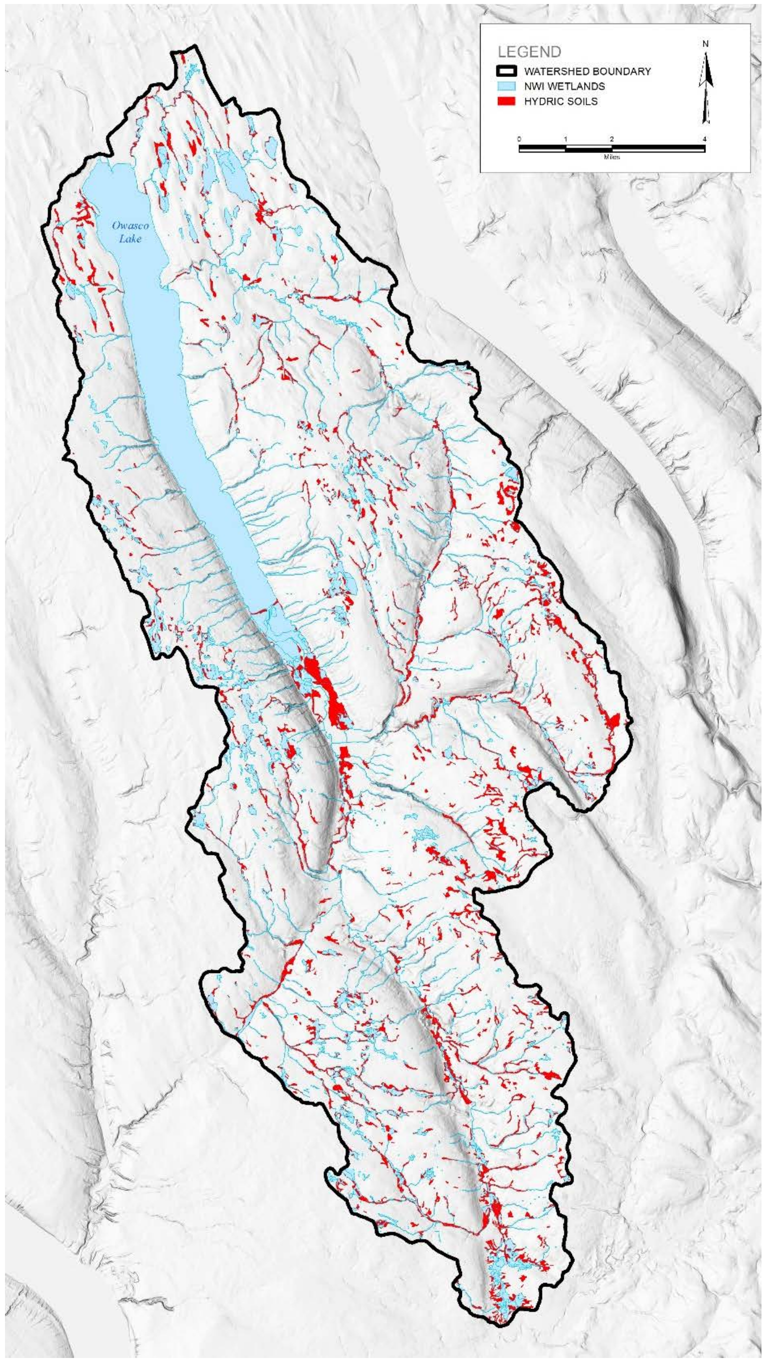

Figure 24. Locations (depicted in red) of either hydric, very poor, or poorly drained soils in the Owasco Lake watershed. Note the hydric soil locations presented are non-overlapping with National Wetland Inventory (NWI) mapped wetlands.

13.5 Monitoring Actions

In addition to the watershed management actions identified in Section 13.1, the following monitoring and research actions should be considered.

Short-term

1. Continue annual CSLAP sampling to conduct routine, long-term monitoring at a state certified laboratory, and to evaluate trends in trophic state indicators and occurrences of HABs in the lake. Align in-lake water quality data collection efforts with overpasses of NASA's Landsat 8 satellite (**Table 9**), 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 9. Landsat 8 overpasses of Owasco Lake from May through October, 2018.

Month	Dates			
May	May 5	May 12	May 21	May 28
June	June 6	June 13	June 22	June 29
July	July 8	July 15	July 24	July 31
August	August 9	August 16	August 25	
September	September 1	September 10	September 17	September 26
October	October 3	October 12	October 19	October 28

2. Expand 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, and inorganic nitrogen. Such nearshore work may also entail event sampling to capture biogeochemical conditions associated with acute specific conditions, such as hot dry periods. Collection of nearshore sediment samples may provide additional beneficial information.

3. Supplement the understanding of the algae species contributing to blooms through taxonomic analysis of samples collected during conditions favorable for HABs formation (i.e., still conditions, elevated water temperatures, recent nutrient inputs). Knowledge of the dominant cyanobacteria in the lake allows for development of species-specific implementation strategies for controlling and managing their abundance.

4. Supplement data on cyanotoxin concentrations during confirmed and suspicious blooms.

5. Continue water quality study/monitoring efforts of tributaries to the lake to provide a long-term data set of nutrient concentrations, physical parameters, and discharge that can be used to evaluate lake health and predict HAB formations. This effort should be carefully aligned with the procedures used in the

development of the 9E plan in order to keep the 9E nutrient loading model current.

6. Maintain and enhance community and/or volunteer monitoring efforts of water quality conditions in the lake, in conjunction with OLWIP, CCDPED, and CSLAP, particularly during the growing season. This includes continuation of the successful HAB surveillance and monitoring network established between NYSDEC, OWLA, and OLWIP over the last several years.

13.6 Research Actions

To help understand the stresses that lead to HABs and develop management strategies to prevent the potential formation of HABs in Owasco Lake, the following research actions are recommended for evaluation:

Short-term

1. Conduct pilot studies to document effectiveness of site-specific nonpoint source load abatement (such as Minnesota stormwater filters). This includes an evaluation of the best approach(es) to document the effectiveness of management action, and quantifying conditions *before* actions are conducted (e.g., baseline conditions) to accurately assess their effectiveness.
2. Conduct water quality sampling in tributaries and/or in discharge points in the lake during or following heavy rainfall events, as permissible, to document nutrient inputs that may contribute to localized HABs facilitated by storm events. Sub-watersheds should be selected strategically in order to evaluate nutrient inputs across a range of conditions (e.g., varying extents of agricultural land).
3. Collect water samples of total soluble phosphorus in the lake (through CSLAP or other existing monitoring programs at state certified laboratories) to quantify phosphorus bioavailability for cyanobacteria. In addition, evaluate nonpoint source loadings in the context of soluble phosphorus, which is the form readily available for algal growth (in contrast to total phosphorus, which includes both soluble and particulate forms).
4. Document the spatial extent and abundance of dreissenid mussels (both zebra and quagga mussels) and Asian clam (*Corbicula fluminea*) in the lake to determine the relative important of increasing bioavailable phosphorus that likely contributes to phytoplankton, including cyanobacteria, growth. Additionally, The NYSDEC should encourage and support research into management options for dreissenids and better understanding of their natural population cycles.
5. Utilize sediment and surface water sample data to model water column mixing and nutrient loading from bed sediments. Run model simulations of various in-lake management options to identify effective means to mitigate internal loading.

These options could include the addition of phosphorus-binding agents, dredging/capping, and hypolimnion water withdrawal.

6. Analyze the Owasco Lake watershed to characterize areas of potential septic system impact and collect data in the lake appropriate to quantify the impact from the on-site septic systems in Owasco Lake and/or tributaries.

Mid-term

1. Integrate ongoing nutrient monitoring studies in the Owasco Inlet, Sucker Brook, Dutch Hollow Brook and Veness Brook with in-lake water quality data to support optimization of phosphorus reduction BMPs in these sub-watersheds.
2. Conduct localized studies of groundwater quality and hydrology. Although general information on groundwater resources, utilization, and management approaches are available on the watershed level. Detailed assessments of near-Lake groundwater nutrient levels, elevations, and lake infiltration rates are lacking.
3. Analyze the potential benefits or disadvantages of reducing summer water levels, particularly on shoreline erosion, septic system, and wastewater discharges.

Long-term

1. Build a long-term database of physical and chemical water quality parameters to permit a multivariate statistical analysis of the drivers most responsible for HABs in the lake.

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 Owasco 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.

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. Encourage public participation in initiatives for reducing phosphorus and documenting/tracking HABs, such as volunteer monitoring networks and/or increasing awareness of procedures to report HABs to NYSDEC.
2. 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.
3. 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. Support Land Trusts through volunteering and financial support to facilitate land protection measures and purchases/acquisitions of conservation preserves within the Owasco Lake watershed.
3. Support Owasco Lake watershed conservation groups on education and outreach efforts to lakeshore and watershed residents about how their actions affect water quality.
4. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.

5. Coordinate with Department of Health to support the local health departments to implement onsite septic replacement and inspection activities.
6. 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.
7. 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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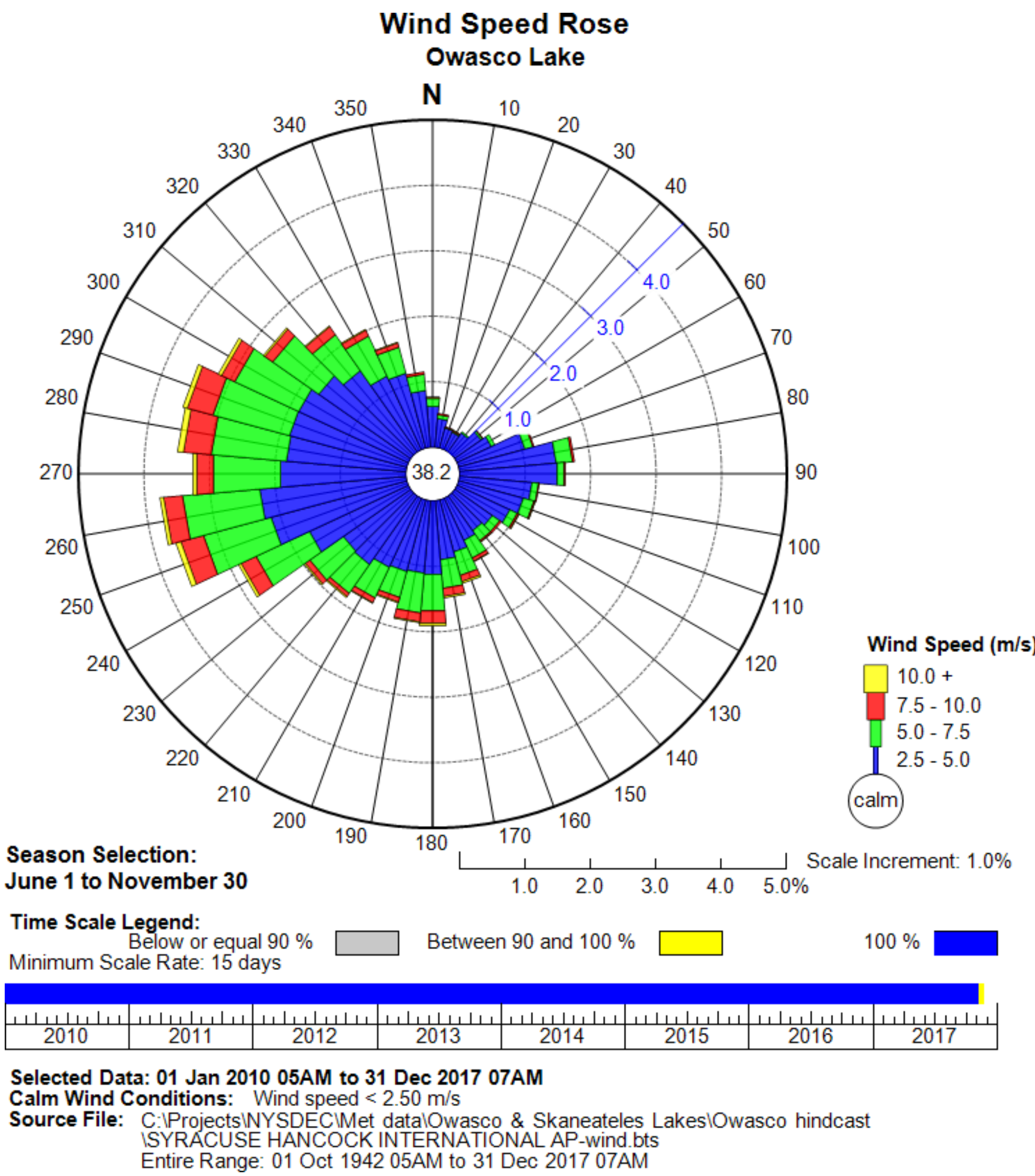
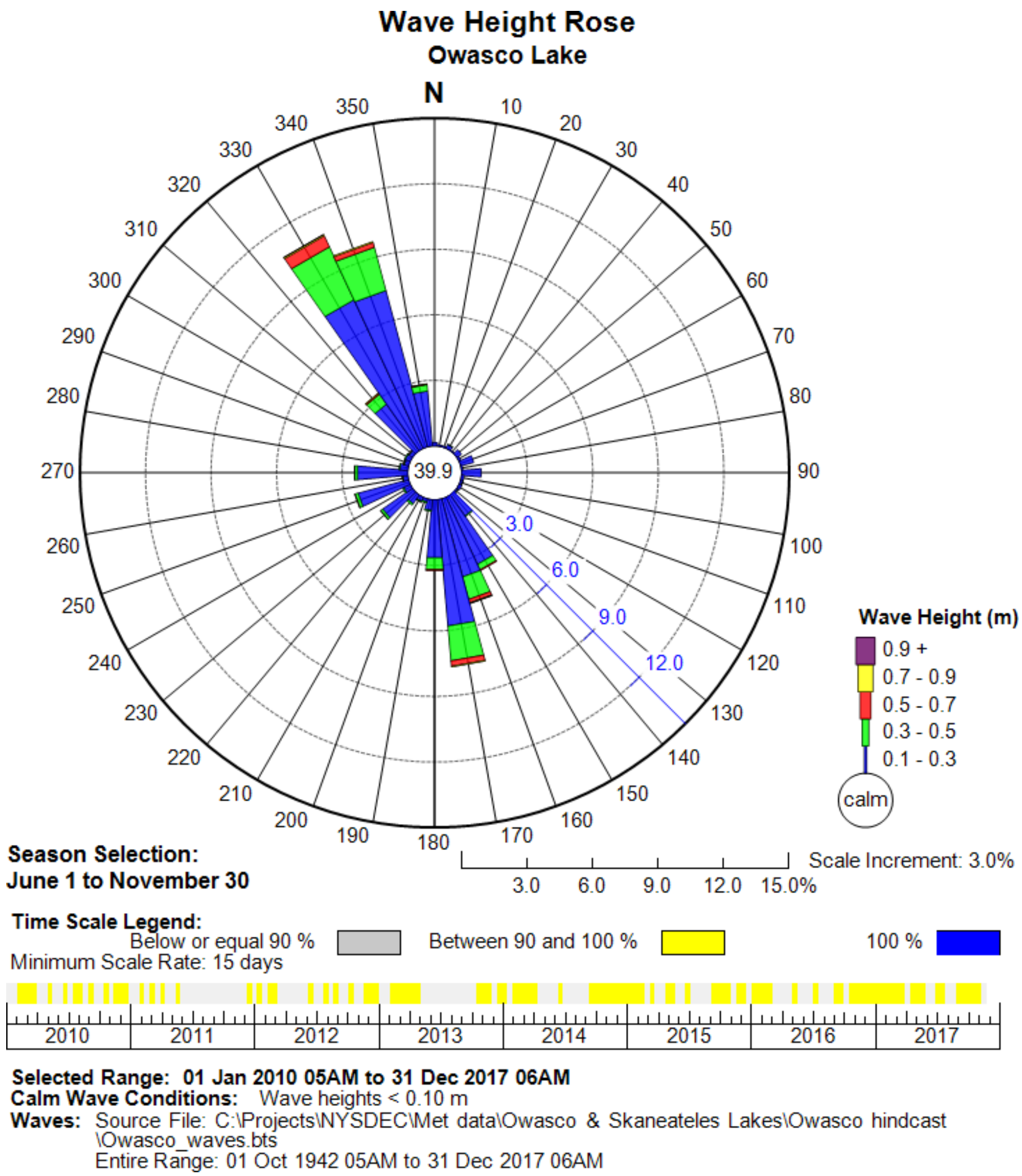
Appendix A. Wind and Wave Patterns



Wind speeds at Owasco Lake from 2010 to 2017, during the months of June through November, indicate that stronger winds were generally out of the west.



Wave height patterns from 2000 to 2017, during the months of June through November, indicate wave heights were greater in the northwestern and southern portions of Owasco Lake.

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**.

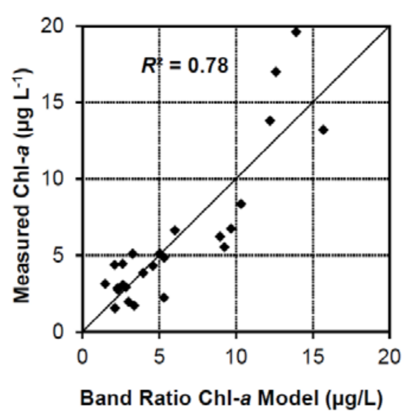


Figure C1. Measured and modeled chlorophyll-a concentrations for Lake Champlain, from Trescott 2012.

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

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 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.

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

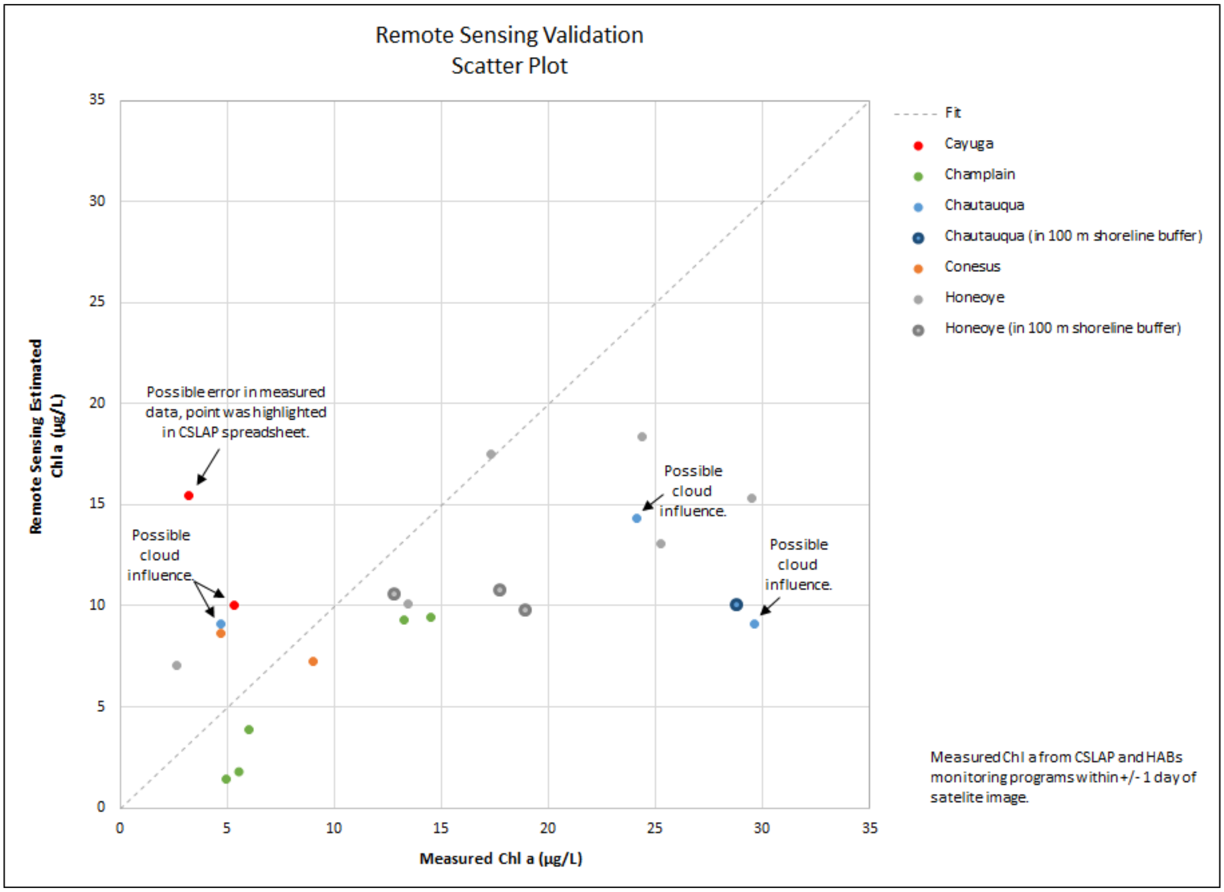


Figure C2. Measured and modeled chlorophyll-a concentrations for Cayuga Lake, Lake Champlain, Chautauqua Lake, Conesus Lake, and Honeoye Lake (2016-2017 data).

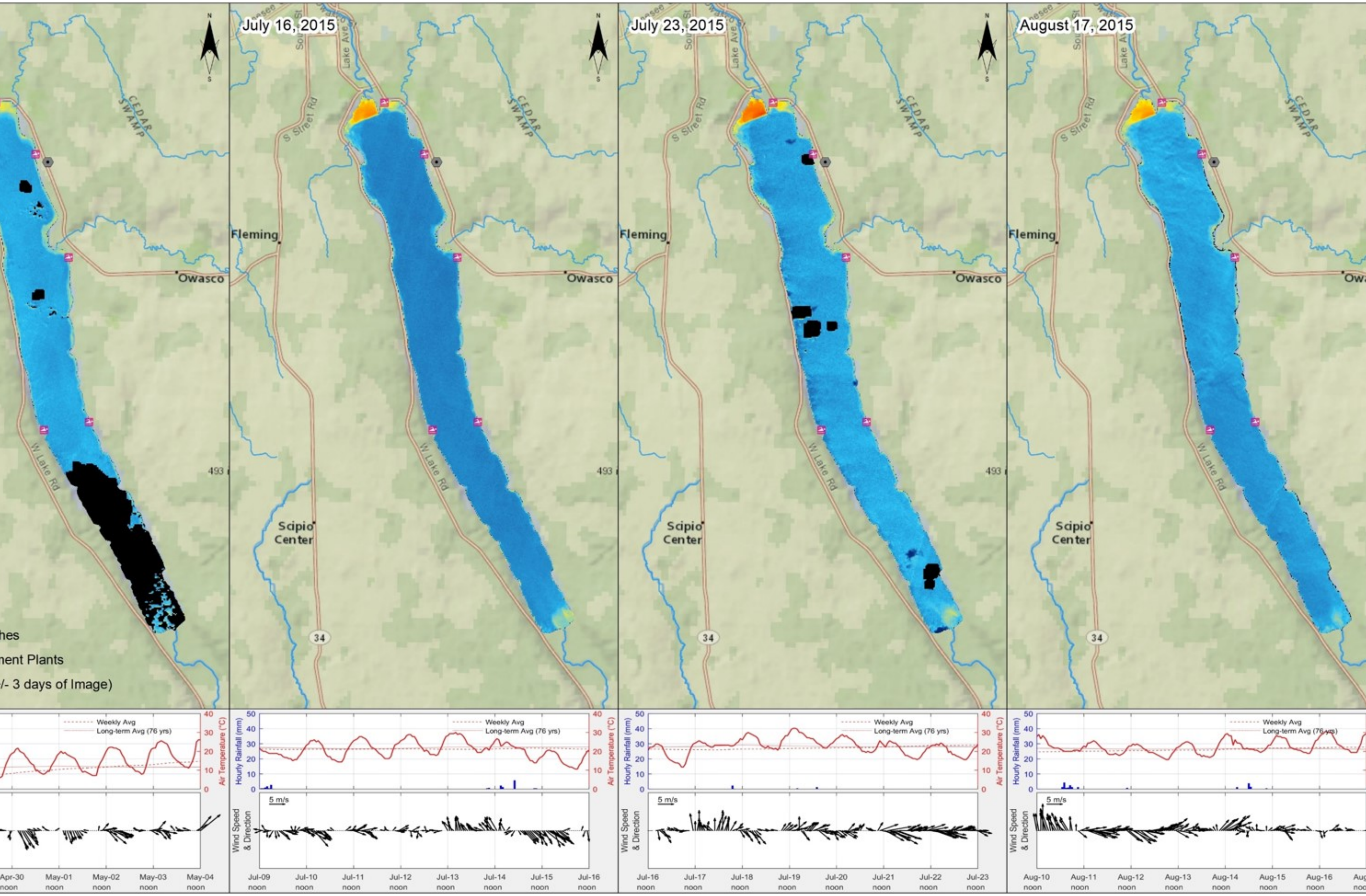
Limitations of the Method

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.



3 Miles

Kilometers

Plots

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

Satellite Derived Chlorophyll a

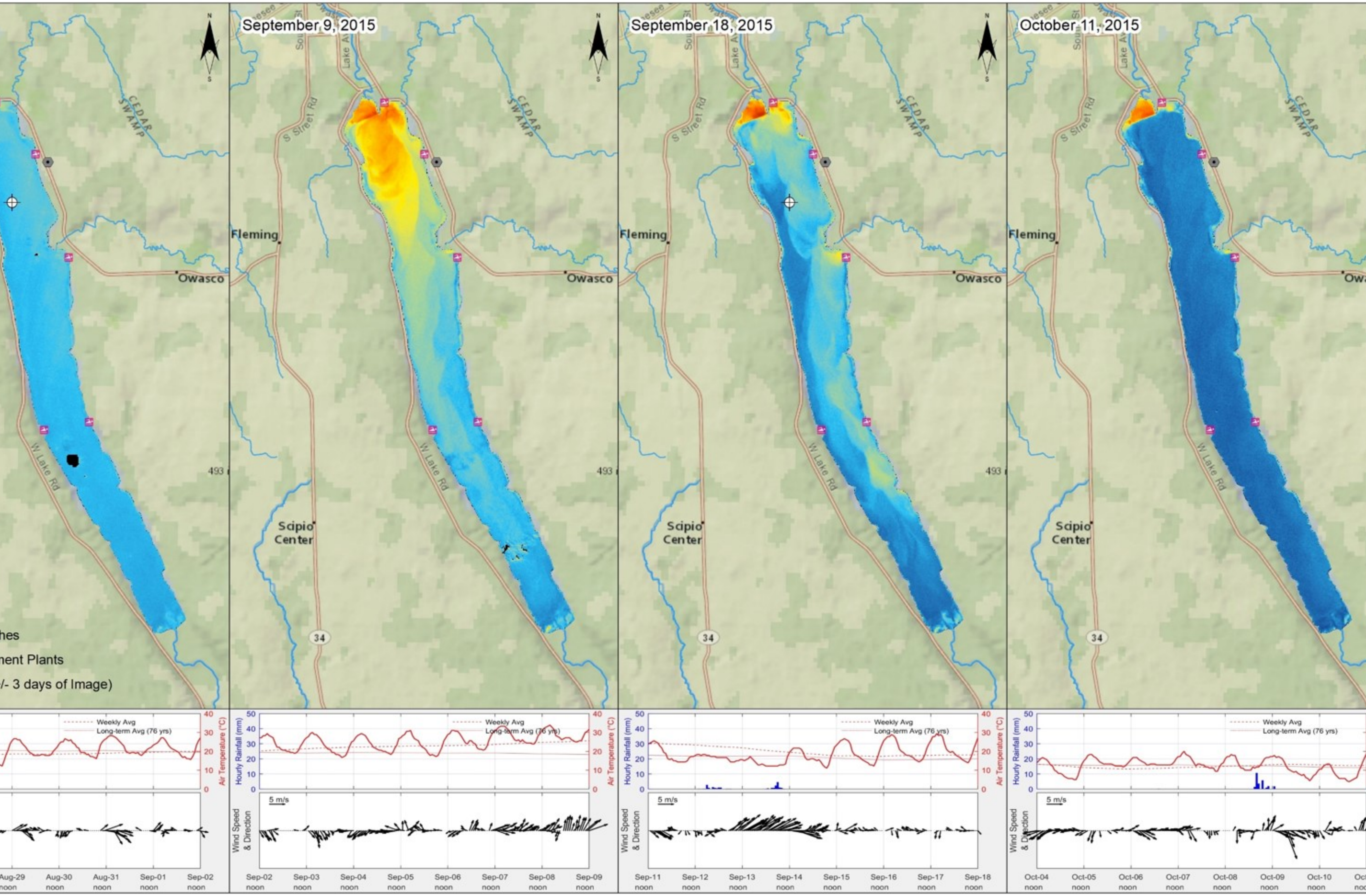
Chl-a Data is Derived from NASA's LandSat 8 Satellite

Data Gaps are Caused by Haze and Clouds

Disclaimer

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

Basemap: National Geographic World Imagery Layer.
Spatial Reference: WGS 1984 UTM Zone 18N



3 Miles

Kilometers

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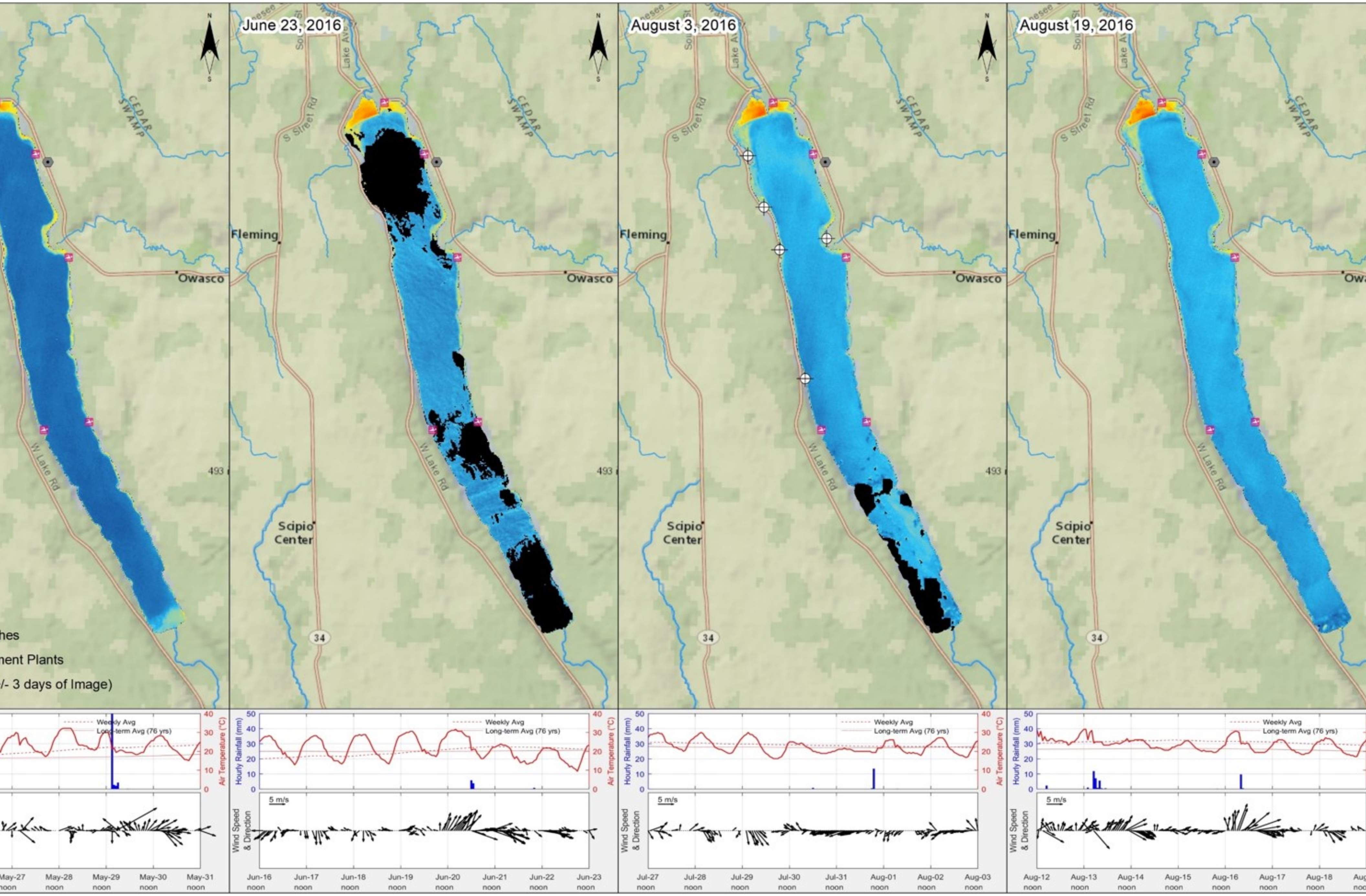

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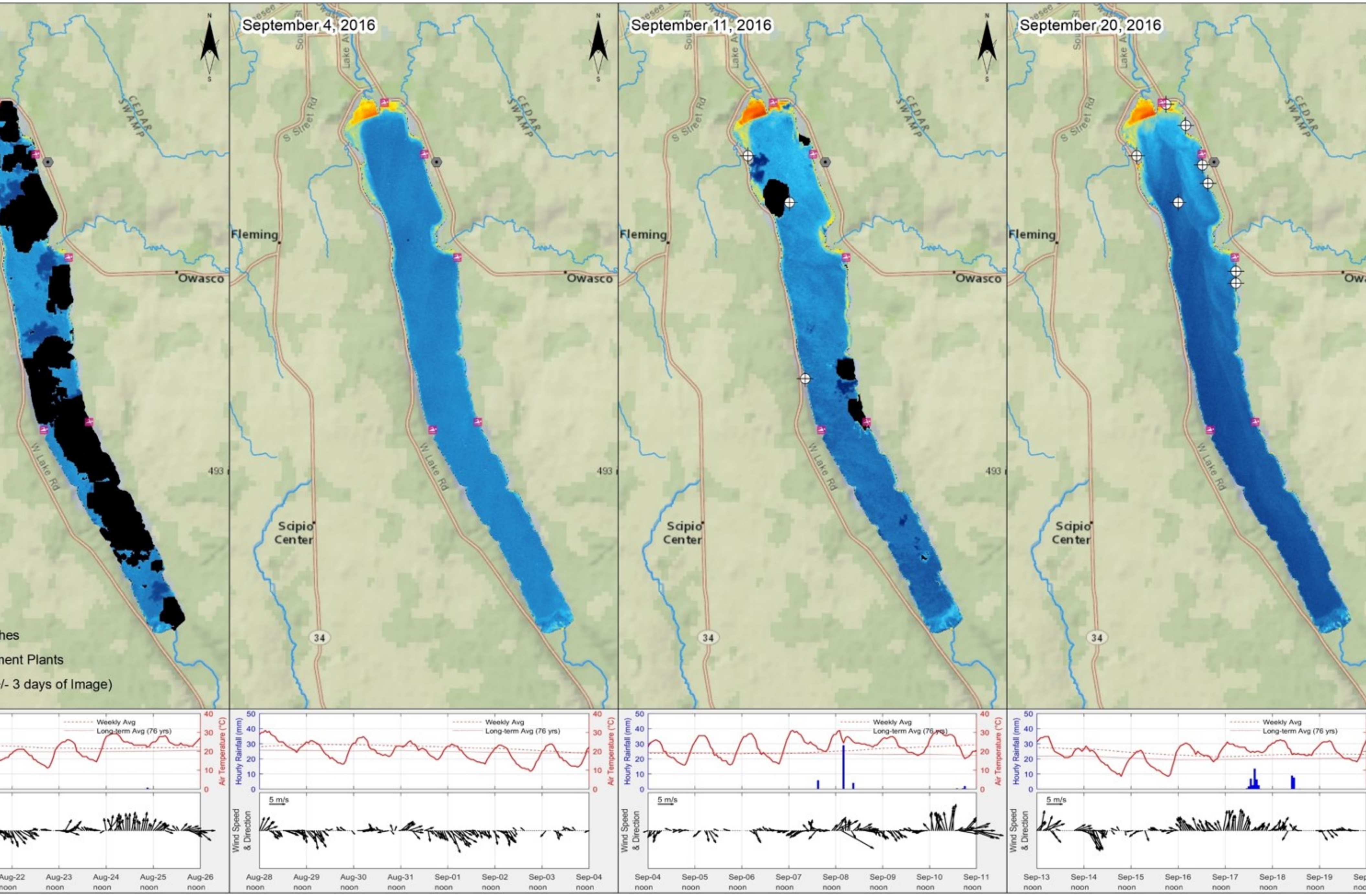

3 Miles

Kilometers

Plots

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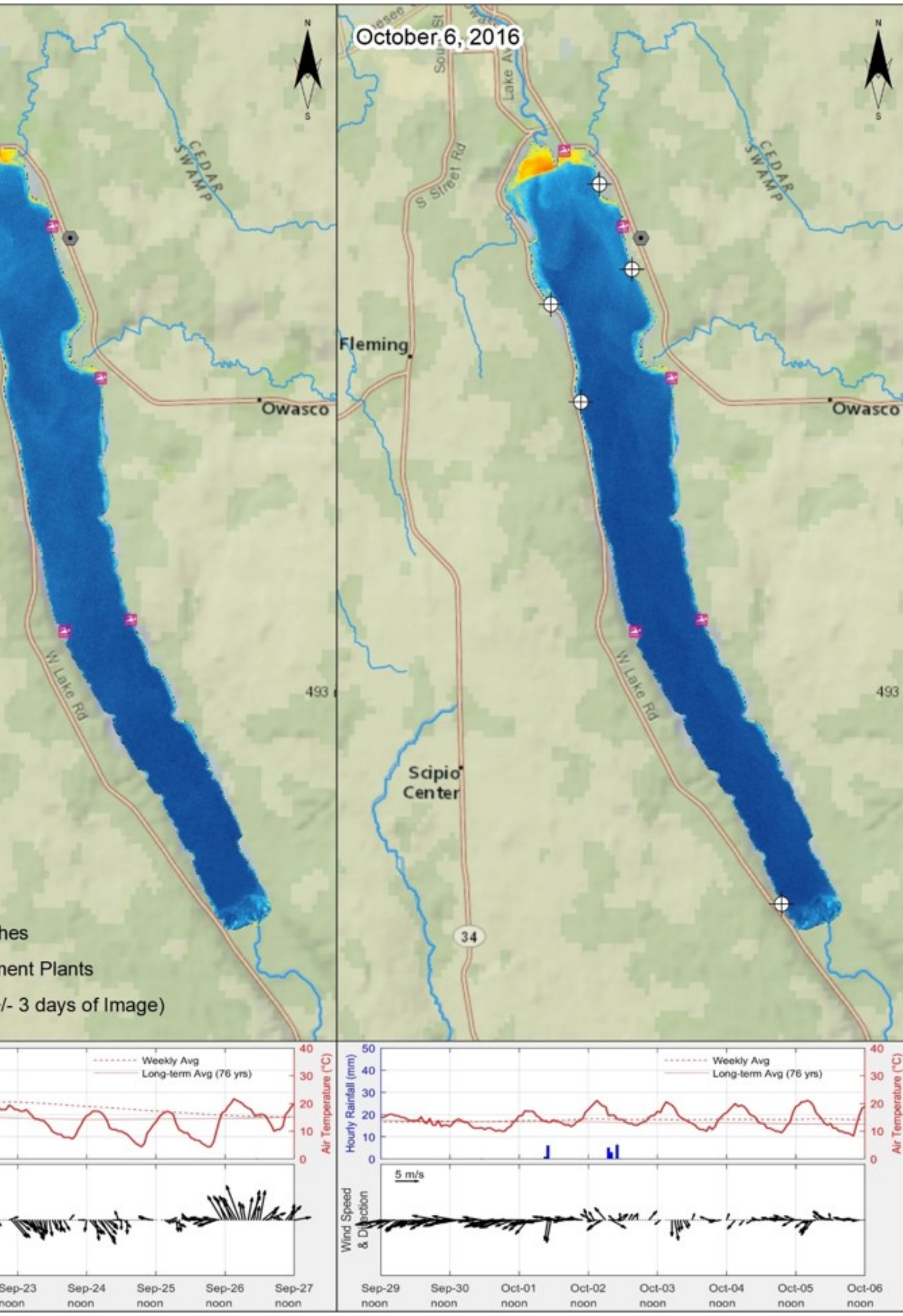

3 Miles

Kilometers

Plots

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

Satellite Derived Chlorophyll a

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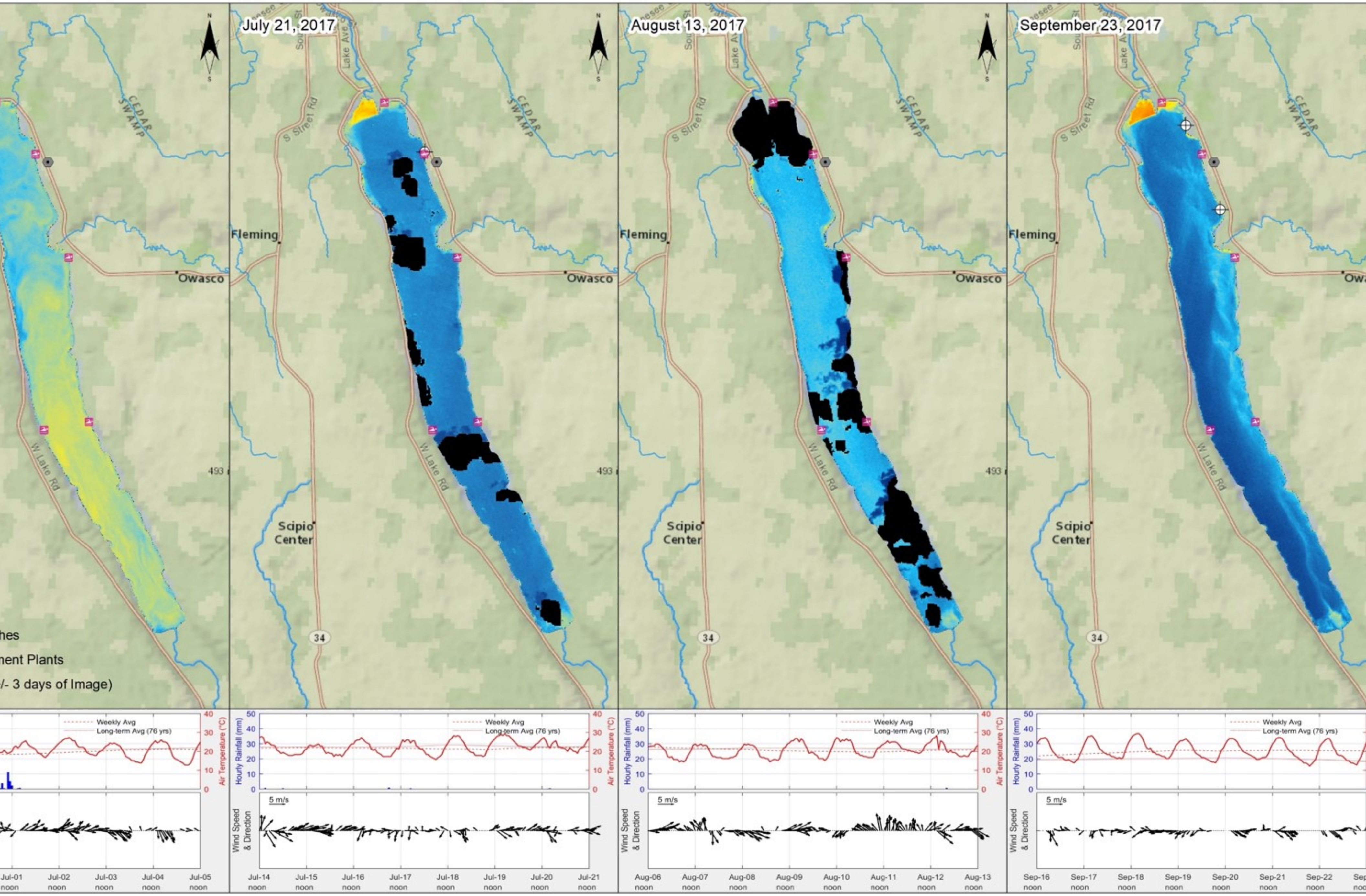

3 Miles
Kilometers

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
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Basemap: National Geographic World Imagery Layer.
Spatial Reference: WGS 1984 UTM Zone 18N

Appendix D. WI/PWL Summary

Owasco Lake (0706-0009) Impaired

Waterbody Location Information

Revised: 05/01/2018

Water Index No:	Ont 66-12-43-P212	**Water Class:**	AA(T)
Hydro Unit Code:	Owasco Lake (0414020113)	**Drainage Basin:**	Oswego-Seneca-Oneida
Water Type/Size:	Lake/Reservoir 6796.9 Acres	**Reg/County:**	7/Cayuga (6)
Description:	entire lake		

Water Quality Problem/Issue Information

Uses Evaluated	**Severity**	**Confidence**
Water Supply	Threatened	Suspected
Public Bathing	Impaired	Known
Recreation	Stressed	Known
Aquatic Life	Fully Supported	Known
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), PATHOGENS, Sediment and turbidity
Suspected: ---
Unconfirmed: ---

Source(s) of Pollutant(s)

Known: Agriculture, WILDLIFE/OTHER SOURCES
Suspected: Municipal Discharges, On-Site/Septic Systems, Soil Erosion, Streambank Erosion
Unconfirmed: ---

Management Information

Management Status: Verification of Problem Severity Needed
Lead Agency/Office: DOW/BWAM
IR/305(b) Code: Impaired Water Requiring a TMDL (IR Category 5, 4c)

Further Details

Overview
Owasco Lake is assessed as an impaired waterbody due to primary contact recreation use that is impaired by pathogens.

Use Assessment
Owasco Lake is a Class AA(T) waterbody, required to support and protect the best uses as a water supply source for drinking, culinary or food processing purposes, primary and secondary contact recreation, and fishing. The lake is also designated as a cold water (trout) fishery.

This classification also means that the quality of the water is to be maintained in order to allow for its use as a drinking water source with disinfection and additional treatment only to remove naturally present impurities. Water from Owasco Lake is used for human consumption and limited irrigation. The City of Auburn, the Town of Owasco, and some lakefront property owners draw water from the lake. In total approximately 55% of Cayuga County's population obtain their drinking water from the lake. In 2016, the combined users drew more than 1.7 billion gallons of water from the lake, serving more than 46,000 residents of Cayuga County. (Cayuga County Health Department, City of Auburn Drinking Water Report, Town of Owasco Drinking Water Report, 2016).

NYSDEC's water supply use evaluation focuses on the lake water prior to treatment, and does not reflect the quality distributed for use after treatment. Monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. That being said, water supply use in Owasco Lake is threateneddue to the elevated elevatedchlorophyll/algae levels that create the potential for 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. DBPs in drinking water can include trihalomethanes (TTHMs), haloacetic acids (HAAs), bromate, and chlorite. Currently municipal water systems drawing from the Lake – City of Auburn and Town of Owasco – do not exceed the MCLs for TTHMs or HAAs. However municipal systems that purchase water from these primary suppliers have exceeded the MCL for DBPs periodically over the past few years.

Microcystin, a toxic chemical associated with harmful algal blooms (HABs) has been detected in trace amounts in the source waters and on rare occasions in the finished water from Owasco Lake. The City of Auburn and Town of Owasco use activated carbon to address taste and odor complaints likely associated with excessive algae. Per the classification regulations, the use of activated carbon filtration for Class AA is limited to removing naturally occuring impurities, and this need for additional treatment may indicate water supply use may be impaired. Toxins have not exceeded levels of concern within the distribution system (Cayuga County Health Department and NYSDEC/DOW, BWAM, October 2014, NYSDEC/DOW, BWAM/LMAS, April 2018)

Primary contact recreation use is impaired due to the temporary/ocassional closures of public beaches for swimming from 2014 through 2017, as a result of the occurance of HABs. In 2000, Owasco Lake was found to be impaired due to primary contact recreation use impairement from elevated pathogen indicators from wildlife, however due to the age of the data (more than 10 years old) those impacts cannot be confirmed and additional sampling is needed to verify current conidtions (DEC/DOW, BWAM/SBU, April 2018).

Fishing use is fully supported in Owasco Lake. The lake supports an excellent fishery with a variety of species, including lake trout, walleye, northern pike, smallmouth bass and panfish. The lake is actively managed for sport fishing. (DEC/DFWMR, Region 7, October 2014)

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. (NYSDOH Health Advisories and NYSDEC/DOW, BWAM, April 2018)

Impacts from habitat and hydrologic modification are also thought to contribute to the weed and algal growth and the impact on recreational uses. Zebra mussel infestation of the lake has increased lake clarity. The increased clarity allows for greater penetration of light which supports plant growth inthe lake. In addition mussels filter particulate-bound phosphorus and release soluble phosphorus that is more readily available for plant growth. In addition to Zebra mussels, Asian clam have established in the northern end of Owasco Lake and it is likely that Quagga mussles are now present. Hydrologic modification of the inlet in 1948 and 1961 by the Army Corps of Engineers to bypass the Owasco Flats wetland complex at the southern end of the lake is also likely contributing to the water quality impacts on the lake. The value of wetlands in providing a buffer to reduce the runoff of pollutants into waters is well established. Conversely the loss of these wetlands results in increased loads, particularly during wet-weather high flow events. (Finger Lakes Institute, January 2006)

Water Quality Information
In 2017, two sites were monitored on Owasco Lake through NYSDEC's Citizens Statewide Lake Assessment Program

(CSLAP) from June through September. Major trophic state indicators were monitored and show that in the open water, Owasco Lake continues to be mesotrophic (moderately biologically productive). Phosphorus, chlorophyll and clarity measurements were somewhat elevated but typically fall below levels that would suggest impacts to recreational uses.

Shoreline monitoring and sampling results show that HABs Surveillance areas of the lake shore are often elevated for both cyanobacteria and toxins at times in the summer and into the fall. In 2017, Owasco Lake was on the HABS Notification List for 13 weeks. The blooms observed were localized but did become widespread at times, also consistent with observations in previous years. (DEC/DOW, BWAM/LMAS, March 2018).

In 2016, low levels of microcystin (a toxin associated with blue-green algae) were detected in the treated drinking water for the City of Auburn and Town of Owasco. The toxins were below the EPA Health Advisory of 0.3 micrograms per liter for the most sensitive population (children). This was the first reported detection of microcysin toxin in New York State treated drinking water. In 2017, monitoring for the microcystin toxin was conducted at the City of Auburn and Town Owasco Water Treatment Plants from July through early November. No samples of finished water were found to have microcystin concentrations above the detection limit in 2017. (Cayuga County Health Department 2017).

Source Assessment

Nutrient and sediment sources to the Lake include point sources such as wastewater treatment facilities and non-point sources such as runoff from agricultural activities (both animal and crop agriculture), onsite/septic systems, soil erosion, stream bank erosion, fertilized lawns and golf courses, roadside ditches and construction activities. (DEC/DOW, BWAM, October 2014)

Owasco Inlet has been identified as a significant source of nutrients (phosphorus) and sediment to the south end of the Owasco Lake, both of which contribute to aquatic vegetation growth. A 2011 biological assessment of the Inlet revealed elevated nutrient impacts in the stream, though impacts attributed the Groton (V) municipal discharge were shown to be greatly reduced since the plant upgrade to reduce phosphorus. Other nonpoint sources remain as contributing sources. (DEC/DOW, BWAM/SBU and Region 7, December 2014).

Waterfowl (geese and gulls) has been identified as the primary source of pathogen indicators at the north end of the lake. Pathogen indicators from agricultural runoff was noted as a secondary source, while human and pet sources were considered to be minor. (Cayuga County WQMA, January 2000)

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. Owasco Lake was identified for inclusion in this initiative as it is vulnerable to HABs. (DEC/DOW, BWRM, April 2018).

DEC has worked with municipalities to address phosphorus loads to the southern Lake via Owasco Inlet. In 2008, NYSDEC worked with the Village of Groton to install improved phosphorus treatment at its WWTP. Since then the village has significantly reduced the amount of phosphorous being discharged from its facility. The only other significant point source discharge in the watershed is the Village of Moravia Sewage Treatment Plant. (DEC/DOW, Region 7, October 2014)

Owasco Lake benefits from a very engaged network of local stakeholders. This network – which includes the Owasco Lake Watershed Management Council, Owasco Watershed Lake Association, Cayuga County Health and Human Services, Cayuga County Planning and Economic Development, Cayuga County Water Quality Management Agency, Cayuga County Soil and Water District and Cornell Cooperative Extension of Cayuga County – oversees a comprehensive watershed approach necessary to reduce nutrients and other pollutants from various contributors throughout the watershed. Some of the highlights of these efforts include the Cayuga County septic system inspection program, the Owasco Lake Watershed Inspection Program staffed with a Watershed Specialist and Seasonal Inspectors, the Owasco Flats Project to reconnect the Inlet with its floodplain and wetlands and provide riparian buffer, and an active and concerned lake association led by the Owasco Lake Watershed Management Council. (OLWA and NYSDEC/DOW, Region 7, October 2014)

Section 303(d) Listing
Owasco Lake is included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. The waterbody is included on Part 3a for pathogens. Impacts/impairments due to pathogen levels need to be verified in light of the reduced frequency of pathogen-related beach closures. In addition, Owasco Lake is categorized as an IR Category 4c waterbody that is Impaired due to the frequent occurance and spacial extent of harmful algal blooms but a TMDL is not needed because the impairment is due to pollution rather than a pollutant.

Segment Description
This segment includes the entire area of the Lake.

Appendix E. NYSDEC Water Quality Monitoring Programs

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

Appendix F. 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 Owasco 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.