New York State of Opportunity | Department of Environmental Conservation | Department of Health | Agriculture and Markets

HARMFUL ALGAL BLOOM ACTION PLAN HONEOYE LAKE

Photo Credit: Terry Gronwall

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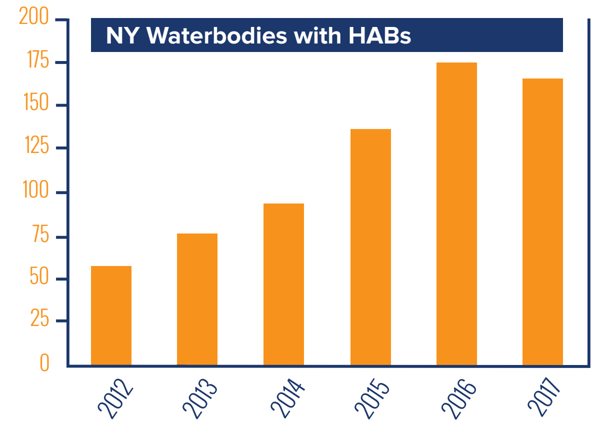
EXECUTIVE SUMMARY

SAFEGUARDING NEW YORK'S WATER

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

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

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



GOVERNOR CUOMO'S FOUR-POINT HARMFUL ALGAL BLOOM INITIATIVE

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

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

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

FOUR-POINT INITIATIVE

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

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

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

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

HONEOYE LAKE

Ontario County

Honeoye Lake, an 1,880-acre lake that is one of the Finger Lakes, is one of the 12 priority lakes impacted by HABs. The lake is used for swimming, fishing and boating. Although it is not a public drinking water source, approximately 300 residences on its shores pump water from the lake for their private water systems, primarily for non-potable use.

The significant sources of phosphorus loading in the lake are:

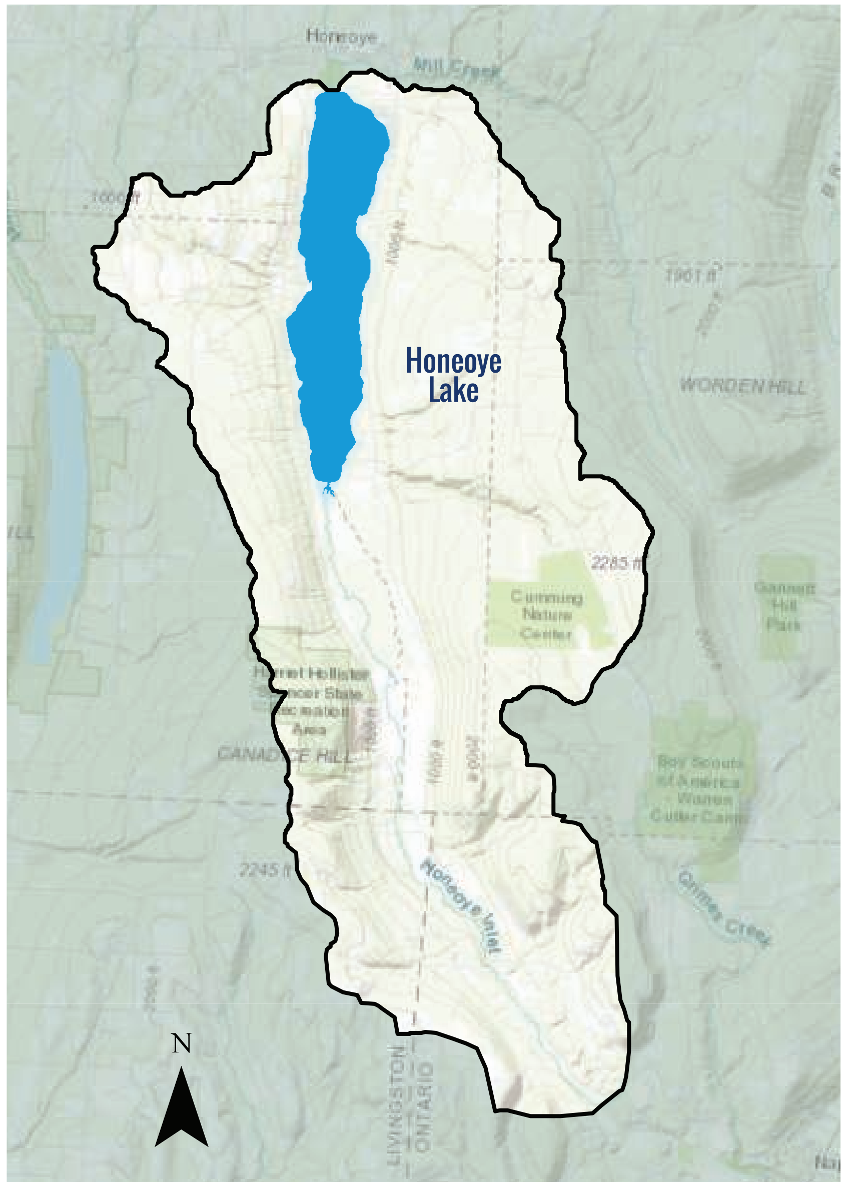
- Internal loading of legacy phosphorus from in-lake sediments; and
- Nonpoint source nutrient inputs from the contributing watershed.

There have been 84 confirmed HABs since 2012, including 14 with high toxins. These blooms have caused closure of the designated swimming beach every year from 2012 to 2107, and led to 104 lost beach days.

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

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

- Complete engineering studies in preparation for nutrient inactivant and aeration destratification applications to address the release of legacy phosphorus from lake sediments;
- Purchase back-up power generators for the 13 sewer life stations to prevent raw sanitary sewage overflow, and install infrastructure to connect additional private systems to municipal sewer systems; and
- Implement multiple stormwater Best Management Practices (BMPs) to reduce nutrient and sediment loading and stabilize riparian habitat.



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.

HONEOYE 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 Honeoye 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 Honeoye Lake and interested members of the public are encouraged to submit comments and ideas to DOWInformation@dec.ny.gov to assist with HABs prevention and treatment moving forward.

NEW YORK STATE RESOURCES

Drinking Water Monitoring and Technical Assistance:

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

Public Outreach and Education:

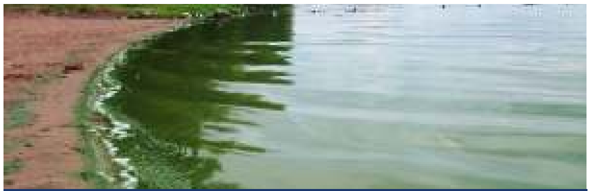
The **Know It, Avoid It, Report It** campaign helps educate New Yorkers about recognizing HABs, taking steps to reduce exposure, and reporting HABs to state and local agencies. The state also requires regulated beaches to close swimming areas when HABs are observed and to test water before reopening.

Research, Surveillance, and Monitoring:

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

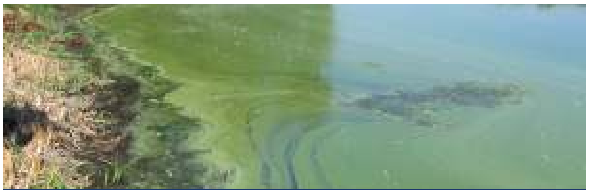
Water Quality and Pollution Control:

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

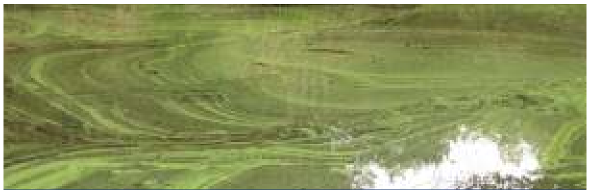


Pea soup appearance

Floating dots or clumps



Spilled paint appearance



Streaks on the water's surface

CONTACT WITH HABs CAN CAUSE HEALTH EFFECTS

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

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1. Introduction

1.1 Purpose

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

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

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

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

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

1.2 Scope, Jurisdiction and Audience

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

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

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

The intended audiences for this Action Plan are as follows:

- New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health (NYSDOH), and New York State Department of Agriculture and Markets (NYSDAM) officials associated with the HABs initiative
- State agency staff who are directly involved in implementing or working with the NYS HABs monitoring and surveillance program
- Local and regional agencies and organizations involved in the oversight and management of Honeoye Lake (*e.g.*, Ontario County Soil and Water Conservation Districts (SWCDs), Western District Departments of Health (DOHs), Honeoye Lake Watershed Task Force, Honeoye Valley Association, and those identified in **Section 4**)
- Lake residents, managers, consultants, and others that are directly involved in the management of HABs in Honeoye Lake.
- Members of the public interested in background information about the development and implications of the HABs program.

Analyses conducted in this Action Plan provide insight into the processes that potentially influence the formation of HABs in Honeoye Lake, and their spatial extents, durations, and intensities. Implementation of the mitigation actions recommended in this HABs Action Plan are expected to reduce blooms in Honeoye 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 Honeoye Lake, and has produced this Action Plan to identify the primary factors triggering HAB events, and to facilitate decision-making to minimize the frequency, intensity, and duration of HABs as well as the effects that HABs have on both lake users and resident biological communities.

2. Lake Background

2.1 Geographic Location

Honeoye Lake is located in the Finger Lakes region of New York, 45 km (28 miles) south of Rochester in southwestern Ontario (**Figure 1**). The Honeoye Lake shoreline is within the Towns of Canadice and Richmond (NYSDEC 2000, NYSDEC 2018a, G/FLRPC 2007).

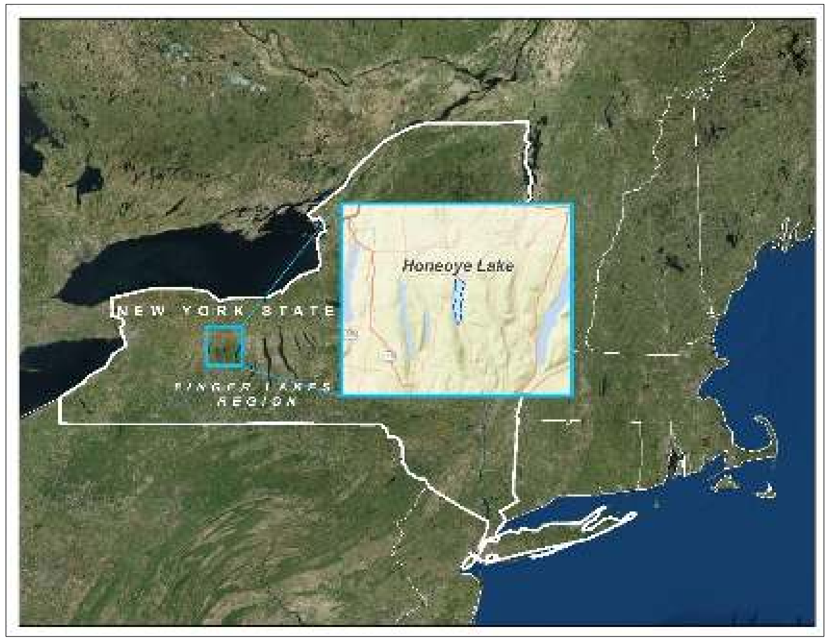


Figure 1. Location of Honeoye Lake within New York State.

2.2 Basin Location

The Honeoye Lake watershed consists of approximately 24,500 acres that extend through six towns in two counties (**Figure 2**): Towns of Bristol, Canadice, Naples, Richmond, and South Bristol in Ontario County and the Town of Springwater in Livingston County (G/FLRPC 2007). The watershed is a part of the larger Genesee River watershed, which covers 614,604 acres in New York (NYSDEC 2018b).

2.3 Morphology

Honeoye Lake is an 1,880-acre lake with a mean depth of approximately 4.9 m (16.1 feet) (**Figure 3**), length of 6.6 km (4.1 mi), and shoreline length of 17.0 km (10.6 mi). Its volume is estimated to be about 9.2 billion gallons (G/FLRPC 2007). The surface area of Honeoye Lake is about one-fifteenth the area of its watershed. This relatively high watershed to lake ratio is often associated with shorter water retention times (e.g., 300 days for Honeoye Lake), as well as relatively high sedimentation rates and land-based loading of phosphorus and other nutrients (*e.g.*, nitrogen).

Honeoye Lake falls into a group of large lakes with relatively shallow depths, similar to other lakes with the HABs initiative (e.g., Conesus and Chautauqua) and other large, shallow lakes in New York State. Approximately 25% of the lake features depths in the 7.5 to 9 m range (25 to 30 feet, the latter being the maximum depth of the lake). The morphology of these lakes is such that the hypolimnion (lower layer of a lake) is relatively thin, stratification leads to rapid depletion of dissolved oxygen and associated accumulation of phosphorus at depth, and shallower depths likely cause portions of the lake to mix periodically throughout the growing season after they have been stratified. Additionally, there is evidence to support internal seiches, or underwater waves that occur due to surface seiches or water current conditions, may influence nutrient cycling in Honeoye Lake (Nelson Hairston Jr, personal communication). These internal seiches, coupled with internal nutrient loading, mix nutrients spatially within Honeoye Lake and thus influence the productivity of phytoplankton, including cyanobacteria.

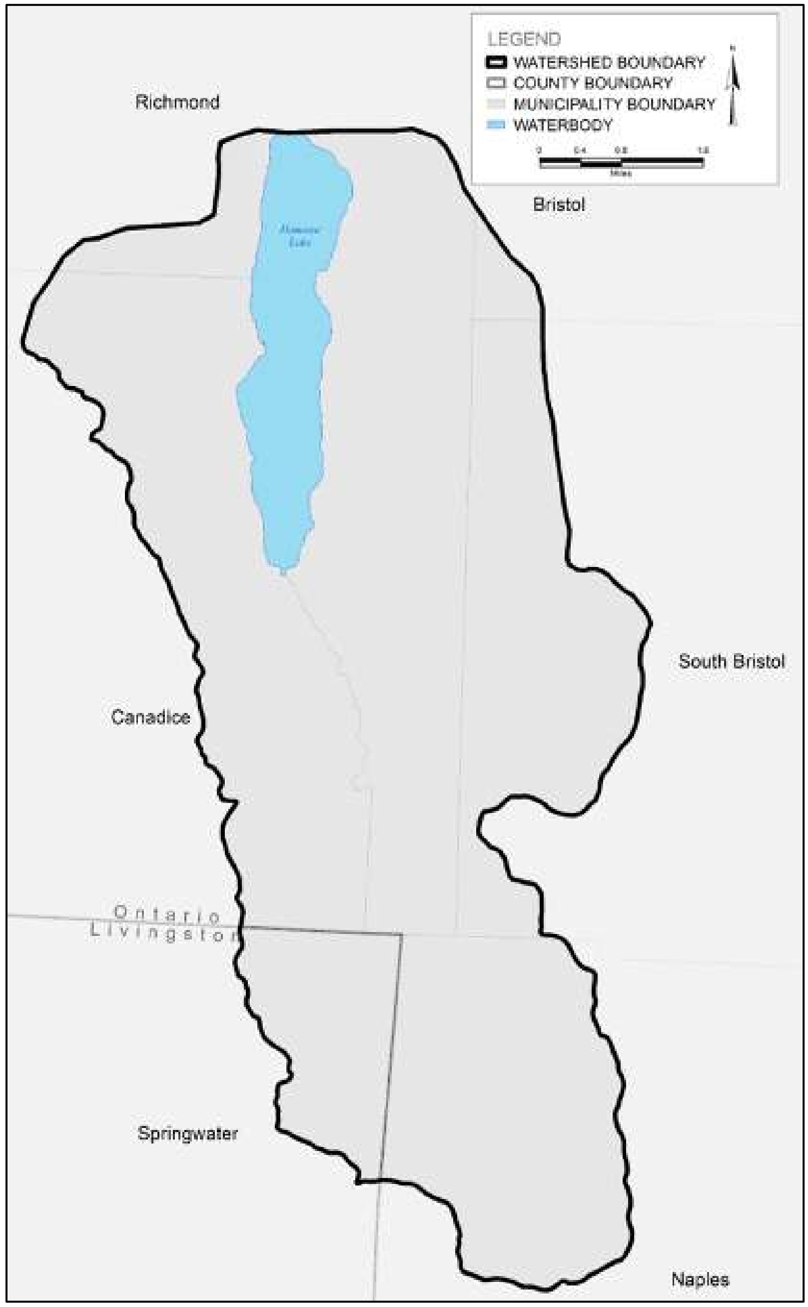


Figure 2. Political boundaries within the Honeoye Lake watershed.

The wind rose in **Appendix A** indicates that the stronger prevailing wind directions influencing Honeoye Lake were from the northwest and southeast from 2004 to 2017 during the months of June through November, as measured at the Dansville Municipal Airport. This can result in a fetch approximately the length of the lake over which wind and wave action can mix the water and transport buoyant cyanobacteria, generally towards the southern and northern ends of the lake. This relatively long fetch suggests that there is a long distance over which wind and waves can mix water throughout much, if not all, of its depth. This promotes mixing throughout the year, especially given the shallower depths of Honeoye Lake relative to other, much deeper, Finger Lakes. However, this mixing may not be constant, as it is dependent on wind and wave action.

Wind-driven accumulation of cyanobacteria may contribute to HABs in the northern and southern ends of Honeoye Lake. The potential for HABs to accumulate in the northern portion from wind-driven accumulation is of concern due to Sandy Bottom Beach being located at the northern end of Honeoye Lake. However, HABs have been documented in most portions of the lake (see **Section 7**).

2.4 Hydrology

Honeoye Lake has a hydraulic retention time, or the amount of time it takes water to pass through the lake, of approximately 300 days. Water flows north to the lake's outlet at the eastern edge of Sandy Bottom Park, then to Honeoye Creek, the Genesee River, and eventually Lake Ontario (G/FLRPC 2007).

Major tributaries to Honeoye Lake include Honeoye Inlet, Briggs Gully, Bray Gully, and Affolter Creek (G/FLRPC 2007).

The Honeoye Lake watershed can be separated into ten subwatersheds (see **Figure 4**): North Shore direct drainage (DD), Times Union Creek, Pinewood Hill DD, Bray Gully, East Shore DD, Briggs Gully, Honeoye Inlet, Canadice Corners DD, Affolter Gully, and West Shore DD (G/FLRPC 2007).

2.5 Lake Origin

The Finger Lakes were created by the repeated advance and retreat of glaciers that gouged the land, deepening and widening valleys. The latest glacial advance occurred about 21,000 years ago, and by about 10,000 years ago the glaciers had melted, leaving debris piles that acted like dams. These dams blocked streams, filling the valleys with water and forming the Finger Lakes (NASA 2013). The Honeoye Lake watershed is now underlain by nearly horizontal bedrock, where the northern end rests on shale and limestone. The central portion of the watershed is shale

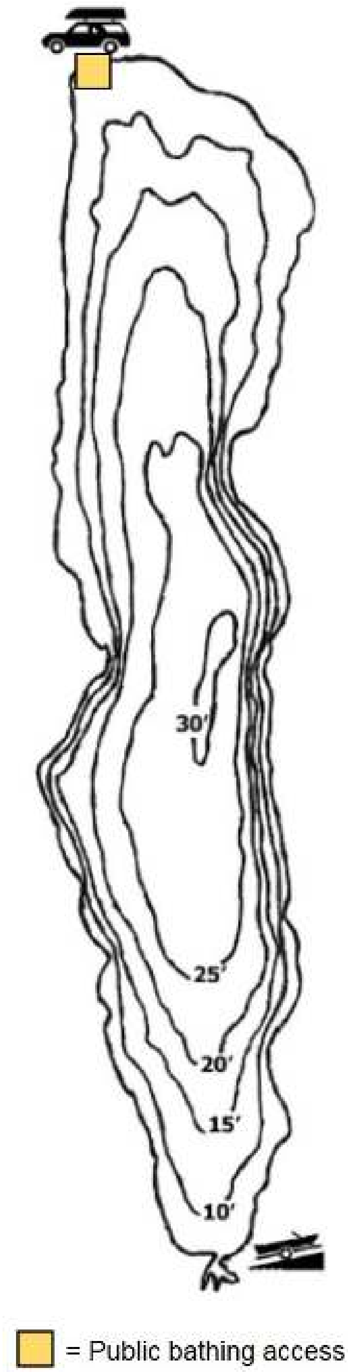


Figure 3. Bathymetric map of Honeoye Lake (*Source*: NYSDEC). The public bathing beach is depicted (yellow square). Note bathymetry was collected in the 1930s, and may contain outdated data.

inter-bedded with siltstone. The southern end rests on inter-bedded grey shales, siltstones, and sandstones.

Highly erodible glacial till covers the bedrock throughout the watershed (G/FLRPC 2007), and contributes to significant sediment movement through the deeply incised tributaries. This sediment load is transported to Honeoye Lake, and will continue until erosion reaches the underlying native bedrock.

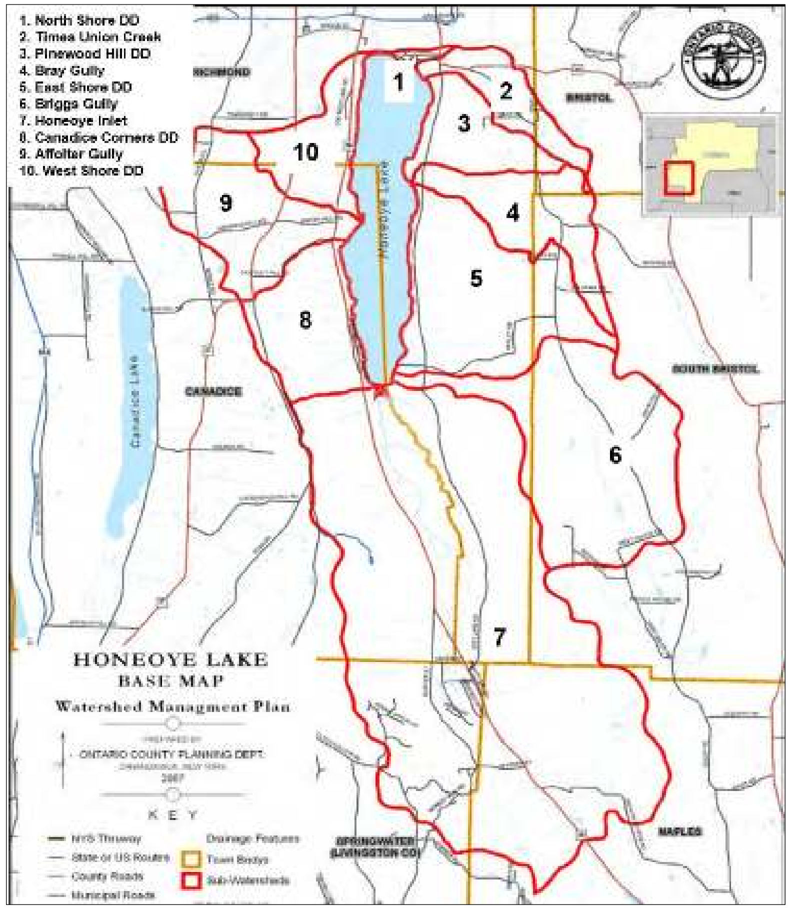


Figure 4. Honeoye Lake subwatersheds (*Source*: G/FLRPC 2007, altered for clarity).

3. Designated Uses

3.1 Water Quality Classification – Lake and Major Tributaries

Honeoye Lake is a Class AA waterbody (NYSDEC 2000), meaning it is suitable for use as a water supply for drinking (with approved disinfection treatments) and culinary or food processing purposes. The lake is also suitable for primary and secondary contact recreation, fishing, and fish propagation and survival.

Honeoye Inlet, Briggs Gully, Bray Gully, and Affolter Creek are all Class C waterbodies (G/FLRPC 2007, NYSDEC 2018c), meaning they are best used for fishing, fish propagation and survival, and primary and secondary contact recreation, although other factors may limit their use for these purposes. These waterbodies are not suitable as water supplies or for public bathing uses.

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

3.2 Potable Water Uses

Honeoye Lake is not used as a source for a public water supply. However, approximately 300 shoreline residences on Honeoye Lake pump water directly from the lake for their private, individual water systems that are generally used for non-potable activities such as toilet flushing (Callinan 2001). It is not known to what extent these private systems filter or treat the water (G/FLRPC 2007). Most of these private systems are in the Town of Canadice, which recently formed a water district in order to eventually serve shoreline residents.

While Honeoye Lake is not used as a public water supply, the United States Environmental Protection Agency (USEPA) sets health advisories to protect people from being exposed to contaminants in drinking water for those waterbodies that do serve this purpose. As described by the USEPA: “The Safe Drinking Water Act provides the authority for EPA to publish health advisories for contaminants not subject to any national primary drinking water regulation. Health advisories describe nonregulatory concentrations of drinking water contaminants at or below which adverse health effects are not anticipated to occur over specific exposure durations (e.g., one-day, 10-days, several years, and a lifetime). Health advisories are not legally enforceable federal standards and are subject to change as new information becomes available.”

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

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

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

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

3.3 Public Bathing Uses

Sandy Bottom Beach Park at the northern end of the lake offers the only public swimming opportunity on Honeoye Lake with 183 m (600 feet) of beach. The beach is heavily used from June until September, and lifeguards are provided by the Town of Richmond. (NY Falls 2018, G/FLRPC 2007).

3.4 Recreation Uses

Honeoye Lake is a popular summer destination, particularly for the greater Rochester area, because it offers a wide variety of recreation opportunities to residents and tourists, including boating, swimming, fishing, waterskiing, ice fishing, and kayaking. Public boat launches are located at Honeoye Lake Boat Launch State Park and Sandy Bottom Beach Park; Honeoye Inlet Wildlife Management Area allows the public to hand launch vessels. Parks, preserves and wildlife management areas along the shoreline also offer picnic areas, playgrounds, athletic fields, camping, hiking, hunting, and other forms of recreation (NY Falls 2018).

3.5 Fish Consumption/Fishing Uses

Both open water and ice fishing are permitted in Honeoye Lake in accordance with general statewide fishing regulations. **Table 1** details the special fishing regulations that also apply (NY Freshwater Fishing 2018). Honeoye is known for its excellent sportfish opportunities, and supports an outstanding panfish fishery (NYSDEC 2018a). The New York State Department of Health (NYSDOH) advises eating no more than four fish meals a month from the Finger Lakes region, including Honeoye Lake (NYSDOH 2017). Note that the species listed in **Table 1** are regulations for the Finger Lakes generally, and certain species may not be present in Honeoye Lake.

Table 1. Honeoye Lake fishing regulations.

Species	Open Season	Minimum Length	Daily Limit	Method
Northern Pike	1st Sat. in May – March 15	22”	5	Ice fishing permitted
Walleye	1st Sat. in May – March 15	18”	3	
Brown Trout **Rainbow Trout** **Lake Trout** **Atlantic Salmon**	All year	15”	5 in combination. Catch shall include no more than 1 rainbow trout or 3 Atlantic salmon	
Black Bass	3rd Sat. in June – March 15	12”	5	
	March 16 – Fri. Preceding 3rd Sat. in June	Catch and release only		
Alewife (sawbellies)	Possession prohibited			

3.6 Aquatic Life Uses

Fish

Consistent with its waterbody classifications, Honeoye Lake is suitable for fish propagation and survival. Macrophyte stands provide excellent fish habitat, including spawning sites, feeding areas and protective refuge for juvenile fish from predators (HLWTF 2008). Both coolwater and warmwater fish communities can be found in the lake, including (NYSDEC 2018a):

- black crappie, (*Pomoxis nigromaculatus*)
- bluegill, (*Lepomis macrochirus*)
- chain pickerel, (*Esox niger*)
- largemouth bass, (*Micropterus salmoides*)
- smallmouth bass, (*Micropterus dolomieu*)
- walleye, (*Sander vitreus*)
- pumpkinseed, (*Lepomis gibbosus*)
- yellow perch, (*Perca flavescens*)

The NYSDEC has a current management emphasis to maintain a relatively high density of predator species to control the abundant panfish populations. Honeoye Lake was first stocked with walleye around the turn of the century and is now stocked with 8.7 million walleye fry by the NYSDEC annually (NYSDEC 2018a).

Careful management of the fishery in Honeoye Lake, coupled with the absence of observable impairment to the aquatic life use in the lake (as reported in the Honeoye Lake Priority Waterbody List [WI/PWL] fact sheet [NYSDEC 2016]), 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 Honeoye Lake.

Dreissenid Mussels

Zebra mussels (*Dreissena polymorpha*) were first discovered in Honeoye Lake in 1998, in near-shore areas with a substrate suitable for forming attachments. Zebra mussels have since moved into deeper waters and now colonize depths to 4 m (13.1 feet) in Honeoye Lake, with larger mussels found in shallower water which have rockier substrates suitable for long-term survival. In 2015, quagga mussels (*Dreissena bugensis*) were first documented in Honeoye Lake. Both invasive mussel species can influence phytoplankton assemblages by selectively filtering certain phytoplankton (i.e., green algae) from the water column, leaving other taxa, such as cyanobacteria, to remain (Vanderploeg et al. 2001).

The potential for dreissenid mussels to influence the formation and potential extent of HABs in Honeoye Lake is further described in **Section 9**.

Aquatic Plants

Honeoye Lake's nearshore area and depths of up to 4.6 m (15 feet) support abundant rooted aquatic vegetation. Aquatic plant surveys conducted by the Finger Lakes Community College have identified several abundant and common plant species including (Gilman et al. 2014):

- eelgrass, (*Vallisneria americana*)
- Eurasian watermilfoil, (*Myriophyllum spicatum*)
- coontail (*Ceratophyllum spicatum*)
- common waterweed, (*Elodea* spp.)
- water stargrass (*Heteranthera dubia*)
- naiads (*Najas* spp.)
- large-leaf pondweed (*Potamogeton amplifolius*)
- clasping leaf pondweed, (*Potamogeton perfoliatus*)

Surveys conducted by Gilman and colleagues in 1984,1994, 2004, and 2014 documented 27 different species of aquatic plants (Gilman et al. 2014). Based on these studies, eelgrass, pondweeds (*Potamogeton* spp.), Eurasian watermilfoil, and water stargrass are the predominant plant species (NYSDEC 2018a). Additional information regarding aquatic plants can be found in **Section 6.3**.

4. User and Stakeholder Groups

Honeoye Lake provides a myriad of recreational opportunities to not only residents, but also tourists and visitors from the greater Rochester area. Access to Honeoye Lake is available to the public via the local beach, parks, and boat launches.

Several citizen advocacy groups have formed with the shared goal of protecting the water resources of Honeoye Lake and its watershed, including those focused on the entire Finger Lakes region. These include:

- The Honeoye Valley Association (HVA) was founded in 1985 and advocates for the responsible use of the natural resources of the Honeoye Lake watershed through several community programs and involvement in lake level management, boating safety, water quality testing, aquatic vegetation control, stream clean-up, and public education (HVA 2018)
- The Honeoye Lake Watershed Task Force (HLWTF) was formed in 1998 through HVA initiatives to bring together watershed stakeholders to improve water quality throughout the watershed. The HLWTF consists of a voting member from each of the towns within the watershed and from HVA, and receives technical support from Finger Lakes Community College, Ontario County SWCD, Ontario County Planning Department, NYSDEC, and others. The HLWTF advocates for water quality management through voluntary cooperation, testing, special projects, education, and grant funding applications (HVA 2018)
- Concerned citizens of Honeoye Lake and its watershed have formed several organizations with varying areas of interest such as weeds in the lake, bacterial contamination, hunting, fishing, and flooding. These organizations include the Honeoye Lake Watershed Association (1950-66), Genesee Valley Trappers (late 1950s to present), Honeoye Fish and Game Club (1947- present), Honeoye Lake Cottagers Association (1966-67), and the Honeoye Environmental Action League (1970-88) (HVA 2018)
- Several regional groups have formed with the overarching goal of protecting the region and its natural resources. These include:
    - The Finger Lakes-Lake Ontario Watershed Protection Alliance (FLLOWPA) stems from conservation efforts dating back to the mid-1980s where it began as the Water Resources Board of the Finger Lakes Association. FLLOWPA 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) was founded in 1989 to conserve land within the region, and has protected 19,000 acres through the creation of public nature preserves and private property conservation (FLLT 2018).
    - The Finger Lakes Regional Watershed Alliance (FLRWA) was formed in 2010 as a collaboration between nine Finger Lake and watershed organizations whose mission it is to preserve and protect the region's watersheds (FLRWA 2018).
    - The Genesee/Finger Lakes Regional Planning Council (G/FLRPC) was established in 1977 by a joint resolution approved by its eight original member counties, including Genesee, Livingston, Monroe, Ontario,

Orleans, Seneca, Wayne, and Yates. Wyoming County was admitted in 1986. The G/FLRPC works to identify, define, and inform its member counties of issues and opportunities critical to the physical, economic, and social health of the region by providing forums for discussion, debate, and consensus building. G/FLRPC develops and implements focused action plans to address these issues with clearly defined outcomes, which include programs, personnel, and funding (G/FLRPC 2018).

5. Monitoring Efforts

5.1 Lake Monitoring Activities

Honeoye Lake and several of the Finger Lakes have been the subject of scientific study for decades due to their socioeconomic importance to the State of New York. Results from these studies are summarized in **Section 6**.

The NYSDEC conducted a study in the late 1990s to replicate comparative investigations of the Finger Lakes not conducted systematically on all eleven Finger Lakes since at least the 1970s. 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. Honeoye Lake was included in this evaluation.

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 Disinfectant By-Products (DBPs) study was conducted in 2004 in response to the USEPA initiation of a National Nutrient Strategy (USEPA, 1998) that called on states to establish a numeric nutrient criteria (NNC). A total of 21 lakes, including Honeoye Lake, were included in the NYSDEC DBPs study, which focused on lakes designated as 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 DBPs).

Citizen Statewide Lake Assessment Program (CSLAP) sampling has been conducted on Honeoye Lake between 1996 and 2000 and again in 2017 at two water quality sampling locations: North and Mid/South. **Section 6** details the physical, chemical, and biological condition of Honeoye Lake based on data collected through the CLSAP program.

Efforts to examine and quantify hydrologic and pollutant loading conditions within the Honeoye Lake watershed, in partnership with The Nature Conservancy and HLWTF, were detailed in the *Update of the Hydrologic and Nutrient Budgets of Honeoye Inlet* *and Honeoye Lake* (Princeton Hydro 2014). The Honeoye Inlet watershed was of particular interest, being the largest of Honeoye Lake's subwatersheds.

The Finger Lakes Community College (FLCC) operates the Muller Field Station near the southern end of Honeoye Lake where faculty, staff, and students conduct fish surveys and other research of Honeoye Lake and its watershed. The Station offers field-based academic programs, laboratory experiences, community outreach, and the opportunity to participate in or observe local research projects. College and university students, local K-12 students and their teachers, community members, environmental organizations, and agencies are all welcome visitors to the Station (FLCC 2018, G/FLRPC 2007).

Individual researchers have studied Honeoye Lake's water quality since the early 20th century. Earlier studies related to nutrient loadings, water clarity, sedimentation, and biological surveys are detailed in Honeoye Lake's Watershed Management Plan (G/FLRPC 2007). More recently, Starke (2010) summarized a water quality monitoring program from 2003-2010, and Gilman (2011) studied chlorophyll-a levels as they relate to algal productivity within Honeoye Lake. Hobart and William Smith Colleges Finger Lakes Institute (FLI) has conducted limnological research on the 8 easternmost Finger Lakes dated back to the early 2000s, including monitoring in Honeoye Lake (Halfman 2017). In addition, Cornell University (Nelson Hairston Jr.) has conducted research specifically to address HABs in Honeoye Lake, including investigating the role of internal seiches and upwelling of legacy nutrients in contributing to HABs in the lake.

The HLWTF began conducting water quality sampling in 2003, and in 2012, the HLWTF partnered with NYSDEC to conduct regular surveillance and sampling efforts for HABs at multiple locations throughout the lake. These efforts include episodic bloom sampling that supports NYSDEC's HABs Notifications program and routine sampling at locations prone to blooms.

5.2 Tributary Monitoring Activities

The following tributaries to Honeoye Lake have been monitored as part of the NYSDEC Rotating Intensive Basins (RIBS) program:

- Macroinvertebrate assessments of an unnamed tributary (Unnamed tributary to Honeoye Lake) (RICM_T9-0.4) in Richmond (upstream of East Lake Road) in 2009 (BAP = 8.59), 2014 (BAP = 7.26), and 2015 (BAP = 6.7) reflected the following:
    - Water quality in the slightly impacted range in 2014, but near the non-impacted threshold.
    - Very good water quality with non-impacted conditions in 2009. Samples were dominated by clean-water species typical of natural communities with minimal human impacts.
    - Aquatic life was fully supported in this tributary.

- Sampling at another unnamed tributary (Unnamed tributary to Honeoye Lake – SUNS_T10-0.2; at West Lake Road in Canadice) reflected slight to moderate impacts (BAP = 5.0), but low stream flow influenced this sample so the validity of the sample was questioned (Upper Honeoye Creek Watershed WI/PWL 2016).

- A macroinvertebrate assessment of Honeoye Inlet in Naples (at Route 36) (HONI – 5.8) in 2014 (BAP = 7.24) reflected the following:
  - Good water quality with conditions in the slightly impacted range but approaching non-impacted and communities typical of natural conditions.
  - The macroinvertebrate community showed some signs of alteration as some expected sensitive species were not present and the overall species richness was somewhat lower than expected.
  - This evaluation was consistent with results from sampling conducted at the same site in 1995 (BAP = 6.33) and 1999 (BAP = 7.38) (Upper Honeoye Creek Watershed WI/PWL 2016).

6. Water Quality Conditions

Honeoye Lake can best be classified as eutrophic, with the greatest threat being nutrient (phosphorus) levels, and algal and aquatic plant growth (Upper Honeoye Creek Watershed WI/PWL 2016). 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 water quality monitoring stations in Honeoye Lake through NYSDEC monitoring

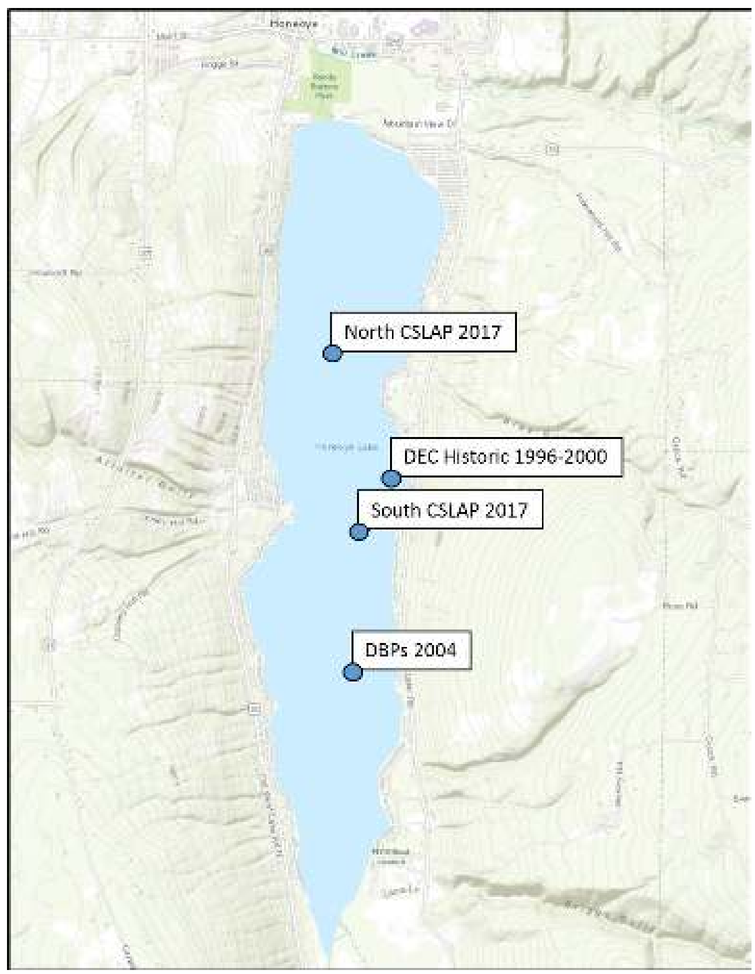


Figure 5. Historic and current Honeoye Lake water chemistry sample locations.

programs from current (e.g., 2017, CSLAP) and historic locations are depicted in **Figure 5**:

- *North* - 2017 (CSLAP)
- *Mid/South* - 1996 to 2000 (DEC Historic); 2004 (DBPs); 2017 (CSLAP)

Patterns and trends in the multiple years of data were evaluated for the Mid/South sampling location but could not be completed for the North sampling location where only one year of data is available. Trends were evaluated using a nonparametric correlations coefficient (Kendall's tau, τ) to determine if time trends were significant, assumed for p-values less than 0.05. Water quality data used in this analysis were limited to those that were collected under a State-approved Quality Assurance Project Plan (QAPP), and analyzed at a laboratory certified under the Environmental Laboratory Approval Program (ELAP). For Honeoye Lake, water quality data included those collected through CSLAP, DBPs, and the HLWTF. 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.

The data provided in **Table 2** indicate that current TP concentrations in the North and Mid/South locations of Honeoye Lake in 2017 were higher compared to other Finger Lakes.

Table 2. Regional summary of average surface TP concentrations (mg/L, ± standard error) for New York State lakes, 2012-2017 (CSLAP and Lake Classification and Inventory (LCI)), and the average TP concentration (± standard error) in Honeoye Lake in 2017 (CSLAP).

Region	Number of Lakes	Average TP (mg/L)	Average TP North (mg/L) 2017	Average TP South (mg/L) 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)	0.033 (± 0.007)	0.039 (± 0.009)
Western NY	47	0.045 (± 0.008)	-	-

Annual average total phosphorus concentrations were similar at the North and South sampling locations in 2017 (**Table 2**), but both were greater than the New York State guidance value for TP value of 0.02 mg/L. Thus, future management actions to protect water quality should likely focus on reducing TP concentrations.

Water clarity (based on Secchi depth, m), TP (mg/L), and chlorophyll-a (μg/L) concentrations are used to assess trophic state using New York State criteria (**Table 3**). In 2017, both the North and South locations were indicative of eutrophic (highly productive) conditions.

Table 3. New York State criteria for trophic classifications (NYSFOLA 2009) compared to averages for Honeoye Lake (CSLAP 2017, ± standard error).					
Parameter	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Honeoye North 2017**	**Honeoye South 2017**
Transparency (m)	>5	2-5	<2	1.8 (± 0.2)	1.6 (± 0.2)
TP (mg/L)	<0.010	0.010-0.020	>0.020	0.033 (± 0.007)	0.039 (± 0.009)
Chlorophyll-a (μg/L)	<2	2-8	>8	19.2 (± 5.2)	25.1 (± 7.3)

6.1 Physical Conditions

Honeoye Lake is relatively shallow but deep enough to allow for the development of a relatively thin hypolimnion during summer. As noted above, 25% of the lake area features depths between 7.5 to 9 m range (25 to 30 feet). Research conducted by Cornell University has indicated that for both a dry year (2016) and wet year (2017), the disruption of the hypolimnion through mixing with the epilimnion occurred one or more times in late August and September (Nelson Hairston Jr., personal communication). There is also evidence to suggest that the hypolimnion becomes anoxic soon after thermal stratification develops in late May or more typically, mid-June. The development of anoxic conditions around mid-June can trigger an increase in phosphorus (e.g., soluble reactive phosphorus (SRP)) concentrations in the hypolimnion around the same time. SRP is a form of bioavailable phosphorus immediately available to support algal growth. This accumulated pool of SRP is pulsed into the epilimnion during both wind-driven mixing events and seasonal turnover at the end of seasonal thermal stratification.

Average annual water clarity measurements, as represented by Secchi depth, in Honeoye Lake generally indicate a mesotrophic (moderate productivity) to eutrophic condition (**Figure 6**). There was a statistically significant decreasing trend in Secchi depth at the Mid/South sampling locations from 1996 to 2017 ($p = 0.006$, $\tau = -0.442$) (**Figure 6a**). Additional water clarity data should be collected, particularly from the northern portion of Honeoye Lake, with updated trend analyses performed to identify potential long-term patterns that could inform future management actions. Secchi disk transparency readings regularly exceeded the New York State Sanitary Code requirements for siting new bathing beaches (1.2 m, or 4 feet, minimum, NYSDOH 2018). Of the eight easternmost Finger Lakes that is annually monitored by the FLI (Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles, and Otisco), Honeoye Lake average annual water clarity was the lowest in both 2015 (1.6 ± 1.1) and 2016 (2.3 ± 1.3 m, the latest year where annual averages were available) (Halfman 2017).

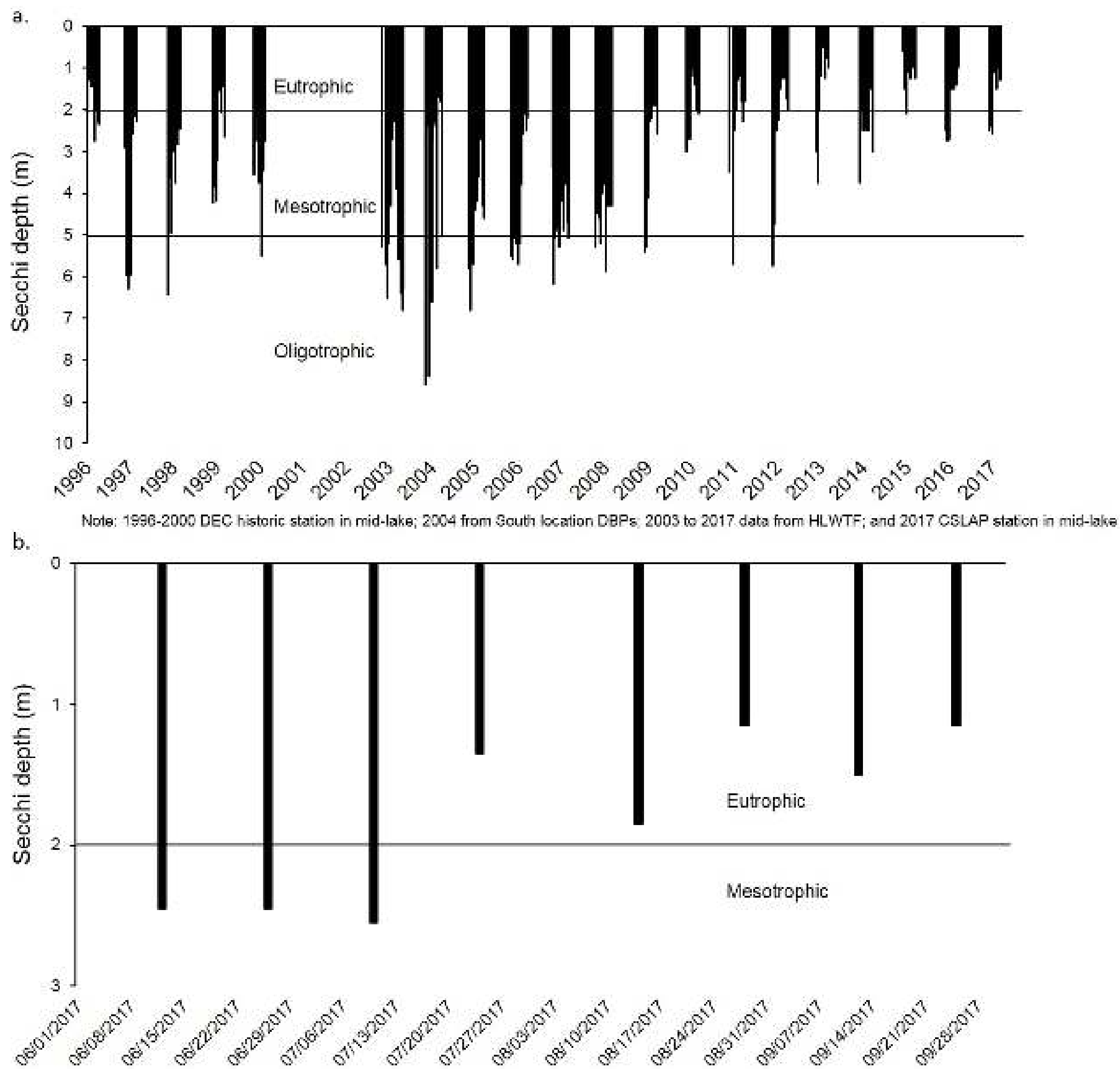
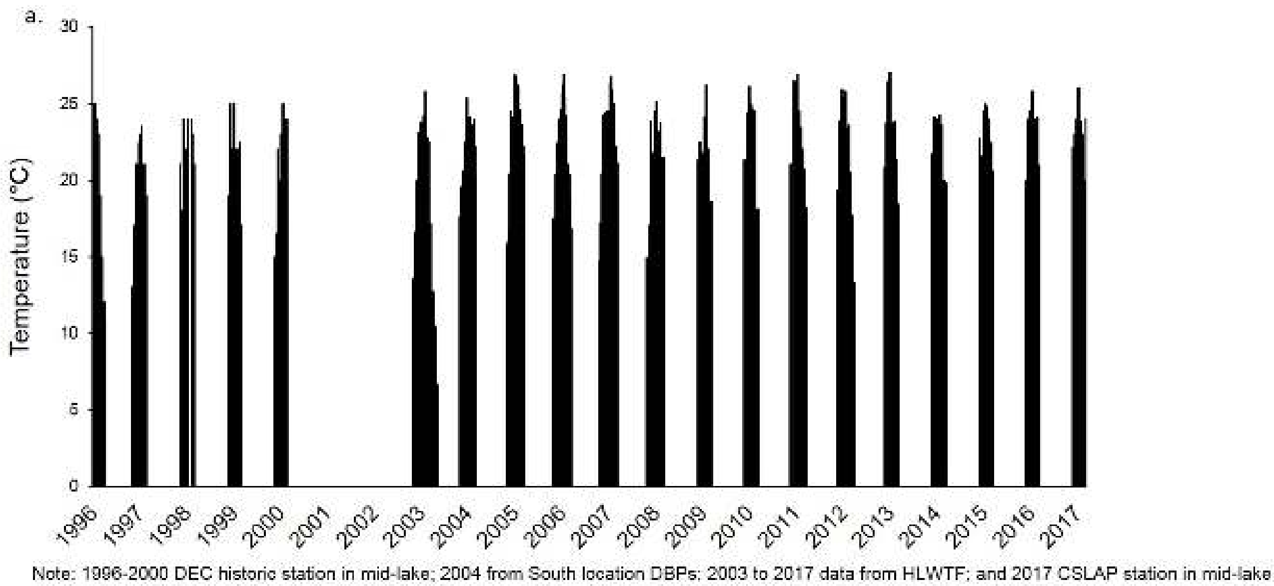


Figure 6. (a) Secchi depth (m) measured at the Mid/South location in Honeoye Lake from 1996 to 2000, and 2003 to 2017 (CSLAP, DBPs, and HLWTF). (b) Secchi depth measured at the North sampling location in 2017 (CSLAP).

A trend in surface water temperature (°C), based on annual average values from the Mid/South segment, showed a statistically significant increasing trend ($p < 0.001$, $\tau = 0.568$, **Figure 7a**). The seasonal pattern in surface water temperature at the North sampling location in 2017 generally indicated an early- to mid-season peak (e.g., July) in water temperature (**Figure 7b**).

Understanding temperature changes of a waterbody both within a season and among years is important to 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). Temperature profiles for Honeoye Lake in 2017 (FLI) indicate weak thermal stratification beginning in June, and a decreased depth of the thermocline by September at two sites in Honeoye Lake (**Figure 8**). The temperature profile patterns in 2017 were typical in previous years of sampling. The presence of a thin hypolimnion, established by thermal lake stratification, suggests a strong likelihood for internal nutrient loading. When Honeoye Lake mixes following a stratification period, phosphorus that had been released from the sediment is transported to the upper waters and made available to support the growth of algae, including cyanobacteria.



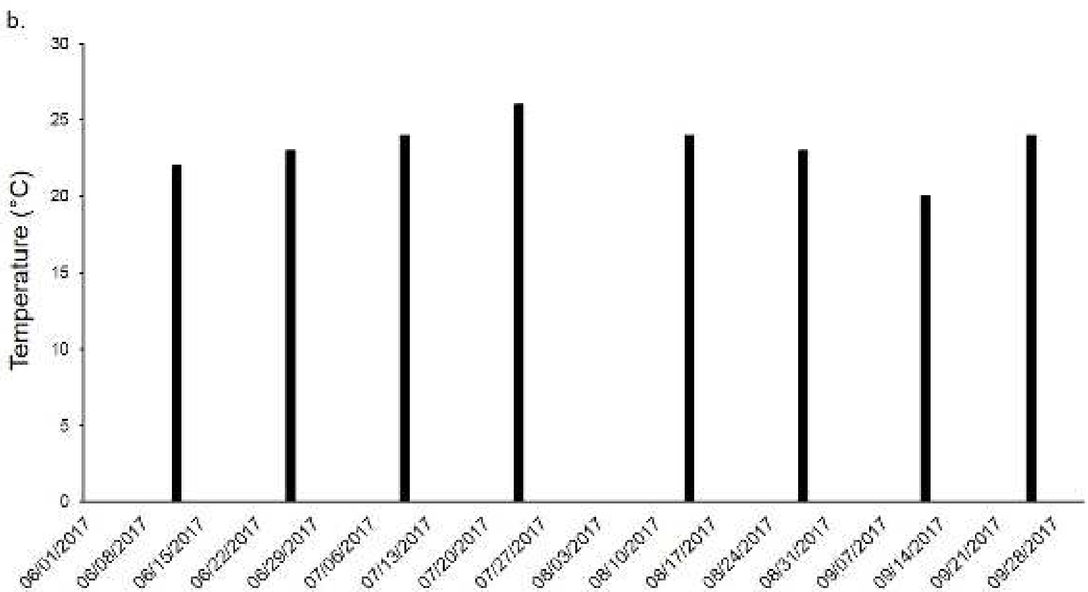


Figure 7. (a) Surface water temperature (°C) measured at the Mid/South location in Honeoye Lake from 1996 to 2000, and 2003 to 2017 (CSLAP, DBPs, and HLWTF). (b) Surface water temperature measured at the North sampling location in 2017 (CSLAP).

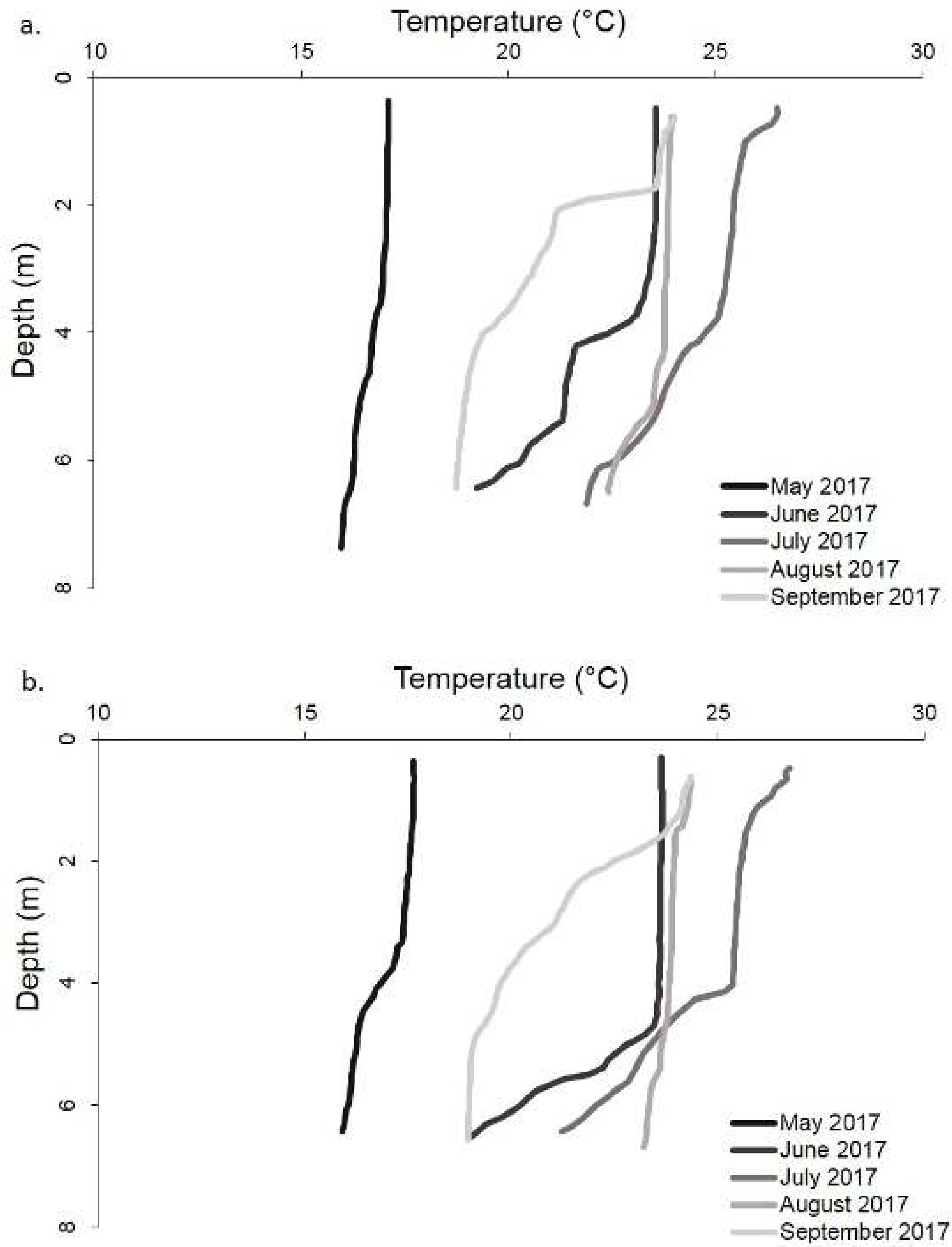


Figure 8. Temperature profiles in Honeoye Lake in 2017, collected from (a) 42°44.32'' N, -77°30.72'' W and (b) 42°45.15'' W, -77°30.68'' W. The observed water temperature profile in the 2017 was typical of previous years (Data provided by John Halfman, Hobart and William Smith Colleges).

6.2 Chemical Conditions

Studies conducted by Pearsall and Robinson (2001), Gilman (2003), and Starke (2006) indicate low dissolved oxygen (DO) levels in the deeper waters of Honeoye Lake during late summer. Profiles of DO in Honeoye Lake in 2014 (the latest year with validated data, FLI) at two sample locations indicate that concentrations approached hypoxia (< 2 mg/L) during the growing season (**Figure 9**). Decreased DO concentrations at depth are the primary cause of internal nutrient loading.

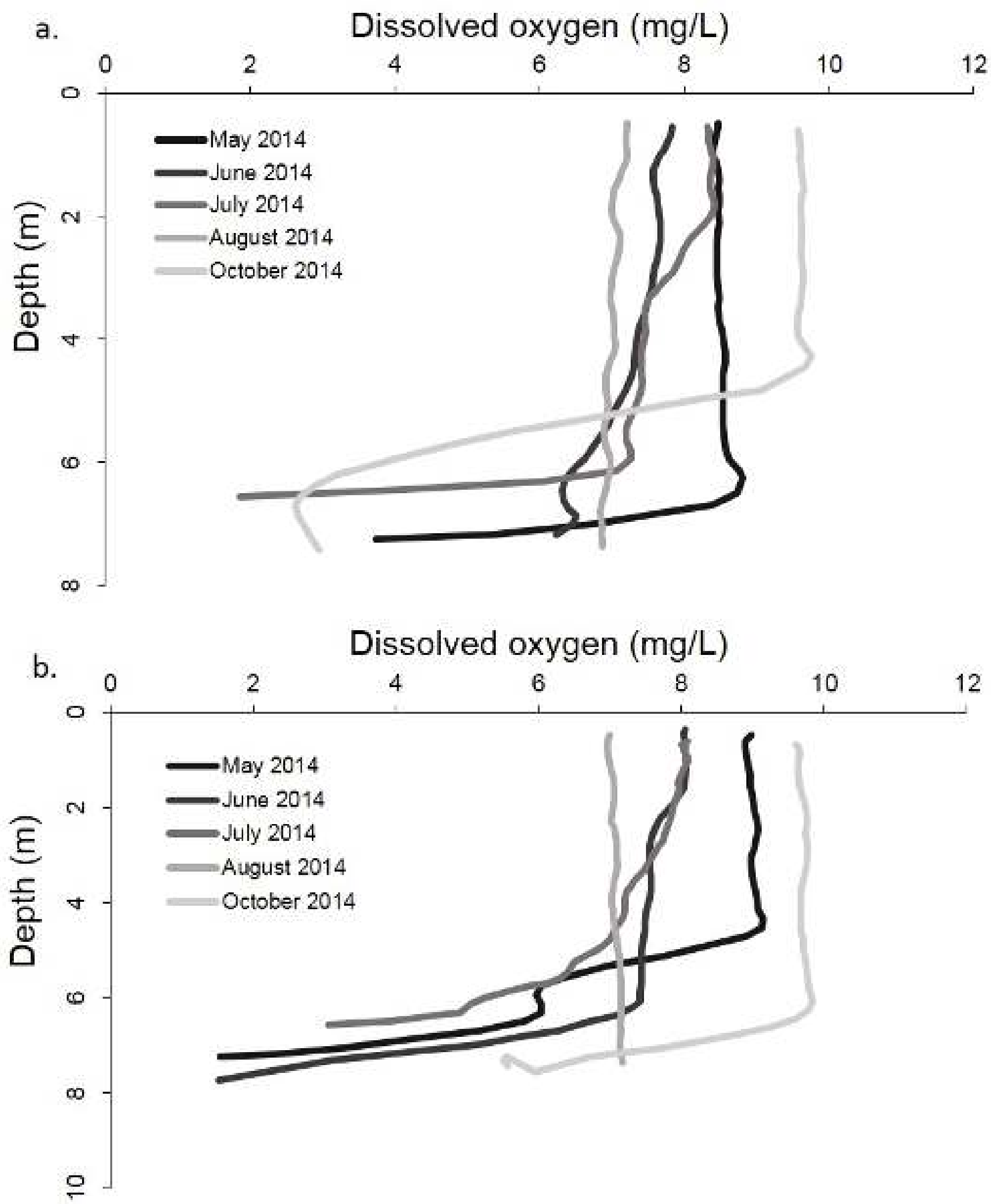
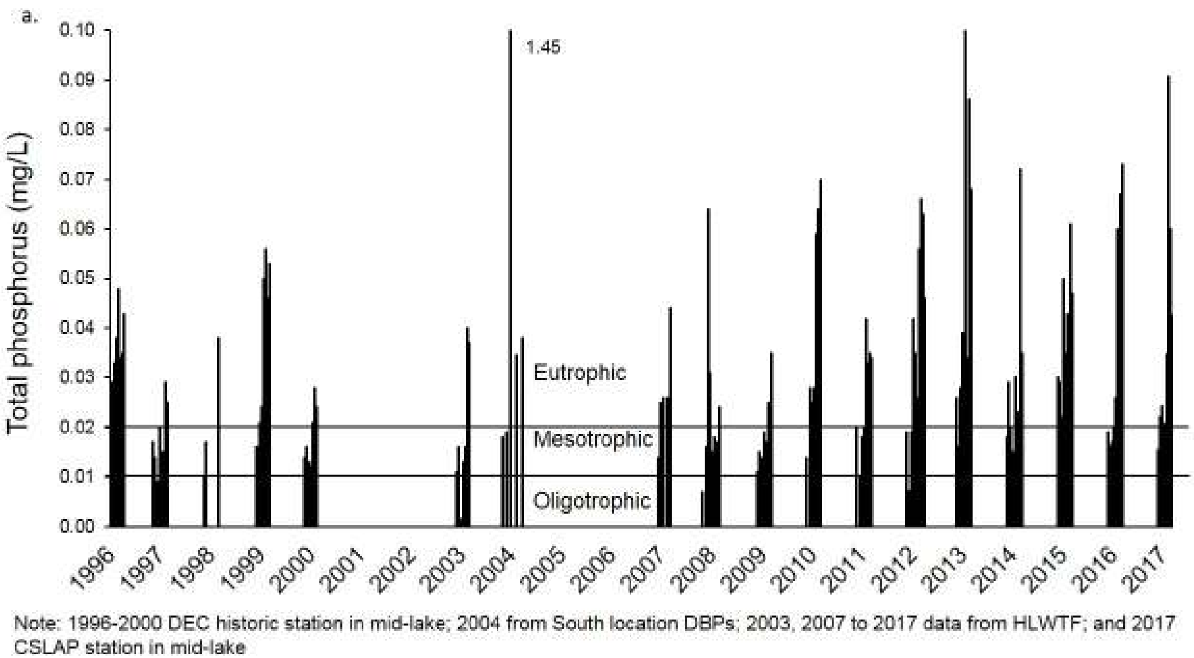


Figure 9. Dissolved oxygen (DO) profiles in Honeoye Lake in 2014, collected from (a) 42°44.32'' N, -77°30.72'' W and (b) 42°45.15'' W, -77°30.68'' W. The observed DO profile in the 2014 was typical of previous years (Data provided by John Halfman, Hobart and William Smith Colleges).

The NYSDEC's Finger Lakes water quality study (Callinan 2001) indicates Honeoye Lake experienced an increase in total phosphorus (TP) levels from the early 1970s to the late 1990s. TP levels within the lake were above the NYSDEC TP guidance value of 20 µg/L during the late 1990s, and there were sustained periods of deep water hypoxia during the growing season that contributed to the release of legacy phosphorus from sediment (Callinan 2001).

Total phosphorus (TP) concentrations (mg/L) in Honeoye Lake generally indicate eutrophic conditions (see **Figure 10a**). Seasonal trends in TP suggest a late season peak (**Figure 10b**). There was not a significant time trend in annual average TP observed from 1996 to 2017 in the Mid/South portion of Honeoye Lake ($p = 0.088$, $\tau = 0.294$) (**Figure 10a**).



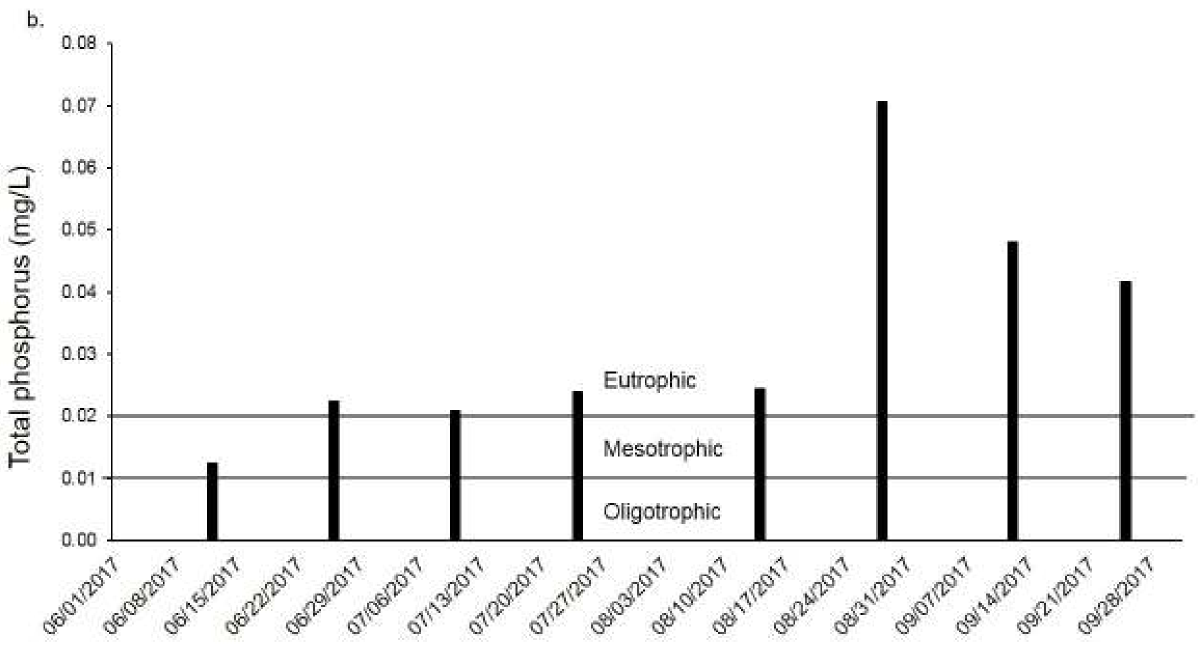


Figure 10. (a) Total phosphorus (TP) concentrations (mg/L) measured at the Mid/South location in Honeoye Lake from 1996 to 2004, and 2007 to 2017 (CSLAP, DBPs, and HLWTF). (b) Total phosphorus concentrations measured at the North sampling location in 2017 (CSLAP).

The TP concentrations measured in 2017 at the surface (1.5 m [5 feet]) and bottom of Honeoye Lake at the Mid/South and North sampling locations are provided in **Figures 11a and 11b**, respectively. The Mid/South bottom sample was collected at 7.5 m (24.6 feet), and the North bottom sample at 5.5 m (18 feet). The data in **Figure 11a** indicate a strong inverse relationship throughout the year at the Mid/South location, which is consistent with a stratified system that experiences intermittent mixing. The data in **Figure 11b** indicate relatively consistent concentrations between top and bottom, indicative of a basin that is mixed by forces such as internal wave action on a more consistent basis.

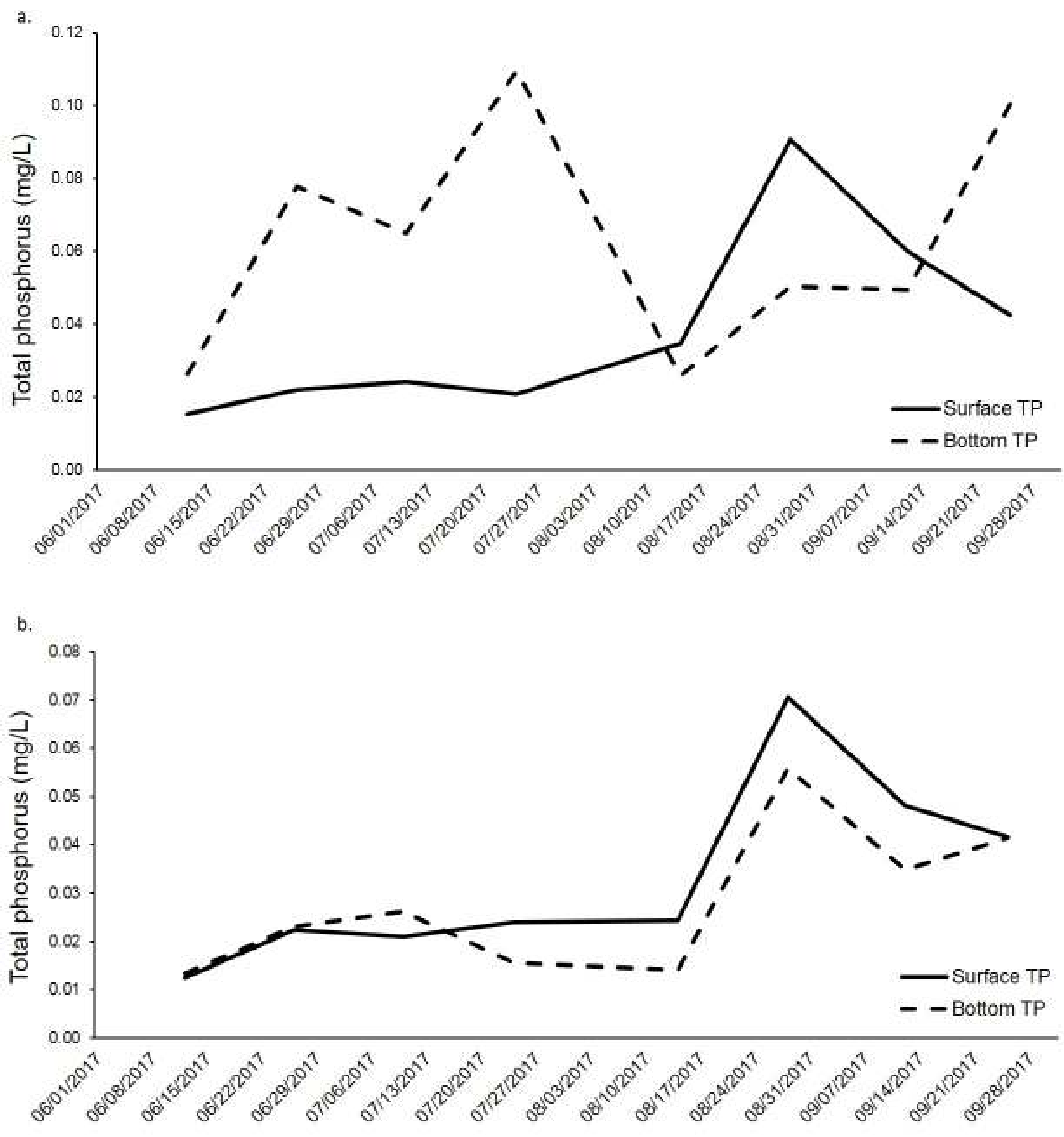


Figure 11. (a) Total phosphorus concentrations (mg/L) of surface (solid lines) and bottom (dashed lines) samples collected from the (a) Mid/South and (b) North locations (CSLAP).

Total nitrogen (TN) concentrations (mg/L) for 2017 are plotted in **Figure 12a** for both the Mid/South and North sample locations. The 2017 data suggest a general increase in TN concentrations during the summer.

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. The TN:TP ratio was often lower than 29:1 and generally decreased throughout the summer of 2017 (**Figure 12b**), indicating that TP concentrations increased disproportionately to TN.

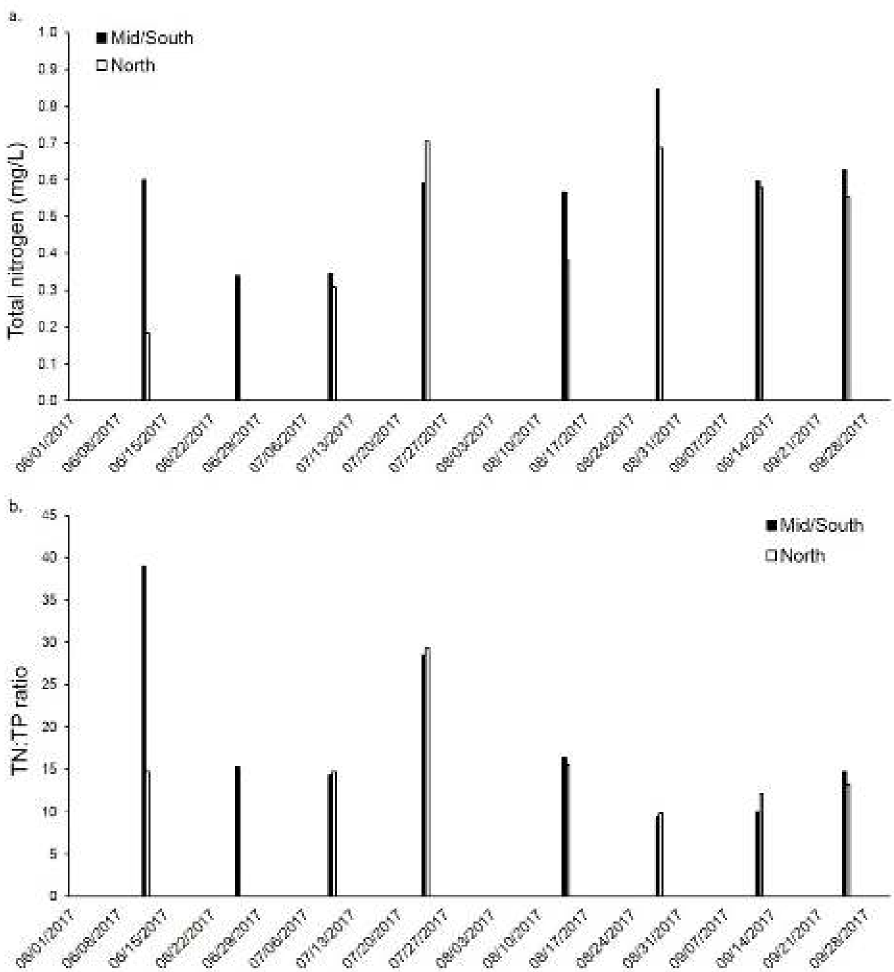


Figure 12. (a) Total nitrogen (TN) concentrations (mg/L) measured at the Mid/South and North locations in Honeoye Lake in 2017 (CSLAP). (b) Total nitrogen to total phosphorus (TP) concentrations (by mass) measured at the Mid/South and North sampling locations in 2017 (CSLAP).

6.3 Biological Conditions

Results from Past Studies

The *Honeoye Lake Macrophyte Management Plan*, prepared by HLWTF, indicates that macrophyte growth in Honeoye Lake is influenced, in part, by sediment phosphorus concentrations within shallower areas of the lake. The 20-year study of macrophyte dynamics in Honeoye Lake by Gilman indicates that there have been significant shifts in species composition. As summarized in **Table 4** (HLWTF 2008), this shift includes increases in aquatic invasive plants, notably Eurasian watermilfoil. As discussed in **Section 3.6b**, eelgrass, *Potamogeton* spp., Eurasian watermilfoil, and water stargrass are the predominant plant species.

Table 4. Macrophyte species composition shift (based on biomass).

1984	1994	2004	2014
Eelgrass	Eurasian watermilfoil	Coontail	Eelgrass
Coontail	Eelgrass	Eelgrass	Coontail
Common waterweed	Coontail	Eurasian watermilfoil	Water stargrass
Water stargrass	Large-leaf pondweed	Water stargrass	Eurasian watermilfoil
Water marigold	Water stargrass	Large-leaf pondweed	Common waterweed
Large-leaf pondweed	Common waterweed	Common waterweed	Star-leaved duckweed
Pickerel weed	Flat-stem pondweed	Pickerel weed	Large-leaf pondweed
Eurasian watermilfoil	Water marigold	Filamentous algae	Flat-stem pondweed
Star-leaved duckweed	Southern naiad	Water marigold	Clasping-leaf pondweed
Aquatic moss	Pickerel weed	Arrow arum	Small pondweed

Current Study

Chlorophyll-a is a photosynthetic pigment common to all algae, including cyanobacteria, and is often used as a proxy for algal biomass. Average annual chlorophyll-a concentrations in 2017 indicate that Honeoye Lake is eutrophic (see **Table 3**). In addition, there was a statistically significant increasing trend in average annual chlorophyll-a concentrations in the Mid/South segment ($p = 0.004$, $\tau = 0.503$) (**Figure 13a**). Seasonal trends in chlorophyll-a concentrations (μg/L) at the North sampling location in Honeoye Lake generally showed an increasing trend during the growing season, peaking in August (see **Figure 13b)**.

Summer average chlorophyll-a concentrations in Honeoye Lake often exceeded the Class AA threshold of 4.0 μg/L and the Class A threshold of 6.0 μg/L proposed by Callinan et al. (2013). Callinan et al. (2013) indicated that chlorophyll-a concentrations between 4-6 μg/L would be sufficient to reach or exceed the existing USEPA maximum contamination level of 80 μg/L total trihalomethanes concentration for drinking water (USEPA 2006). Total trihalomethanes concentrations are used as a measure of DBPs in drinking water systems. During water treatment, DBPs form when an oxidizing agent (e.g. chlorine) reacts with natural organic matter (NOM). Sources of NOM in lakes includes external (e.g. leaves) and internal sources (e.g. algae). However, as noted above, Honeoye Lake does not presently serve as a public water supply, so it is not known if DBP production is of concern in the lake.

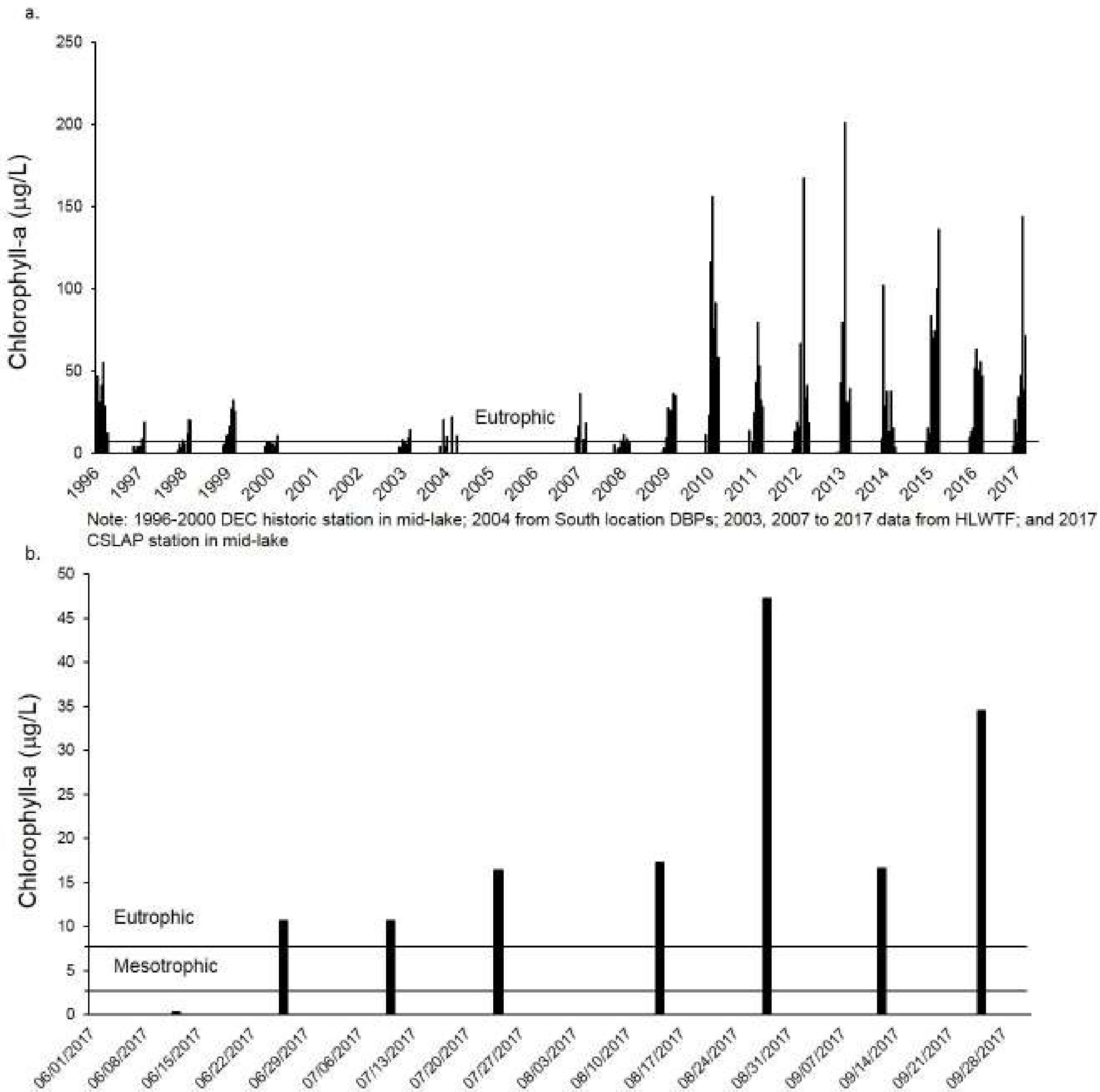


Figure 13. (a) Chlorophyll-a concentrations (µg/L) measured at the Mid/South location in Honeoye Lake from 1996 to 2004, and 2007 to 2017 (CSLAP, DBPs, and HLWTF). (b) Chlorophyll-a concentrations measured at the North sampling location in 2017 (CSLAP).

6.4 Remote Sensing Estimates and 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 (Trescott 2012) for Lake Champlain. 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 14**, chlorophyll-a concentrations have increased since 2015. The highest concentrations occur in August and September. During lake-wide elevated chlorophyll-a events, the locations with the highest concentrations tend to be at the north end of the lake near Sandy Bottom Beach and at the south end of the lake near Honeoye Inlet. These areas also feature water depths of less than 10 ft. In these shallow areas the remote sensing might also be picking up algal mats, submerged aquatic vegetation, and the lake bed. Additional research may help to understand the influence of these factors on the estimated chlorophyll-a concentrations.

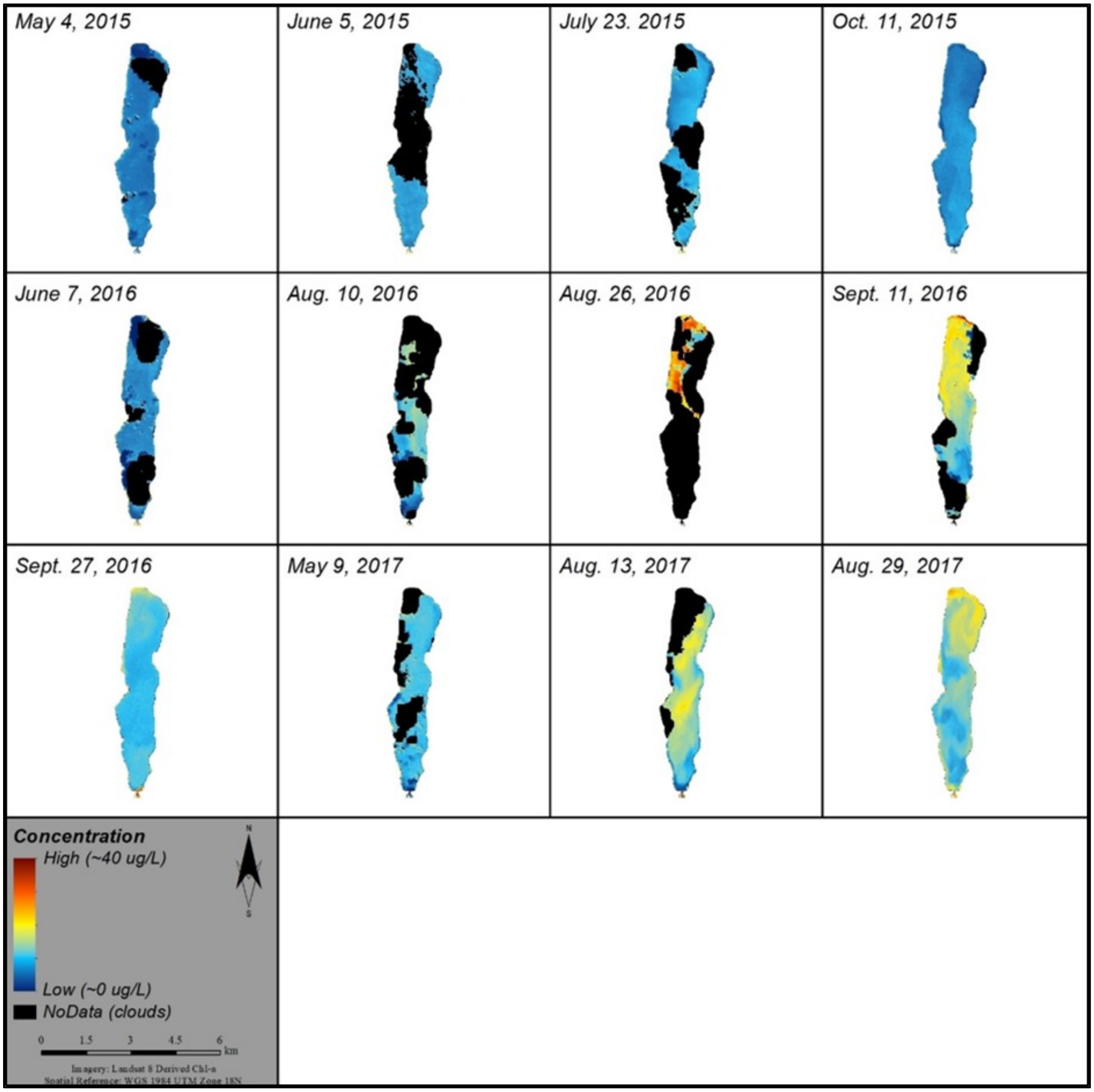


Figure 14. Estimated chlorophyll-a concentrations in Honeoye Lake, 2015 to 2017.

The estimated chlorophyll-a concentrations from the remote sensing analysis were extracted at the CSLAP monitoring stations (North and Mid-lake) to compare the estimates with the measured chlorophyll-a concentrations (**Figure 15**). There was relative agreement between the measured and estimated concentrations when there is coincident data. CSLAP data was not available in 2015 or 2016, however the remote sensing results provides some insight into these time periods with missing in-lake monitoring data.

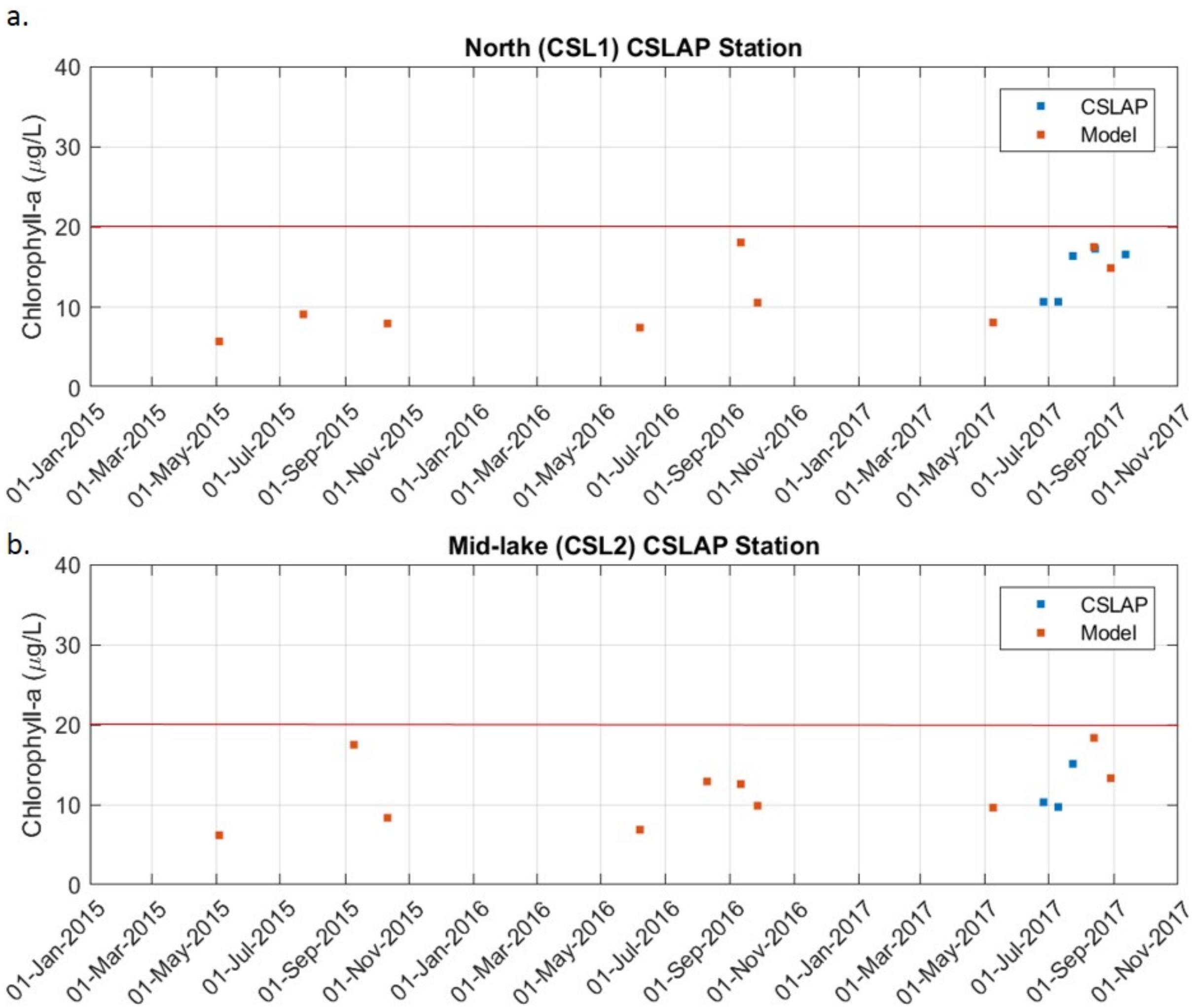


Figure 15. Measured (CSLAP, blue squares) and estimated (Landsat 8, orange squares) chlorophyll-a concentrations from Honeoye Lake, 2015 to 2017. The red lines represent the upper threshold of chlorophyll-a concentration (20 μg/L) for which the remote sensing algorithm was tested in Lake Champlain (Trescott 2012).

7. Summary of HABs

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

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

- **No Bloom**: evaluation of a bloom report indicates low likelihood that a cyanobacteria bloom (HAB) is present
- **Suspicious Bloom**: NYSDEC staff determined that conditions fit the description of a HAB, based on visual observations and/or digital photographs. Laboratory analysis has not been done to confirm if this is a HAB. It is not known if there are toxins in the water.
- **Confirmed Bloom**: Water sampling results have confirmed the presence of a HAB which may produce toxins or other harmful compounds (BGA chlorophyll levels ≥ 25 µg/L and/or microscopic confirmation that majority of sample is cyanobacteria and present in bloom-like densities). For the purposes of evaluating HABs 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

Honeoye Lake has received considerable attention by state agencies, non-governmental organizations, community interest groups, lake users, and other stakeholders because of the documented HABs in the lake. HABs have been reported to the NYSDEC by many data providers including Ontario County Department of Public Health, the Honeoye Lake Watershed Task Force, CSLAP, and members of the public. Extensive HABs surveillance and monitoring in Honeoye Lake is overseen by the Honeoye Lake Watershed Task Force, in collaboration with NYSDEC and SUNY ESF. The entire shoreline of the lake, and some open water sites, are surveyed twice weekly from early summer to early fall, with conditions in at least ten locations documented with visual reports and digital pictures, and at least three locations are sampled each week. HABs in Honeoye Lake have occurred primarily along the shoreline, although HABs have been confirmed in open water locations (see **Appendix D** for a summary of HABs). Many of these blooms are highly ephemeral, with conditions in some locations changing multiple times each week. The frequency in which HAB samples have surpasses NYSDEC blooms status thresholds is summarized in **Table 5**.

Based on NYSDEC data, a total of 84 HABs occurrences of Confirmed or Confirmed with High Toxins have been reported between 2012 and 2017.

Table 5. Number of HABs notifications by bloom status.

Year	Suspicious	Confirmed	Confirmed w/ High Toxins
2012	8	0	0
2013	1	3	11
2014	4	18	2
2015	13	10	1
2016	0	25	0
2017	1	14	0

Of the 70 confirmed samples of HAB from 2012 to 2017, 10 occurred at the north end of the lake, 16 occurred at the south end of the lake, while the remaining 44 occurred in the middle of the lake. Blooms were likely present between surveillance and discrete sampling events, so despite the extensive survey work conducted by HLWTF, the duration of these blooms cannot be easily evaluated.

7.2 Drinking Water and Swimming Beach HABs History

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

In 2018 the USEPA started monitoring for their Unregulated Contaminant Monitoring Rule 4 (UCMR 4) which includes several HAB toxins. In 2018 the USEPA will sample 32 public water systems in New York State. The UCMR 4 is expected to bring further attention to this issue leading to a greater demand for monitoring at public water supplies (PWSs). To help with the increasing demand for laboratory analysis of microcystin, the NYSDOH Environmental Laboratory Approval Program (ELAP) anticipates 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.

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

Table 6. HABs guidance criteria.

NYSDEC Bloom Categories			
Confirmed	**Confirmed w/ high toxins**		**Suspicious**
	Open water	**Shoreline**	
[BGA chlorophyll-a] >25 µg/L	[Microcystin] > 10 µg/L	[Microcystin] > 20 µg/L	Visual evidence 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 < 4 µg/l (USEPA 2016) starting in 2017.	

Public swimming in Honeoye Lake is classified as impaired due to HABs. Ontario County Department of Public Health and the Town of Richmond monitor Sandy Bottom Beach for HABs and have often closed the beach due to their presence. Multiple samples collected from 2012 thru 2014 revealed cyanobacteria and occasionally toxin (microcystin-LR) levels that were at times well above "safe" swimming criteria adopted by the NYSDEC (Upper Honeoye Creek Watershed WI/PWL 2016). However, as noted above, beach closures and advice to lake recreational users about swimming are predicated on visual assessments of blooms, not toxin levels.

A summary of the observations and impacts of HABs at Sandy Bottom Beach in Honeoye Lake from 2012 to 2017 is presented below, indicating number of days the beach was closed (data supplied by NYSDOH):

- 2012 - 27 days
- 2013 – 9 days
- 2014 – 2 days
- 2015 – 13 days
- 2016 – 14 days
- 2017 – 39 days

The USEPA maintains a 2016 draft human health recreational swimming advisory threshold of 4 μg/L (USEPA 2016). 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.

As discussed in **Section 3.2**, Honeoye Lake is not used as a public water supply, but about 300 shoreline residences pump water from the lake. It is not known to what extent these private systems filter or treat the water or the impacts of HABs on the systems (Callinan 2001, G/FLRPC 2007). Thus, HABs do not pose a direct threat to Honeoye Lake residents through regulated drinking water sources.

As recommended by the NYSDOH, it is never advisable to drink water from a surface source unless it has been treated by a public drinking water system regardless of the presence HABs. Surface waters may contain other bacteria, parasites or viruses that can cause illness. If you choose to explore in-home treatment systems, you are living with some risk of exposure to blue-green algae and their toxins and other contaminants. Those who desire to use an intake for non-potable use, and treat their water for contaminants including HABS, should work with a water treatment professional who should evaluate for credible third-party certifications such as National Sanitation Foundation standards (NSF P477; NYSDOH 2017).

7.3 Other Bloom Documentation

Cyanobacteria Chlorophyll-a

Cyanobacteria cell counts and/or chlorophyll-a concentrations can be used to trigger HABs alerts and advisory systems (see **Table 6**). 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 (no confirmed blooms were reported in 2012). Confirmed bloom BGA chlorophyll-a concentrations ranged from 25.2 μg/L (August 2015) to 48,380 μg/L (August 2013) (**Table 5**).

Cyanotoxins

Microcystin concentrations were quantified from shoreline bloom samples, generally collected as a result of visual observations of scum accumulations. Microcystin concentrations ranged from 0.21 μg/L (September 2011) to 255 μg/L (August 2014) (**Table 7**), although microcystin levels have not been detectable in many shoreline bloom samples. Microcystin levels occasionally exceeded the draft human health recreational swimming advisory threshold of 4 μg/L (USEPA 2016). 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 7. Measured toxin and cyanobacteria (BGA) chlorophyll-a concentrations for bloom events (2012-2017, CSLAP, Ontario County DOH, Honeoye Lake Watershed Task Force).

	Microcystin (μg/L)			Cyanobacteria (BGA) chl-a (μg/L)		
Status	**Min**	**Max**	**# of samples**	**Min**	**Max**	**# of samples**
Confirmed	ND	7.3	70	25.2	29794	70
Confirmed with High Toxins	83	255	14	39	48380	14

Cyanobacteria Taxa

Multiple genera of cyanobacteria were identified in samples collected during blooms from 2012 to 2017; however, *Microcystis* and *Dolichospermum* were present in 69% and 62% of qualitative microscopy samples analyzed (n = 84). Both species have the ability to regulate their buoyancy, moving up into the water column to harvest light for photosynthesis, and move down into the water column towards the metalimnion to acquire nutrients (Mantzouki et al. 2016). In addition, *Dolichospermum* is able to fix nitrogen (N_2), providing a competitive advantage over non-nitrogen fixing algae during periods when nitrogen is limiting (Mantzouki et al. 2016). Further research and analysis is warranted to document how the cyanobacteria assemblage in Honeoye Lake contributes to documented HABs.

7.4 Use Impacts

Recreational use of Honeoye Lake is considered impaired, partially due to elevated nutrients (phosphorus) and HABs at the shoreline, consistent with elevated chlorophyll-a levels detected in most monitoring activities conducted through a variety of lake studies. Blooms were also periodically reported in the open water over the last decade, prompting the development of a HAB surveillance and monitoring program on the lake.

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, four Landsat 8 images were available, one in May, June, July and October as shown in **Figure 16**. Lake-wide chlorophyll-a were low (< 10 µg/L) in all four images except for certain nearshore areas. In these shallower areas, the remote sensing might be picking up algal mats, submerged aquatic vegetation, or the lake bed as opposed to chlorophyll-a concentrations. Additional analysis is required to investigate these locations further. In 2015 there were nine reports of HABs, but dates do not coincide with remote sensing images.

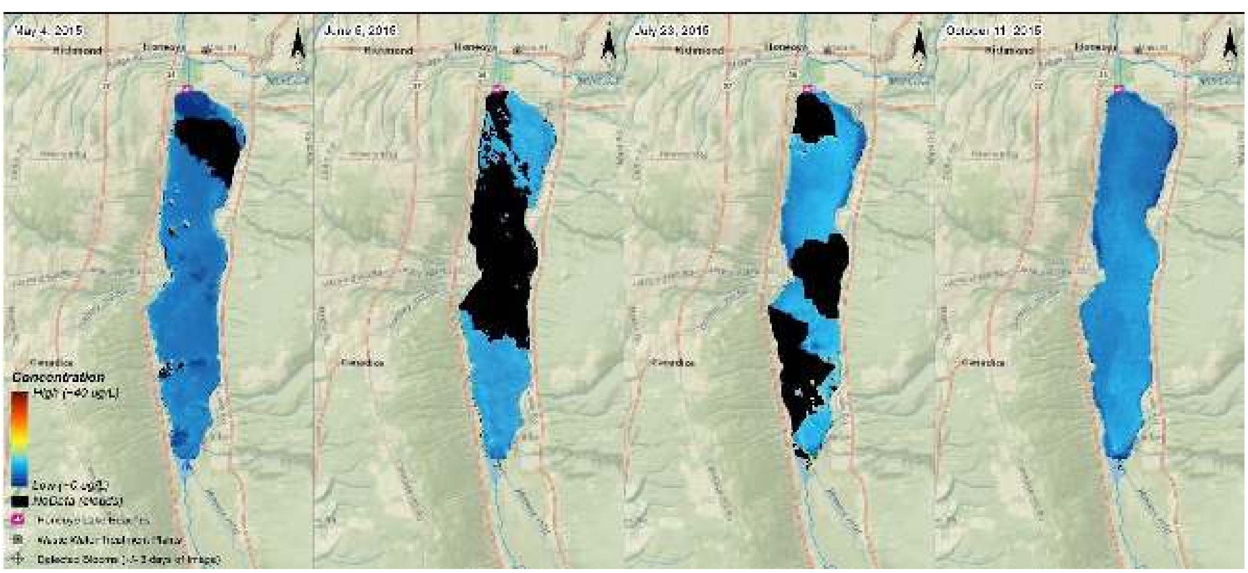


Figure 16. Modeled chlorophyll-a concentrations from four days in Honeoye Lake in 2015.

In 2016, four Landsat 8 images were available, one in June and August and two in September. There was a noticeable increase in lake-wide chlorophyll-a concentrations in 2016 compared to 2015. There was increased estimated chlorophyll-a concentrations on September 11, 2016 compared to earlier in the growing season (e.g., August 10) (**Figure 17**). The high chlorophyll-a concentrations on August 10 and September 11, 2016 compare well to confirmed HABs. Specifically, HABs were reported on August 8, 2016 at four locations, and on September 12, 2016, two widespread HABs were reported in Honeoye Lake. Leading up to both dates were warm air temperatures with winds towards the north. The northerly winds may have contributed to the higher concentrations in the north end and at Sandy Bottom Beach. Honeoye Lake is shallow (max depth of 30 ft), thus the hypolimnion is relatively thin and stratification likely leads to rapid depletion of dissolved oxygen at depth and subsequent internal loading.

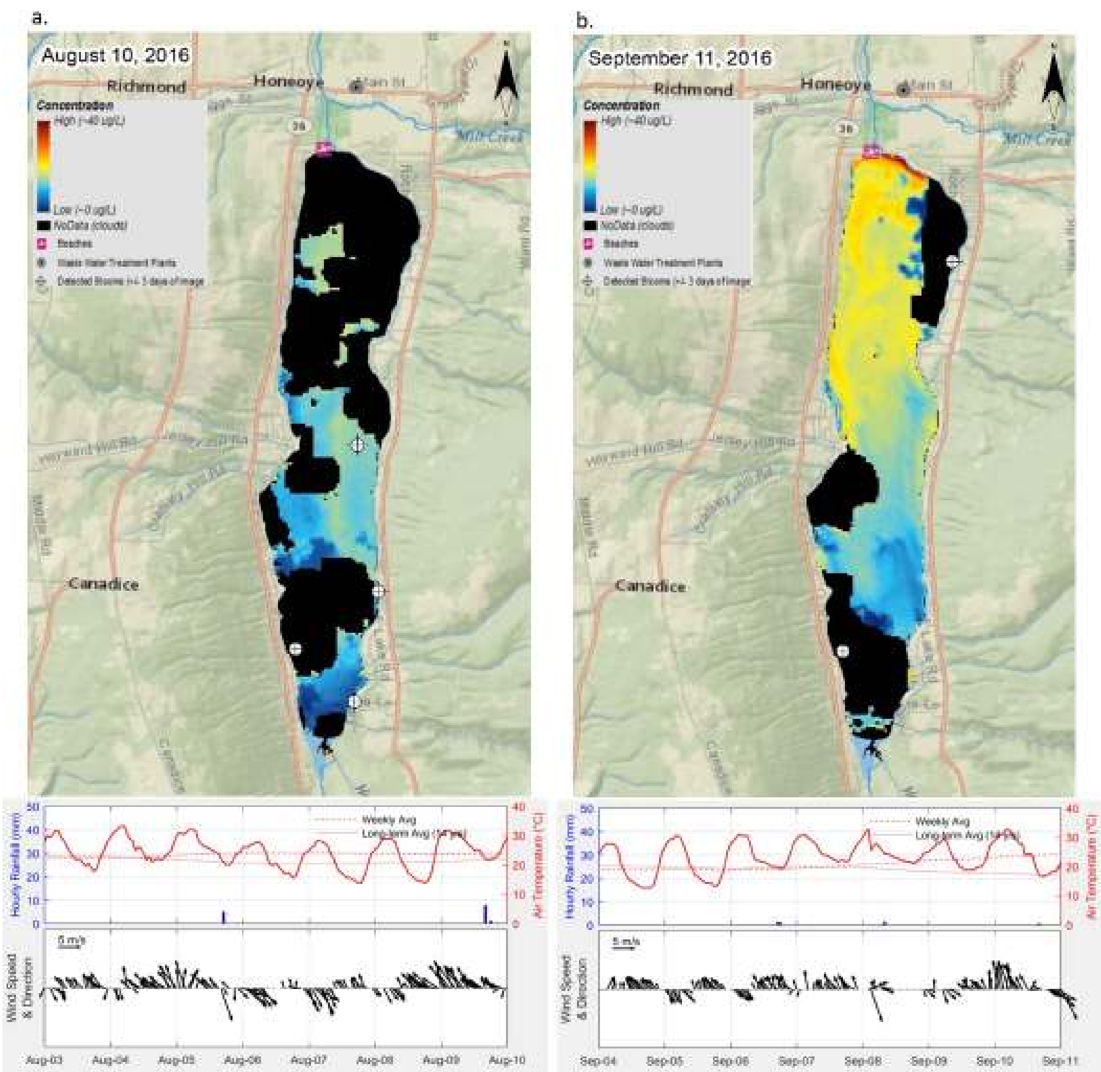


Figure 17. Modeled chlorophyll-a concentrations in Honeoye Lake on (a) August 10 and (b) September 11 in 2016.

In 2017, three images were available May 9, August 13 and August 29. Like 2016, there was a noticeable increase in lake-wide chlorophyll-a concentrations through the growing season (e.g., from May to August 2017). The high chlorophyll-a concentrations evident from the satellite imagery of August 29, 2017 aligned temporally with confirmed reports of HABs on August 28, 2017 at three different locations around the lake as shown in **Figure 18**. Warm air temperatures and north winds occurred on August 28 and 29th. As in 2016, the strong winds may have resulted in lake mixing, bringing phosphorus from bottom waters to the photic zone (upper waters), potentially increasing algal production and associated chlorophyll-a concentrations.

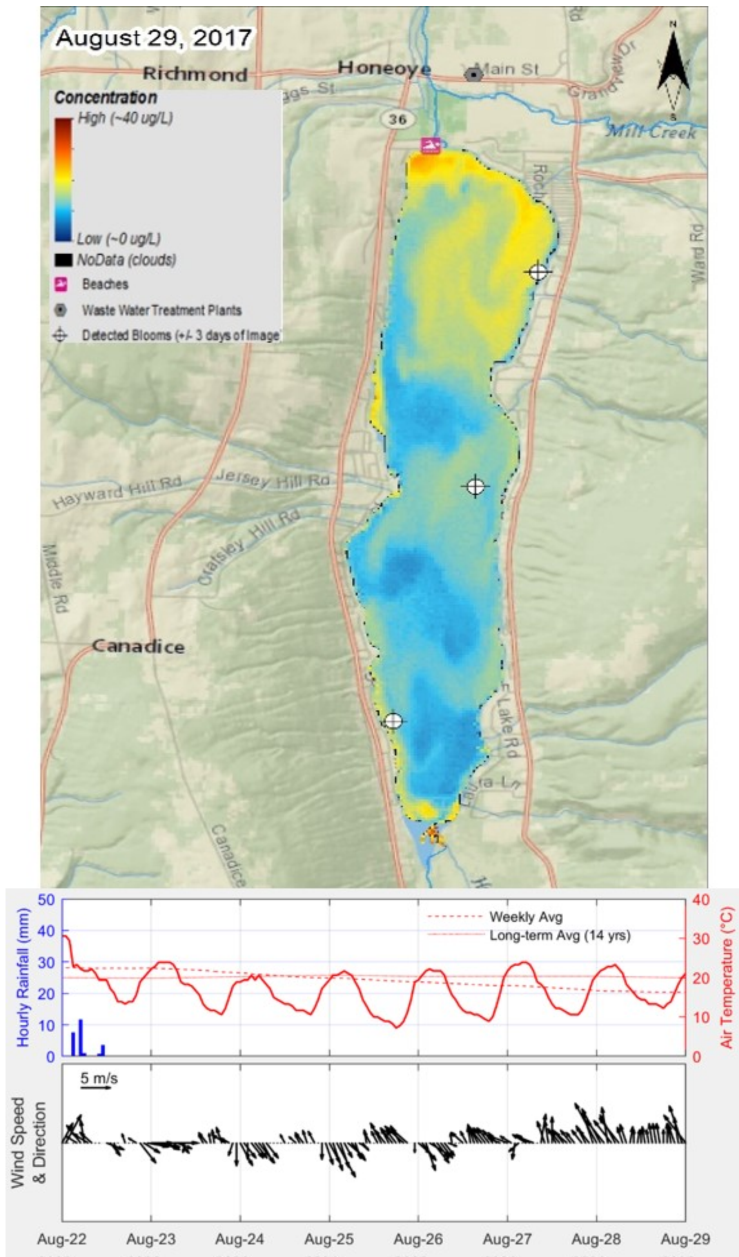


Figure 18. Modeled chlorophyll-a concentrations on August 29, 2017 in Honeoye Lake.

The percentage of the lake surface area with an estimated chlorophyll-a concentration greater than 10 µg/L and 25 µg/L is summarized in **Table 8**. 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 8. Percent (%) of water surface area with an estimated chlorophyll-a concentration (µg/L) above and below 10 µg/L and 25 µg/L in Honeoye 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	83	85	3	0	14
2015-06-05	41	47	7	0	53
2015-07-23	39	58	18	0	42
2015-09-09	15	25	10	0	75
2015-09-25	0	0	0	0	100
2015-10-11	97	99	2	0	1
2016-06-07	59	63	4	0	37
2016-06-23	0	0	0	0	100
2016-08-10	11	34	23	0	66
2016-08-26	0	10	18	8	82
2016-09-11	10	70	61	1	30
2016-09-27	15	99	84	0	1
2017-05-09	16	70	54	0	30
2017-06-10	0	0	0	0	100
2017-06-26	12	13	1	0	87
2017-08-13	6	71	65	0	29
2017-08-29	14	99	85	0	1

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 WI/PWL assessments reflect data and information drawn from numerous NYSDEC programs (e.g. CSLAP) as well as other federal, state and local government agencies, and citizen organizations. All data and information used in these assessments have 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 Honeoye Lake (**Appendix E**) reflects monitoring data collected in 2017. Management and conservation of Honeoye Lake are expected to support the lake's best uses of primary and secondary contact recreation uses, fishing use, and potential drinking water supply source.

Honeoye Lake is an impaired waterbody due to primary and secondary contact recreation uses that are known to be impaired due to excessive nutrients (phosphorus) and low dissolved oxygen.

Water supply source use may be impaired due to elevated nutrient and algae levels in the lake that may result in the formation of disinfection by-products in finished drinking water. In addition, primary and secondary contact recreation uses are also impaired by the frequent closure of Sandy Bottom Beach by the county health department due to harmful algal blooms.

The WI/PWL fact sheet identifies agricultural nonpoint sources and failing and/or inadequate on-site septic systems as likely sources of nutrients. These nutrient loads may impact water supply use (though such impacts have not been verified) and may contribute to lower dissolved oxygen levels in the lake, thereby impacting the ability to support aquatic life.

Honeoye Lake is included on the NYS Section 303(d) List of Impaired Waters Requiring a TMDL for oxygen demand and phosphorus.

8.2 Source Water Protection Program (SWPP)

The NYSDOH Source Waters Assessment Program (SWAP) was completed in 2004 to compile, organize, and evaluate information regarding possible and actual threats to the quality of public water supply (PWS) sources based on information available at the time. Each assessment included a watershed delineation prioritizing the area closest to the PWS source, an inventory of potential contaminant sources based on land cover and the regulated potential pollutant source facilities present, a waterbody type sensitivity rating, and susceptibility ratings for contaminant categories. The information 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. As described in **Section 3.2**, Honeoye Lake is not used as a public water supply and is, therefore, not evaluated as part of the SWAP program.

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 scorecard for Honeoye Lake suggests algae levels impact potable water source and recreation use and stress aesthetic conditions in the lake (**Figure 19**).

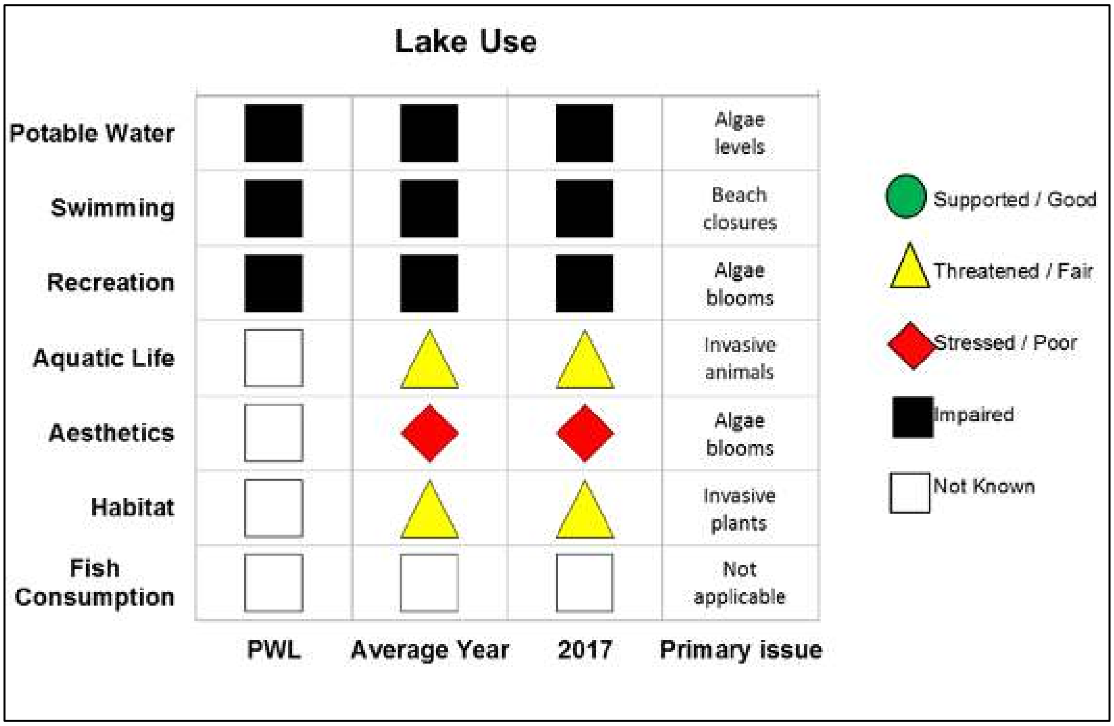


Figure 19. Honeoye Lake 2017 CSLAP scorecard.

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.

Honeoye Lake exhibits several factors - elevated phosphorus readings, presence of dreissenid mussels, relatively long fetch length - that render the lake susceptible to HABs. These conditions may be exacerbated by seasonal release of nutrients from bottom to surface waters under conditions of periodic anoxia in deep water.

To evaluate if lake-specific HABs triggers were important for Honeoye Lake, in addition to those observed at the state scale, additional statistical analyses were performed with Honeoye Lake data spanning from 2012 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 Dansville Municipal Airport station. Estimated maximum wave heights were calculated from wind speed and direction data, fetch distances across the lake, and water depths along the fetch length. The fetches were measured in 10 degree increments along the compass rose, taking the longest distance across the lake. Using this data, an hourly wave hindcast covering the duration of the wind field measurements was generated (Donelan 1980). Note that water quality variables were not assessed in this analysis because water quality measurements 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.

Both approaches to the logistic regression indicated that precipitation patterns were correlated with HABs in Honeoye Lake. Specifically:

- *Dry conditions (low precipitation) the day of an observed bloom* (p = 0.024) (**Figure 20**)

Note that the statistical analysis was suggestive of increasing wave heights in the 5 to 10 days leading up to an event as being marginally correlated with HABs in Honeoye Lake (p = 0.052).

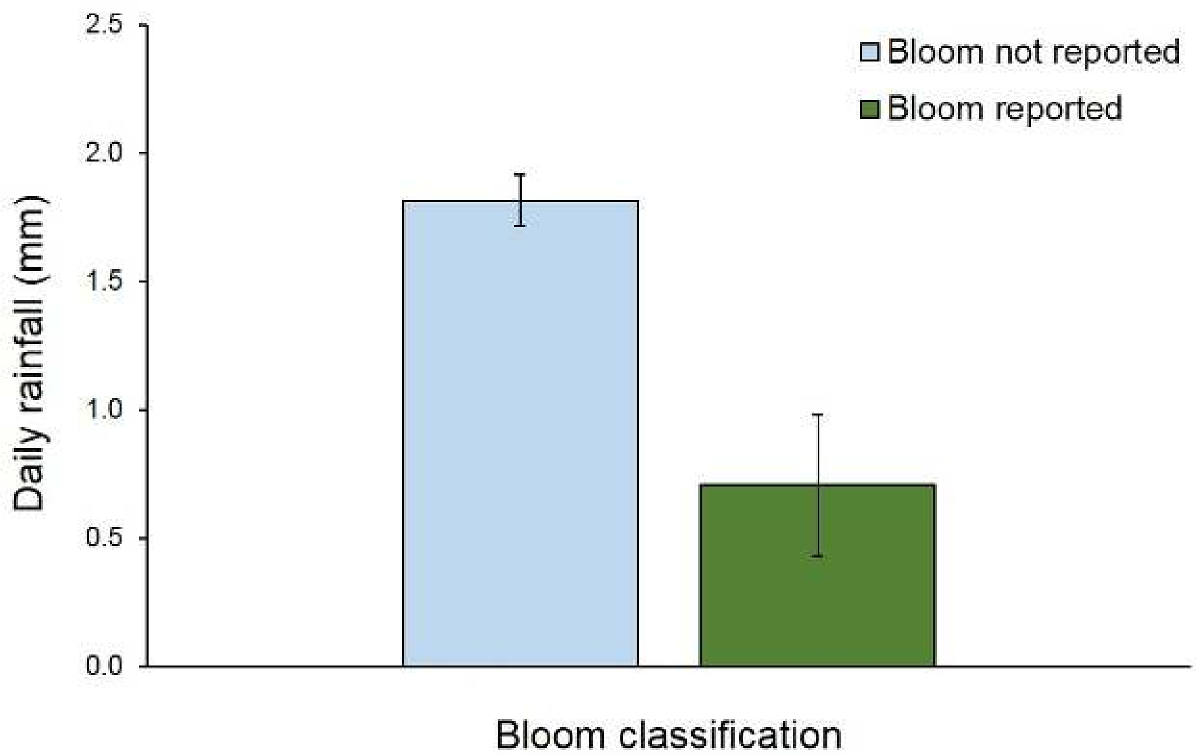


Figure 20. Average daily rainfall (mm) (± standard error) during reported blooms (green bar) and dates with blooms not reported (blue bar).

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

10. Sources of Pollutants

Honeoye Lake is a relatively small, shallow lake Finger Lake with a large watershed. Model estimates (using CE-QUAL-W2, a two-dimensional water quality and hydrodynamic model conducted by NYSDEC) indicate that internal nutrient loading dominates the annual total phosphorus budget. A thin, anoxic lower layer develops within the lake in deeper waters, generally below 18 ft. (5.5 m). This small volume holds the phosphorus generated by anoxic sediments, which may explain the steady progression to very high phosphorus concentrations at deep sampling points later in the year. Because the lower layer of the lake is thin, wind events during the late summer tend to drive turnover and mixing. This allows the nutrients to mix within the lake water column.

10.1 Land Uses

Honeoye Lake has a watershed of approximately 24,500 acres, with a watershed to lake ratio of approximately 15. As part of the 2015 Total Maximum Daily Load (TMDL) update (NYSDEC 2015), land use percentages within the Honeoye Lake drainage basin were estimated using digital aerial photography and geographic information system (GIS) datasets and are summarized in **Table 9**. **Figure 21** depicts the watershed land uses (Gilman and Schultz, undated).

Table 9. Land use percentages, Honeoye Lake Watershed.

Land Type	% of Watershed
Forests	70
Open Water	7
Grassland	6
Mowed Lawn	5
Cropland	4
Wetland	4
Shrubland	3
Other	1

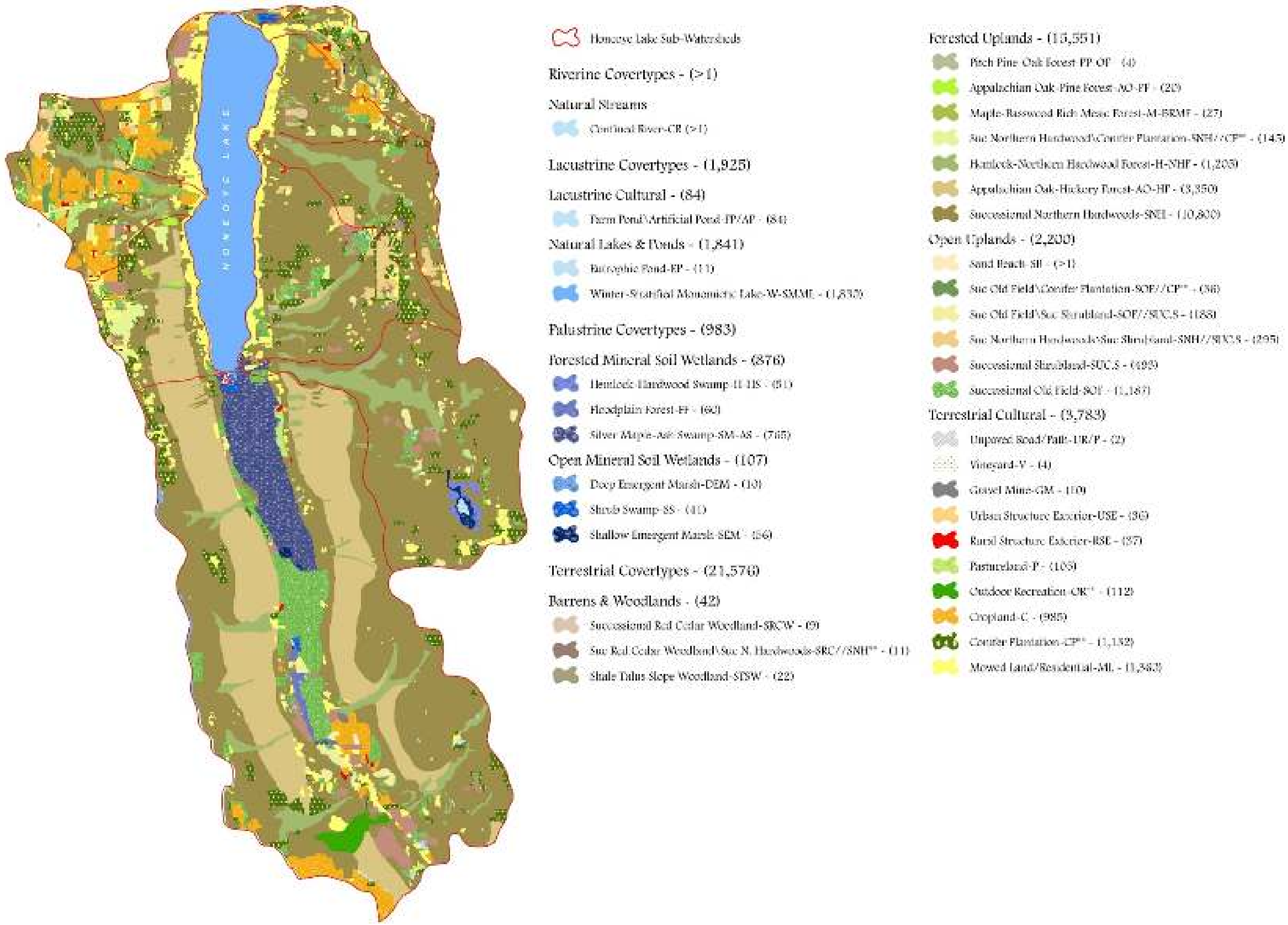


Figure 21. Honeoye Lake watershed land use (Source: Gilman and Schultz, undated).

10.2 External Pollutant Sources

While land uses such as agricultural, industrial, commercial, and high density residential are commonly associated with elevated nutrient loading, these uses are not common in the Honeoye Lake watershed, except for the residential development along the Honeoye Lake shoreline. Pollutant loading estimates were generated using the ArcView Generalized Watershed Loading Function (AVGWLF) watershed model and are summarized in **Table 10.**

Table 10. Phosphorus loading percentages, Honeoye Lake Watershed

Source Type	Percentage (%)
Internal	92.4
Forest	4.3
Developed Land	3.3

Based on the available data, the majority of external nutrient loading to Honeoye Lake enters via tributary streams or from the shoreline (HLWTF 2008). Other sources of external loading include septic systems and precipitation falling directly on the lake's surface (G/FLRPC 2007). The relatively low loading estimates associated with external sources suggests that management actions should be focused on internal loading, which is estimated to be contributing much higher levels of phosphorus.

10.3 Internal Pollutant Sources

Model estimates indicate that internal loading contributes approximately 93% of the total phosphorus load to Honeoye Lake. The high internal loading contribution is consistent with the morphometry of Honeoye Lake - thin hypolimnion that becomes anoxic, develops high phosphorus concentrations as a result, and then mixes with the epilimnion (either episodically or during seasonal turnover). Honeoye Lake may have historically greater external phosphorus loadings from the watershed based on historical land use, resulting in excess "legacy" phosphorus found within the sediment over time. When conditions permit, this legacy phosphorus can then be released from sediment into the water column.

The part of the lakebed that is of greatest concern in terms of contribution to internal loading is the area where the depth exceeds approximately 18 ft – the area where a hypolimnion can develop (i.e., approximately 1,000 acres).

In addition to internal nutrient loading from legacy sediment, dreissenid mussels also contribute to greater bioavailable phosphorus through the elimination of wastes, and thus play a critical role in overall phytoplankton growth, including cyanobacteria (see **Section 9**).

10.4 Summary of Priority Land Uses and Land Areas

As discussed in **Sections 10.2** and **10.3**, loading occurs predominately through internal release of legacy phosphorus from the lake sediment.

11. Lake Management / Water Quality Goals

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

- Reduce internal loading through implementation of actions recommended in **Section 13.1**
- Maintain forest health such that nutrient loading to the lake remains low relative to its extent of cover within the watershed
- Minimize the contribution of nutrients conveyed by stormwater runoff from surrounding lands
- Incorporate stormwater management facilities into developed land to minimize nutrient concentrations within runoff

12. Summary of Management Actions to Date

The Honeoye Lake TMDL update (NYSDEC 2015) identifies nutrient sources as listed in **Section 10**. To date, the following actions have been completed to help further define sources and reduce nutrient loading into Honeoye Lake:

Septic systems

Failing onsite wastewater treatment systems (OWTS, septic systems) are recognized as a significant concern within the Honeoye Lake watershed municipalities. The Ontario County Planning Department drafted the Model Local Law for On-Site Individual Wastewater Treatment which provides a means of addressing the proper operation, maintenance and inspection of failing OWTS. The law recommends inspection of existing wastewater treatment systems prior to a change of use, prior to conveyance of real property, and when the structure is to be expanded by an area greater than 50%. These and other recommendations may be incorporated into local law so that systems are designed, installed, maintained, and functioning properly (G/FLRPC 2007).

NYSDEC developed a statewide training program for onsite wastewater treatment system professionals to reduce loading associated with septic systems. The Onsite Wastewater Treatment Training Network (OTN) was formed and has been provided financial and staff support by the NYSDEC since its formation (NYSDEC 2018d).

12.1 Local Management Actions

The Honeoye Lake Watershed Task Force met on January 25, 2018 to discuss the following proposed projects for 2018:

- Weed harvesting program – areas of the lake where aquatic vegetation will be harvested.

- Completion of the following water quality improvement projects (WQIPs) to improvement stormwater runoff in urban areas:
    - Installation of pre-fabricated sediment traps in drainage ways.
    - Installation of debris guards to reduce the volume of trash and organics in stormwater.
    - Conduct a workshop to educate the public on forestry BMPs to be utilized throughout the watershed.

The 2007 *Honeoye Lake Watershed Management Plan* was developed to promote the continued sustainability of Honeoye Lake and the surrounding region. The overall goals of the Watershed Management Plan include:

1. Improve water quality of Honeoye Lake
2. Improve the quality of water resources in the Honeoye Lake watershed
3. Protect the natural resources within Honeoye Lake's watershed
4. Identify challenges and barriers to water quality protection and suggest means to overcome them
5. Protect the high quality of life enjoyed by residents within the Honeoye Lake watershed
6. Improve water-dependent recreational opportunities
7. Retain and attract business and improve local economic development opportunities
8. Consider economic, social, and other incentives for water quality protection

The Ontario County SWCD, in partnership with NYSDEC, Honeoye Lake Watershed Task Force, Finger Lakes Community College, The Nature Conservancy, and US Fish and Wildlife Service, have implemented the Honeoye Lake Inlet Restoration Project to help reduce nutrient inputs into Honeoye Lake from the Honeoye Inlet, partly in an effort to minimize the occurrence, intensity, and duration of HABs in the lake. Nutrient and hydrologic budgets of Honeoye Lake subwatersheds were modeled, and it was concluded that 1-year storm events are responsible for up to 70% of the external nutrient loading, and the Honeoye Inlet supplies approximately 50% of the external TP input. The objectives of the project are to allow water to slow down and spread out, use nature to filter out sediment and nutrients, increase opportunities for recreation, and improve habitat for fish and other wildlife. Planned and/or completed activities include plugging agricultural ditches, recreating meanders in the channel, constructing backwater wetlands, and reconnecting flow to the floodplain (Ontario County SWCD 2017).

The NYSDEC is developing a TMDL due to Honeoye Lake's high priority rating and listing on the NYSDEC's 2004 CWA Section 303(d) list of impaired waterbodies that do not meet water quality standards due to phosphorus impairments. **Section 12.6** provides more detail on the TMDL. It is anticipated that the TMDL, in conjunction with this Action Plan, will help the NYSDEC and involved organizations and citizens to achieve many, if not all, of the goals of the Watershed Management Plan.

12.2 Agricultural Environmental Management Program

The New York State Agricultural Environmental Management (AEM) framework that was created by the New York State Department of Agriculture and Markets (NYSDAM) and the NYS Soil and Water Conservation Committee as a voluntary, incentive-based program that helps farmers make common-sense, cost-effective, and science-based decisions to meet business objectives while protecting and conserving New York State's natural resources. Soil and Water Conservation Districts in agricultural counties lead the local AEM effort, including Ontario County within the Honeoye Lake watershed; Livingston County does not have an AEM Plan in place though they were involved in production of the Ontario County AEM Plan.

The Ontario County SWCD worked in partnership with the following organizations to develop an *Agricultural Environmental Management (AEM) Strategic Plan* (Ontario SWCD 2015), intended to promote the sustainable economic viability of agriculture in Ontario County through informed environmental stewardship and the implementation of conservation practices:

- Members of the Agricultural Advisory Committees of Canandaigua Lake, Central Lowlands and the Northern Watersheds
- Cornell Cooperative Extension
- USDA NRCS
- Farm Service Agency and Finger Lakes Resource Conservations and Development Council
- Ontario County Water Resources Council, Canandaigua Lake Association, and Honeoye Lake Watershed Task Force
- Seneca Lake Area Partners in Five Counties
- Town of Farmington and the Town of Manchester agricultural advisory committees
- Municipal Highway Departments
- Yates, Seneca, Wayne, Monroe and Livingston County Soil and Water Conservation Districts
- Northwest New York Dairy, Livestock, and Field Crops Team of Cornell Cooperative Extension

The goal of Ontario County AEM Plan is to utilize coordination and teamwork to efficiently and cost effectively address natural resource concerns on the farm as prioritized through a watershed approach.

In the Honeoye Lake watershed, the AEM Plan identifies the contamination of both surface and groundwater resources from nutrients, sediments, pathogens and pesticide runoff as the top priority for improvement. Suspected sources of these pollutants include nutrients and pathogens from failing onsite waste water treatment systems, agricultural runoff, construction and road bank erosion, and erosion of legacy sediments. The stated objectives of the AEM Plan include:

Objective 1: Promote the AEM process in the watershed.

- Conduct Tier I Surveys and Tier II assessments on new volunteer farms in the watershed
- Prioritize farms and projects through Agricultural Adaptation Councils (AACs)
- Maintain database and GIS of participants
- Continue Education and Outreach

Objective 2: Continued contact and progress with current participants in the watershed.

- Conduct Tier 5As to update data base and AAC
- Conduct Tier 5Bs to insure practices are maintained and working and promote successes
- Continue contact with participants to promote stewardship
- Address resource concerns thru agricultural nonpoint source grant program where appropriate
- Identify and design best management practices for priority farms.

Many AEM-sponsored activities have been undertaken within the Honeoye Lake watershed to address important environmental challenges including improving water quality (**Table 11**). The tiered process is as follows (NYSSWCC 2018):

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

Table 11. Total number of AEM projects conducted in the Honeoye Lake watershed (2011-2017).

	Tier 1	Tier 2	Tier 3A	Tier 3B	Tier 4	Tier 5A	Tier 5B
Total number of AEM projects	9	6	3	0	0	2	1

12.3 Funded Projects

Funded projects include those facilitated by programs specifically targeting water quality improvement and the agricultural community in New York State, such as the Water Quality Improvement Program (WQIP) and the Agricultural Nonpoint Source Abatement and Control Program (ANSACP) program. These programs have supported the implementation of BMPs within the Honeoye Lake watershed. Examples of BMP systems implemented that contribute to an improvement in water quality include filter strip installation, pasture management, erosion control, diversions, and runoff control.

12.4 DEC Issued Permits

Article 17 of New York's Environmental Conservation Law (ECL) entitled "Water Pollution Control" was enacted to protect and maintain the State's surface water and groundwater resources. Under Article 17, the State Pollutant Discharge Elimination System (SPDES) program was authorized to maintain reasonable standards of purity for State waters. NYSDEC issues Multi-Sector General Permits (MSGPs) under the SPDES program for stormwater discharges related to certain industrial activities. MSGPs have been issued for numerous active facilities in Ontario County (NYSDEC SPDES Permit Program, undated). Some of the facilities are within the Honeoye Lake watershed, and therefore may influence water quality conditions in Honeoye Lake.

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

12.5 Research Activities

In addition to the monitoring activities discussed in **Section 5**, the Finger Lakes Community College's Muller Field Station provides a base for field-based academic programs, laboratory experiences, community outreach, and local research projects (FLCC 2018). In addition, several independent researchers continue to monitor and study water quality conditions in Honeoye Lake.

For example, Nelson Hairston, Jr. of Cornell University is involved in a study centered on internal wave action in Honeoye and its potential effect on internal nutrient loading. Findings to date, which appear to be consistent with the information provided in **Section 6.1**, indicate the following:

- Honeoye Lake is sufficiently deep to thermally stratify and shallow enough to allow complete mixing. It is also productive enough that decreased dissolved oxygen at depth causes the release of phosphorus from sediment in the hypolimnion, Subsequent lake mixing allows this legacy phosphorus to be available for algal productivity.
- Temperature difference between the hypolimnion and epilimnion is relatively small, so the amplitude of internal waves is large relative to lake size.
- The shallow nature of Honeoye Lake limits the width and depth of the thermocline and hypolimnion so that they are susceptible to internal wave action.
- Turbulence caused by internal waves breaking at the ends of the lake transport nutrients from the hypolimnion to the illuminated surface waters more strongly than is likely for other lakes.
- External loading is low compared with other lakes, making internal loading especially important (Hairston 2017).

These findings support the recommendation that strategies aimed at reducing internal loading should be the primary focus of future management actions within Honeoye Lake.

Currently, the Finger Lakes Institute at Hobart and William Smith Colleges is collaborating with Wright State University in order to evaluate the possible role of nitrogen promoting HABs. The project is funded by the Great Lakes Research Consortium.

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 important 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 YSI probe; Secchi depth also was recorded. Water samples were collected from just below the surface (1.5-m depth) and at two-thirds 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 15 m in both Skaneateles and Seneca lakes (both are generally less than 10 m during the growing season).

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

A TMDL is currently being developed by the NYSDEC for Honeoye Lake to supplement other management plans that have been developed and are discussed herein.

13. Proposed Harmful Algal Blooms (HABs) Actions

13.1 Overarching Considerations

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

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

13.1.1 Phosphorus Forms

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

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

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

13.1.2 Climate Change

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

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

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

For more information about climate change visit 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 Honeoye Lake.

Steering committee members:

- Bruce Gilman, Finger Lakes Community College
- Lisa Cleckner, Finger Lakes Institute
- Corey Figueiredo, Future Forest Consulting
- Terry Gronwell, Honeoye Lake Watershed Task Force
- Victor DiGiacomo, NYSDAM

- Bob Capowski, NYSDEC
- Karis Manning, NYSDEC
- Lewis McCaffrey, NYSDEC
- Pradeep Jangbari, NYSDEC
- John Strepelis, NYSDOH
- Tom Harvey, Ontario County Planning Department
- Bill Wright, Ontario County Public Works
- Megan Webster, Ontario County Soil and Water Conservation District (SWCD)
- Neil Swanson, Swanson Farm
- Jim Howe, The Nature Conservancy
- Kristine Singer, Town of Canadice
- Caroline Sauers, Town of Richmond

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

As described throughout this HABs Action Plan, the primary factors that contribute to HABs in Honeoye Lake include:

- Internal loading of legacy phosphorus from in-lake sediments.
- Nonpoint source nutrient inputs from the contributing watershed.

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

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

13.3 Honeoye Lake Priority Projects

13.3.1 Priority 1 Projects

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

Short-term (3 years)

1. Complete a bench scale test and engineering study in preparation of nutrient inactivant application to sequester the legacy phosphorus within the bottom sediments.

2. Purchase back-up power generators for the 13 sewer lift stations near the lake that currently lack them to prevent raw sanitary sewage from overflowing into the lake during a power outage. Once purchased, each unit should be installed and tested.
3. Install the necessary infrastructure to connect additional private systems to municipal sewer systems if they fail to meet the separation distance(s) specified for that municipality.
4. Implement multiple stormwater BMPs to reduce nutrient and sediment loading into Honeoye Lake, including:
    a. Acquisition of land and/or establish conservation easements on high-priority, water quality sensitive lands within the watershed.
    b. Preservation of hillside integrity with vegetation or other stabilizing material to minimize runoff. Utilize natural depressions and sediment catches in roadside ditches, particularly along steep slopes to limit nonpoint source nutrient loads from within the watershed.
    c. Implementation of roadside ditch improvement projects that are likely to contribute the greatest reduction in erosion. Best management practices could include:
        i. Timing of cleanout to minimize vegetative loss.
        ii. Check dams to reduce water velocity and erosion potential.
        iii. Properly sizing culverts and stream channels to avoid incision, downcutting, aggradation and other erosion.
        iv. Use of vegetative cover to assist in ditch bank stabilization.
    d. Utilization 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).
5. Stabilize riparian habitat through funding conservation easements and installing vegetative plantings and stream stabilization structures (e.g., rock or log vanes, rock or log revetments). A landscape analysis to identify priority locations needs to be completed prior to implementation. This project may include:
    a. Establish vegetated riparian buffers to inhibit or restrict nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams.
    b. Rehabilitate degraded vegetated buffers to improve riparian habitat function.

Mid-term (3 to 5 years)

1. Complete engineering design of an aeration destratification system to address and minimize the release of legacy phosphorus from lake sediments. Prior to implementation, regulatory approvals from the NYSDEC, USACE, and other agencies will be needed. The design will need to identify the following:
    a. Number and locations of air diffusers and compressors
    b. Pipe size, dimensions, and material
    c. Detailed cost estimate

Long-term (5 to 10 years)

1. If results from bench test and engineering study suggest that a nutrient inactivant would be appropriate, then apply nutrient inactivant to targeted portions of the lake that are likely to be associated with internal phosphorus release based on the results of the bench scale test. This project would need to include the following prior to field implementation:
    a. Preparation of an environmental impact statement (EIS) to comply with the State Environmental Quality Review Act (SEQRA).
    b. Apply for and receive regulatory approvals from the NYSDEC, USACE, and other agencies.
    c. Note that New York State is developing an approach for safely and legally using nutrient inactivants, and until that process is completed, the use of any inactivants in Honeoye Lake is prohibited.

2. Deploy air diffuser heads, compressors, and associated tubing to targeted portions of the lake based on the results of the engineering design.

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. Evaluate the presence of terrestrial invasive species, including forest pests that affect hemlock, ash, and other tree species that are currently integral to watershed stabilization. Disruption by these pest species could exacerbate erosion and nutrient loading to Honeoye Lake. Forest research and management should be implemented to extent feasible to identify and control these and other pests as a proactive means to minimize impacts. Strategic planting of species less susceptible to impacts of infestation or other forest management measures may be considered in areas where canopy loss will result in significant system destabilization.

2. Evaluate potential shoreline stabilization measures that could be implemented at shoreline locations, including Sandy Bottom Park, to reduce wave-induced erosion associated with seiche action in the lake. Measures should be implemented based on the results of the evaluation.
3. Purchase additional equipment to mechanically harvest, store, transport, and dispose of nuisance and undesirable aquatic vegetation and implement a harvesting program. This program would be targeted at improving the effectiveness of existing harvesting programs (e.g., collecting cut/floating macrophyte fragments) and collecting localized near-shore accumulations of vegetation during the summer and fall seasons.
4. Design and conduct a pilot study to evaluate the effectiveness of Zequanox at reducing zebra and quagga mussel populations. Prior to implementation, regulatory approvals from the NYSDEC, USACE, and other agencies will be needed.

13.3.3 Priority 3 Projects

Priority 3 projects are considered important, but may not have a similar immediate need as Priority 1 and 2 projects.

Short-term (3 years)

1. Provide funding for replacement of failing septic systems within 250 ft of the Honeoye Lake shoreline and tributaries.
2. Evaluate the use of cyanobacteria mitigation strategies at the Sandy Bottom Park beach, including algaecides, ultrasonic devices, water circulation systems, and/or physical barriers to protect the swimming area from the negative impacts of HABs on recreation.
3. Complete a model of hydraulic loading and sediment accumulation within Honeoye Lake and 35 of its tributaries to develop a maintenance plan to periodically remove material from targeted locations to minimize negative long-term impacts on stream and lake water quality.
4. Promote watershed stewardship and the use of BMPs through an educational outreach program that includes printed materials, workshops, signage, and symposium events. Topics may include the use of zero phosphorus fertilizer, septic system maintenance, landscaping BMPs, invasive species spread prevention, green infrastructure practices, shoreline restoration, and erosion control BMPs. Demonstration projects (e.g., rain gardens) should be included to encourage participation.
5. Encourage the use of the forestry BMPs detailed in the New York state Forestry Best Management Practices for Water Quality (NYSDEC 2011) in logging

operations. An educational outreach program can be implemented to promote the understanding and utilization of BMPs such as:

a. Locate landings on frozen or firm, well drained soils a minimum of 61 m (200 ft) from streams, lakes, or wetlands to minimize sediment and nutrient export.

b. Install water bars on sloped logging roads to minimize erosive concentrated stormwater flow.

c. Install stabilized construction entrances at highway entrances to minimize tracking of mud onto roadways.

d. Seed and mulch disturbed areas as soon as practicable.

e. Minimize ground disturbance and tree cutting within riparian zones.

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. Stop or reduce application of herbicides to rights-of-way and stream banks at road crossings.
2. Work with the Honeoye Lake Watershed Task Force (HLWTF) and other organizations to preserve and restore critical resource areas including wetlands and floodplains targeted at sediment reduction.
3. 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 local SWCDs and other partners, and include:

    - 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.
    - 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).

- Stream bank stabilization using both hard armoring and natural stream design methods to lessen the potential for severe and sudden sedimentation from large and/or re-occurring storm events.
- Installation of control facilities at the outlets of drainage swales (prior to entering the lake or tributaries) to promote sediment and nutrient capture
- Implement runoff reduction BMPs for farmsteads: roof runoff management, barnyards, laneways/access roads, and bunk silos
- Establish vegetated riparian buffers to inhibit or reduce nutrient-rich stormwater runoff and eroded soil from reaching the lake or tributary streams
- Rehabilitate degraded vegetated buffers to improve riparian habitat function on tributaries to Honeoye Lake.

4. Construct wetlands or enhance/restore existing wetlands within the watershed to reduce nutrient loads. **Figure 22** shows the locations within the Honeoye Lake watershed that have either hydric, very poor, or poorly drained soils, but are not currently mapped wetland habitats according to the National Wetland Inventory (NWI) database. These locations should be targeted for proposed new wetlands as they are more likely to support wetland hydrology and vegetation.

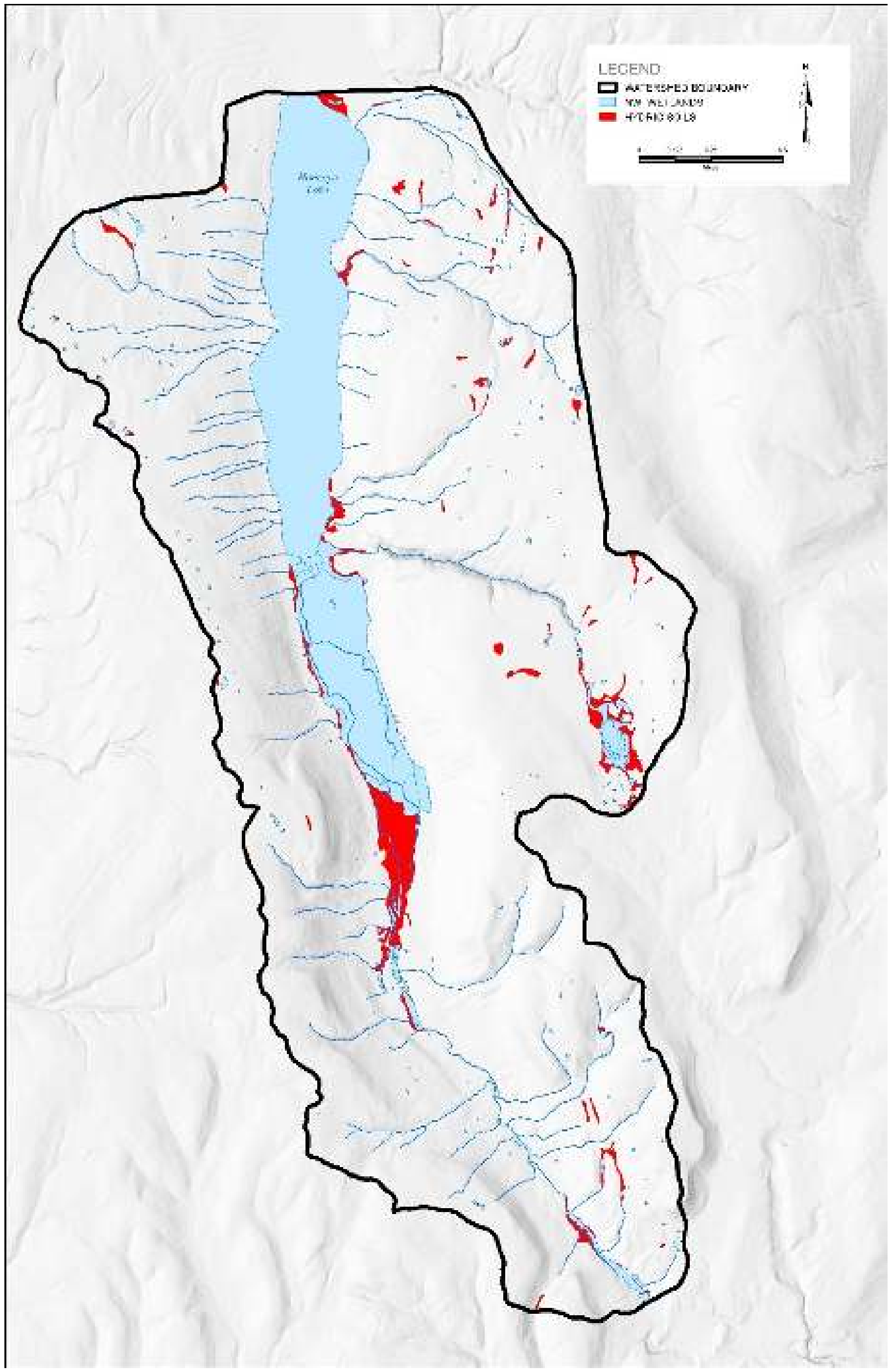


Figure 22. Locations (depicted in red) of either hydric, very poor, or poorly drained soils in the Honeoye Lake watershed, which are not mapped as wetlands per the National Wetland Inventory (NWI).

13.5 Monitoring Actions

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

Short-term

1. Maintain use of local certified laboratories to which lake water samples can be sent to streamline the testing process and response.
2. Model water column mixing and nutrient loading:
   a. Incorporate parameters into model so that it mimics current conditions in terms of seasonal nutrient and HAB concentrations.
   b. Use model to simulate various management options to identify effective means to control HABs.
3. Focus on the area of lakebed that features depths greater than 18 ft where an anoxic hypolimnion can develop for targeted data collection on internal loading. Consider a secondary evaluation to investigate shallower water areas that may become anoxic for shorter periods of time, and where the water column may mix more frequently, but the onset of anoxic conditions still contributes to internal nutrient loading.
4. Align in-lake water quality data collection efforts with overpasses of NASA's Landsat 8 satellite, to the extent possible (**Table 12**). This alignment will allow for the effective use of satellite imagery when characterizing lake conditions based on corresponding field data.
5. Develop a map based on the sample results that identifies areas with elevated concentrations of legacy phosphorus that contribute significantly to elevated levels of phosphorus and cyanobacteria that could be contributing to HABs.

Table 12. Landsat 8 overpasses of Honeoye Lake from May through October 2018.

Month	Dates	
May	May 12	May 28
June	June 13	June 29
July	July 15	July 31
August	August 16	NA
September	September 1	September 17
October	October 3	October 19

13.6 Research Actions

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

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

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

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

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

13.7 Coordination Actions

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

Short-term

1. 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 Honeoye Lake watershed.
3. Identify opportunities to encourage best management practice implementation through financial incentives and alternative cost-sharing options.
4. Coordinate with Department of Health to support the local health departments to implement onsite septic replacement and inspection activities.
5. 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.
6. 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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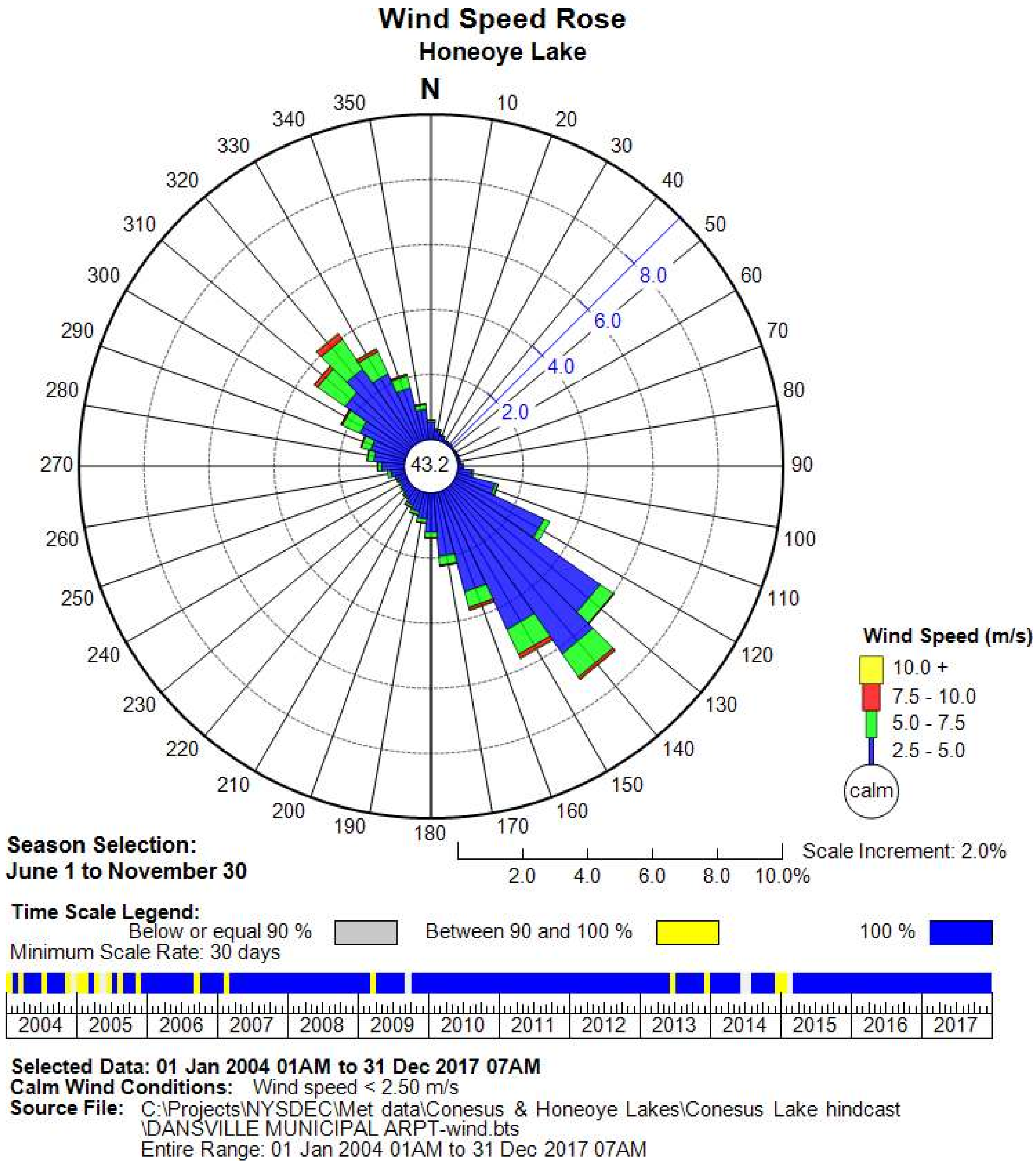
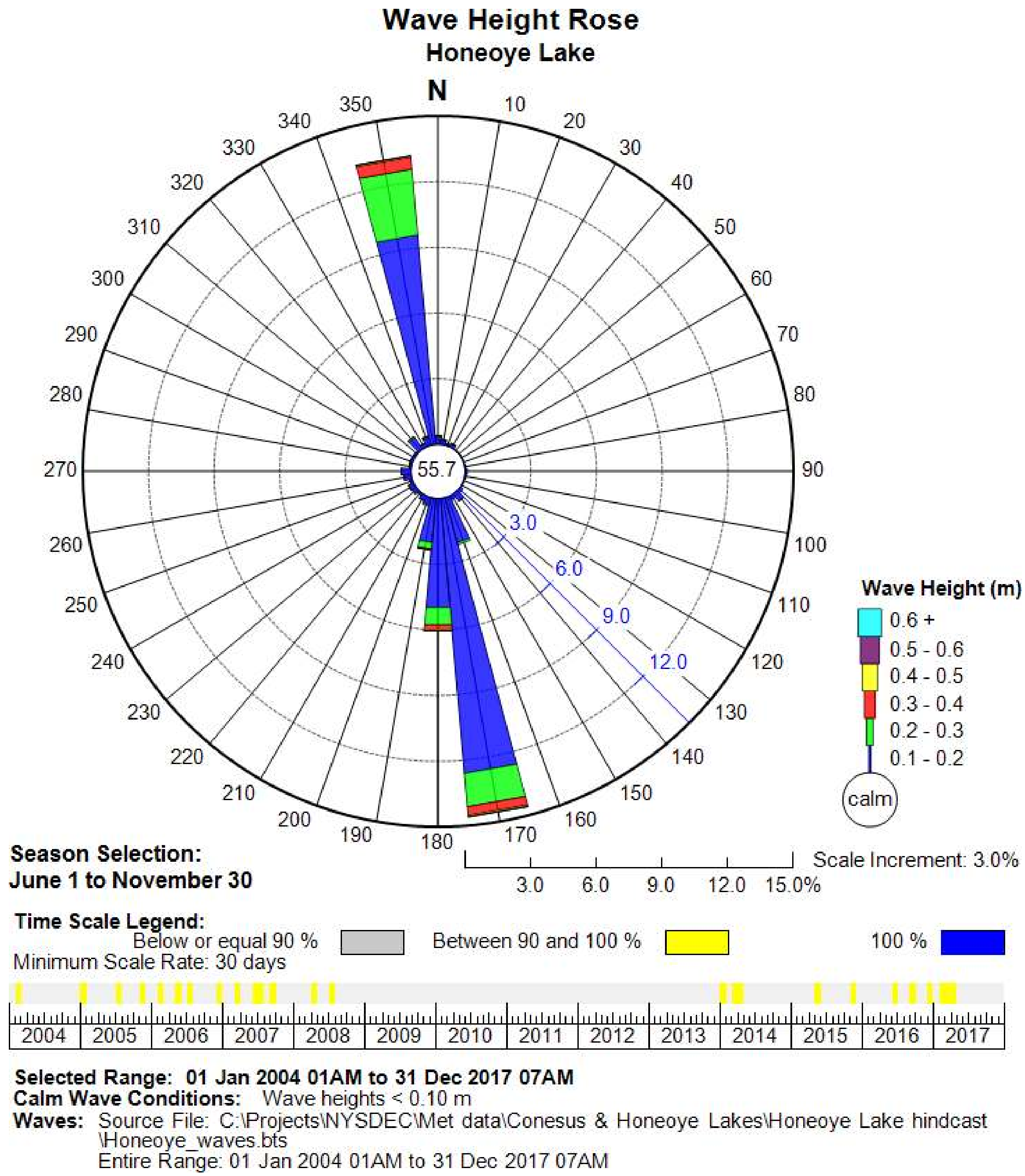
Appendix A. Wind and Wave Patterns



Wind speeds in Honeoye Lake from 2004 to 2017, during the months of June through November, indicate that stronger winds were generally out of the northwest and southeast.



Wave height patterns from 2004 to 2017, during the months of June through November, indicate wave heights were greater in the northern and southern portions of Honeoye 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**.

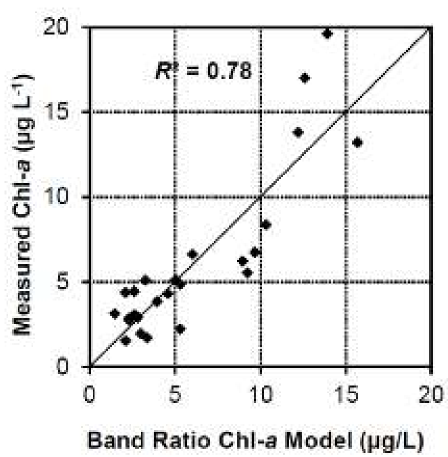


Figure C1. Measured and modeled chlorophyll-a concentrations for Lake Champlain, from Trescott 2012.

[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.

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

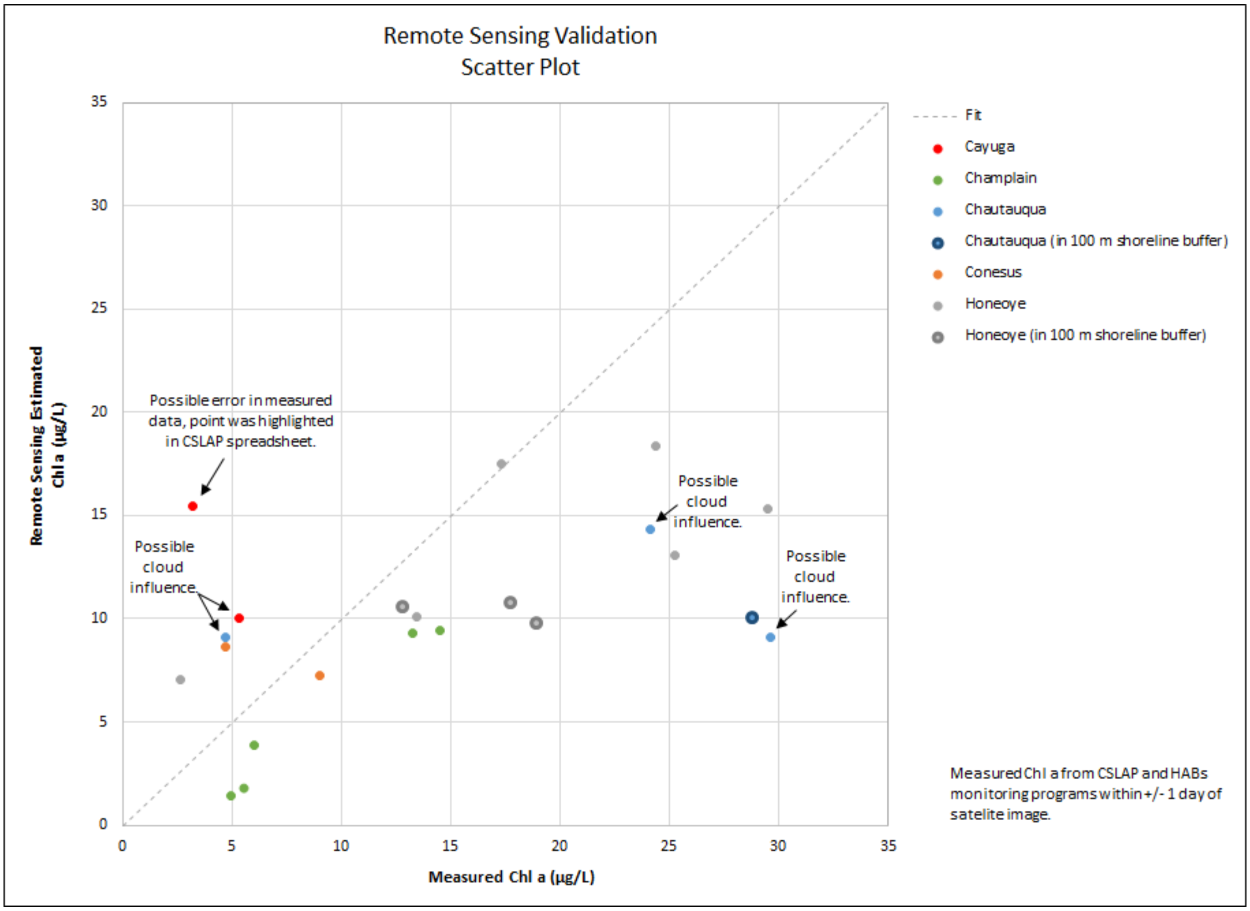


Figure C2. Measured and modeled chlorophyll-a concentrations for Cayuga Lake, Lake Champlain, Chautauqua Lake, Conesus Lake, and Honeoye Lake (2016-2017 data).

Limitations of the Method

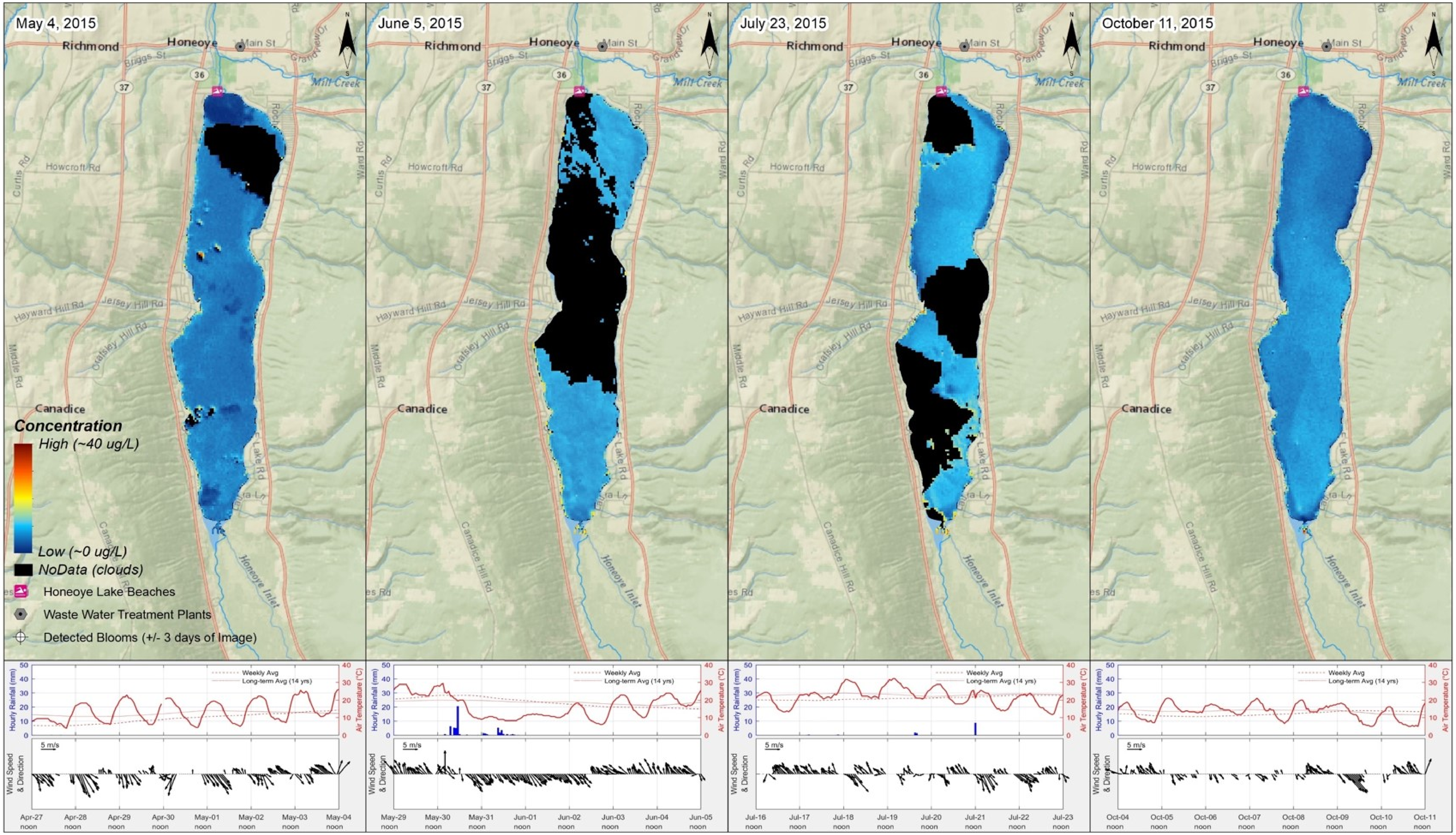
The remote sensing chlorophyll-a model was developed for Lake Champlain using four years of coincident in-situ chlorophyll-a measurements and Landsat 7 imagery. The model was calibrated and cross-validated using samples that were collected within one day of the satellite overpasses and imagery that was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



1:60,000

0 0.5 1 1.5 Miles

0 1 2 Kilometers

Plots

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

Satellite Derived Chlorophyll a

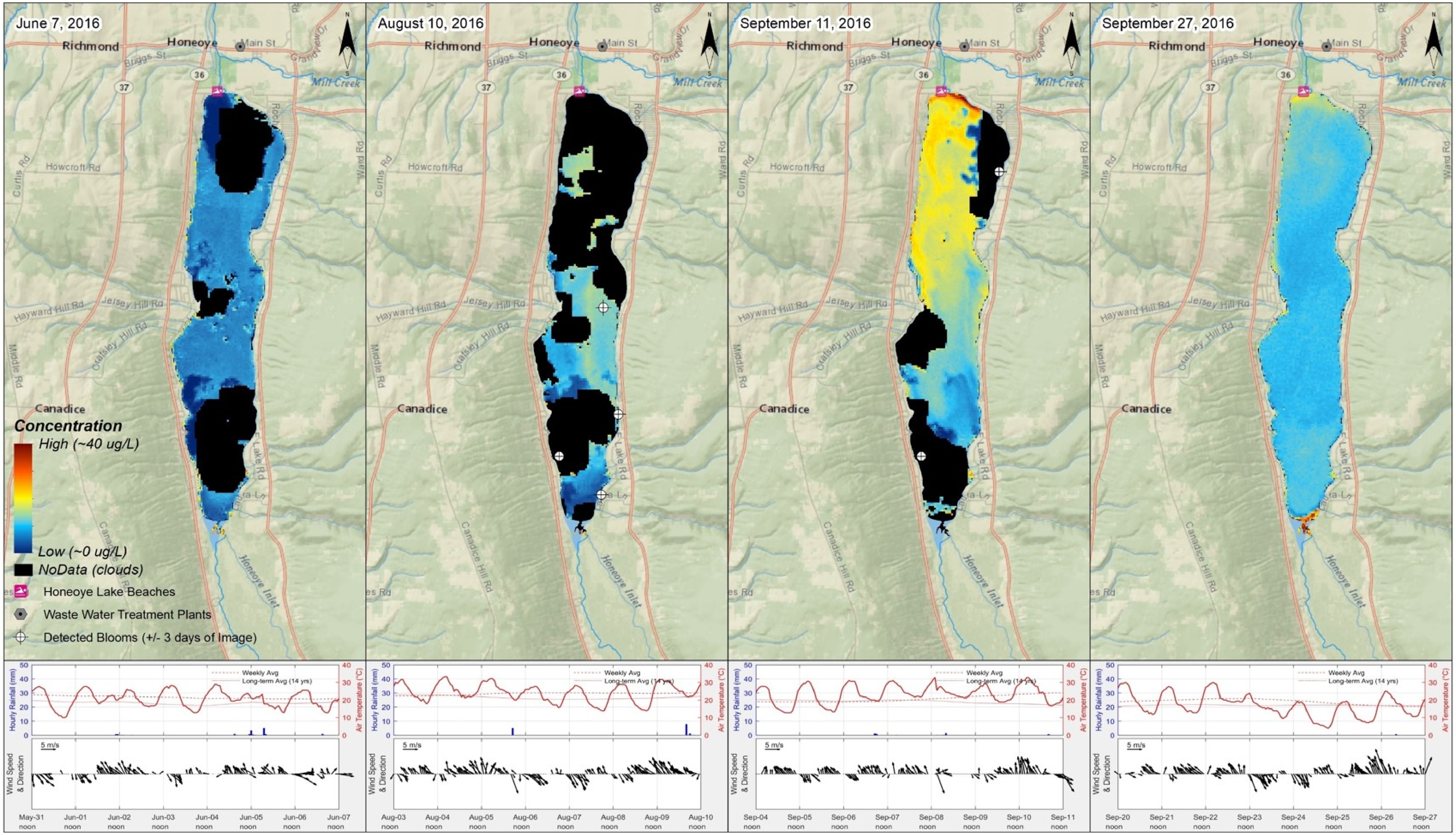
Chl-a Data is Derived from NASA's LandSat 8 Satellite

Data Gaps are Caused by Haze and Clouds

Disclaimer

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

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



1:60,000

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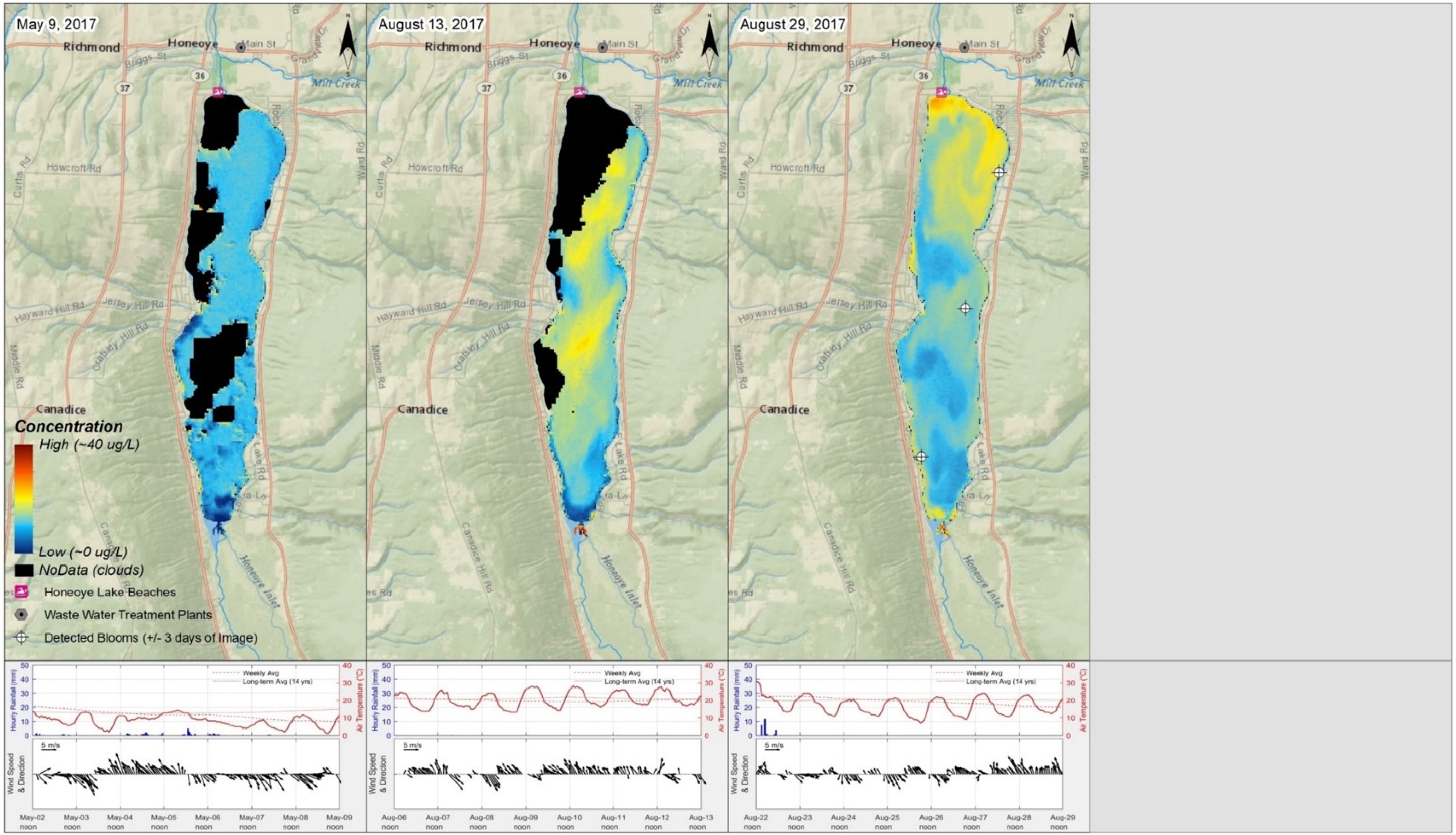

1:60,000

0 0.5 1 1.5 Miles

0 1 2 Kilometers

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

Appendix D. HABs History

Table 1. History of HABs in Honeoye Lake, 2012-2017.

Date	Bloom extent	HAB status	Bloom location	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
8/2/2012*	NR	S	RT	NA	23.3	NA	0	54.7	5.7	NA
8/9/2012	NR	S	RT	NA	22.7	NA	0	12	4.6	NA
8/15/2012	NR	S	RT	NA	20.8	NA	0	37.9	5.1	NA
8/21/2012	NR	S	RT	NA	17.8	NA	0	6.5	3.6	NA
8/27/2012	NR	S	RT	NA	23.7	NA	0.6	0.6	5.1	NA
9/5/2012	NR	S	RT	NA	22.3	NA	6.3	36.7	4.1	NA
9/12/2012	NR	S	RT	NA	17.9	NA	0	45.6	4.6	NA
7/11/2013	LL	S	RT	NA	21.8	NA	4.8	48.9	6.2	NA
7/17/2013*	NR	C/HT	SB	3334-3847	27	NA	0	32	4.6	NA
7/29/2013*	NR	C - C/HT	SB	56.7 - 12078	17.4	NA	1.1	38.7	5.7	NA
8/7/2013	NR	C/HT	SB	33733	22.2	NA	0	1.4	6.7	NA
8/12/2013*	NR	C/HT	OW - SB	200.8 - 48702.5	19.6	NA	0	24.9	3.1	NA
8/19/2013	NR	C/HT	SB	6251	21.1	NA	0	10.7	4.6	NA
9/9/2013	NR	C	SB	147.2	14.6	NA	0	13.6	5.7	NA
9/23/2013*	NR	C/HT	SB	126.1 - 266	11.7	NA	0	21	7.7	NA
10/7/2013	NR	C	SB	166.5	19.7	NA	13.3	50.4	7.2	NA
6/16/2014	NR	C	OW	34.68	21.7	NA	0	9.4	5.1	NA
6/23/2014	NR	C	SB	16692.5	20.9	NA	0	7.7	5.7	NA
6/27/2014*	NR	C - C/HT	SB	2323 - 21588	21.3	NA	0	36.2	2.6	NA
7/3/2014	SL	S	RT	NA	21.8	NA	0.9	31.3	4.1	NA
7/10/2014	LL	S	RT	NA	18.1	NA	0	25.9	4.6	NA
7/14/2014*	NR - WL	C	OW - SB	77.63 - 29793.75	22.6	NA	0	31.8	5.1	NA
7/30/2014*	NR	C	OW - SB	81.02 - 159.59	16.6	NA	0	37.2	5.7	NA

8/4/2014*	NR	C - C/HT	SB	38.24 - 66.21	21.1	NA	0.5	74.3	3.1	NA
8/18/2014*	WL	C	SB	56.45 - 87.65	18.1	NA	0	9.8	3.6	NA
8/25/2014	NR	C	SB	1396.5	20	NA	0	22.2	4.6	NA
8/29/2014	SL	S	RT	NA	15.7	NA	0	19.1	3.6	NA
9/8/2014*	WL	C	OW - SB	43.67 - 90.48	16.1	NA	0	15.8	5.7	NA
9/12/2014	SL	S	RT	NA	12.3	NA	0.3	6.9	5.7	NA
9/15/2014*	WL	C	SB	429.88 - 9430.5	13.9	NA	0	8.7	4.1	NA
10/16/2014	WL	C	OW	30.24	16.2	NA	0	18.7	3.6	NA
7/27/2015*	WL	C - S	OW - SR	22.36 - 90.95	23.6	NA	0	15.3	4.6	NA
8/3/2015*	WL	S	OW	NA	23.6	NA	1.8	6.1	9.3	NA
8/10/2015	WL	S	OW	NA	21.7	NA	0.3	5.7	6.7	NA
8/17/2015*	NR	C	OW	155.55 - 229.49	24.5	NA	0	33.2	4.6	NA
8/31/2015*	NR	C	OW	26.55 - 290.5	23.3	NA	0	0	5.7	NA
9/8/2015*	NR	C - S	OW	29.51 - 56.82	26	NA	0	0	4.6	NA
9/14/2015*	NR	C - S	OW - SR	1596.5	15	NA	3.2	47.9	7.2	NA
9/21/2015*	NR	S	OW	NA	12.1	NA	0	48.3	5.1	NA
10/14/2015	NR	C/HT	OW	150	12.7	NA	0	0	6.7	NA
7/25/2016*	SL	C	SR	36.15 - 39.17	24.2	NA	3.1	14.1	4.6	NA
8/1/2016*	LL	C	OW - SR	50.57 - 114.68	22.3	NA	0	10	6.2	NA
8/8/2016*	LL	C	OW - SR	40.98 - 390.28	21.2	NA	0	11.4	3.6	NA
8/15/2016*	WL - NR	C	SR	35.73 - 104.54	22.4	NA	0	29.8	3.1	NA
8/22/2016*	SL	C	SR	97.76 - 246.53	19.2	NA	0	47.9	7.2	NA
8/29/2016*	LL	C	SR	35.9 - 533.5	23.6	NA	0	36.9	4.1	NA
9/6/2016*	LL	C	SR	40.09 - 307.23	21.5	NA	0	1.6	3.6	NA
9/12/2016*	WL	C	SR	130.11 - 260.12	17	NA	0	6.1	5.1	NA
9/19/2016	SL	C	SR	121.33	21.6	NA	4.8	19.1	3.1	NA
7/4/2017*	SL	C	SR	28.9 - 187.7	19.9	NA	0	18	4.1	NA
7/31/2017	SL	C	SR	56	22.2	NA	0	7.4	5.1	NA
8/25/2017	SL	S	RT	NA	16	NA	0	36.3	6.2	NA

8/28/2017*	SL	C	SB - SR	32.1 - 40.4	16.7	23	0	25.5	7.2	Available
9/4/2017*	SL	C	SR	29.1 - 76.9	19.1	NA	0	7.8	9.3	NA
9/11/2017	WL	C	SR	48.5	13.6	NA	0	17.4	4.1	NA
9/18/2017*	WL	C	SB	45.44 - 138.75	23.3	NA	0	1.8	3.6	NA
10/2/2017	LL	C	SR	114.01	11.8	NA	0	2	4.6	NA
10/10/2017	SL	C	SR	217.06	19.1	NA	0.6	33.8	4.1	NA

NOTES:
* Multiple samples collected on day
NA = Not available
Bloom extent: LL = large localized, WL = widespread/lakewide, SL = small localized, NR = not reported
HAB status: S = suspicious, C = confirmed, C/HT = confirmed with high toxins
Location: OW = open water, RT = report of bloom (usually not sampled), SB = shoreline bloom,
SR = shoreline routine sample
Chlorophyll-a concentrations quantified with fluoroprobe

Appendix E. WI/PWL Summary

Honeoye Lake (0402-0032) — Impaired

Waterbody Location Information

Revised: 05/01/2018

Water Index No:	Ont 117- 27-P57	**Water Class:**	AA
Hydro Unit Code:	Headwaters Honeoye Creek (0413000302)	**Drainage Basin:**	Genesee River
Water Type/Size:	Lake/Reservoir 1796.6 Acres	**Reg/County:**	8/Ontario (35)
Description:	entire lake		

Water Quality Problem/Issue Information

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

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

Known: LOW D.O./OXYGEN DEMAND (OXYGEN DEMAND), NUTRIENTS (PHOSPHORUS), Algal/Plant Growth

Suspected: ---

Unconfirmed: ---

Source(s) of Pollutant(s)

Known: AGRICULTURE, Internal Loading, Urban/Storm Runofff

Suspected: On-site Septic Systems,

Unconfirmed: ---

Management Information

Management Status: Restoration/Protection Strategy Needed

Lead Agency/Office: DOW/BWRM

IR/305(b) Code: Impaired Water Requiring a TMDL (IR Category 5)

Further Details

Overview

Honeoye Lake is assessed as an impaired waterbody due to primary and secondary contact recreation uses that are known to be impaired by nutrients (phosphorus) and resulting low dissolved oxygen, and excessive algae. Nutrient loads may also impact water supply use and may contribute to lower dissolved oxygen levels in the lake, which may impact the support of aquatic life. Internal sources of nutrients are considered to be the source of impact. Internal loading, agricultural nonpoint sources and failing and/or inadequate on-site septic systems are considered to be likely sources of nutrients.

Use Assessment
Honeoye Lake is a Class AA waterbody, required to support and protect the best uses of a water supply source for drinking, culinary or food processing purposes, primary and secondary contact recreation, and fishing

Regarding water supply use, monitoring of water quality at the tap is conducted by local water suppliers and public health agencies. Water supply use in the waterbody may be impaired by elevated nutrient and algae levels in the lake that may result in the formation of disinfection by-products (DBPs) in finished potable water and make treatment to meet drinking water standards more difficult. DBPs are formed when disinfectats such as chlorine used in water treatment plants react with organic matter (e.g. natural organic acids, single-celled organisms, decaying vegetation) present in the source water. Prolonged exposure to DBPs may increase the risk of certain health effects. (DEC/DOW, BWAM and NYSDOH, Public Water Supply, December 2014).

Primary and secondary contact recreation uses are impaired by elevated nutrients (phosphorus), excessive algae, and poor water clarity. These uses are also impaired by the frequent closure of Sandy Bottom beach by the county health department due to harmful algal blooms. These blooms have been well documented through an extensive shoreline surveillance program established by the Honeoye Lake Watershed Task Force and NYSDEC. Secondary-contact recreation use (boating, fishing) is also affected by excessive aquatic vegetation and the presence of invasive plant growth (Eurasian watermilfoil, curly leafed pondweed). Dense rooted aquatic vegetation severely impacts recreational uses of the lake. Mechanical harvesting of vegetation, intended to allow access to the open waters for boating and bathing, has been conducted by Ontario County for several years. (DEC/DOW, BWAM, July 2015, April 2018)

There are no known restrictions to fishing use. Concerns have been noted regarding hypolimnetic oxygen depletion impacts on aquatic life support, although impacts to the fisheries have not been documented. Honeoye is a highly regarded fishing lake, with walleye, largemouth bass, smallmouth bass and chain pickerel as the dominant sportfish specie. Walleye is currently stocked (8.7 million fry annually) into the lake by the NYSDEC. In addition to its excellent sportfish opportunities, the lake also supports an outstanding panfish fishery for bluegill, pumpkinseed, yellow perch and black crappie. While it is likely that zebra mussels affect phytoplankton (algae and cyanobacteria) dynamics in the lake, the effect of these invasive mussels on other aquatic life is not known. (DEC/DFWMR, Region 8, July 2015, NYSDEC/DOW, BWAM, April 2018)

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

Water Quality Information
Honeoye Lake was monitored through NYSDEC CSLAP in 2017. Major trophic indicators were monitored and show that Honeoye Lake is characterized as eutrophic. Chlorophyll-a levels often exceeded the NYSDEC criteria indicating impaired conditions for potable water supplies, due to a high likelihood of producing potential carcinogens (based on chlorophyll a levels greatly exceeding 4 µg/l) during chlorination of raw water (Finger Lakes Study, 1990). Total phosphorus and clarity results correspond to impacted recreational uses.

In 2018, the hypolimnion of the lake showed low oxygen concentrations during winter (DEC FL Water Hub Winter Sampling 2018), and became hypoxic during the growing season. The cause(s) of this dissolved oxygen depletion are uncertain, although excessive growth of algae and cyanobacteria contribute to this oxygen depletion. The results from this study are summarized in the Water Quality Study of the Finger Lakes on the NYSDEC website (http://www.dec.ny.gov/lands/25576). (DEC/DOW, BWAM, July 2015)

Since at least 2003, Honeoye Lake has been sampled by a partnership including the Honeoye Lake Watershed Task Force, Ontario County Soil and Water Conservation District, and the Community College of the Finger Lakes. Water quality monitoring included total and soluble phosphorus at multiple depths, chlorophyll a, and water clarity. The monitoring plan was expanded to include extensive harmful algae bloom (HABs) surveillance and monitoring at multiple locations on a weekly basis from early June through late October since 2013, in collaboration with NYSDEC and SUNY ESF. (DEC/DOW, BWAM/LMAS, July 2015).

Each of the Finger Lakes were added to the New York Citizens Statewide Lake Assessment Program (CSLAP) starting in 2017. Two sites in Honeoye Lake were sampled biweekly from June through September, and water quality results from this study showed significantly higher lake productivity (lower water clarity in response to higher phosphorus and chlorophyll *a* levels) that reported in the 1990s NYSDEC study. These data also suggest slightly lower lake productiveiy in the norther sections of the lake. Continuing data collection will help to evaluate if these differences represent a long-term trend, and if water quality gradients are present in the lake. Summary reports from this sampling will be posted on the websites from NYSDEC (http://www.dec.ny.gov/lands/77853.html) and the New York State Federation of Lake Associations (http://www.nysfola.org/cslap/).

The NYSDEC HABs Notification program confirmed the presence of HABs in Honeoye Lake during the recreational seasons of 2012 through 2017. In 2017, Honeoye Lake was on the HABs Notification list for 14 weeks. The blooms observed in 2017 ranged from small localized to widespread/lakewide blooms. More information about this program can be found at http://www.dec.ny.gov/chemical/77118.html) (DEC/DOW, BWAM, April 2018).

Source Assessment

Based on the surrounding land use and other knowledge of the waterbody, internal loading, agriculture, onsite septic systems, and urban stormwater runoff are likely sources of nutrient pollution resulting in Low Dissolved Oxygen in the waterbody and increase in the growth of algae/plants. The lake is surrounded by development; in some areas a 2nd and 3rd tier of development has occurred. A perimeter sewer goes around 2/3 of lake. Most lakeside homes are connected but ones further back are not. Steep slopes and poor soils cause problems with on-site systems. (DEC/DOW, Region 8, 1996).

A (draft) TMDL for the lake in 2018 indicated that 92% of the phosphorus load from the lake comes from sediment release from internal (aerobic and anaerobic) sources. The bulk of this (> 85%) comes from aerobic release of nutrients from decay of organic sediments (DEC/DOW, BWAM, April 2018).

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. Honeoye Lake was identified for inclusion in this initiative as it is vulnerable to HABs.

Section 303(d) Listing

Honeoye Lake is included on the current (2016) NYS Section 303(d) List of Impaired/TMDL Waters. The waterbody is included on Part 1 of the List as an impaired waterbody requiring TMDL development for phosphorus and corresponding low dissolved oxygen. (DEC/DOW, BWAM/WQAS, May 2017)

Segment Description

This segment includes the entire lake. The waters of the Lake are Class AA.

Appendix F. NYSDEC Water Quality Monitoring Programs

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

Appendix G. Road Ditches

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

Road Ditch Impacts

Roadside ditch management represents a critical, but overlooked opportunity to help meet watershed and clean water goals in the Honeoye 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.