5.4.5 Harmful Algal Bloom

This section provides a profile and vulnerability assessment of the harmful algal bloom (HAB) hazard for Tompkins County.

The hazard profile is organized as follows:	The vulnerability assessment is organized as follows:
• Description • Extent • Previous Occurrences and Losses • Probability of Future Occurrences • Climate Change Impacts	• Impact on Life and Safety • Impact on General Building Stock • Impact on Community Lifelines • Impact on Economy • Impact on Environment • Cascading Impacts on Other Hazards • Future Change that may Impact Vulnerability • Changes Since 2014 HMP • Identified Issues

5.4.5.1 Profile

The profile contains a description of the HAB hazard, extent, location, previous occurrences and losses, climate change projections and the probability of future occurrences.

Hazard Description

Cyanobacteria were among the first life on the planet and were responsible for the oxygen-rich atmosphere. However, some cyanobacteria also produce toxins that threaten humans and animals. Because of their color, cyanobacteria are also referred to as blue-green algae, and when they form colonies, are called harmful algal blooms (HAB), though not all are harmful.

Algae are a diverse group of aquatic organisms that have the ability to photosynthesize. They can be found in a wide range of environments, include lakes, ponds, oceans, hot springs, and land (Live Science 2020). Most algae are harmless and are considered an important component of the food web. Certain types of algae can grow rapidly, forming blooms, and covering all or portions of a lake. There are some species of algae that produces toxins which can be harmful to humans and animals. Algae blooms that produce toxins are referred to as harmful algal blooms (HABs) (NYSDEC 2020). More than 40 cyanobacterial species are confirmed or suspected to produce toxins (Graham and Wilcox 2000).

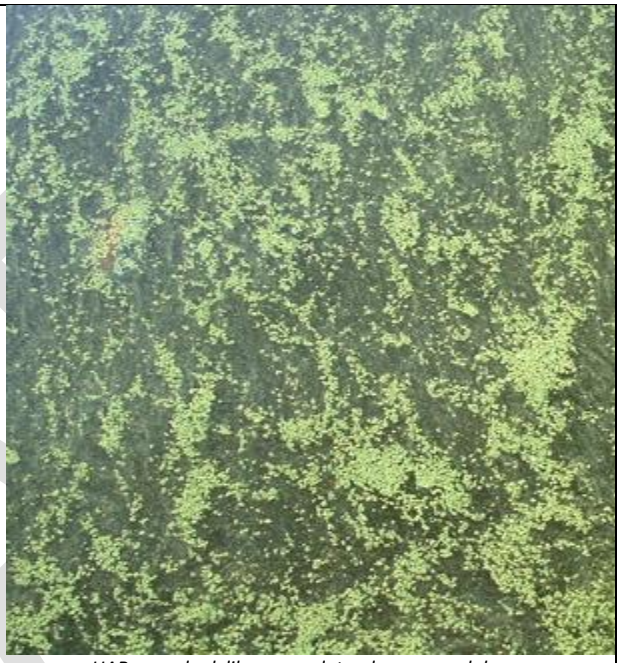
HABs are usually trigged by a combination of water and environmental conditions, including excess nutrients (phosphorus and nitrogen), excessive sunlight, low-water or low-flow conditions, still waters, and warm temperatures. The timeframe of HABs depends on weather conditions and characteristics of the lake. They can last for a few hours (short-lived) to several weeks or longer (long-lived) (NYSDEC 2020).

Identifying Harmful Algal Blooms

The appearance of HABs can vary greatly. According to the NYSDEC, colors can include shades of green, blue-green, yellow, brown, red, or white. The physical appearance of these blooms can include floating dots or clumps and streaks on the water's surface as illustrated in Figure 5.4.5-1. Some blooms can also resemble spilled paint on the water's surface or change the appearance of water to that of pea soup (NYSDEC 2017a).

Figure 5.4.5-1. Examples of Harmful Algal Bloom Visual Appearance

HABs may look like parallel streaks, usually green, on the water surface.



HABs may look like green dots, clumps, or globs on the water surface.

HABs may look like blue, green, or white spilled paint on the water surface.

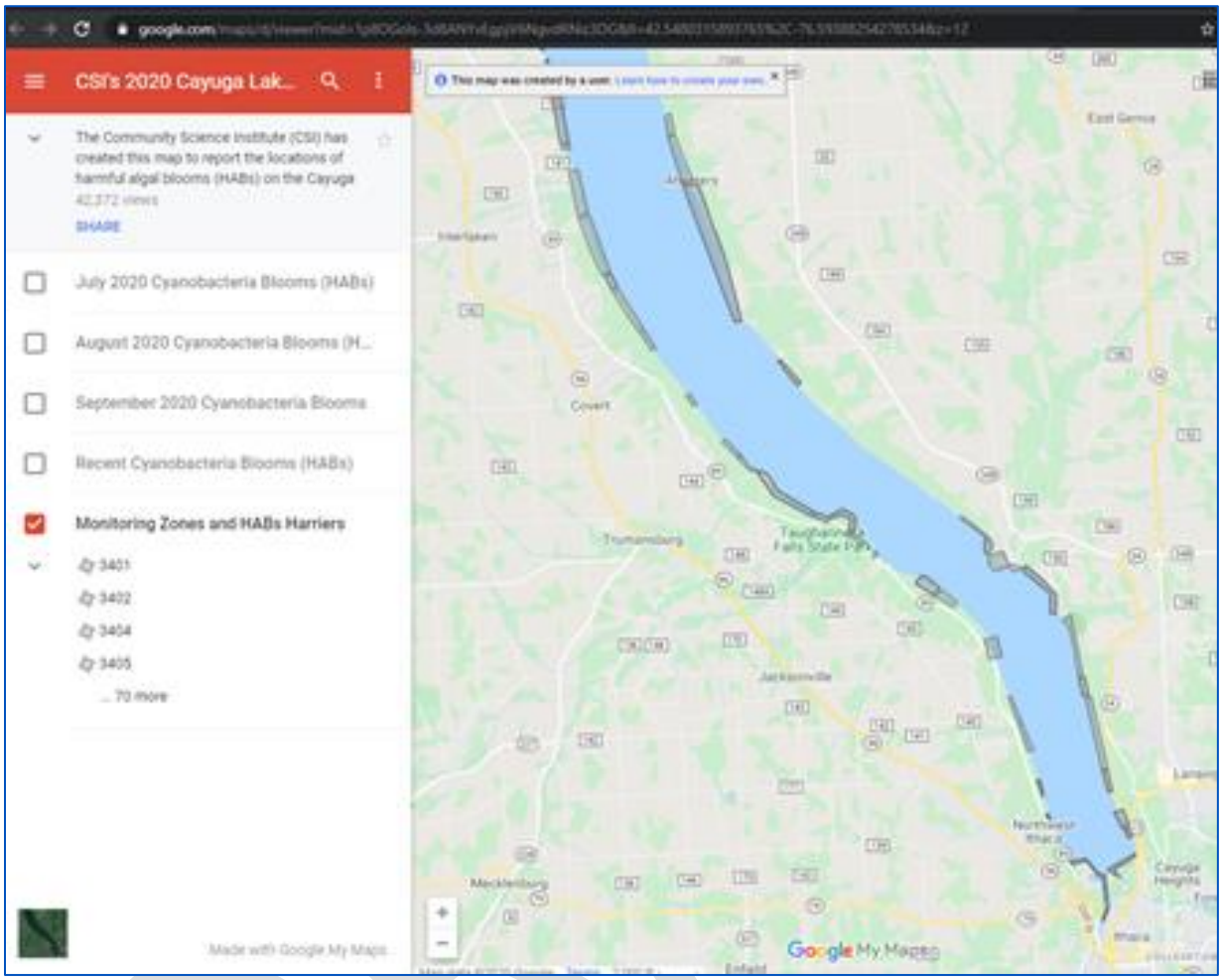
HABs may make the water look bright green or similar to pea soup.

Source: NYSDEC 2016

The NYSDEC Lake Classification and Inventory Program, Citizen Statewide Lake Assessment Program volunteers, and partner HAB monitoring programs collect and report information about the status of waterbodies in New York that may be impacted by HABs (NYSDEC 2018). NYSDEC maintains a statewide interactive map on HABs reports.

On a more local Level, the Community Science Institute located in Ithaca is a non-for-profit organization that has a volunteer-based HABs monitoring program for Cayuga Lake. Figure 5.4.5-2 shows the Cayuga Lake shoreline sections in Tompkins County regularly monitored by volunteers in 2020.

Figure 5.4.5-2.Cayuga Lake Monitoring Program Map



Source: Community Science Institute

The presence of HABs will trigger official beach closures, drinking water restrictions, advisory signs, press releases, and notifications on websites such as the NYSDEC Harmful Algal Blooms Notifications Page and the Tompkins County Department of Health. Children and animals should be kept away from waters suspected of containing HABs, and fishing or eating fish should be prohibited.

Location

Tompkins County has significant exposure and vulnerability to the HAB hazard, as described below.

- Shorelines of the Tompkins County waterbodies with documented HABs are publicly accessible, which can increase the chance of exposure. Many of the county's waterbodies, primarily Cayuga Lake, are popular recreation lakes and have an abundance of lake users, tourism and shoreline development. While DEC guidance requires the public to close the swimming facilities when blooms are detected, there is still a significant risk of exposure for

public that might not be familiar with HABs where the water is accessible from locations other than regulated swimming beaches, such as private residences and boats in the water.

- HABs are currently being experienced throughout the entire Finger Lakes region which can have a significant negative impact on the tourism and local businesses which rely on that tourism.
- Land use changes (residential and commercial development and changes in agricultural practices) are known to be connected to water quality pollutants, which could lead to increased occurrences of HABs. Such development can be the increase of impervious surfaces, agricultural development, and the degradation of existing riparian buffers.
- Because Tompkins County has a major agricultural sector, farm runoff that may contain nutrients directly enters the streams and lakes and provides the nutrients for excessive plant and cyanobacteria growth.
- Locations that rely on surface water intake for drinking water are most exposed to the impacts of HABs, and the three main water purveyors in the County have their own HABs plans. Most of the County residents that are not on municipal water rely on groundwater from deep wells.

In recent years, NYS DEC records have documented HABs on two main and several smaller waterbodies in Tompkins County. The two main waterbodies, Cayuga Lake and Dryden Lake, have a combined 166.5 miles of shoreline of which 51.5 miles are in Tompkins County. Table 5.4.5-1 breaks down the total shoreline miles per lake and the shoreline miles per lake in Tompkins County.

Table 5.4.5-1. Shoreline of Major Waterbodies in Tompkins County with Documented HABs in recent years

Lake	Shoreline Miles (total)	Shoreline Miles (in Tompkins County)	Surface Area (Acres)
Cayuga Lake*	165	50	42,612
Dryden Lake	1.5	1.5	40
Total	**166.5**	**51.5**	**42,652**

Source: NYS GIS
*Note: * - Indicates drinking water source.*

While most HAB contact occurs along shorelines of Cayuga and Dryden Lakes, blooms can take place anywhere in the waterbody, as well as on smaller waterbodies, such as ponds. According to the Tompkins County Natural Resource Inventory, 6.42% of Tompkins County is made up of surface water, that is, streams, lakes, and wetlands.

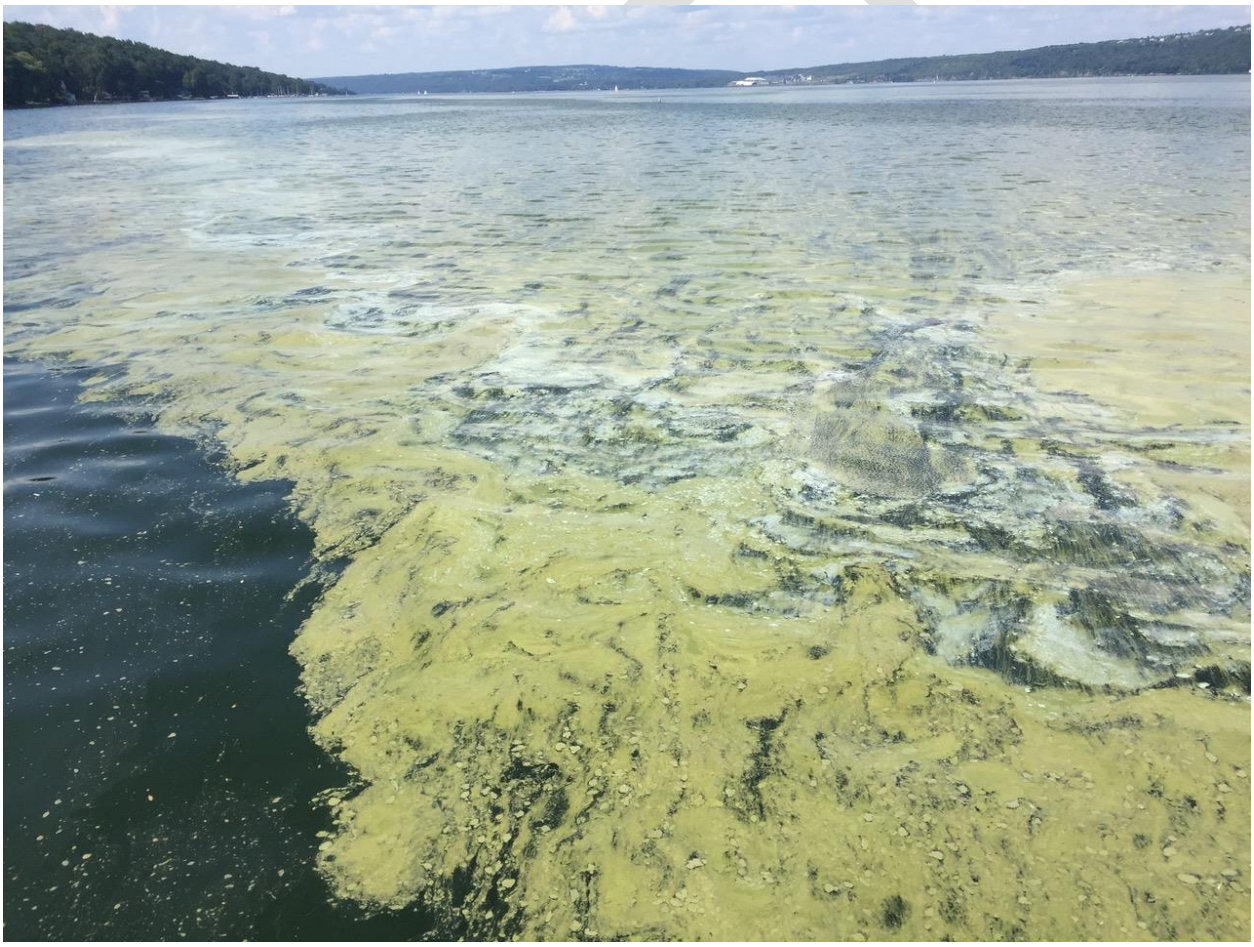
Extent

The NYSDEC uses visual observations, photographs, and laboratory sampling results to determine if blooms are comprised of cyanobacteria or other types of algae. Figure 5.4.5-3 is a photograph of a cyanobacteria bloom at Cayuga Lake. NYS DEC staff will set bloom statuses for waterbodies that are being investigated for harmful algal blooms:

- **Suspicious Bloom**: NYSDEC staff have determined that conditions fit the description of a cyanobacteria HAB based on visual observations and/or digital photographs. Laboratory analysis has not been conducted to confirm whether this suspicious bloom is a HAB. It is not known if toxins are present in the water.
- **Confirmed Bloom**: Water sampling results have confirmed the presence of a cyanobacteria HAB, which may produce toxins or other harmful compounds.
- **Confirmed with High Toxins Bloom**: Water sampling results have confirmed that toxins are present in enough quantities to potentially cause health effects if people and animals come in contact with the water through swimming or drinking (NYSDEC 2018).

Suspicious blooms are reported to NYSDEC, local health departments, or the NYSDOH (NYSDOH 2017).

Figure 5.4.5-3. Cyanobacteria Bloom in Cayuga Lake, Tompkins County



Source: The Cayuga Lake Watershed Network, 2020

The NYSDEC has previously identified HABs in two major and several smaller waterbodies in Tompkins County. There is a possibility for HABs occurring in waterbodies in Tompkins County not subject to monitoring and on private property. The extent of a harmful algal bloom is an estimate of the area of

the waterbody that is impacted. The NYSDEC has four categories to classify extent within their monitoring program (NYSDEC 2018):

- **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 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. Special precautions should be taken in situations when a "Confirmed with High Toxins Bloom" is reported with an open water extent because toxins are likely to be even higher in shoreline areas.

Wind currents can play a large role in the concentrations of algae that float at or near the water surface. Between 2006 and 2017 during the months of June through November, stronger prevailing winds out of the northwest and southeast have influenced the flow and current of the water resulting in driving water borne nutrients and cyanobacteria towards the northern and southern portions of Cayuga Lake. As the water drains north and takes approximately 10 years to enter and exit the lake (also known as water retention time) the water that enters from the south and the 140 tributaries that contribute to the water supply of Cayuga Lake determine the overall quality of the water. Most of these tributaries are small and intermittent and can drastically vary in terms of water quality based on season and amount of precipitation leading to the constant fluctuation in the lake's water quality.

Previous Occurrences and Losses

For this HMP update, HAB events were researched from 1972 to 2020. The NYSDEC began HAB testing and issuing notifications for New York waterbodies in 2012. The 2018 DEC Lake Monitoring Program includes the Lake Classification and Inventory Survey (LCI), the Citizens Statewide Lake Assessment Program (CSLAP) and several individual lake sampling programs. Table 5.4.5-2 lists events identified by the NYSDEC HAB Program between 2012 and 2019. This table includes events specific to Tompkins County as well as events listed for neighboring counties but on a shared waterbody, keeping in mind that cyanobacteria blooms can spread on waterways.

Table 5.4.5-2. Harmful Algal Bloom Events in Tompkins County or Lakes Bordering Tompkins County, 2012 to 2019

	2012	2013	2014	2015	2016	2017	2018	2019
Cayuga Lake	None	None	C	None	C	HT	HT	HT
Dryden Lake	None	None	None	None	HT	C	S	S
S (Suspicious Bloom): DEC staff determined that conditions fit the description of a cyanobacteria HAB based on visual observations and/or digital photographs								

	2012	2013	2014	2015	2016	2017	2018	2019
C (Confirmed Bloom): Water sampling results have confirmed the presence of a cyanobacteria HAB which may produce toxins or other harmful compounds HT (Confirmed with High Toxins Bloom): Water sampling results confirmed that there were toxins present in quantities to potentially cause health effects if people or animals came in contact with the water								

Source: NYSDEC 2020

Probability of Future Events

HABs appear to be a recent occurrence in Tompkins County or have only recently been officially reported and recorded. Even with these blooms becoming increasingly common, season and year-to-year fluctuations make predicting their occurrence difficult (U.S. Environmental Protection Agency [EPA] 2017). Despite this uncertainty, the impact of HABs on the environment, human health, and local economies cannot be discounted, especially in the Finger Lakes Region where tourism and agriculture are the primary economic drivers.

Table 5.4.5-3 lists probabilities of occurrences of documented HAB events in waterbodies in the county. The information used to calculate probabilities of occurrences is based on NYSDEC database records that only date back to 2012. It is possible that HABs were present in waterbodies before 2012 but were not identified or monitored. It is also possible that events have taken place in waterbodies that went unreported.

Table 5.4.5-3. Probability of Occurrence of Harmful Algal Bloom-Related Events

Hazard Type	Number of Occurrences Between 2012 and 2019	Percent Chance of Occurrence in Any Given Year
Harmful Algal Bloom	58	100%

Sources: NYS DEC 2020
Note: Probabilities were calculated from years 2012 to 2019. NYS DEC data only included harmful algal bloom events back to 2012.

During the Tompkins Steering Committee and Planning Committee meetings, the occurrence of harmful algal blooms was discussed. In Section 5.3, the identified hazards of concern for Tompkins County were ranked. Probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Partnership, the probability of occurrence of HAB in Tompkins County is considered "frequent" (hazard event has 100% annual probability and may occur multiple times per year).

Climate Change Impacts

Increases in temperature may result in increased frequency of HABs. Most HABs take place during the summer months when water temperatures are warmest. Different species of cyanobacteria are dominant at different times of the summer months. When lakes are at their warmest, mixing of the water column is less likely. When lakes are stagnant, cyanobacteria are able to grow thicker and faster. In addition, the lower density of warm water allows algae to float to the surface faster. As they grow

and reproduce, cyanobacteria absorb more sunlight at the surface, further increasing the lake temperature and promoting more blooms (EPA 2017a).

Annual average precipitation is projected to increase by up to five percent by the 2050s and by up to 10 percent by the 2080s. During the winter months, additional precipitation will most likely occur, in the form of rain, and with the possibility of slightly reduced precipitation projected for the late summer and early fall. Northern parts of New York State are expected to see the greatest increases in precipitation (NYSERDA 2014).

The projected increase in precipitation is expected to occur via heavy downpours and less in the form of light rains. Rising air temperatures intensify the water cycle by increasing evaporation and precipitation, which can cause an increase in rain totals during storm events, with longer dry periods between those events. Thus, it is important to note that while projected droughts are indicated to decrease over time, that does not necessarily mean wetter seasons. Rather, it is expected that while overall volume of precipitation is not expected to increase drastically, the patterns will be more extreme, and the volume of precipitation/ hour is going to increase to a significant degree. Alternating periods of drought and heavy rainfall increase the likelihood of nutrient runoff into waterways, which can fuel algal blooms (EPA 2017a).

Warmer temperatures could lead to an increase of the length of the growing season and increase the likelihood of HABs. In addition to warmer temperatures and heavy precipitation events, carbon dioxide levels are forecast to continue to increase. Higher levels of carbon dioxide in the atmosphere and water can lead to increased algal growth, particularly for cyanobacteria that float at the surface (EPA 2017a).

5.4.5.2 Vulnerability Assessment

To understand risk, a community must evaluate assets that are exposed and vulnerable to the identified hazard. All assets surrounding and relying on the waterways and water in the County are exposed to the harmful algal bloom hazard. The following text evaluates and estimates the potential impact of the harmful algal bloom hazard on the County.

Impact on Life, Health, and Safety

Impacts of harmful algal blooms on life, health, and safety depend on several factors, including the severity of the event and whether citizens and tourists have become exposed to waters suspected of containing toxins associated with cyanobacteria. Routes of exposure include consumption, inhalation, and dermal exposure. The population living near or visiting waterbodies is at risk for exposure as well as those that use those waterbodies for recreation, fishing, and water supply. Contact with water containing harmful algal blooms can cause various health effects including diarrhea, nausea or vomiting; skin, eye, or throat irritation; and allergic reactions or breathing difficulties (CDC 2020).

Individuals most vulnerable to HABs events include those relying on surface water intake for drinking water exposed to HABs

Populations in Tompkins County that rely on surface water intake for drinking water are most exposed to the impacts of harmful algal blooms. Cayuga Lake, Fall Creek, and Six Mile Creek are surface water resources that provide drinking water within Tompkins County. According to the 2018 American Community Survey 5-Year Population Estimates, Tompkins County has 102,962 persons living in its communities. Although not all residents rely on these surface water resources for drinking water, these waterbodies are also used for recreational activities. The Tompkins County Department of Health updates their website with beach closures, including links to NYS Parks.

Impact on Community Lifelines

The typical impact harmful algal blooms have on community lifeline critical facilities are shutdowns of water intakes from the surface waters that are impacted by blooms and their toxins. Water treatment plants can remove variable amounts of microcystin from drinking water depending on the active removal process used by the water treatment plant (EPA 2020). However, applying the wrong treatment process at a specific state in treatment could damage the facility and release cyanotoxins rather than remove them. The EPA has summarized the effectiveness of treatment options for harmful algal blooms (refer to Table 5.4.5-4).

Fall Creek supplies drinking water to Cornell University, and because the water intake is run-of-the-river, HABs are unlikely to form and be a threat to the drinking water. The City of Ithaca uses Six Mile Creek for its drinking water. The intake is located in a reservoir that could, but has not, experience HABs. The City has a Cyanotoxin Management Plan and performs regular monitoring and testing. Bolton Point, which provides water to residents in its five member municipalities as well as other customers, has its water intake in Cayuga Lake. In 2019 Bolton Point developed a cyanotoxin treatment plan should toxins appear in the raw water.

Table 5.4.5-4. Assessment of Treatment Options for HABs

Treatment Process	Relative Effectiveness
Intracellular Cyanotoxins Removal (Intact Cells)	
Pre-treatment oxidation	Oxidation often stresses or lyses cyanobacteria cells releasing the cyanotoxin to the water. If oxidation is required to meet other treatment objectives, consider using lower doses of an oxidant less likely to lyse cells. If oxidation at higher doses must be used, sufficiently high doses should be used to not only lyse cells but also destroy total toxins present (see extracellular cyanotoxin removal).
Coagulation/ Sedimentation/ Filtration	Effective for the removal of intracellular toxins (cyanobacteria cells). Ensure that captured cells accumulated in sludge are removed frequently to release toxins. Ensure that sludge supernatant is not returned to the supply after sludge separation.
Membranes	Effective for removal of intracellular cyanotoxins (cyanobacteria cells). Microfiltration and ultrafiltration are effective when cells are not allowed to accumulate on membranes for long periods of time. More frequent cleaning may be required during a bloom event.

Treatment Process	Relative Effectiveness
Flotation	Flotation processes, such as Dissolved Air Flotation (DAF), are effective for removal of intracellular cyanotoxins since many of the toxin-forming cyanobacteria are buoyant.
Extracellular (Dissolved) Cyanotoxins Removal	
Membranes	Depends on the type of cyanotoxin, membrane material, membrane pore size distribution, and influent water quality. Nanofiltration is generally effective in removing extracellular microcystins. Reverse osmosis filtration is generally applicable for removal of microcystins and cylindrospermopsin. Cell lysis is highly likely. Further research is needed to characterize performance.
Potassium Permanganate	Effective for oxidizing microcystins and anatoxins. Further research is needed for cylindrospermopsin. Not effective for oxidizing saxitoxin.
Ozone	Very effective for oxidizing microcystins, anatoxin-a, and cylindrospermopsin. Not effective for oxidizing saxitoxin.
Chloramines	Not effective.
Chlorine dioxide	Not effective at doses typically used in drinking water treatment.
Free Chlorine	Effective for oxidizing microcystins as long as the pH is below 8. Effective for oxidizing cylindrospermopsin and saxitoxin. Not effective for oxidizing anatoxin-a.
UV Radiation	UV radiation alone is not effective at oxidizing microcystins and cylindrospermopsin at doses typically used in drinking water treatment. When UV radiation is coupled with ozone or hydrogen peroxide (called "advanced oxidation"), the process is effective at oxidizing anatoxin-a, cylindrospermopsin, and with high UV doses, microcystins.
Activated Carbon Adsorption	Powdered activated carbon (PAC): Effectiveness of PAC adsorption varies based on type of carbon, pore size, type of cyanotoxin, and other water quality parameters such as natural organic matter (NOM) concentration. Wood-based activated carbons are generally the most effective at microcystins adsorption. More research is needed to evaluate PAC's effectiveness at adsorbing cylindrospermopsin, anatoxin-a, and saxitoxin, however the limited research has demonstrated promising results. Doses in excess of 20mg/L may be needed for complete toxin removal, especially if NOM concentrations are high. Granular activated carbon (GAC): Effectiveness of GAC adsorption varies based on type of carbon, pore size, type of cyanotoxin, and other water quality parameters such as NOM concentration. GAC is effective for microcystins, and likely effective for cylindrospermopsin, anatoxin-a and saxitoxin. The condition of the carbon is an important factor in determining GAC's effectiveness for cyanotoxin removal. GAC may need to be regenerated more frequently to ensure adequate adsorption capacity for HAB season.

Source: EPA 2020

Impact on the Economy

Economic impacts from harmful algal bloom events are difficult to quantify in Tompkins County. Nationally, these events have caused significant economic loss. For example, the Centers for Disease Control and Prevention estimates that the fishing industry loses as much as $34 million a year in sales

due to contamination (CDC 2020). Recreation and tourism industries also lose millions of dollars each year because of beach closures and presence of HABs in waterbodies. Further, monitoring and management programs can cost states and local governments millions of dollars each year.

Overall, Tompkins County may experience the greatest economic impact in its tourism sector if HABs events continue for long periods of the summer months. News of a closure of a body of water or beach can result in tourists avoiding the area and the numerous events that rely on local waterbodies, especially Cayuga Lake. Even after closures are lifted, negative public reaction can persist and continue to impact tourism revenue and property values.

Impact on the Environment

Harmful algal blooms can release toxins that lead to fish and invertebrate kills. Animals that prey on fish and invertebrates in surface waters, such as birds and mammals including dogs, may be affected if they ingest impacted prey. Both harmful and non-harmful algal blooms can have drastic impacts on oxygen levels in surface waters. When algae begin to die off following a bloom, bacteria begin to decompose the organic material. This decomposition consumes dissolved oxygen and releases carbon dioxide. If the bloom and die off is large enough, dissolved oxygen levels in aquatic systems can rapidly crash. Anoxic conditions connected to algal blooms have resulted in large fish and invertebrate kills (CDC 2020).

Cascading Impacts on Other Hazards

Harmful algal blooms can exacerbate the impacts of disease outbreak. Species and persons that are exposed to cyanobacteria may become poisoned, experience gene alterations, or disease (EPA 2020). More information about disease outbreaks can be found in Section 5.4.1 (Disease Outbreak).

Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in the county can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The county considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Projected Development

As discussed in Section 4, areas targeted for future growth and development have been identified across the county. Harmful algal blooms could impact any areas of growth located near waterbodies that are vulnerable to harmful algal blooms. As increased development is often associated with

stormwater and runoff issues, harmful algal blooms may become more likely in areas of increased development. The specific areas of development are indicated in tabular form and/or on the hazard maps included in the jurisdictional annexes in Volume II, Section 9 of this plan.

Projected Changes in Population

According to population projections from the Cornell Program on Applied Demographics, Tompkins County will experience a continual population increase from 2020 through 2040 (over 6,040 people in total by 2040). The U.S. Census Bureau also shows that the population in Tompkins County has increased 0.6-percent between 2010 and 2019 (U.S. Census Bureau 2020). As a result, an increase in the population could also change the number of persons at risk of becoming exposed to a harmful algal bloom event.

Climate Change

Tompkins County will see an increase in both temperature and precipitation amounts as a result of climate change. As discussed above, a warming climate will allow for an extended growing period for algal blooms. Additionally, increases in precipitation will generate more stormwater runoff, which can lead to increased nutrient loads entering waterways from leached nutrients in the soil or fertilizers on agricultural lands. Warmer temperatures and increased nutrient loads will allow for algal blooms to grow and spread more rapidly. These changes will increase the County's overall vulnerability to harmful algal blooms.

Change of Vulnerability Since the 2014 HMP

Harmful algal blooms are a new hazard of concern for Tompkins County.

Identified Issues

- In Tompkins County, the primary threat from HABs is economic impact to the surrounding region. While public health problems caused by HABs is the initial concern for the county, because Tompkins County is a large tourist destination, park closures and water contamination can cause a more serious and chronic economic impact on local businesses. For preventative measures, the County would not only have to focus on HABs in Tompkins County, but also need to collaborate with neighboring counties in order to reduce the treats caused by HAB.
- There is a need to track and identify harmful algal blooms incidence and to continue to build relationships with lake committees to communicate information about HABs.
- Develop a HABs Strategy to formulate mitigation options for harmful algal blooms range from expensive structural projects (e.g. replacement of septic systems with community to wastewater) to minor projects such as the installation of aerators, or maintenance projects such as dredging legacy chemicals found in lake sediments and road ditch improvements.