2019 Water Quality Reports

For Worcester's Recreational Waters

Water Quality Monitoring Reports and City Initiatives to Improve Water Quality for Recreation and Economic Development

Published through the Worcester Department of Public Works and Parks
Lakes and Ponds Program

Bell Pond • Lake Quinisgamond • Coes Reservoir • Indian Lake

Executive Summary

Background

The City of Worcester has over 20 lakes and ponds which contribute recreational and economic possibilities to city residents. They range in size from one to 500 acres, and in depth from 3 to almost 100 feet. Most of these waterbodies are man-made, relics of the American Industrial Revolution, when streams were dammed to make reservoirs to power mill factories. These factories were responsible for the influx of residents to Central Massachusetts that eventually turned Worcester into a thriving city. While no longer a factory town, Worcester today still has many of the relics of this bygone age, including these reservoirs.

Today, these waterbodies support a plethora of recreational activities, including fishing, swimming, sailing, rowing, wind surfing, jet skiing, and many others. They undoubtedly contribute to the quality of life of residents, as well as provide a vehicle for economic development through the hosting of events around these activities. However, the ability of people to enjoy these activities depends on high water quality. High water quality is defined by water that can support healthy fish populations, is free from bacteria and toxins that can make you sick, and is not choked by plants, litter, and animals that are compromising public safety and ecological health.

Unfortunately, Worcester's lakes and ponds face stresses associated with being located in an urban environment. The increased area of impervious surfaces in cities, as well as increased population density, can contribute to water quality impairments, including nutrient and sediment loading, bacteria, litter, and invasive aquatic organisms. Historically, groups of neighbors advocated for the protection and improvement of conditions leading to water quality degradation in their lakes and ponds by forming Watershed Associations and Friends Groups. These groups often called upon the local and state government for technical assistance or funding for the management of these resources.

The Lakes and Ponds Program

In 2016, The City of Worcester Department of Public Works and Parks initiated the Lakes and Ponds Program with the goal of monitoring and improving the City's Blue Spaces in collaboration with local stakeholders, including the Watershed Associations and Friends Groups. The program had 4 tasks: Monitoring, Management, Education, and Promotion. Monitoring is considered the most fundamental part of the program, as all management decisions and educational programs are informed by the analysis of monitoring data.

The Lakes and Ponds Program monitors water quality in the four largest waterbodies with public access in the form of a public beach or boat ramp. Bell Pond, Coes Reservoir, Lake Quinsigmond, and Indian Lake. Lakes and their major tributaries are visited up to 14 times per year and a range of water quality parameters are collected. The data collected is analyzed and used to inform decisions around invasive aquatic plant and cyanobacteria management, design stormwater improvement projects, determine lake closures, and monitor water quality changes from year to year.

Results from the 2019 water quality monitoring season suggest that our lakes and ponds continue to be threatened by urban stressors including invasive aquatic plants and animals, nutrient loading, bacteria, and litter. However, over the years that the Lakes and Ponds Program has existed, the City has made great strides in refining management plants for these threats, and is better equipped to respond and prevent them from interrupting recreation. Our lakes and ponds are safe to use for recreational activities on most days, and we continue to develop solutions to increase the number of days that they are open.

This report serves to outline and explain the results of 2019 monitoring program, as well as the management solutions we have developed in response for each of the four program lakes. While its is not possible to display, analyze, and discuss all data and projects here, more information on any water quality topic can be requested at *dpw@worcesterma.gov*. We hope that this report serves to inform the public about the initiatives occurring at their waterbodies, and directs them to ways they can get involved to keep their Blue Spaces beautiful.

Contents

Water Quality Monitoring Background

The Monitoring Program

Prior to the creation of the Lakes and Ponds Program, it was generally understood that there were water quality challenges that needed management in the City's Blue Spaces. Several Watershed Associations had contracted water quality studies, and even some limited management at their waterbodies. However, the relative severity of these challenges to one-another had not been assessed, and there was no basis for the prioritization of funding for these projects on a city-wide level. Additionally, there was no long term dataset available to track improvements or degradation of water quality at most sites.

The Lakes and Ponds Program made it a priority to develop a Water Quality Monitoring Program in order to assess the relative water quality challenges as well as develop a baseline of health to track changes over time. To do so, the Program identified the most probable Water Quality Impairments that Worcester's Blue Spaces were facing, and identified sampling methods and indicators to quantify their impact. Next, the Program identified the procedures and locations to be sampled that would most accurately represent the entire waterbody, or a potential sources of contamination. Methodologies and indicators chosen were published in a Quality Insurance Project Plan (QAPP), which was submitted to and approved by the Massachusetts Department of Environmental Protection (Mass DEP) in Spring of 2017.

Water Quality Impairments

Many of the challenges that our waterbodies face are related to their location in a post-industrial city. The increased area of impervious surfaces associated with cities, including streets, sidewalks, parking lots, and rooftops prevent rainwater from being absorbed into the ground, where it is naturally filtered though soils. Instead, the water collects and runs across these surfaces, picking up dirt containing nutrients and other pollutants along the way. This water is then funneled into catch basins or stormwater drainage where it eventually enters waterways. There these pollutants have the potential to impair water quality by promoting harmful algal blooms, casing human illness, or the shallowing of the waterbody through sedimentation. Stormwater is one of the main sources of inland water contamination.

Another threat to Worcester's lakes and ponds come from the density of people that live near and recreate on them. If not done responsibly, human use can come with litter and hitchhikers in the form of invasive aquatic plants and animals that can impair our ability to enjoy our Blue Spaces. We will further explain these impairments in the following sections.

Other Water Quality Indicators

Some impairments we can measure directly, but there are other indicators that we measure to help us make informed management decisions. These are usually instantaneous measurements taken using probes and other instruments, and include parameters such as temperature, dissolved oxygen, and transparency. We will further explain the importance of these measurements in the following sections.

Sampling Procedures and Locations

After determining what measurements were to be taken, we needed to determine when, where, and how. The Lakes and Ponds Program samples the major tributaries, or rivers flowing into the lakes, the outflows (where the water exists the lakes), as well as the deepest portion of the lakes at the surface and the bottom. The idea is to understand water quality going into the lake, dynamics in the lakes, and the quality of the water as it leaves. Core parameters were collected twice monthly, May through October of 2019, however, additional data from other sources was also referenced to make conclusions and management decisions.

Water Quality Impairments

Bacteria

Recreational contact with water contaminated by bacteria may make people ill. *Escherichia coli, or E. coli,* are a type of bacteria found in the digestive tract of warm-blooded animals, including humans. They can enter our waterways from pet and goose waste running into the water, from human waste from illicit sewer connections to the storm water system, or from leaking septic tanks. The Commonwealth of Massachusetts has strict water quality standards for public bathing beaches, and Worcester Inspectional Services tests the water for *E. coli* on a weekly basis during the summer months. If the readings are too high, the city is required to close the beach until readings return to safe levels.

Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), are the basic food sources of aquatic plants and algae. An excess of either N or P can promote algal blooms and excessive plant growth. They can come from fertilizers, pet and goose waste, and urban and agricultural runoff that wash into the storm sewer system or over land. Nitrate (NO_3) can encourage harmful algal blooms that deplete oxygen in the water column and can cause fish kills. Ammonia (NH_3) can be toxic to fish. P is a limiting nutrient in lakes and ponds, meaning that excess P will be used up immediately by plants and algae, and is therefore an important indicator of lake health. We test water quality samples for NO_3, NH_3, Total Phosphorus (TP), and Total Dissolved Phosphorus (TDP), once to twice a month in each waterbody.

Trash and Litter

Litter, or inappropriately disposed wastes, is harmful to the ecology, aesthetic, and recreational value of lakes and ponds. Improperly discarded plastic and styrofoam products can be mistaken as food by aquatic organisms and can kill them. Mounds of trash and rotting organic material can cause infestation by disease-carrying vermin. Additionally, they look and can smell unpleasant to beachgoers and hikers. Finally, sharp objects like syringes, broken metal, or glass can pose a threat to swimmers and other beach visitors. We make observations of litter at the point of access to each of our waterbodies on a twice-monthly basis.

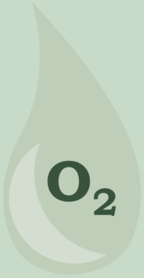
Invasive Aquatic Plants and Animals

Native aquatic plants are vital parts of any lake ecosystem, providing food, shelter and oxygen to other aquatic organisms. An invasive plant is a plant that not originally come from the area. These plants become nuisances because their natural constraints, such as predators or environmental limitations, do not exist in their new home, allowing them to multiply at a rate much more rapidly. When aquatic plants become too numerous, they can reduce our ability to enjoy our lakes and ponds. Invasive aquatic plants can arrive by hitching rides on boats, pets, or boots to get from place to place. Some are released with good intentions as a beautiful addition to a landscape. We perform aquatic vegetation surveys periodically at our lakes and ponds, as well as collect observations of plants and animals from the community.

Industrial Contaminants

As a post-industrial urban center, legacy pollutants and new contaminants of concern from industrial processes may have access to our recreational waters. These contaminants may cause a range of negative health and environmental effects and include the compound categories of volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), petroleum hydrocarbons (TPH), perfluoroalkyl substances (PFAS), and metals.

Other Water Quality Indicators



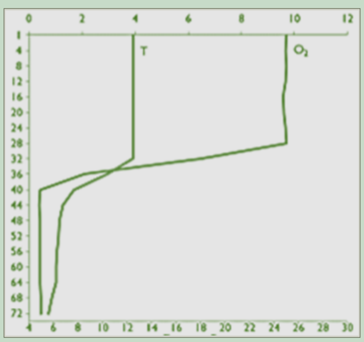
Dissolved Oxygen

Oxygen in the water is important to aquatic life, just like it is for life on land. Algae, plants, fish, and other aquatic organisms require a certain amount of oxygen to survive. Dissolved oxygen (DO) is therefore an important indicator of water quality. It is a highly variable parameter with daily and seasonal variation. DO levels can be affected by temperature, pressure, rate of photosynthesis and respiration by aquatic life, decomposition, aeration, and diffusion. Low DO can lead to fish kills and may be the result of nutrient loading which stimulates algae growth, or by decomposition of organic material. We measure DO *en situ* with an oxygen probe twice monthly.

Temperature

Water temperature is important to both the biological activity and water chemistry in a lake. Organisms tend to live in a preferred band of temperatures, and when temperatures are too cold or warm, their populations may decrease. Additionally, water temperature affects the speed of chemical reactions and how much oxygen can be held in the water. Warmer temperatures can also promote harmful algal blooms. We measure oxygen *en situ* with a temperature probe twice monthly

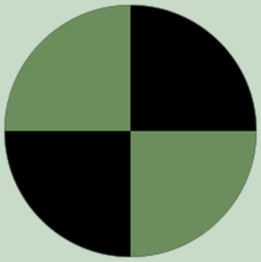
Stratification



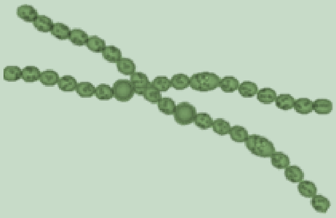
Warmer water is less dense than cold water, which means that during the summer when the surface of the water heats up in deep lakes, the warmer layer floats on top of the cooler water below, creating a barrier that prevents oxygen from the air or produced by plants at the surface from mixing easily with the lower portions. As the warm weather continues, oxygen is depleted in the lower portions. Additionally, this barrier means that nutrients associated with algal blooms build up in the lower portion of the lake until the water cools again in the Fall, causing a plume of nutrients to be cycled into the upper portion of the lake all at once, where they can be accessed by plants, algae, and bacteria. We observe stratification by measuring DO and temperature at 1-4 foot intervals between the surface and the bottom of the lake once monthly.

Secchi Transparency

One indicator of water quality is clarity, or how transparent the water is. Algae, microscopic organisms, eroded particles, and re-suspended bottom sediments are factors that interfere with light penetration and reduce water transparency. Clear water allows light to penetrate and encourages the growth of aquatic plants, which provide food, shelter, and oxygen to aquatic organisms. Turbid waters, or water filled with particles, will warm up faster as it absorbs heat from sunlight which causes oxygen levels to fall because as warm water can hold less oxygen than cool water. Finally, clear waters are pleasant to the eye, and safer for recreational contact. We measure transparency using a Secchi disk twice monthly at each waterbody.



Cyanobacteria



Algae are simple plants that use sunlight for energy and quickly absorb N and P for nutrients. Cyanobacteria are bacteria that use sunlight, N, and P in a similar way. While they are present in small numbers in healthy ecosystems, under warm, high nutrient conditions they can reproduce quickly, causing a bloom. In addition to being unsightly, and smelly, these blooms can cause low oxygen conditions that are harmful to aquatic life. Cyanobacteria can also produce toxins that are harmful to humans and pets. It is therefore important to know algae and cyanobacteria dynamics in our lakes and ponds. We measure cyanobacteria density by taking cell counts from water samples in our most at risk waterboodies, as well as through visual observation at lower risk lakes.

Sampling Overview

Sampling Locations

Samples were collected at the major tributaries, outlets, and deepest points of Bell Pond, Indian Lake, Lake Quinsigamond, and Coes Reservoir. Samples were taken at the surface and the bottom of each lake.

Tributaries are significant because they can tell us about quality of the water as it flows into the lake, and help us to identify potential sources of pollution. Once in the lake, water quality can change. We can get an idea of the average water quality by taking measurements in the deepest, usually central portions of the lakes. Because there is usually a temperature and light gradient between the surface and bottom of the lake, and these factors can affect water chemistry, we take our in-lake measurements at both the surface and one foot off the bottom of the lake. Finally, we collect samples at the outflows of lakes to assess the quality of the water as it flows downstream.

Parameters and Sampling Frequency

Twice Monthly: Temperature, DO, TP, Secchi, bacteria, cyanobacteria, litter
Once Monthly: TSS, NO_3, NH_3
Twice Yearly: VOCs, SVOCs, PCBs, TPH, pesticides, PFOS, metals, invasive aquatic plants

Bell Pond

Tributaries Sampled:

None

Outlets Sampled:

None

In-Lake Locations Sampled:

Deep Site

Lake Quinsigamond

Tributaries Sampled:

Coal Mine Brook
Poor Farm Brook
Billings Brook (Shrewsbury)

Outlets Sampled:

Irish Dam (Grafton)

In-Lake Locations Sampled:

Coes Reservoir

Tributaries Sampled:

Tatnuck Brook

Outlets Sampled:

Coes Dam

In-Lake Locations Sampled:

North Site
South Site

Indian Lake

Tributaries Sampled:

Ararat Brook

Outlets Sampled:

Indian Lake Spillway

In-Lake Locations Sampled:

North Site
South Site

Bell Pond

Surface Area: 11 acres

Max Depth: 17.5 feet

Location: Bell Hill

Amenities: City beach, trails

Tributaries: Spring-fed

Interesting Fact: Bell Pond used to be a drinking water and fire protection water source for the City of Worcester! Today, the water is still very clean relative to other urban lakes.

Management Summary:

Prior to the creation of the Lakes and Ponds Program, there was no water quality management taking place at Bell Pond, as there were no known water quality concerns. The first ever monitoring was performed at Bell Pond in 2017, confirming visual assessments that the water quality was high, but that litter was a problem. In 2019, the Lakes and Ponds Program focused on using education and citizen science to elevate Bell Pond and the challenges of litter on health, recreation, and wildlife, in addition to programed semi-monthly monitoring.

Water Quality Summary:

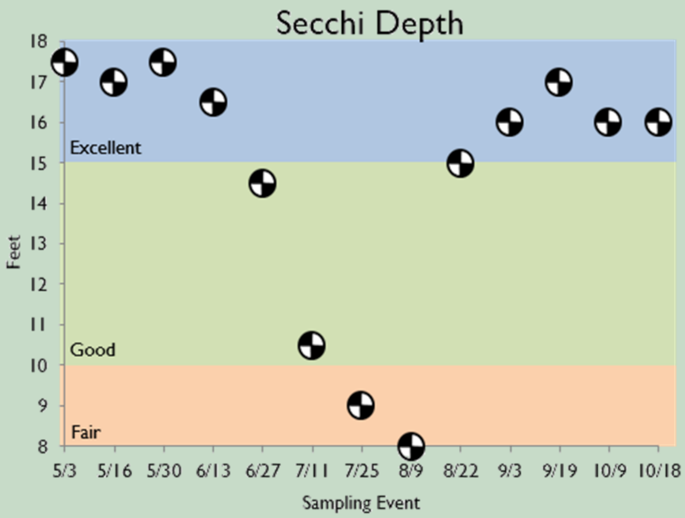
For most of 2019's sampling season, Bell Pond seemed to be following the same water quality trends that we witnessed in previous years. However, in September, we witnessed cyanobacteria around the pond's beach, presumably caused by geese.

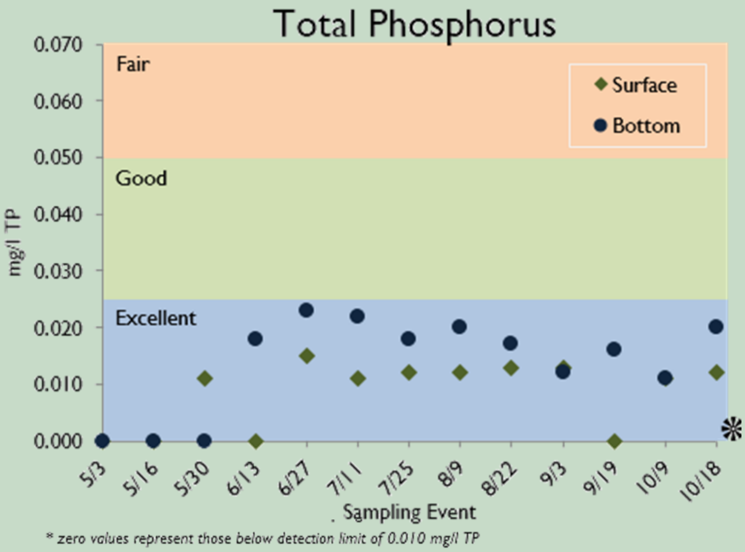
Clarity

For most of the sampling season, clarity at Bell Pond was considered "excellent" at over 15 feet of transparency. Only from mid-July through early– August did Secchi clarity drop into the "good" and "fair" category, and rebounded back to excellent by mid August.

Nutrients

Phosphorus levels in Bell Pond were considered "excellent" all season at both the surface and the bottom of the pond. Results were highest during the summer months, but results suggests little risk for harmful algal blooms to occur.



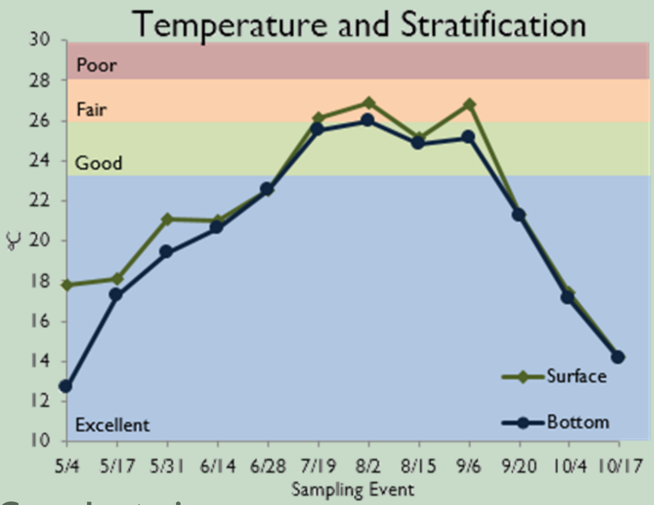


* *zero values represent those below detection limit of 0.010 mg/l TP*

Bell Pond *continued*

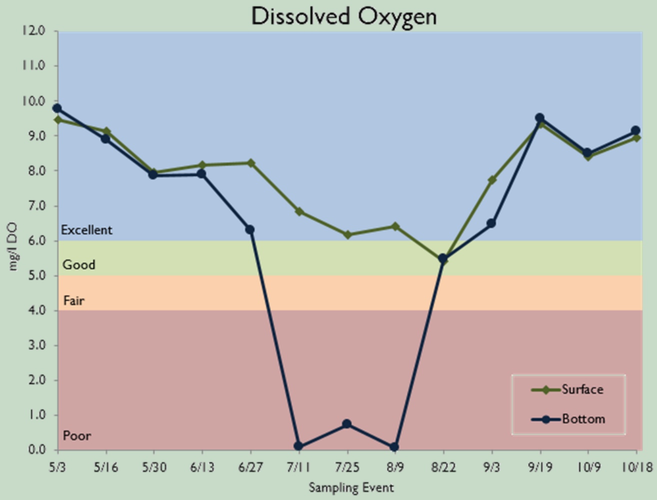
Temperature and Stratification

Temperature data suggests that Bell Pond is well mixed, with surface and bottom temperatures being very similar. Temperatures are considered "excellent" until July sampling events, when they reach the "fair" category for several events until late September. Given more nutrient inputs, these higher temperatures could drive harmful algal blooms.



Dissolved Oxygen

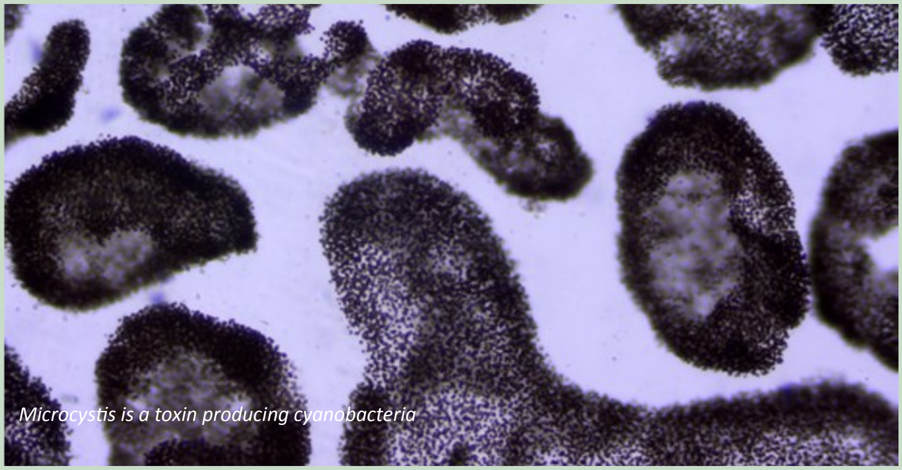
Oxygen concentrations are considered "excellent" at the surface of Bell Pond, apart from the 8/22 event, when it was considered "good". Concentrations at the bottom are considered "poor" in July and early-August. Profile data suggests this occurs in only the bottom foot of the pond. These results suggest that higher than desired temperatures are not negatively affecting oxygen availability.



Cyanobacteria

Bell Pond is sampled as part of the Worcester Cyanobacteria Monitoring Collaborative (WCMC). Because it has had historically low phosphorus levels, it was not considered "at risk" for harmful algal blooms. However, on September 14th, WCMC volunteers reported a green scum on the surface of the water right by the shoreline. Samples revealed the cyanobacteria *Microcystis*. The Lakes and Ponds program visited the lake soon after and found the bloom to have disappeared, and water quality to be back to normal. However, there were a lot of goose dropping present on the beach. This suggests that the bloom was caused by localized nutrient loading from goose droppings, but that the lake at large was not affected. This was the only cyanobacteria reported in 2019.

On September 14th, volunteers noted a scum line on the shore of Bell Pond

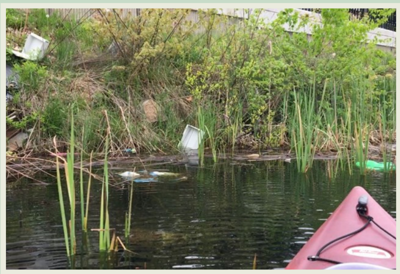


Microcystis is a toxin producing cyanobacteria

Bell Pond *continued*

Litter

Litter is an ongoing challenge at Bell Pond, and it can be frequently seen in and around the lake, both off of the foot-path and Belmont Street. While we do not yet have a way to quantify litter, the clear waters at the pond keep it in the front of our mind.



Bacteria

There were no closures at Bell pond due to bacteria in 2019. In fact, *E. coli* levels did not exceed 24 col/ml, all bathing season, and Bell pond is not threatened by bacteria.

Single day recreational threshold: *>235 col/ml*
5-test Geometric mean: *>126 col/ml*

Bacteria Results at Bell Pond Beach

Date	*E. coli* (col/ml)
25-Jun	4
1-Jul	16
8-Jul	24
15-Jul	8
22-Jul	<4
29-Jul	5
5-Aug	<4
12-Aug	20
20-Aug	4
27-Aug	12

Toxins

We did not find any concerning levels of toxins in Bell Pond. During both sampling events, there was no detection of VOCs, SVOCs, PCBs, TPHs, or pesticides. 10 metals were detected and listed below. All of these metals are naturally occurring in New England soils, and did not appear in quantities that would be of concern to human health in the water. Samples came back with low but consistent levels of PFAS, which is unusual because there is no known source of production in the area. Regardless, PFAS levels found in Bell Pond are well below the proposed drinking water standard of 20 ppt, and do not pose a threat to public health.

Bell	VOCs	SVOCs	PCBs	TPH	Pesticides	PFAS	Metals
13-Jun	*ND*	*ND*	*ND*	*ND*	*ND*	*9.57*	*10*
11-Jul	*ND*	*ND*	*ND*	*ND*	*ND*	*9.11*	*8*
						(ppt)	*(# detected)*

Metals detected: Aluminum, Arsenic, Barium, Calcium, Copper, Iron, Magnesium, Manganese, Potassium, Sodium

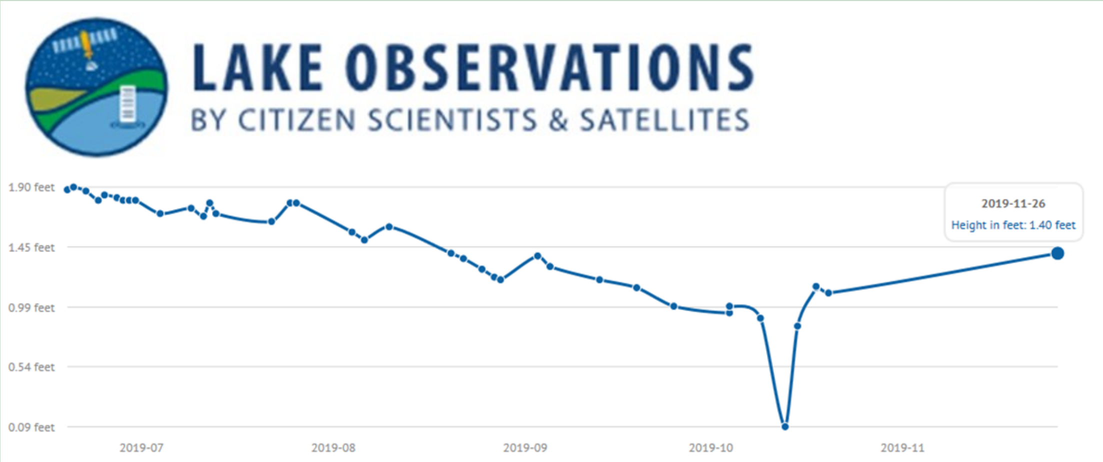
State of the Lake

Bell Pond maintains ***excellent water quality***. There were no closures due to bacteria, clarity is high, and phosphorus levels are low. However, our ability to enjoy this resource is compromised by the presence of ***litter*** and ***geese***. Litter is an eye sore, and can be harmful to human and ecological health. Geese can make a mess of the beach and contribute to localized harmful algal blooms that we witnessed in 2019.

In 2020, the Lakes and Ponds Program plans on continuing its semi-monthly monitoring program in order to ensure that high water quality is maintained. We will also continue to implement projects to build pride and advocacy in Bell Pond, because we believe that the more that Bell Pond is recognized by the community as a resource, the better care that people will take of it.

Bell Pond *continued*

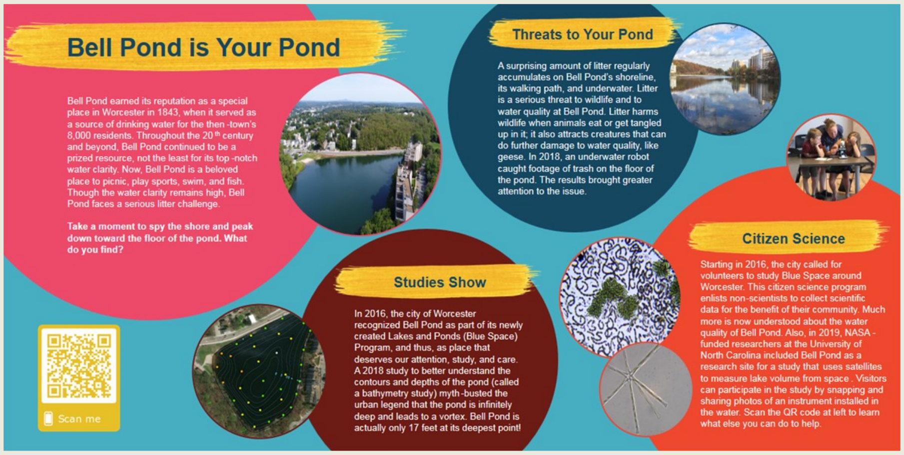
Ongoing Projects



The LOCCS Staff Gauge is located off Belmont Street

Citizen Science

Bell Pond is a part of a worldwide scientific study on freshwater storage! Since June, volunteers have submitted a total of 41 measurements via text message to a citizen science initiative spearheaded by the University of North Carolina and funded through NASA and called "Lake Observations by Citizen Scientists & Satellites". They have captured a drop in the water level of about one foot over the season While we believe this to be a natural cycle for the lake, more data will confirm this and other phenomenon there. Check out www.locss.org to learn more!



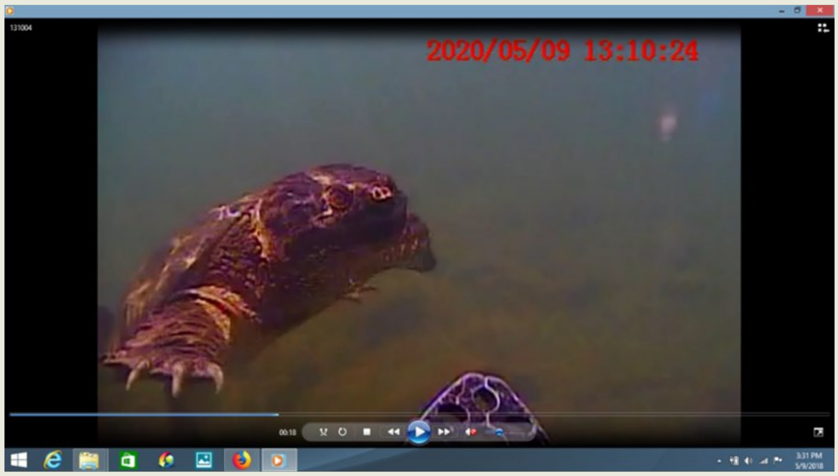
Educational Signage

In order to help people recognize how special a resource Bell Pond is, the Lakes and Ponds Program has teamed up with Worcester State University to design some educational kiosks that help promote the great qualities of Bell Pond, as well as some of the treats to recreation there, including geese and litter. We hope this will improve advocacy and pride in the site!

Projects for 2020

Educational Video Series

In 2018, the Lakes and Ponds Program used an underwater camera to document wildlife and litter accumulation in the bottom of Bell Pond with the intention to create an educational video for the City of Worcester YouTube channel. Over the past 6 months, this project has grown into a larger series called "The Blue Space Minute" which covers all topics regarding water quality in our lakes and ponds. New episodes can be found at: [https://www.youtube.com/user/cityofwoooffical.](https://www.youtube.com/user/cityofwoooffical)



Lake Quinsigamond

Surface Area: 375 acres

Max Depth: 75+ feet

Location: Eastern Worcester border

Amenities: 2 State beaches, public boat ramp

Tributaries: 7+ distinct streams

Interesting Fact: While it looks like a contiguous river, Lake Quinsigamond is actually a series of deep basins connected by relatively shallow water.

Management Summary:

The Lake Quinsigamond Commission began to implement an invasive aquatic plant management plan in 2018 in order to reduce the density of the six invasive aquatic plants currently found there. Being such a large lake, the work is ongoing, though extensive progress has been made. The Worcester Lakes and Ponds Program began regular monitoring of the lake in 2017 to collect data on nutrients, bacteria, and cyanobacteria, which have also been identified as threats to lake health, and which DPW&P is addressing.

Water Quality Summary:

One of the major water quality concerns going into 2019 at Lake Quinsigamond was for fecal bacteria. There had been a high number of state beach closures in 2018 at Regatta Point and Lake Park. Surprisingly, there was only one exceedance of recreational thresholds for one day in 2019, as well as other promising bacteria monitoring results. Invasive aquatic plant management efforts also appeared highly successful. However, some concerning trends around lake temperature and oxygen stratification also emerged, raising concerns about the fate of deep water nutrients.

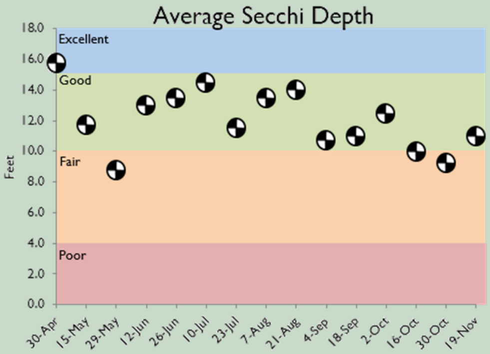
Bacteria

In 2018, the State beaches on Lake Quinsigamond, Regatta Point Beach and Lake Park Beach, were closed for most of the season because water samples there reported high levels of Enterococcus bacteria. Why levels were so consistently high, how bacteria were entering the water, and from what animal they came from were all questions of high concern in 2019. The City teamed up with the Lake Quinisgamond Watershed Association and the Lake Quinsigmamond Commission to develop a water quality monitoring program to help trace the source of the problem. Additionally, the City prepared to test the beaches for DNA biomarkers, which would determine the type of animal the bacteria came from and help to inform management. To the surprise of everyone, there was only one bacteria exceedance at Regatta Point Beach this past summer, on July 23rd. Subsequent testing showed that this was an acute event. Given that so little bacteria was present, the City was not able to take a biomarker sample. While we are unsure of why conditions have changed, there was no threat of bacteria at Lake Quinsigamond beaches in 2019.

Enterococcus	Most Probable Number (MPN)	
Date	*Lake Park*	*Regatta Point*
21-May	4	3
28-May	30	10
5-Jun	2	2
11-Jun	4	4
25-Jun	5	9
2-Jul	15	17
9-Jul	8	48
16-Jul	10	6
23-Jul	28	117
25-Jul	NA	44
6-Aug	2	37
13-Aug	1	11
21-Aug	5	59
28-Aug	2	20

Single day recreational threshold: >61 MPN
5-test Geometric mean: >35 MPN

Lake Quinsigamond *continued*



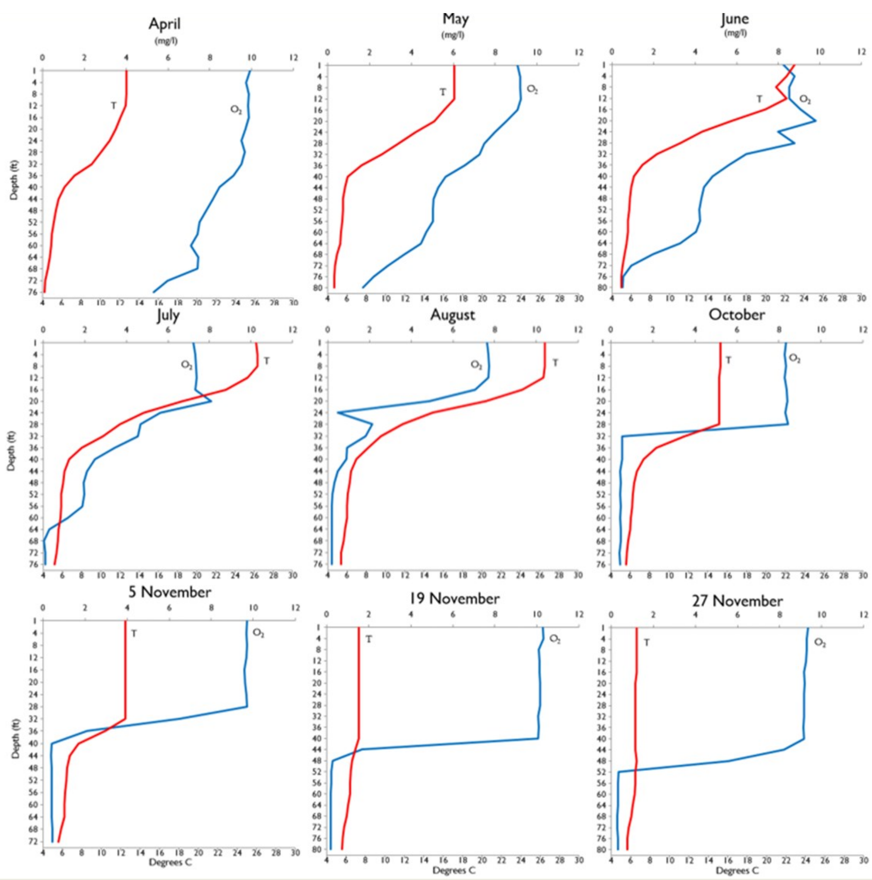
Clarity

Clarity results from the northern and southern sampling sites on Lake Quinsigamond were similar to each other for most of the sampling season. They ranged between 8 and 16 feet, with an average of around 12 feet in depth. They generally received a rating of "good". On two occasions results were in the "fair" category, but, in general, water clarity is very high in Lake Quinsigamond, suggesting high water clarity in the upper portion of the lake.

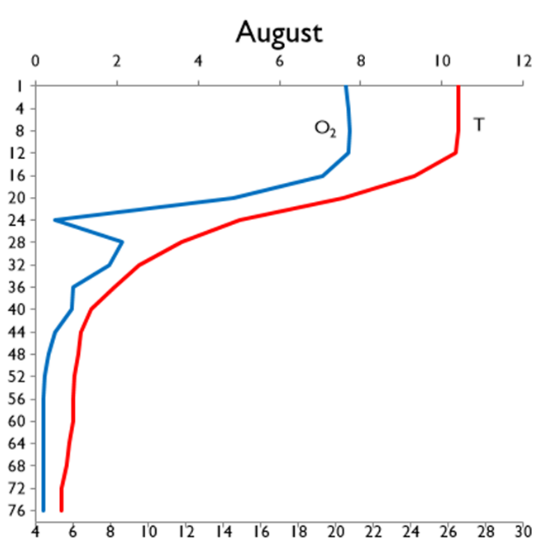
Water Temperature and Stratification

As a deep lake, Lake Quinsigamond experiences stratification during the summer months, causing the reduced mixing of oxygen and nutrients between the warmer upper layers and lower colder lower layers. The bottom layers of the lake remained between 4 and 6 ^{O}C for the entire season, even while the surface increased in temperature to a maximum of 26.4 ^{O}C in August, putting it into the "Poor" category for a waterbody that is supposed to support cold water fish species. Cold water fish, such as the rainbow trout which is stocked twice annually, struggle in temperatures higher than 20 ^{O}C. Usually, these fish will descent into cooler, deeper water if it gets to warm at the surface.

Oxygen deprivation in the water column was first measured in June at a depth of 60 feet, and increased to 21 feet in August. As the weather cooled, mixing was able to resume, but oxygen deprivation still occurred at 49 feet when last measured at the end of November. Our April 2019 results do suggest that the lake mixes completely by spring. Unfortunately for our trout, in August, the water was over 20 ^{O}C until around 20 feet deep, meaning that there was very little territory available that met both temperature and oxygen requirements. This phenomenon, known as "the squeeze", can put stress on cold water fisheries, suggesting fish kills may be possible during extreme heat conditions.



Rainbow trout, like many cold water fish, have a temperature tolerance of about 20° C.

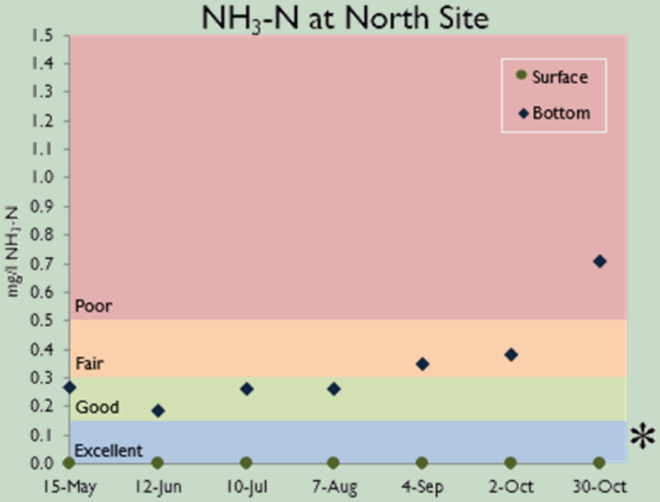


Lake Quinsigamond *continued*

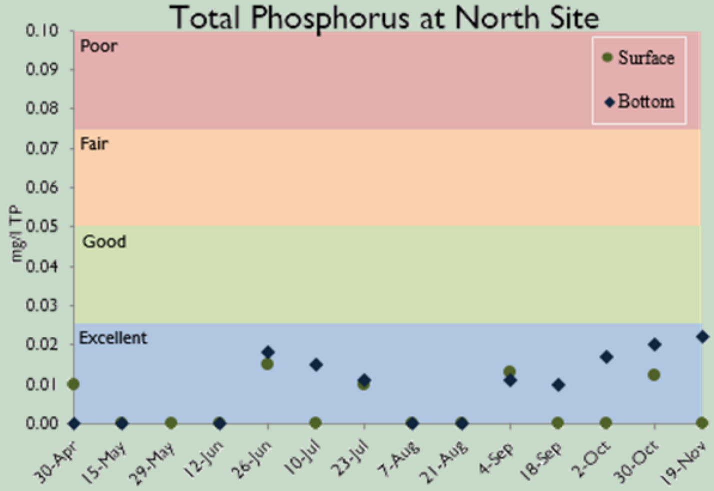
Nutrients

Excessive nutrients may be a concern at Lake Quinsigamond. Besides from possibly affecting fish through heat stress and oxygen deprivation, stratification may contribute to the buildup of nutrients in the lower layers of the lake, as aerobic bacteria are unable to recycle it to forms that are usable by plants. Ammonia (NH_3) results at the Lake were rated as "excellent" (below 0.15 mg/l), or even below detection limits, at the surface in both in-lake sampling locations. Levels at the bottom, however, increased throughout the season, from "good" in May through "fair" and then to "poor" in the fall months. This seems to be a more severe problem at the south site than at the north site. These levels are harmful to fish and other wildlife, though it is unclear at what depth the accumulation reaches critical levels. We expect that this is the result of the inability of aerobic microbes to perform recycling processes at depth. Under more oxygenated conditions, natural bacteria would convert these N compounds into less toxic forms that can be absorbed by plants and other aquatic organisms.

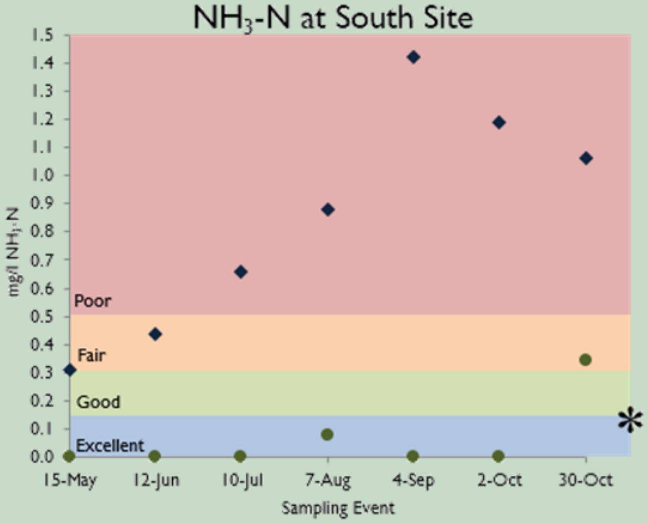
NH_3-N at North Site



Total Phosphorus at North Site

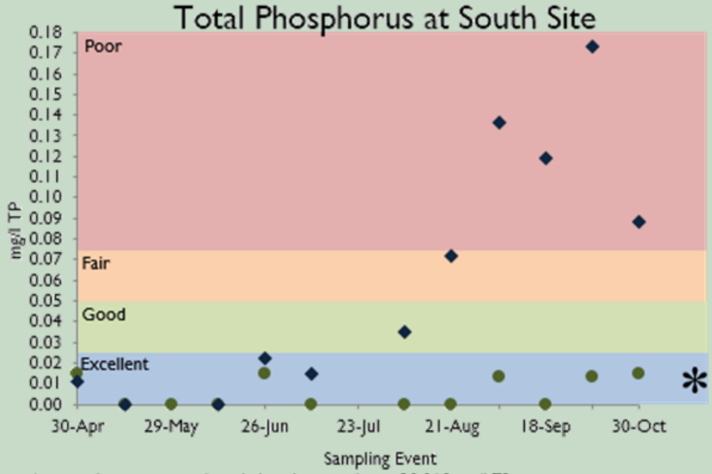


NH_3-N at South Site



* *zero values represent those below detection limit of 0.075 mg/l NH_3*

Total Phosphorus at South Site



* *zero values represent those below detection limit of 0.010 mg/l TP*

This pattern is slightly different when looking at total phosphorus (TP). At both the south and north site, TP concentration do not exceed 0.025 mg/l (and therefore considered "excellent") at the surface all season, with no TP detected on most days, similar to what we saw with NH_3. At the south site, we also see an increase we see the expected buildup of TP over the course of the season, starting in the "excellent" category and increasing to the "poor" category. This is particularly concerning in the late fall, when the temperature begins to drop and the lake begins to mix again, as this P could be made available to algae and cyanobacteria at the lake surface, causing blooms. The TP trend does not occur at the north site, where TP concentrations at the bottom are rated as "excellent" for the entire season.

Lake Quinsigamond *continued*

Toxins

We did not find concerning levels of any toxins in Lake Quinisgamond. We collected samples for almost 200 compounds on July 24th and October 4th. On neither occasion was there detection of VOCs, SVOCs, PCBs, TPH, or pesticides. 10 metals were detected and listed below. All of these metals are naturally occurring in New England soils, and did not appear in quantities that would be of concern to human health in the water. Samples came back with low but consistent levels of PFAS, consistent to what was found in other waterbodies with no known sources, suggesting these are ambient concentrations. These PFAS levels are well below the proposed drinking water standard of 20 ppt, and do not pose a threat to public health.

Quinsig	VOCs	SVOCs	PCBs	TPH	Pesticides	PFAS	Metals
24-Jul	ND	ND	ND	ND	ND	11.1	10
4-Oct	ND	ND	ND	ND	ND	11.0	9

Metals detected: Aluminum, Arsenic, Barium, Calcium, Copper, Iron, Magnesium, Manganese, Potassium, Sodium

Invasive Aquatic Plants

Lake Quinsigamond is impaired by invasive aquatic vegetation. A survey in 2017 concluded that 310 acres of Lake Quinisgamond and Flint Pond were affected by six different invasive species, including Eurasian milfoil, fanwort, curly-leaf pondweed, sacred lotus, brittle naiad, and variable leafed pondweed. Previously, the Lake Quinisgamond Commission had practiced a 30-inch drawdown of the water in the winter months in an attempt to kill unwanted shoreline vegetation through exposure to harsh winter conditions. Herbicide treatments commenced in 2018 in the northern and southern portion of the lake. The middle portion of the lake was not treated because of concerns about the affect of the herbicides on a suspected endangered plant there.

Management continued in 2019, including the drawdown and application of three herbicides based on vegetation present in the area: diquat dibromide, flumioxazin, and glyphosate (all approved by town and city Conservation Commissions). A post-treatment survey was conducted on October 8th and 9th, revealing positive results: a 69 acre reduction in plant cover over 2018, with a 40% decrease in the extent of variable-leaf milfoil, a 75% decrease in Eurasian milfoil, an 85% decrease in sacred lotus, an 87% decrease in fanwort, and a 100% decrease in curly leaf pondweed. Significant progress is therefore being made with invasive plant management.

Eurasian Milfoil
Myrophyllum spicatum

Fanwort
Cabomba caroliniana

Curly-leaf pondweed
Potamogeton crispus

Sacred lotus
Nelumbo nucifera

Brittle naiad
Najas minor

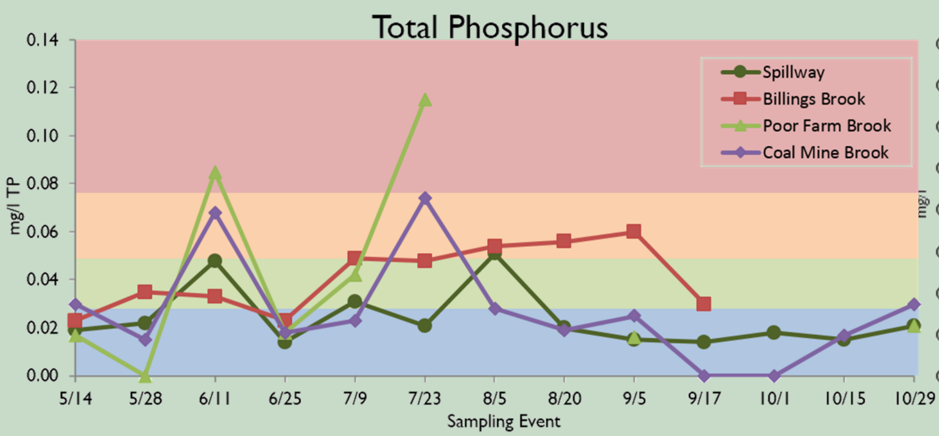
Variable-leaf milfoil
Myriophyllum heterophyllum

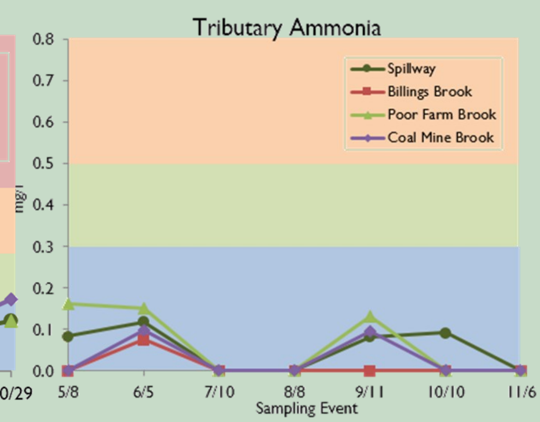
Lake Quinsigamond *continued*

Tributaries and Outflows

Lake Quinisgamond has a number of tributaries that carry rain– and stormwater to it, as well as groundwater flow. The Lakes and Ponds Program sampled three of these tributaries. Coal Mine Brook and Poor Farm Brook are Coldwater Fishery Resources (CFRs), meaning that they can support certain species of cold water fish in certain sections of their length. We also collected samples in the tributary Billings Brook in Shrewsbury, and at the lake outlet, the Irish Dam, in Grafton. Samples at the outlet are assumed to reflect the condition of water quality in Flint Pond. Ammonia (NH_3) concentrations at all of these locations were below 0.02 mg/l for the entire sampling season, therefore considered "excellent". Nitrate (NO_3) levels are also generally not concerning, even while inconsistent, with the majority of the results being less than 1 mg/l, which is considered normal and healthy in freshwater streams. N-based nutrients are therefore not considered problematic in Lake Quinsigamond's tributaries.

Total Phosphorus (TP) levels in these locations were also inconsistent, most likely due to rain events washing nutrients from the streets and roofs into catch basins. Peaks can be seen in all three tributaries on 5/28 and 7/23, when the TP result jump from "excellent" to "fair" and "poor" categories. While Coal Mine Brook tends to have "excellent" levels of TP during most sample events, Billings Brook seems to have a higher ambient concentrations, in the "good" and "fair" range. Poor Farm Brook is often dry in the summer months, so samples can not be taken, but when we can sample is, it seems subject to higher levels of TP during rain events. TP levels at the Spillway tend to stay in the "good" and "excellent" range for most of the season, giving reason to believe that the water in Flint Pond does not have challenges resulting from excessive TP either.





State of the Lake

While still safe for recreation, Lake Quinisgamond's ***water quality and ecology are threatened*** because of ***bacteria***, ***invasive aquatic plants***, and ***nutrients***. While fecal bacteria exceedances and closures at the beaches were fewer this year than in previous years, it is too soon to know that they won't return. While a management plan is in place to reduce invasive plant density, there is still progress that to be made and more education is needed for visiting boaters. Finally, the accumulation of nutrients in the depths of the lake have the potential to cause harmful algal blooms when lake mixing occurs in the fall.

In 2020, the Lakes and Ponds Program will continue to track bacteria sources in the lake with local partners, collaborate with the Lake Quinisgamond Commission for the management of aquatic plants, and implement nutrient interception devices to reduce the impact of stormwater on nutrient loading.

Lake Quinsigamond *continued*

Ongoing Projects

Bacteria Source Tracking

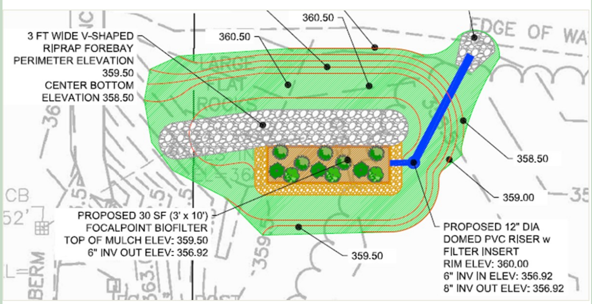
The absence of bacteria exceedances at the beach this year was great news for recreation. However, it is always concerning when a problem fixes itself and you don't know why. This year, the Lakes and Ponds Program, together with the Lake Quinsigamond Watershed Association (LQWA) and the Lake Quinsigamond Commission (LQC), received a grant from Mass DEP to continue and expand its bacteria tracking program. LQWA and LQC will hire a water quality monitor to test 7 sites weekly during the summer months. The City will provide training, technical assistance, and the analytical services to the project. We hope that this program will not only shed some light onto potential bacteria hot spots, but also get more people interested and involved at Lake Quinisgamond.

Continuous Water Quality Monitoring

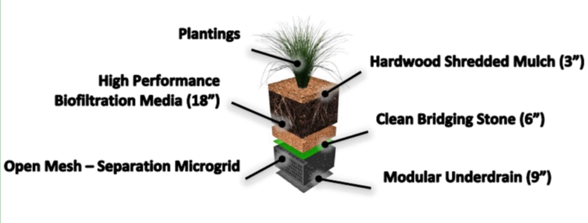
We understand that nutrients that build up in the bottom of the lake in the spring and summer may be problematic for water quality once the lake begins to mix freely again in the fall. However, because of how deep and large the lake is, it is sometimes difficult to know when these changes are happening. One potential solution is the use of continuous monitoring buoys. These solar-powered, Frisbee-sized devices can collect and remotely deliver data on important water quality parameters like water temperature, and pigments associated with cyanobacteria every 15 minutes, 24 hours a day. Previously, this type of technology was inaccessible to small municipalities due to its large price tag. However, advances in monitoring equipment has allowed the price to fall. The data collected from this device would be displayed on a dashboard and give the Lakes and Ponds Program high quality data to inform management decision. The City will work with the Lake Quinisgamond Commission and Donahue Rowing Center to select sites in the northern and southern portions of the lake that would not interfere with navigation. We hope to have the buoys installed by early summer of 2020.

Stormwater Controls

At Lake Quinisgamond, much of the nutrient pollution that enters the waterbody comes from stormwater outflows into tributaries. One low cost, natural method for treating these nutrients is to let stormwater filter through the ground before entering the lake. Last year, the Lakes and Ponds Program and the Worcester Sewer Division identified a particularly concerning storm drain catch basin and outlet into the Lake near Coal Mine Brook. This site was selected to design and permit a biofiltration unit to help treat the stormwater there.



The project uses native plants in layers of soil and rocks to filter the stormwater, removing nutrients and bacteria. The natural capacity of the system is augmented by an underdrain. There will also be an educational kiosk to teach people about stormwater management.



Coes Reservoir

Surface Area: 90 acres

Max Depth: 16 feet

Location: Webster Square/Columbus Park

Amenities: City beach, walking trails, playground

Tributaries: Tatnuck Brook

Interesting Fact: Coes Reservoir was created when Tatnuck Brook was dammed for hydropower for the Coes Knife Factory, where the monkey wrench was invented!

Management Summary:

Water quality management at Coes Reservoir began recently, when it came to the attention of the Tatnuck Brook Watershed Association that the invasive aquatic plant, the water chestnut, was aggressively spreading in the northern cove. As more monitoring took place, the management plan has expanded from the mechanical harvesting of these plants to include more techniques and target species as new threat emerged. Currently, Coes is managed for three invasive aquatic plants and cyanobacteria, using a mixture of mechanical and chemical treatments.

Water Quality Summary:

Going into 2019, the Lakes and Ponds Program was focusing on implementing changes in its invasive aquatic plant management plan in order to tackle a new species, fanwort, discovered there in late 2018. The new herbicide treatment kept target species back during the swimming season, but the efficacy won't be fully known until 2020. The Lakes and Ponds Program also monitored and treated for cyanobacteria, and there were no recorded exceedances or closures, although a late season bloom was spotted at the end of October. Additionally there were not closures for fecal bacteria at the beaches, and no threat of industrial toxins present in the reservoir.

Bacteria

There were no closures at the public beach at Coes Reservoir due to exceedances in fecal bacteria indicators. All 10 of the samples analyzed for *E. coli* at Binienda Beach came back below the recreational threshold of 235 col/ml, and most were below 100 col/ml. Bacteria contamination is therefore not a concern at the public beach. This past year, the Blackstone River Coalition also collected *E. coli* samples on Tatnuck Brook where it crosses Mill Street near Tatnuck Square, right near a storm drain outlet. What they found was that this area had higher levels of *E. coli*, often exceeding the recreational threshold, though not high enough to suggest a sanitary sewer misconnection. It is expected that bacteria at this location is diluted by other water sources or dies off before making it to Coes Reservoir to affect beach samples.

Bacteria Results at Binienda Beach	
Date	*E. coli* (col/ml)
25-Jun	4
1-Jul	60
8-Jul	56
15-Jul	20
22-Jul	16
29-Jul	60
5-Aug	8
12-Aug	112
20-Aug	224
27-Aug	28

Tatnuck Brook at Mill Street	
Date	*E.coli* (col/ml)
20-Apr	291
11-May	344
1-Jun	649
8-Jun	1986
15-Jun	326
22-Jun	93
29-Jun	>2417
6-Jul	214
13-Jul	727

Single day recreational threshold: >235 col/ml
5-test Geometric mean: >126 col/ml

Coes Reservoir *continued*

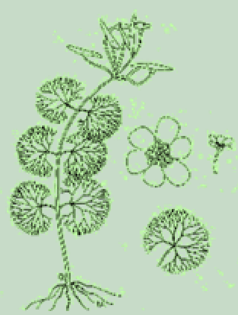
Invasive Aquatic Plants

Coes Reservoir is afflicted by three invasive aquatic plants: water chestnut (*Trapa natans*), Eurasian milfoil (*Myrophyllum spicatum*), and fanwort (*Cabomba caroliniana*). Water chestnut is found in primarily the northern portion, blocking access to the water from the shoreline there. It is a particularly challenging plant to eradicate because it drops seeds that can survive up to 10 years in the sediment of the lake. The City has dedicated itself to the long term management of this plant using a mechanical harvester, which, much like a floating lawnmower, cuts and collect these plants from the surface of the water. We contracted the harvester to remove plants for about three weeks in early July. Volunteers from Tatnuck Brook Watershed Association conducted a hand pulling of water chestnuts to gather plants in shallower areas that were missed by the harvester on August 3rd, and a treatment of Clearcast, an herbicide specific for water chestnut, was applied on August 21 to ensure that all remaining plants were killed.

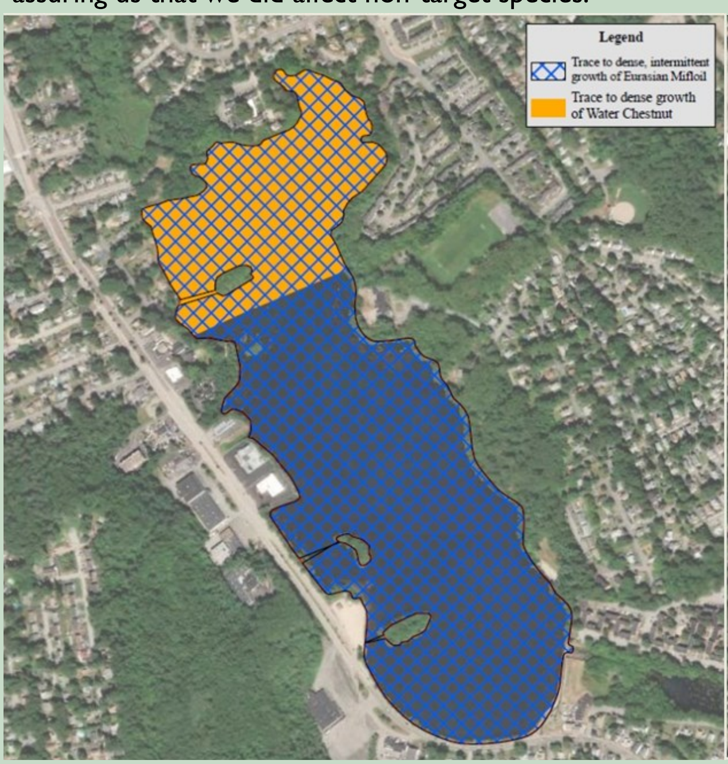
Prior to 2018, Eurasian milfoil was found throughout the entire reservoir, making swimming difficult in the late summer. Also in 2018, we discovered fanwort in the upper portion of the reservoir. Milfoil and fanwort reproduce through fragmentation. When little pieces are cut off, they can self propagate in a new location. For this reason, a harvester is not an ideal method for removing them. The City contracted the application of the herbicide Sonar in 2019 for or the first time. Unlike the previous herbicide that we had used there, which was a contact herbicide that only killed foliage, Sonar is a systemic herbicide that will kill the roots of the plant, preventing it from growing back the following year and reducing the need to treat again in 2020. Sonar applications were applied on Coes Reservoir on June 28th, August 24th, and September 24th to ensure that the necessary water concentration was maintained.

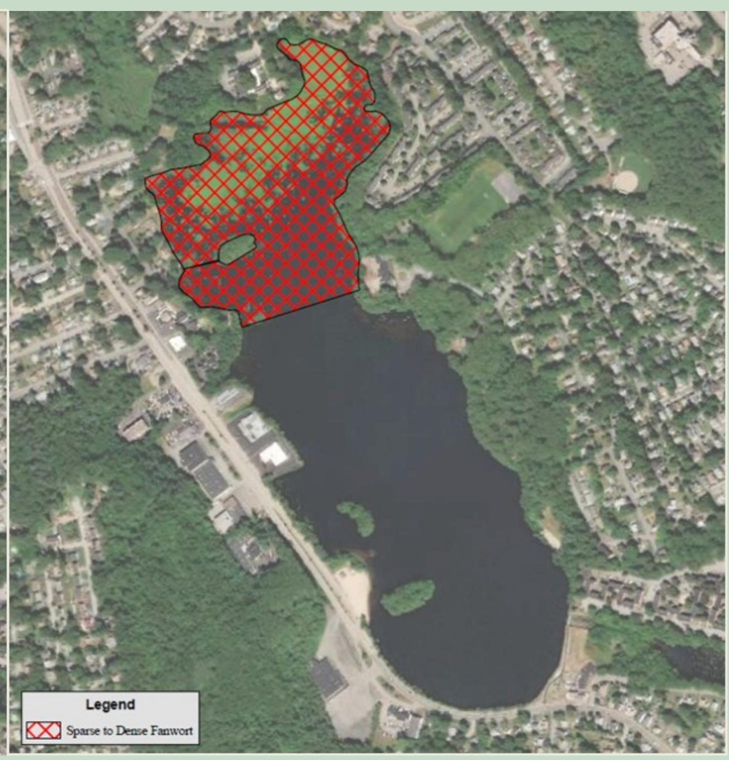
In early October, an aquatic plant survey was performed and there was no occurrence of either milfoil or fanwort at Coes. In the northern portion of the Reservoir, water chestnut was observed in trace to sparse densities. Native waterlily species and water shield were also observed, assuring us that we did affect non-target species.

Water Chestnut
Trapa natans



Fanwort
Cabomba caroliniana



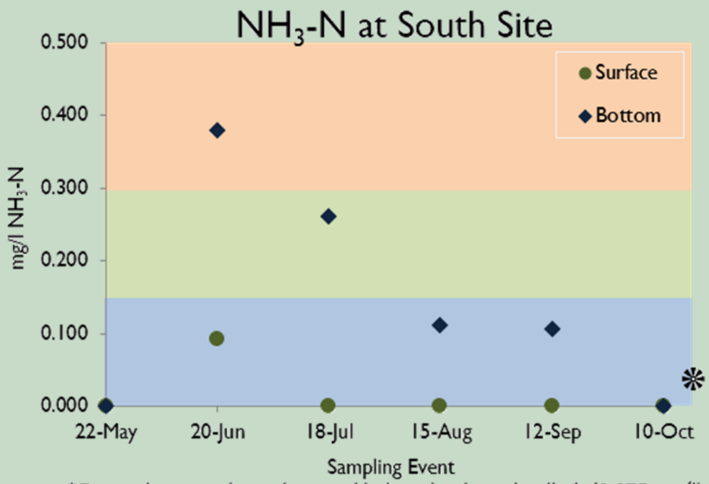


Coes Reservoir *continued*

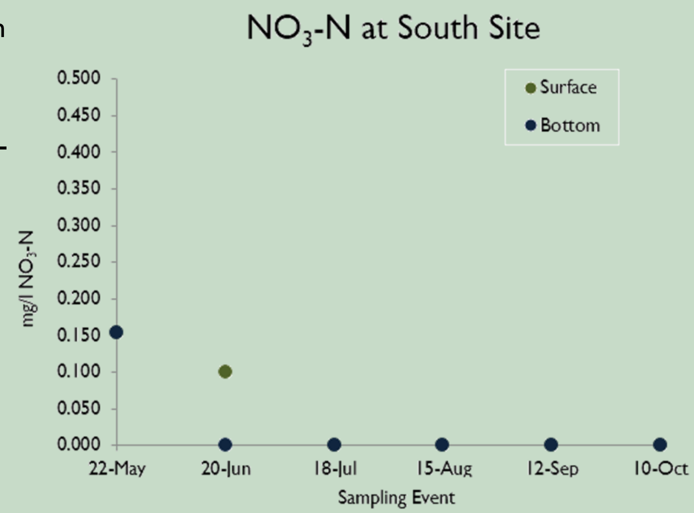
Nutrients

The City of Worcester measured NO_3 and NH_3 on the surface and the bottom of Coes Reservoir monthly and TP twice monthly during the sampling season. In general, the results from both the north and south site were comparable. NO_3 levels were below the detection limit of 0.050 mg/l for most of the sampling season at both the surface and the bottom, and never rose above 0.15 mg/l. These results are even lower than results we observed in 2018. NH_3 results were rated as "good" or "excellent" for the entire sampling season, except for on June 20th, when bottom readings at the south site was considered "fair", and even while the surface had an "excellent" rating of 0.10 mg/l.

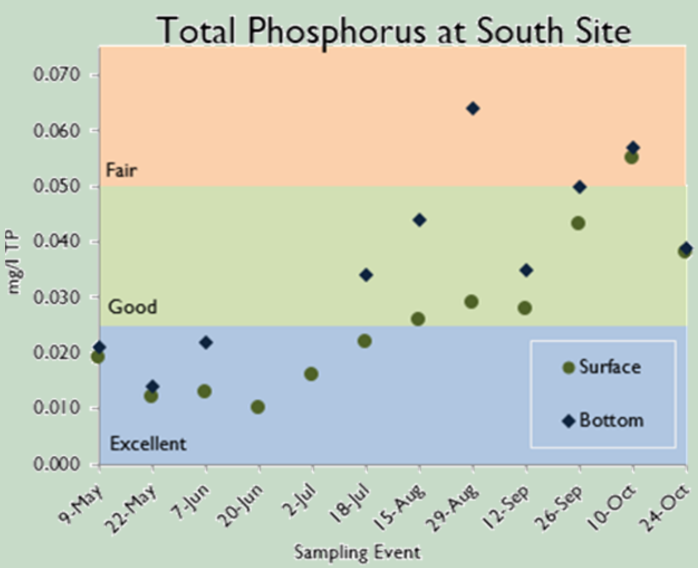
TP levels in Coes Reservoir increased throughout the 2019 sampling season at both the north and south sites. Both surface and bottom sample results were rated as "excellent" until around mid July, when they entered the "good" category, and the "fair" category by the beginning of October. Curiously, levels decreased back to "good" for the final sampling event on October 24th. In general, concentrations at the bottom of the water column are higher than those at the surface. This accumulation of P is concerning as it has the potential to promote the growth of cyanobacteria when paired with high temperatures. We saw cyanobacteria densities begin to rise in mid July, even when TP was still considered to be in the "excellent" range at the surface, while the temperature peaked at "fair". We will therefore continue to monitor these two factors closely.

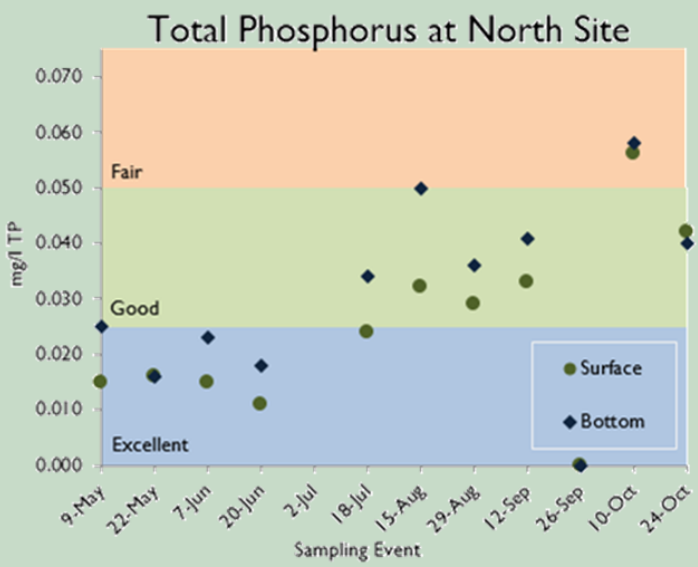


*Zero values are those that read below the detection limit (0.075 mg/l).



*Zero values are those that read below the detection limit (0.050 mg/l).

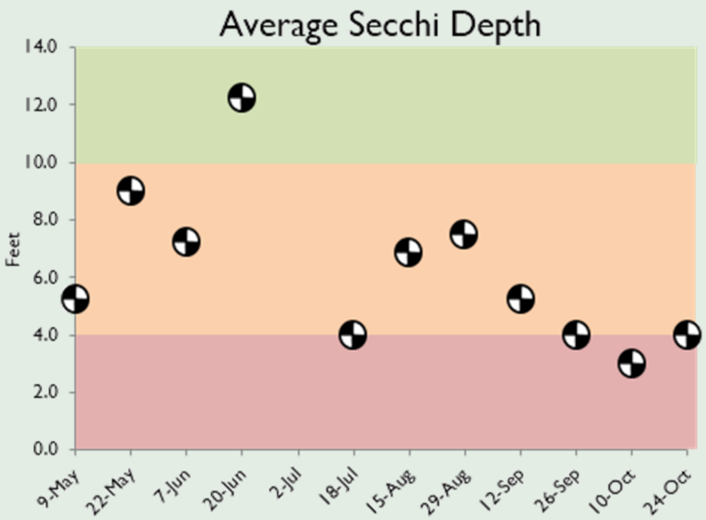




Coes Reservoir *continued*

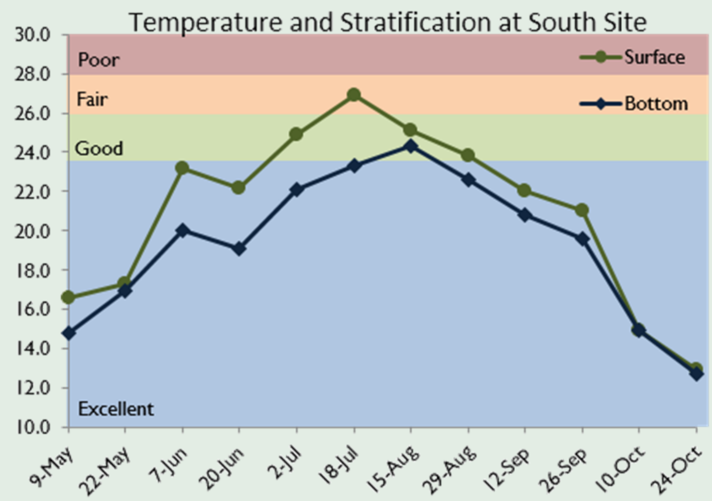
Clarity

Coes Reservoir was tested for Secchi clarity at the two in-lake locations. Readings were very similar in each location, however, Secchi clarity was slightly higher in the south site than in the north site. Average water clarity ranged from 3.5 to 12.5 feet in depth, but is generally between 4 and 10 feet, and as such rated "fair". On only one occasion during the sampling season did the clarity reach the "good" range. Reduced clarity at Coes seems to come from both algae and dissolved organic materials that release tannins and turn the water tea colored.



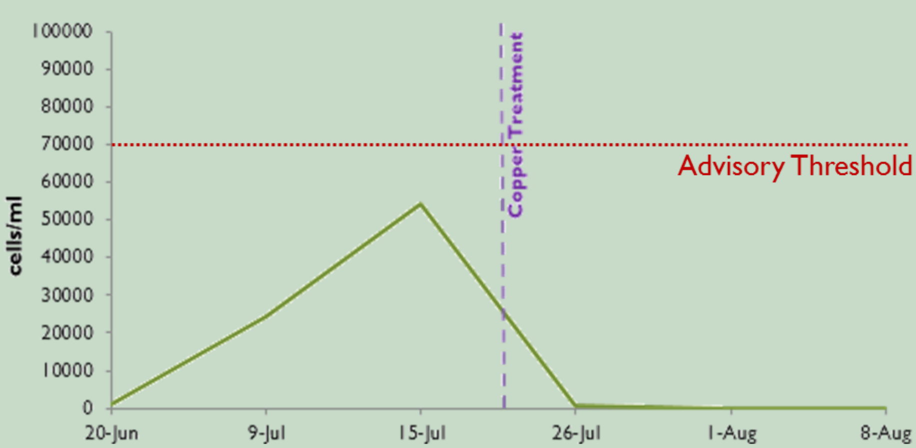
Temperature and Stratification

Temperature at the surface and bottom of Coes Reservoir increased throughout the season, peaking at the surface at about 27 °C on July 18th and around 24 °C on the bottom the following sampling date on August 15th, before going back down. Most of the temperature readings at the bottom were rated "excellent", apart from the August 15th event, when it was "good". At the surface, the temperature was in the "excellent" category until July 2nd, and then starting September 12th. It was rated "good" or "fair" during these other summer months, creating conditions that may be stressful to fish or promoting HABs.



Cyanobacteria

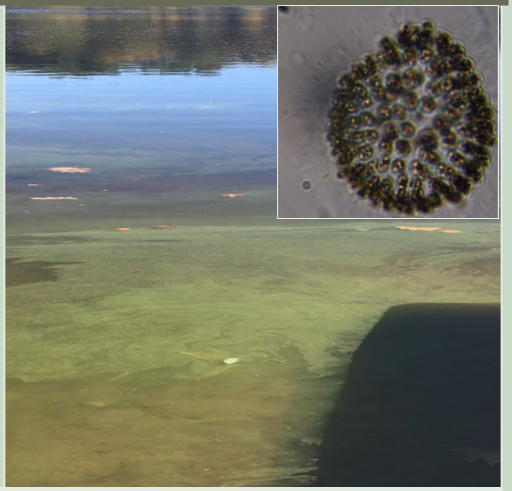
There were no closures at Coes Reservoir due to cyanobacteria in 2019. In 2017, the Lakes and Ponds Program determined that Coes Reservoir was at risk for HABs caused by high densities of cyanobacteria. Since then, we have contracted the collection of cyanobacteria samples at the beach area ever two weeks during the summer months in order to be able to respond to rising densities before they reach the advisory threshold for closing a waterbody. Concentrations remained fairly low from the end of June through early July, but showed signs of increasing based on results from July 15th, which recorded about 55,000 cells/ml. Using this data, we decided to apply a treatment of the algaecide copper sulfate on July 23rd. Results from the next sample taken on July 26th indicate that the treatment was successful at bringing down the concentration to almost zero, where it remained through the first week of August. Given these results and the end of the swimming season at Coes, sampling ceased for the reminder of August. While there is a possibility of a bloom at Coes, the current management plan seems adequate for protecting public health from cyanotoxins.

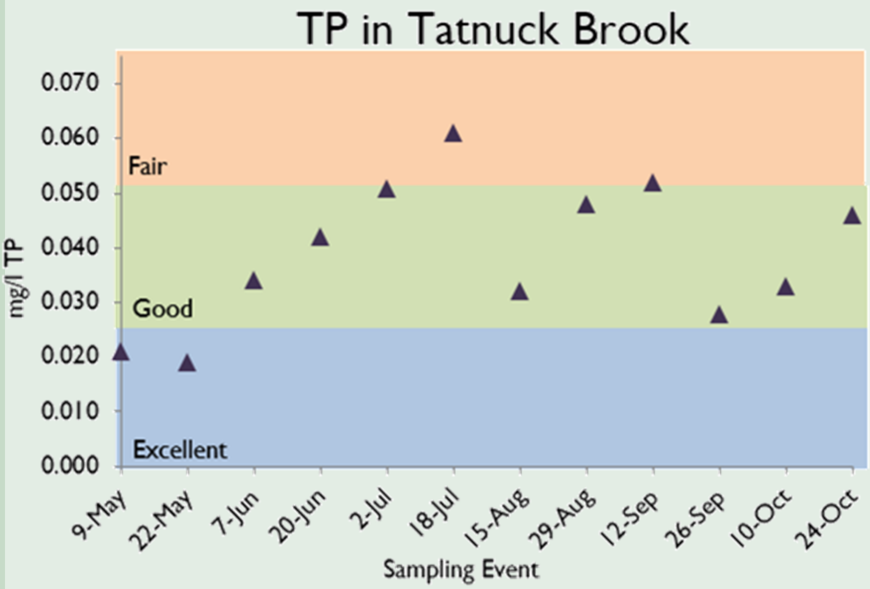


Coes Reservoir *continued*

Late season scum

While cyanobacteria density testing continued until the end of the bathing season without any exceedances or visual indication of an HAB, there was a scum mat observed at the shoreline near the beach in late-October during a routine water quality sampling event. Initial in-house microscopy identified the organism to be *Woronichinia*, a cyanobacterium. However, when a sample was collected for an official count the next day, the water was reported to be a brown color, and the sample came back dominated by diatoms, which are not considered harmful at our lakes. Like at Bell Pond, we had witnessed a quick, localized bloom, that we only saw because we were in the right place at the right time. Luckily, because the beach was closed, it is unlikely that anyone was directly exposed to it.





Tributaries

At Coes Reservoir, the major natural tributary is Tatnuck Brook, a cold water fishery resource (CFR). Tatnuck Brook had total phosphorus concentrations that ranges from 0.019 to 0.061 mg/l throughout the sampling season, representing a range of ratings from "excellent" to "fair" for a tributary. The highest concentrations recorded occurred on days following major rain events, suggesting that most of the TP entering Tatnuck Brook is stormwater. Dissolved oxygen levels in the brook were consistently "excellent", above 6 mg/l, and temperatures also generally stayed in the "excellent" category, below 23°C.

Toxins

We did not find concerning levels of any toxin in Coes Reservoir We collected samples for industrial contaminants on July 12th and two months later on September 12th. On both occasions, there was no detection of VOCs, SVOCs, PCBs, TPH, or pesticides. 11 metals were detected, 10 of which were similar to those found at other lakes and ponds, but also including low levels of zinc on one occasion. All of these metals are naturally occurring in New England soils, and did not appear in quantities of concern to human health in the water. Samples came back with higher levels of PFAS than other waterbodies. While still not a level of concern for recreation, it is curious that Coes has significantly higher concentrations then other lakes.

Coes	VOCs	SVOCs	PCBs	TPH	Pesticides	PFAS	Metals
12-Jul	ND	ND	ND	ND	ND	34.7	11
12-Sep	ND	ND	ND	ND	ND	38.5	10

Metals detected: Aluminum, Arsenic, Barium, Calcium, Copper, Iron, Magnesium, Manganese, Potassium, Sodium, Zinc

Coes Reservoir *continued*

State of the Lake

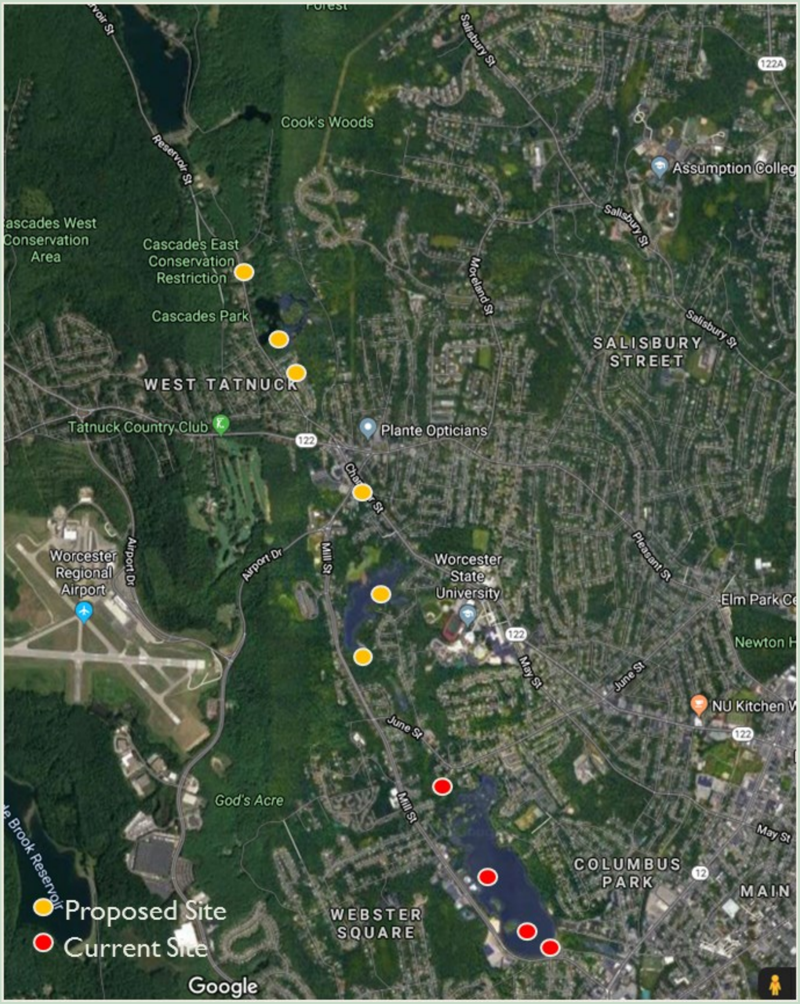
While still safe for recreation, Coes Reservoir's ***water quality and ecology remain threatened*** because of ***cyanobacteria***, ***nutrients***, and ***invasive aquatic plants***. The good news is that our management plans seem to be working to keep these threats under control. Nutrient levels in the reservoir increase in both in lake sampling locations throughout the sampling season, presumably because of external loading through stormwater inputs from places like Tatnuck Brook. Less-than-"excellent" water temperatures in the reservoir in the summer months give cyanobacteria some good growth conditions, and we predict that, without intervention with an algaecide treatment, there would have been a bloom at Coes Reservoir. Likewise, management of water chestnut, milfoil, and fanwort keeps ecological and recreational function high in the lake. Additionally, there were no closures due to fecal bacteria indicator exceedances, and there were no considerable levels of toxins in the water.

In 2020, the Lakes and Ponds Program will continue to examine nutrient dynamics, and other indicators in Tatnuck Brook and its impoundments in partnership with the Tatnuck Brook Watershed Association.

Ongoing Projects

Watershed Sampling Collaboration

Coes Reservoir is the last Worcester impoundment on the Tatnuck Brook, but this waterway actually enters the City in the northwest from the much more rural Town of Holden, right from the Holden II Worcester drinking water reservoir. From there, it crosses the Worcester landscape, which becomes increasingly urban, and occasionally pauses in several other impoundments before it gets to Coes Reservoir. These include Cooks Pond, Patch Reservoir, and Patch Pond. We know from conductivity data collated this past year by Worcester State students, in addition to *E. coli* data, that water quality changes over this landscape, and we cannot assume that the water quality results we see in Coes apply to the other lakes. In 2020, the Lakes and Ponds Program will team up with Tatnuck Brook Watershed Association to train volunteers to take several of the same samples that the City is currently taking at Coes throughout this stretch of brook. This way, we will have a better understanding of how water quality changes throughout the watershed, which will better inform management at these other locations.



Indian Lake

Surface Area: 190 acres

Max Depth: 17 feet

Location: Greendale/Northern Worcester

Amenities: 2 City Beaches, Public Boat Ramp

Tributaries: Ararat Brook

Interesting Fact: Indian Lake was originally only 90 acres, and was expended to over 200 in the 1800s to provide consistent water to the Blackstone Canal. The lake was reduce to its current size when I-190 was built.

Management Summary:

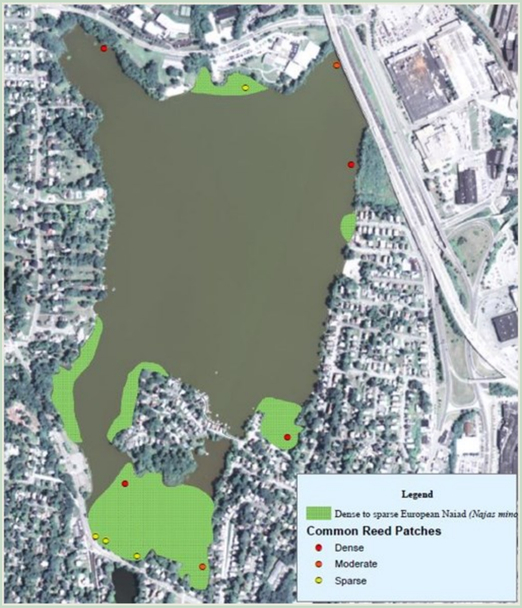
As such an important recreational resource in the City of Worcester, the water quality of the lake has been a high priority for some time. Previously, Indian Lake has relied heavily on chemical means to combat cyanobacteria, and a combination of a drawdown and chemical treatments to manage invasive aquatic plants. Moving forward, the City would like to move away from performing in-lake chemical treatments.

Water Quality Summary:

In its long management history, Indian Lake has oscillated between periods of dominance by aquatic plants and algae. Today, Indian Lake is listed on the 2016 Integrated List of Waters for invasive aquatic macrophytes including Eurasian Milfoil (*Myriophyllum spicatum*). Due in part to high concentrations of phosphorus (P) entering from the watershed, primarily through Ararat Brook, the Lake experiences high densities of cyanobacteria, or blue green algae, during the summer months. Thankfully, the toxins that cause cyanobacteria to be dangerous to public health, have not been detected in significant concentration by the Lakes and Ponds Program. The Lakes and Ponds Program is working to develop a chemical-free approach to dealing with both of these challenges, and is optimistic that is can be done. Indian Lake is not subject to chronic beach and lake closures due to fecal bacteria exceedances, and there was no evidence of harmful levels of industrial contaminants in the water samples analyzed this past summer.

Invasive Aquatic Plants

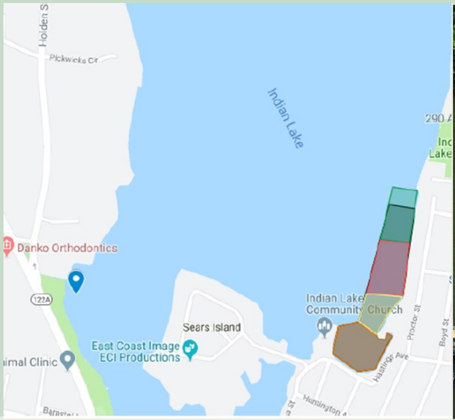
Indian Lake has been documented to have three invasive aquatic plants: Common reed, Eurasian milfoil, and brittle naiad. During the 2017 season, little nuisance aquatic vegetation was observed apart from the Common Reed, which was treated with glyphosate. Common Reed was treated again in in the fall of 2018 and 2019, in order to ensure that the remaining stands were knocked back. During the early summer of 2018, there were some complaints of Milfoil confirmed in the eastern portion of the lake, above Sears Island. The Lakes and Pond Program responded quickly with a diquat dibromide treatment, in order to ensure that the plant did not spread. The treatment was immediately successful, and the milfoil was suppressed. However, in 2019, because it was such a small patch, we were able to go a chemical free route and use manual extraction. We will continue to utilize the drawdown to address the naiad. This is performed by lowering the level of the water in the lake to expose the roots of these plants to the freezing temperatures in the winter, with the intention of killing them.



Indian Lake *continued*

Chemical-Free Invasive Aquatic Plant Management

In order to address the Eurasian milfoil in the eastern portion of Indian Lake, the City hired a team of specially trained divers to go down to the bottom of the lake and individually remove the plants. Manual removal ensures that the root ball is removed and no fragments are allowed to spread and form new plants. Over three days in August, this team covered about 7.5 acres of area in the low light conditions and were able to remove a half cubic yard of milfoil, while leaving native vegetation alone. In addition to these weeds, they pulled out a large amount of plastic and rubber-based litter, which could have sat at the bottom of the lake indefinitely.



Toxins

Like in the other lakes and ponds in Worcester, we did not find concerning levels of any toxins in Indian Lake. Although we only were able to collect a single sample, on June 19, the results are consistent to the results we obtained at other lakes and ponds, reinforcing their creditability. There was no detection of VOCs, SVOCs, PCBs, TPH, or pesticides. 10 metals were detected and listed below. All of these metals are naturally occurring in New England soils, and did not appear in quantities that would be of concern to human health in the water. Samples came back with low concentrations of PFAS, consistent to what was found in other waterbodies with no known sources, suggesting these are ambient concentrations. PFAS levels found in in Indian Lake are well below the proposed drinking water standard of 20 ppt, and do not pose a threat to public health.

Indian	VOCs	SVOCs	PCBs	TPH	Pesticides	PFAS	Metals
18-Jun	ND	ND	ND	ND	ND	8.78	10

Metals detected: Aluminum, Arsenic, Barium, Calcium, Copper, Iron, Magnesium, Manganese, Potassium, Sodium

Date	Clason Beach	Shore Park	Geometric Mean
25-Jun-19	160	48	
01-Jul-19	32	12	
08-Jul-19	64	16	
15-Jul-19	28	* 508	
16-Jul-19	N/A	72	
22-Jul-19	16	* 420	
23-Jul-19	N/A	* 3400	* 242.33
24-Jul-19	N/A	* 9200	* 863.66
25-Jul-19	N/A	70	* 581.02
26-Jul-19	N/A	30	* 487.69
27-Jul-19	N/A	85	* 354.31
28-Jul-19	N/A	50	* 152.36
29-Jul-19	10	105	62.28
05-Aug-19	4	36	
12-Aug-19	12	32	
20-Aug-19	8	12	
26-Aug-19	16	4	

Single day threshold: *>235 col/ml*
5-test Geometric Mean: *>126 col/ml*

Bacteria

Indian Lake had several closures this past summer due to fecal bacteria exceedances at its beaches, as well as one due to a sewer main break at Proctor Ave. For beach closures, only Shore Park was affected, and there were four days in which the daily recreational threshold of 235 col/ml was surpassed. However, in the last case, the exceedance was so far above the threshold that it took 4 additional days of low test results for the average of the results to dip below the 5 day requirement of 126 colonies. Geese seen hanging out at the beach are the suspected culprits, and a poorly timed rain storm may have been responsible for washing some of their waste into the swimming area and raising fecal bacteria levels. There was a whole lake closure due to a sewer main break during construction activity on Proctor Ave on August 29th. This was a minor event with little sewage making its way to the lake itself, but the closure occurred out of an abundance of caution.

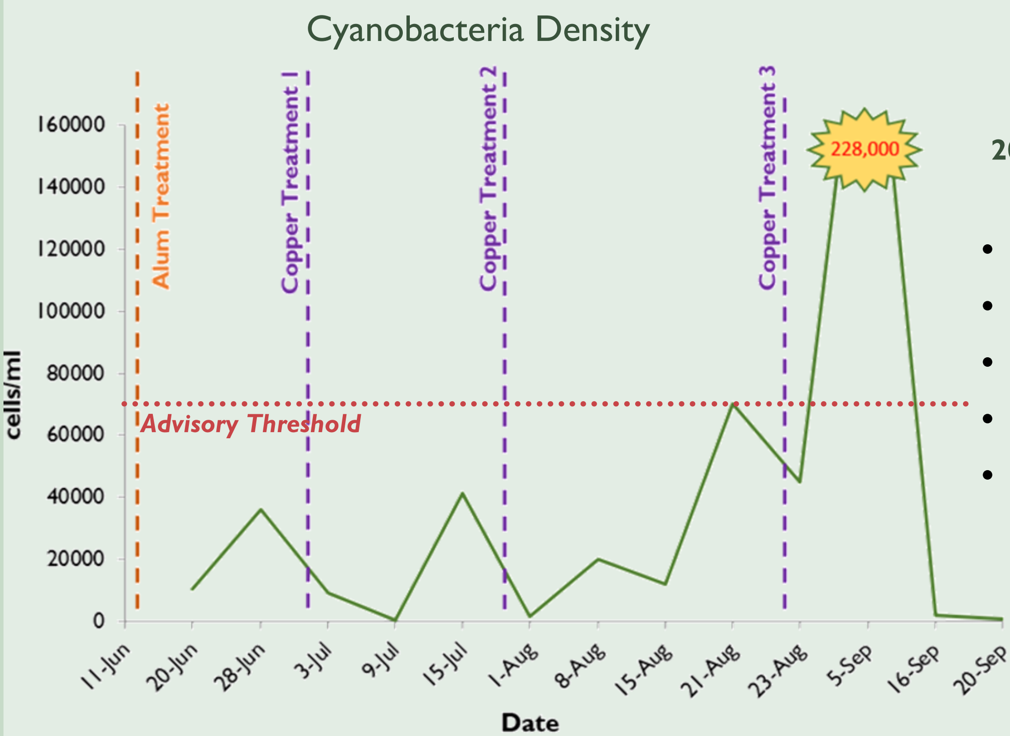
Indian Lake *continued*

Cyanobacteria

In 2017, the Lakes and Ponds Program began to collect semi-monthly cyanobacteria cell density samples at Indian Lake in order to inform decisions for the use of preventative measures to ultimately prevent the need for having to close the lake due to a cyanobacteria bloom. Those measures include applying aluminum sulfate (ie "alum") or copper sulfate to the lake surface. Alum is a product commonly used in drinking water filtration that strips sediments with phosphorus out of the water and make it unavailable to cyanobacteria for use to reproduce. It is applied in the beginning of the season and it buys some time before the cyanobacteria density increases very quickly. After spring rainstorms wash more phosphorus into the lake, however, cyanobacteria density may increase again and we must use an algaecide to make sure that we do not exceed the 70,000 cell/ml threshold and need to close the lake. Copper sulfate is that algaecide.

In 2019, we applied an alum treatment on June 11th, which may have helped to keep the cyanobacteria density low in the beginning of the season. However, when the sample came back from the June 28th sampling date at 40,000 cell/ml, a copper sulfate treatment was ordered to bring the concentration down. It succeeded in doing so for almost a month, but on July 15th, the sample indicated that density was on the rise again, and a second copper treatment was applied. This one seemed to have longer lasting effects, but a third treatment was still needed on August 22nd, when results came back just below the advisory threshold. This was the first time the Lakes and Ponds Program had applied three copper treatments in one year. On September 5th, the cell count ballooned quickly to almost 230,000 cell/ml and, because the 70,000 cells/ml threshold was surpassed, the lake was forced to close to recreation. Thankfully, the official swimming season was over, unfortunately, it was still beautiful out, and people wanted to use the lake. A toxin analysis and another cell count was ordered. The toxin test results indicated that levels were well below even conservative thresholds for a danger to public health, and the next cell count came back very low as well, leaving question to the accuracy of the September 5th result. However, it wasn't until the second low result came back at the end of September that the lake could be opened again.

While cyanobacteria is still a concern at Indian Lake, without the current management plan, we predict that the lake would have been closed for the summer by a bloom in early July.



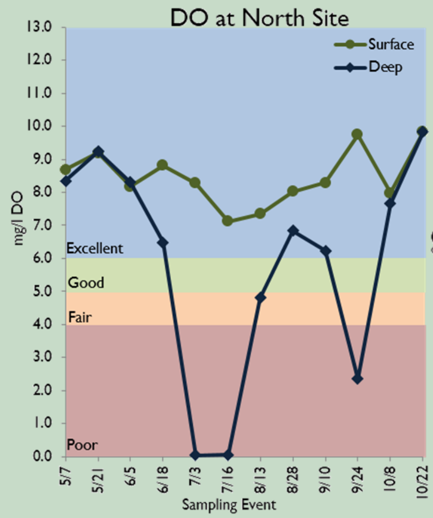
2019 Cyanobacteria Treatments at Indian Lake

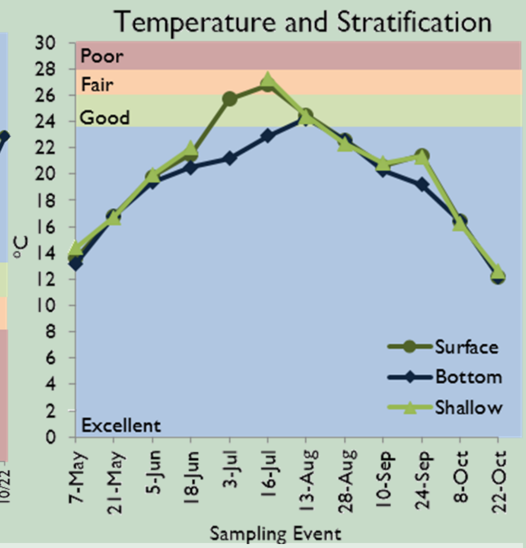
- *11 June:* Aluminum Sulfate
- *2 July:* 1st Copper Sulfate
- *25 July:* 2nd Copper Sulfate
- *5 September:* Exceedance
- *20 September:* 2nd Low Sample

Indian Lake *continued*

DO, Temperature and Stratification

Dissolved oxygen concentrations at the surface of Indian Lake were constantly in the "excellent" category and above 7.5 mg/l DO. At the bottom, however, there were some periods of oxygen depravation. On 7/3, 7/16, and 9/24, DO levels at the bottom were in the "poor" category, below 4 mg/l. However, profiling indicates these conditions only occur in the bottom foot of the water column, and should not be negatively affecting fish. The temperature at the surface of the lake was considered "excellent" for 9 of the 12 measurements, and only "fair" for two. The lake was pretty well mixed, with the temperature at the bottom only differing from the surface in the early summer months. Higher surface temperatures may be helping contribute to harmful algal blooms but shouldn't be negatively affecting fish populations.



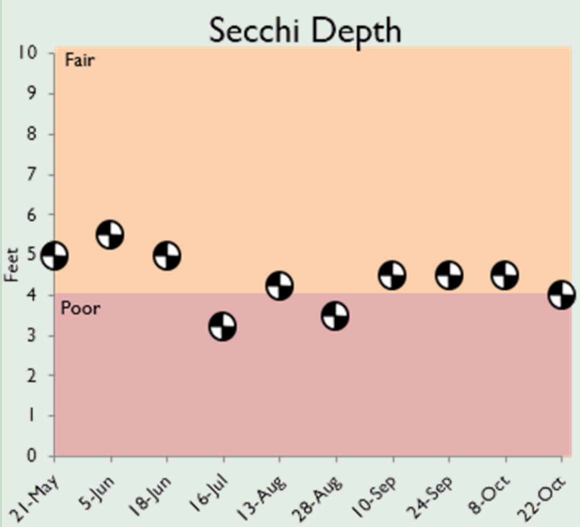


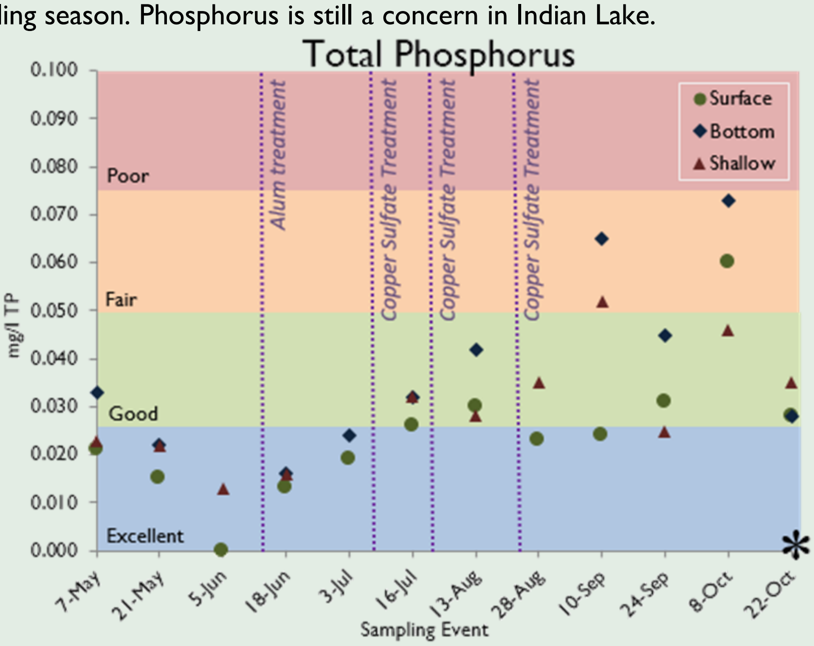
Clarity

Secchi transparency at Indian lake was between three and six feet all season long, receiving a rating of between "poor" and "fair". This poor clarity could be attributed to algae and cyanobacteria. While not ideal, is not necessarily a threat to public health, though could be a swimming safety concern. Curiously, the alum treatment was administered on June 11, and the following secchi reading on June 18th was slightly less than that taken prior to the alum treatment.

Nutrients

Indian Lake has a state-mandated budget for phosphorus loading in order to bring concentrations in the lake down to 0.027 mg/l from the 2002 lake-wide estimate of 0.044 mg/l. In 2019, the average concentration of TP at the surface of Indian Lake was at the two sampling sites was 0.027 mg/l, with results at the north deep site being slightly lower, and those at the south shallow site being slightly higher. However, readings too far above these, combined with other factors like elevated temperatures, may be sufficient to trigger an algal or cyanobacteria bloom, such as that which occurred at the end of the sampling season. Phosphorus is still a concern in Indian Lake.





* zero values represent those below detection limit of 0.010 mg/l TP

Indian Lake *continued*

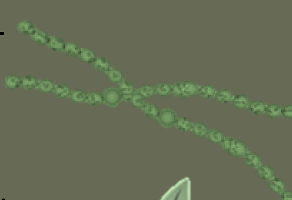
Tributaries

Indian Lake has several natural tributaries, including Ararat Brook from the north, and the smaller, more intermittent Delany Brook, from the west. Previous studies and years of monitoring have suggested that Ararat Brook be a major transporter of P to the lake, but where this P entered the brook was unknown. In 2018, the Lakes and Ponds Program contracted a study of Ararat Brook to determine if there were places on the brook where we could focus nutrient reduction efforts. Seventeen outfalls or in stream sites were chosen along the three branches that eventually make up the brook. The catchment areas, or watersheds for each of these outfalls were delineated. Samples were collected four times over the course of over a year during wet and dry weather events and measured for P, bacteria, and other water quality parameters.

The good news is that the results suggest that there are no illicit connections of sanitary sewer lines to stormwater outfalls. However, it also suggests that there is no "smoking gun" or easy fix to stop P from entering the brook, and that the average P discharge from the brook into the lake is 0.06 mg/l, which is considered, "fair", and likely to be contributing to the HABs in Indian Lake.

State of the Lake

Water quality at Indian Lake remains highly threatened for ***cyanobacteria*** due to ***phosphorus loading***, and ***invasive aquatic plants***. Even with intensive monitoring and preventative measures, the lake reached cyanobacteria advisory densities, closing the Lake for about two weeks this past September. It is suspected that a bloom would have occurred earlier without intervention. Ararat Brook is suspected to be a major source of the phosphorus that is enriching the lake and feeding cyanobacteria. Invasive aquatic plants, including Eurasian Milfoil, Common Reed, and Naiad, are present in the lake, but management of these species has shown promise to eradicate them, and eventually control any populations that return using non-chemical methods. There were several instances in which the public beach Shore Pare was closed due to exceedances in fecal bacteria, but these seemed to be acute events. In total, the lake or a beach was closed for 17 days for health advisories, including cyanobacteria and fecal bacteria exceedances. The good news is that at no point were there more than trace levels of cyanotoxins detected in the water, nor were there any concerning levels of other industrial toxins.



In 2020, the Lakes and Ponds Program will focus on continuing to implement the Invasive Species Management Plan, as well as reducing the amount of phosphorus that enters the lake from stormwater, as well as Ararat Brook itself with the goal of eliminating he need for in-lake chemical treatments.

Indian Lake *continued*

Ongoing Projects

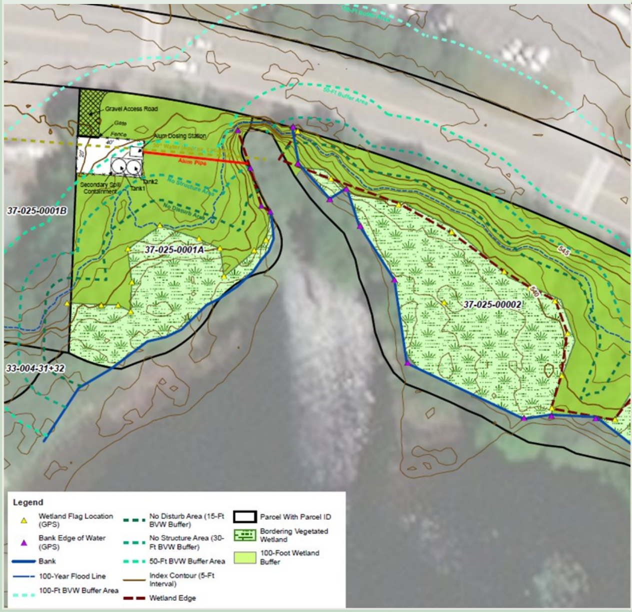
Biofiltration of Nutrients in Stormwater

One of the major contributors to cyanobacteria blooms in Indian Lake is phosphorus, which primarily enters the lake through stormwater runoff. In less developed areas, rain has a chance to filter trough the ground before entering lakes and ponds. This past year, we decided to route some of the water that falls on the Shore Park parking lot to a biofiltration unit which uses native plants in layers of soil and rocks to filter the stormwater, with the capacity of the system augmented by an underdrain. In doing so, contaminants from the parking lot do not go directly into the lake. Channeling the water from the parking lot though the unit also results in less beach erosion.

Alum Dosing Station Feasibility Study

Ararat Brook is the major tributary to Indian Lake, and has many storm drain outfalls that carry stromwater runoff containing phosphorus into Indian Lake. The influx of phosphorus every time it rains is in part why lake-wide aluminum sulfate treatments are only temporally effective at reducing lake phosphorus levels. However, over the past year we have performed a feasibility study that has determined that by applying alum little my little to the mouth of the brook, we can immobilize phosphorus before it enters the lake. We were able to determine that we could effectively reduce the average lake P levels while decreasing the total amount of alum used, saving us money in the long run. These would not only reduce the likelihood of an HAB occurring, but would also significantly increase the clarity of the water in Indian Lake, making it safer and more attractive for swimming.

In 2020, we will be able to move to the next phase of this project. This spring we will be permitting and contracting the construction of the station, and this summer we will be calibrating and monitoring the results, with the goal of eliminating in lake treatments by 2021.



Citywide Efforts

Summary: The momentum to improve our city's waterbodies stretches beyond the monitoring work of the Lakes and Ponds Program. It includes watershed associations, universities, and nonprofit organizations, and committed individuals. Projects have included water quality monitoring, lake surveys, and invasive aquatic plant management. Recently, these groups have begun to work together even more to achieve their collective mission. The following section details some of the exciting projects that these groups have initiated together.

Fisheries History and Improvement Project

The Worcester Fisheries History and Improvement Project, is a collaborative effort by the LQWA, TBWA, ILWA, and the City of Worcester to improve the access to and the quality of our fishing resources through collaboration and storytelling. The goal of the project is to engage anglers to tell their stories of fishing in Worcester over time, assess and solve water quality threats to fishery health, and engage urban youth and others in their waterbodies through fishing. In December of 2019, we applied for a $30,000 grant from the Mass Environmental Trust, which we will hear back from by May. Until then, we are moving forward with an angler survey, which is currently live, in order to begin gathering data, engaging anglers, and getting the word out about the project.

As part of this project, we are examining the fish tissue for common toxins. Last summer, the Massachusetts Department of Environmental Protection visited four of our program ponds to collect a variety of fish using an electro fishing boat. The tissue of these fish will then be tested to determine if there are toxins accumulating in them that make them a danger to ingest.

Catch Basin Stenciling

One of the primary routes nutrient pollution enters our lakes and ponds is through our stormwater system, which begins at the catch basin. While only intended to carry rain, some people do not know that these drains lead to our lakes and ponds, and unfortunately will dump all sorts of potential pollutants down them that can eventually harm our fish and wildlife. One way to stop this from happening is by putting placards on catch basins, which tell people where they lead. In November of last year, the City held a stormwater workshop in which people looked at maps of the drain infrastructure in their neighborhood and identified where local catch basins emptied in waterways in order to prioritize areas for stenciling. Come spring, they will be partnering with the Sewer Department to label the basins they have prioritized with the hopes of raising awareness about catch basins and water quality.

Citywide Efforts *continued*

Worcester Cyanobacteria Monitoring Collaborative

The Worcester Cyanobacteria Monitoring Collaborative (WCMC) is a group of volunteer citizen scientists that collects water samples to examine under a microscope for cyanobacteria and other phytoplankton which are then photographed and uploaded to a public online database. This information contributes to a worldwide study on the geographic and temporal dynamics of cyanobacteria, but also lends to a local understanding of water quality. In 2019, the WCMC completed its 3rd year of the program, and it was its most successful year yet, with 11 lakes and ponds throughout the region represented and almost 30 volunteers. These volunteers brought the total number of observations up over the years up to 70, making Worcester one of the best represented regions in the program.

Get Involved!

There are so many ways that you can contribute to your local waterways. You can join a ***Watershed or Friends Group*** in your neighborhood that does programing around a local pond. You can become a ***volunteer for the Conservation Commission***, which administers the Wetlands Protection Act locally. You can become ***a citizen scientist*** with the Worcester Cyanobacteria Monitoring Collaborative (WCMC) or the Blackstone Headwaters Coalition and collect water quality samples in your lakes and streams. For less of a commitment, you can ***start or join a local clean-up event***, removing litter from our blue and green spaces. The Regional Environmental Council has an Earth Day Cleanup every year that needs volunteers. You can ***attend a workshop*** to learn how to identify invasive aquatic plants, or reduce your property's contribution to nutrient loading through landscape design. You can even ***buy a rain barrel*** to reduce your property's contribution to stormwater, while saving money on your water bill. ***Talk to your neighbors and representatives***, and tell them why you care about your blue spaces, and how we can better support them. Make sure to learn about local, state, and federal politician's platforms on the environment, and ***vote in all elections*** based on those issues that are important to you. Finally, ***support your Department of Public Works and Parks***, who are working hard to keep our Blue Spaces beautiful. Visit ***http://www.worcesterma.gov/water-sewer/recreational-waters*** to learn more about the Lakes and Ponds Program.