

Indian Lake

2022 Water Quality Report



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The City of Worcester Lakes and Ponds Program

Background

Indian Lake has a long history in Worcester for industry and recreation. Originally a natural 100-acre lake called North Pond, it was dammed and expanded in the 1800s to 220 acres in order to supply water to the Blackstone Canal until it closed in 1848. More recently, the construction of I-190 caused the reduction of the lake's area to its current size of 190 acres. The Commonwealth considers Indian Lake a "great pond", meaning that it was larger than 10 acres in its original state, and is therefore within the jurisdiction of Chapter 91, a law which protects public rights to access a waterway. Much of the shoreline of the lake is zoned as residential and privately owned, although there are three city parks allowing public access to the water. I-190 borders the lake on the northeastern shore. Indian Lake's main tributary is Ararat Brook, which enters from the north. The lake empties over a spillway into a culvert on the eastern side of the lake, which eventually flows into Salisbury Pond to the south. There is a small residentially populated island, called Sears Island, connected by a causeway to the mainland. To the south is a small pond called Little Indian Lake, which is connected to the main lake by a small culvert under Grove Street. Indian Lake has a maximum depth of about 17 feet, with the deepest point in the north-eastern portion.

Indian Lake is popular for recreation, with two city-maintained beaches, Clason Beach and Shore Park, as well as a city-maintained boat ramp at Morgan Park open all summer long. The lake supports swimming, fishing, motorized and non-motorized boating, and water skiing. Indian Lake is home to a variety of sport fish including largemouth bass, smallmouth bass, white perch, yellow perch, black crappies, bluegills, pumpkinseeds, carp, and northern pike.

The following report details the results of a collection of water quality monitoring programs in 2022, as well as the exciting projects and opportunities the City of Worcester's Lakes and Ponds Program intends on implementing in 2023.

Water Quality Summary

As an urban lake, Indian Lake feels the pressures of the city. It is listed on the Massachusetts Impaired Waters 303d List as Category 4a for low dissolved oxygen and non-native plants. It received a TMDL, or a nutrient budget, for phosphorus in 2002. Cyanobacteria have historically been a challenge at the lake, sometimes forming bloom conditions that necessitate the restriction of recreational activities. However, management by community groups and the Lakes and Ponds Program has led to fewer and shorter lake closures over the past few years.

In 2021, the Lakes and Ponds Program rated water quality at Indian Lake as “Good”. Water temperatures were healthier at the surface and the bottom of the lake than the year before, and there were a reduced number of beach closures due to fecal bacteria exceedances. Invasive aquatic plants were successfully managed, although by reducing the presence of the invasive, habitat was opened to native plants, which then took advantage of the opportunity and increased in population to nuisance levels before management occurred. Cyanobacteria management had “Fair” results, and although the lake was safe for recreation for all of the swimming season, a late season bloom caused a 14-day closure in mid-late September. 2021 was the first year the Lakes and Ponds Program was able to quantify litter in a small portion of the lakefront, and results were “Good”.

Overall, water quality in 2022 continued to be rated as “Good”. L&P’s management plans were effective at keeping the lake open and safe for recreation, though the dry season assisted in this. There were no lake closures due to cyanobacteria, and no beach closures due to fecal bacteria exceedances. The generally higher clarity in the lake may have promoted the growth of native plants to nuisance levels, but L&P’s response was swifter than the previous year. There were no sightings of the invasive Eurasian Milfoil in the end-of season plant survey. Finally, monitoring for industrial and emerging contaminants did not reveal results in concentrations that would concern recreational users.

Effects of Drought on Indian Lake

2022 was a very dry summer overall in Massachusetts, with the Central Region of the state in drought conditions between May and September and in Level 3 Critical Drought from July through August. This resulted in a significant drop in water level through the summer at Indian Lake, with the low level mark 2.2 feet below the spring peak. When the water level was at its lowest, bottom sediments were exposed in shallower areas of the lake. These exposed areas became more sensitive to disturbance from wave action. Large waves from motorized boats caused the dried sediment containing plants and debris to become dislodged and float into the middle of the lake. Residents and lake goers began to see unidentified masses floating in the water at Indian Lake. These masses were large at times, and floated around the lake, at time lodging themselves into the shore near private property.

Although they are an unusual sight, these mounds are not believed to be a public health issue. This phenomenon is related to the extraordinary drought conditions of the summer of 2022 and is not expected to occur in more typical years. The Lakes and Ponds Program will continue to watch for similar situations and develop monitoring and management approaches as needed.



Management Summary

Indian Lake has had management plans for cyanobacteria and invasive aquatic plants since the Lakes and Ponds Program's inception. Given a combination of factors that lead to elevated cyanobacteria growth, preventative lake treatments of aluminum sulfate, or "alum", and copper sulfate are often required to avoid cyanobacteria blooms and keep the lake safe for recreation. Due to constraints of the lake management company contracted by L&P, the routine spring alum treatment was postponed to 27-Jun, leading to a preventative copper sulfate treatment on 13-Jun to keep cyanobacteria populations low. As weather conditions and data suggested an elevated bloom risk in late summer, L&P contracted a second preventative copper sulfate treatment on 31-Aug. Together, with an unusually dry year, cyanobacteria concentrations were safe for recreation for the entire summer.



Figure 1 – View of Indian Lake from Morgan Park

Improved goose management fencing was developed for 2022, and it was implemented inconsistently at Shore Park Beach, where it presented some technical issues. Despite this, in 2022 there were no beach closures due to fecal bacteria at the lake's two beaches. This is likely also due to less rainfall carrying goose droppings from the beach into the lake.

Because Indian Lake was effectively treated with the systemic herbicide ProcellaCOR in 2021, the invasive aquatic plant, Eurasian Milfoil, did not regrow and therefore did not require treatment in 2022. This gave an opportunistic native plant, Thinleaf Pondweed, a chance to grow rapidly, overtaking the southern portion of the lake. In response, the Lakes and Ponds Program treated it with the herbicide diquat dibromide (trade name: Reward) in mid-August, to allow the lake to be navigable.

Sampling Analysis and Overview

Indian Lake was visited semi-monthly from May through October and sampled at four locations: The major aboveground tributary, Ararat Brook; the middle of each of the two basins of the lake (the northern site, which is about 17 feet deep and the southern site, which is about 5 feet deep); and the outlet at the spillway, located in the eastern part of the lake (see *Figure 2*). At the in-lake locations, probe measurements and water samples were collected one 1 foot below the surface of the water ("surface"), and two 2 feet off of the bottom of the lake ("bottom"). Parameters evaluated included: Secchi depth, temperature, dissolved oxygen (DO), pH, total phosphorus (TP), total dissolved phosphorus (TDP), and *Escherichia coli* (*E. coli*). Samples were also collected for total suspended solids (TSS), ammonia (NH₃), and

nitrate (NO₃) on a monthly basis. This year, L&P also collected samples to be analyzed for industrial contaminants and emerging contaminants of concern on two occasions. Altogether, there were 12 sampling events. Even though 2022 was a dry year overall, 6 of the 12 sampling days at Indian lake were considered “wet weather” days with rainfall totals greater than 0.25 inches in the 24 hours prior to sampling. Those days include 3-May, 17-May, 9-Jul, 19-Jul, 6-Sep, and 20-Sept. On 6-Sep sampling was conducted during heavy rainfall. Results from wet weather days are denoted with the symbol ☁️ in the figures.

Samples were collected by a contractor for cyanobacteria cell density as needed. Additionally, Worcester Department of Inspectional Services tested for *E. coli* as an indicator for harmful bacteria on a weekly basis during the summer months at Shore Park Beach and Clason Beach.

Raw data are displayed and explained in this report. No statistical analysis has been performed. Subsequent ratings of “Excellent”, “Good”, “Fair”, and “Poor” for reported values are based on the Massachusetts Department of Environmental Protection’s SMART Monitoring Watershed Report Card Criteria.



Figure 2 – Aerial view of Indian Lake and approximate sampling locations.

Quality Assurance/Quality Control

The Lakes and Ponds Program strives to have a robust data set. L&P therefore uses Quality Assurance/Quality Control checks to ensure that data are representative of local conditions and meet precision and accuracy standards. Review of QAQC check results identifies data that need to be flagged and/or censored before they are shared and can highlight issues that affect data quality. When data failed to meet acceptable criteria for these checks, they were either flagged as being slightly less robust or censored entirely. Flagged data points are marked with a red flag 🚩 and censored data are not included in this report. For more information on L&P’s data quality, please contact greenworcester@worcesterma.gov.

Fecal Bacteria

Recreational contact with water contaminated by certain fecal bacteria may cause illness. *Escherichia coli*, or *E. coli*, are a type of bacteria found in the digestive tract of warm-blooded animals including geese, pets, and humans. While most strains are harmless, some can make you very sick. These bacteria enter the water in many ways, including direct contact with animal waste, runoff from the shoreline and

impervious surfaces like paved roadways during rainstorms, leaking septic tanks, and illicit sewer connections that empty sewage to the stormwater system. The Commonwealth of Massachusetts has strict regulations for bathing beaches, and Worcester Inspectional Services collected samples for *E. coli* weekly at public beaches during the swimming season to ensure that the water is safe for direct contact, closing beaches if the results were above the recreational threshold. L&P collected samples for *E. coli* at the surface of certain in-lake sites during all sampling events to assess *E. coli* conditions in open water. Samples were sent to an external lab for analysis.

Fecal Bacteria at Indian Lake. There were no beach closures at either Shore Park Beach or Clason Beach in 2022 due to *E. coli* recreational threshold exceedances. Results from testing conducted by Inspectional Services ranged between undetected and 100 colonies/100ml, with most results falling in the range considered “Excellent” (see *Tables 1&2*).

In-lake results for *E. coli* also indicated low bacteria, with the northern in-lake sampling site’s results ranging between 1 and 61 colonies/100 ml, falling within the ranges considered “Excellent” and “Good”. In 2022, bacteria were not a problem at Indian Lake, and L&P rated bacteria at Indian Lake during 2022 as “Excellent”.

E. COLI (col/100ml) AT NORTHERN SITE	
DATE	RESULT
3-May	1
17-May	61
7-Jun	10
21-Jun	6
6-Jul	11
19-Jul	4
2-Aug	3
16-Aug	3
6-Sep	4
20-Sep	6
4-Oct	10
19-Oct	22

	SHORE PARK BEACH	CLASON BEACH
DATE	RESULT	RESULT
27-Jun	52	52
5-Jul	100	40
11-Jul	12	12
18-Jul	8	8
25-Jul	16	12
1-Aug	8	<4
8-Aug	52	<4
15-Aug	52	16
22-Aug	8	8

Excellent	Good	Beach closure
Fair	Poor	

Results in colonies/100 ml

Tables 1 & 2 – There were no beach closures at Indian Lake in 2022 due to fecal bacteria indicator exceedances. All results from open water sampling were considered “Excellent” or “Good”.

Water Clarity

Water clarity is a measure of the transparency of water. Algae, microscopic organisms, eroded particles, and re-suspended bottom sediments are factors that interfere with light penetration and reduce water transparency. Clear water allows sunlight to penetrate the depths of a waterbody, supporting growth of aquatic plants, which provide food, shelter, and oxygen to aquatic organisms. Clear water is also pleasant to the eye and safer for recreational contact. Turbid water, or water filled with particles, absorbs more heat from sunlight. This reduces the water’s capacity to hold oxygen, creating favorable conditions for algal and cyanobacteria blooms, which further reduce clarity. Water clarity can be measured with a Secchi disk or by quantifying Total Suspended Solids (TSS). A Secchi disk is a weighted black and white disk on a calibrated line that is lowered into the water until it is no longer visible. Secchi readings were collected on each lake visit by L&P. TSS is a measure of the dry weight of suspended particles in a given amount of water. TSS samples were taken monthly and submitted to an external lab for analysis.

Water Clarity at Indian Lake. At the beginning of the season, Secchi depth readings were on the higher end of the expected range for Indian Lake, between 6.50 and 8.00 feet (see *Figure 3*). As the season went on, readings generally fell between 4.25 and 5.75 ft, slightly higher than the expected range for summertime. While a reduction in clarity in the early season is expected based on past years results, it occurred earlier this year, which may be due to the delayed spring alum treatment, which removes nutrient-containing sediments from the water column, slowing the growth of cyanobacteria populations. Despite this, Secchi depth remained stable throughout the season and never fell into the range considered “Poor”, as often happens in the late summer at this lake. At the northern sampling site, surface TSS results ranged between undetectable and 7.6 mg/l, remaining in the range considered “Excellent” during all sampling events. These results were comparable to those in years past. Results from the bottom in the northern site and the southern site all fell below 10 mg/l, though there was an increase in TSS as Secchi depth decreased over the course of the season. Overall, L&P rates water clarity at Indian Lake as “Fair”.

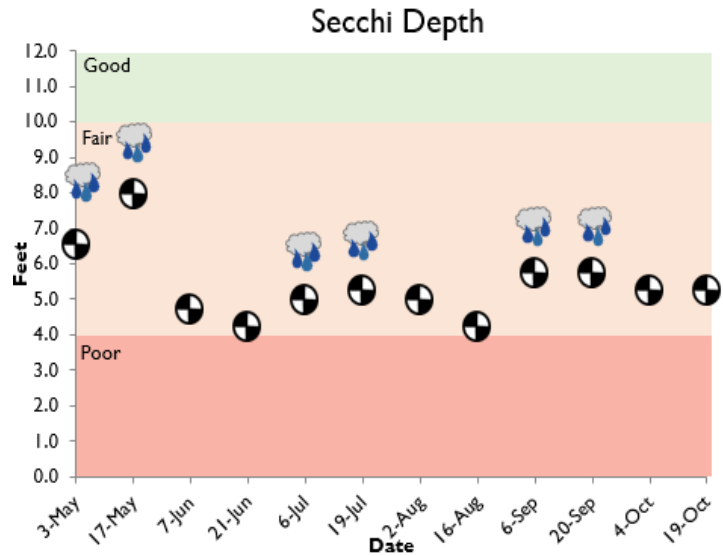


Figure 3 - Secchi depth was rated as "Fair" all season. Depths ranged from 4.25-8.00 feet.

Temperature

Water temperature is important for understanding both the biology and chemistry of aquatic ecosystems. Because many organisms prefer to live in a narrow temperature range, understanding temperature across the area and depth of a water body is essential. Temperature is also a determining factor in the speed of chemical reactions and the ability of water to hold oxygen. As temperature increases, water can hold less dissolved oxygen. Temperature dynamics in lakes can also determine the level of mixing experienced throughout the water body, affecting the distribution of

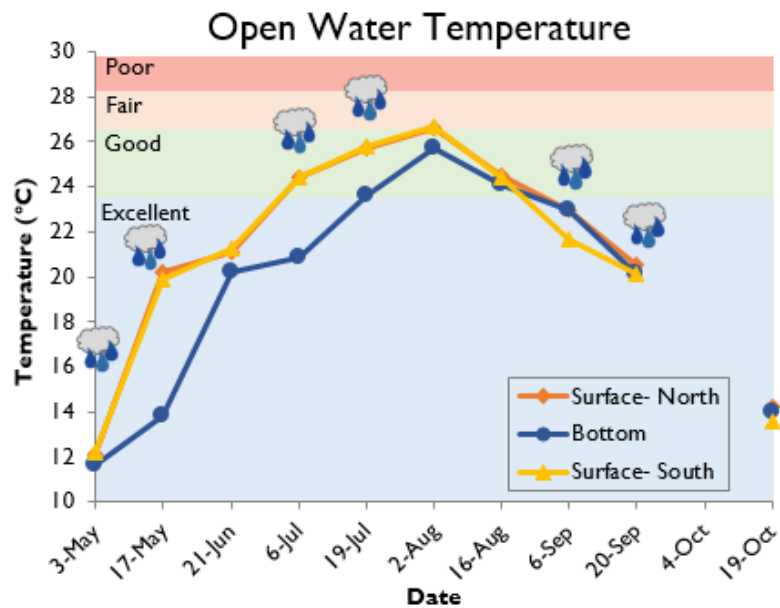


Figure 4 - Water temperature remained in the "Excellent" and "Good" categories throughout the 2022 season.

oxygen, nutrients, and organic matter throughout the lake. Temperature was measured using a temperature sensor on a handheld probe at the water's surface, and two feet from the bottom at the in-lake locations during every sampling event.

Temperature at Indian Lake. Surface temperatures at the northern and southern sites were similar to each other throughout the season, ranging between 12.1°C and 26.7°C, and following expected seasonal variation (see Figure 4). Bottom temperature at the northern site was lower than the surface, ranging between 11.6°C and 25.7°C. Temperature readings rose at all sites from the beginning of the season until late summer, with a maximum temperature recorded at each site on 2-Aug. Apart from this one reading, all readings fell in the "Excellent" and "Good" categories. From 2-Aug on, temperature fell at all sites, and the variation between surface and bottom temperature reduced. L&P rates temperature at Indian Lake as "Good".

Dissolved Oxygen

Oxygen dissolved in water is essential to aquatic life just as it is to life on land. Dissolved oxygen (DO) is a highly variable parameter that is controlled by many factors, including temperature, pressure, aeration, diffusion, rate of photosynthesis, rate of respiration and more. When water temperature rises, water can hold less dissolved oxygen, potentially causing stress to aquatic organisms. Thermal stratification, which is layering in the water column based on temperature, can also create a barrier to waterbody mixing, creating areas with depleted DO in some deeper portions of waterbodies. Increased algal growth followed by excessive decomposition of organic material can also lead to low oxygen conditions, and potentially causing fish kills. DO was measured using a galvanic DO sensor on a handheld probe at the water's surface, and two feet from the bottom at the in-lake locations.

Dissolved Oxygen at Indian Lake.

DO at the surface of the lake at the northern site was high throughout the season, and consistently in the range considered "Excellent" (see Figure 5). As observed in past years, the bottom of the northern site experienced anoxia, or no-oxygen conditions, during the middle of the summer. Four of the five readings between 7-Jun and 2-Aug reported DO below 4 mg/l, having a rating of "Poor". Surface DO at the southern site was similar to the northern site except during late summer, between 19-Jul and 16-Aug, when the readings were slightly higher.

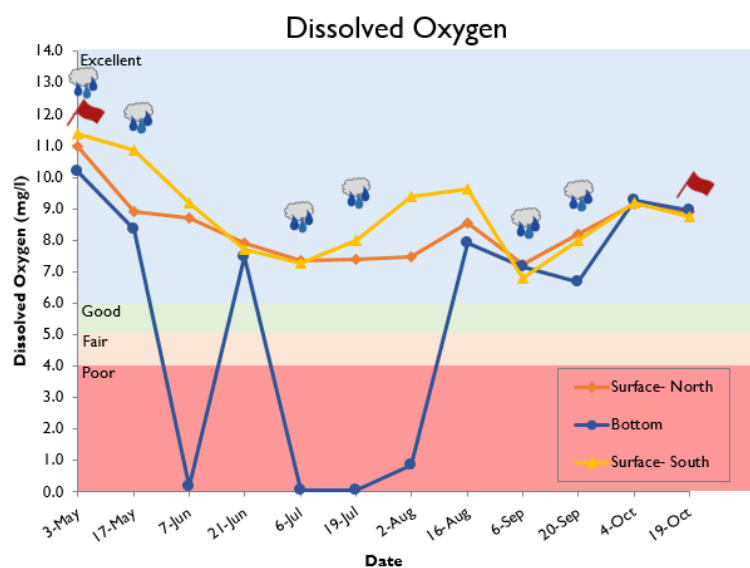


Figure 5 - Dissolved Oxygen was considered "Excellent" at the surface, throughout the season. Bottom dissolved oxygen reached the "Poor" category in June, July, and August.

water column, monthly depth profiles were taken. These included DO readings at the water's surface and at 5 ft increments until the bottom was reached. At 10 feet down, there were still high concentrations of DO, suggesting that there is ample space for aquatic organisms to thrive. L&P ranks DO at Indian Lake in 2022 to be "Excellent".

pH

pH is the concentration of hydrogen ions (H⁺) in a solution. The more H⁺ ions that are present, the more acidic the solution. On a scale of 0-14 units, 7 is a neutral pH. As pH increases from 7, the solution is more basic, and as pH decreases from 7, it becomes more acidic. In aquatic ecosystems, pH affects most chemical and biological processes including species distribution, growth rate, reproductive success, and nutrient dynamics in lakes. A high pH can promote chemical reactions that release phosphorus from lake sediments. Healthy lakes in our area have a pH between 6.5 and 8.5. pH was measured using an ion-selective electrode (ISE) pH sensor on a handheld monitoring probe. Readings were taken at the water's surface and two feet from the bottom.

pH at Indian Lake. pH at the surface of Indian Lake varied throughout the season in 2022 (see *Figure 6*). Surface pH at the northern site ranged between 7.6 and 9.0 with the highest reading taken on 6-Jul. Surface pH in the southern site had an even wider range of 7.5 to 9.4. After the copper sulfate treatment on 13-Jun, and an alum treatment on 27-Jun (both to address cyanobacteria concerns), pH readings fell closer to the neutral range at both surface sampling sites. As seen in previous years, surface pH readings were higher at the southern site than the northern site in late summer. Bottom pH at the northern site was more consistent through the season, ranging from 7.3 to 8.1. Indian Lake experiences some of the most basic readings of any lake in the Lakes and Ponds Program. Due to this, and the sudden swings in pH between sampling events, L&P rates pH as "Fair" at Indian Lake.

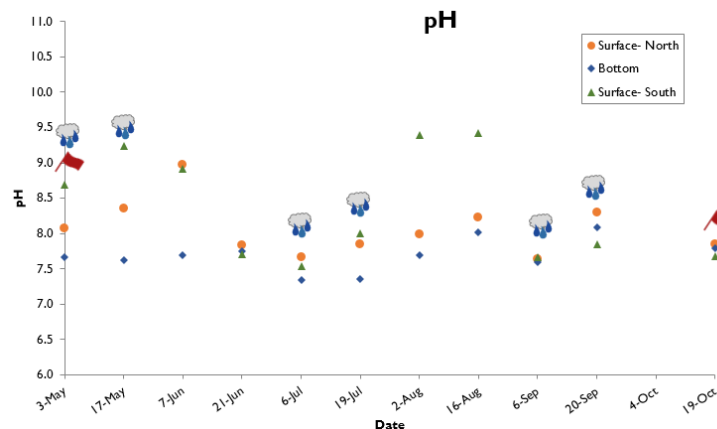


Figure 6 - Surface pH was higher than bottom pH and fluctuated throughout the season. Bottom pH readings were more consistent throughout the season.

Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), are food sources for aquatic plants and algae. Although plants and algae are the basis of aquatic food chains, and necessary for a healthy lake ecosystem, an overabundance of nutrients can lead to issues such as harmful algal blooms and excessive plant growth. Common nutrient inputs to urban lakes and ponds include fertilizers, pet and goose waste, illicit sewer connections to the stormwater system, and runoff that flows over land into the stormwater system.

Additionally, under the right conditions, P can be released from the sediments at the bottom of the lake, becoming more available for uptake by organisms. To examine the nutrients present in program lakes, L&P collected samples for several compounds and submits them to an external lab for analysis. To measure N, samples were collected for nitrate (NO₃) and ammonia (NH₃) at all sites monthly. As extensive issues were noted with QA/QC checks performed by the laboratory, the data collected for NH₃ were not considered suitable for inclusion in this report. To measure P, samples were collected for total phosphorus (TP) twice a month at all sites, and total dissolved phosphorus (TDP) twice a month at all bottom sites. TDP was also analyzed to understand how much P is dissolved in the water and available for use by aquatic organisms.

Nutrients at Indian Lake. In 2022, TP concentrations at the in-lake sites were generally lower than in previous years. At the northern site, surface results ranged from 0.014 to 0.036 mg/l, all but one result was at or below 0.025 mg/l and therefore rated as “Excellent” (see Figure 7). At the bottom of the northern site, concentrations were higher in the beginning of the season, though still in the “Good” range, while lower towards the end of the season. The surface samples at the southern site generally had a higher concentration of TP than the northern site, mostly falling in the range considered “Good”. All but one TDP result at the bottom of the northern site were undetectable, with the one detected result rated as “Excellent”. NO₃ results were low at all in-lake sites. All but three results were undetectable, and those detected were below 0.6 mg/l; in the range considered, “Excellent”. Because of the outsized role that P plays in cyanobacteria dynamics at Indian Lake, L&P rates nutrients in 2022 at Indian Lake as “Good”.

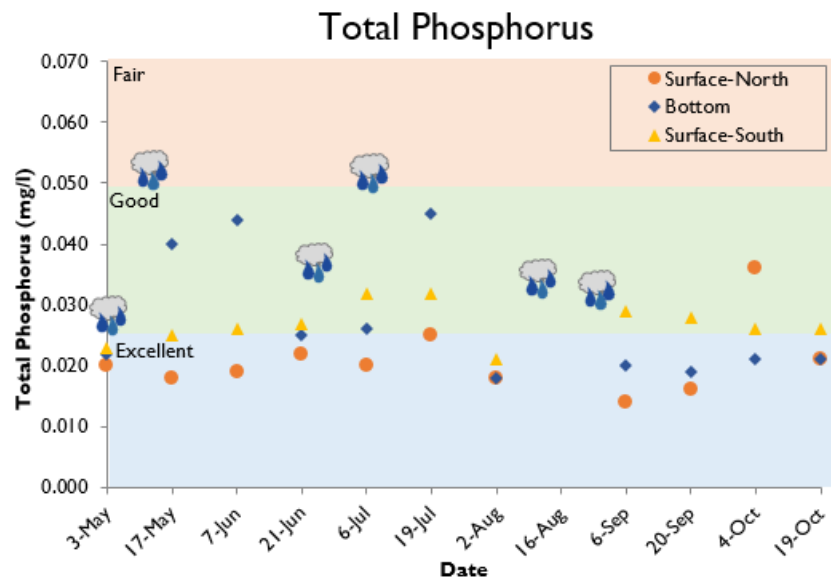


Figure 7 - Total phosphorus was categorized as "Excellent" to "Good" throughout the season. Total phosphorus at the surface-north and bottom sites was generally lower than the surface-south site.

Cyanobacteria

Cyanobacteria are naturally occurring microorganisms in lakes and ponds. Using sunlight and nutrients such as N and P, cyanobacteria behave similarly to plants and algae. While normal at low densities in healthy ecosystems, under the right conditions, some species of cyanobacteria can reproduce quickly causing potentially harmful blooms. Cyanobacteria blooms, in addition to being unsightly and smelly, can produce toxins that are harmful to humans and pets. Blooms also have the potential to create anoxic conditions that can cause fish kills.

To understand the abundance of cyanobacteria and make decisions regarding lake management and safe access, L&P contracted the collection of samples for cyanobacteria cell counts, or enumerations, on a weekly basis at Shore Park to determine bloom risk. When results were above the recreational threshold of 70,000 cells/ml it was considered to be blooming, and the water would have needed to be closed to recreation until cell counts fell below this level naturally. During cyanobacteria blooms, L&P would have also contracted the collection of samples for cyanotoxin analysis to establish whether they are present in concentrations that could be harmful to humans or pets. When possible, L&P attempted to use preventative lake treatments, such as the application of algicide, to stop blooms from occurring by reducing the cell counts before they exceed the recreational threshold.

Cyanobacteria at Indian Lake. Indian Lake has favorable conditions for cyanobacteria growth, including warm water, elevated pH, and steady external nutrient inputs through stormwater in Ararat Brook. L&P has documented cyanobacteria blooms over the past years, necessitating the creation of a management plan utilizing algicides and flocculants. Results from weekly enumerations contracted by L&P in 2022 ranged between 161 and 22,632 cells/ml of cyanobacteria, never crossing the recreational advisory threshold of 70,000 cells/ml (see Figure 8). Due to constraints of the lake management company contracted by L&P, the routine spring alum treatment was postponed to 27-Jun, leading to the recommendation of a preventative copper sulfate treatment on 13-Jun to keep cyanobacteria populations low. Previous year's data indicated elevated bloom risk in late summer, L&P contracted a second preventative copper sulfate treatment on 31-Aug. After one more period of growth, cyanobacteria populations declined as the weather grew colder. Compared to previous years, these results show slower growth of cyanobacteria populations and no disruption of recreational activities due to blooms. L&P rates cyanobacteria as "Good" in 2022.

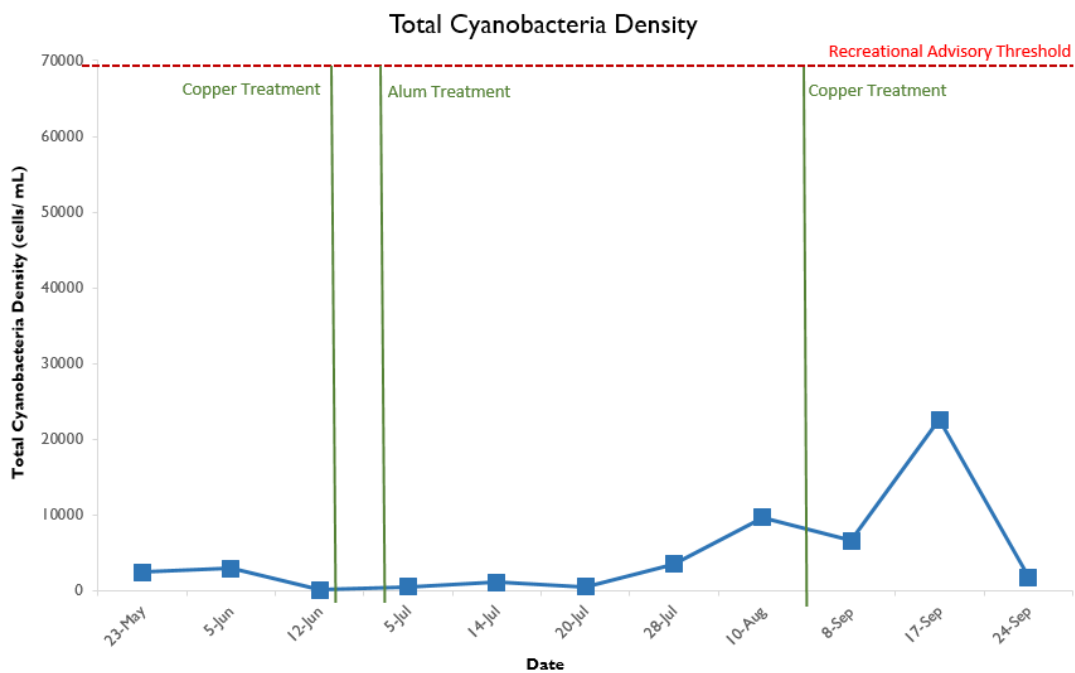


Figure 8 – Cyanobacteria density at Indian Lake remained well below the recreational threshold of 70,000 cells/ml all season.

Tributaries

Tributaries are streams that flow into a lake or pond. They collect surface runoff from rain or snowmelt along with some groundwater and carry it through the stream channel to the waterbody. In some cases, tributaries make up a large portion of the water going into the lake, and the quality of the water in these tributaries can give us hints about where certain impairments in the lake are originating. Outlets are the major exits for water in the lake. Most of the abovementioned water quality parameters were measured at the major natural tributaries and outlets of the lakes in the Worcester Lakes and Ponds Water Quality Monitoring Program.

Tributaries at Indian Lake. In Indian Lake's main tributary, Ararat Brook, TP results ranged widely from undetected to 0.070 mg/l. However, most results fell in the ranges considered "Excellent" and "Good" (see Figure 9). The sample with the highest concentration, 0.070mg/l, was taken on 6-Sep, a wet weather day with a 24 hour precipitation total of 2.31 inches. Although Indian Lake was sampled on 5 other wet weather days, 6-Sep was the only one on which the tributary sample was collected when rain was still falling, so the sample represents something closer to the first-flush of the system, when pollutants collected in the stormwater system are first washed into the waterbody. Results for TP at the spillway were similar to those at the tributary, except for 6-Sep, when the TP results were relatively lower at the spillway.

E. coli results at Ararat Brook were less consistent than those at the beaches or open water, with higher concentrations of bacteria occurring during late season rain events (see Figure 10). Three of the samples, all taken on wet weather days, were rated as "Poor", with the 9-Sep result over 14,000 col/100 ml. Even with this, samples taken in the middle of the lake on that same day were rated "Excellent", confirming our understanding that bacteria do not live for very long outside of a warm-blooded animal.

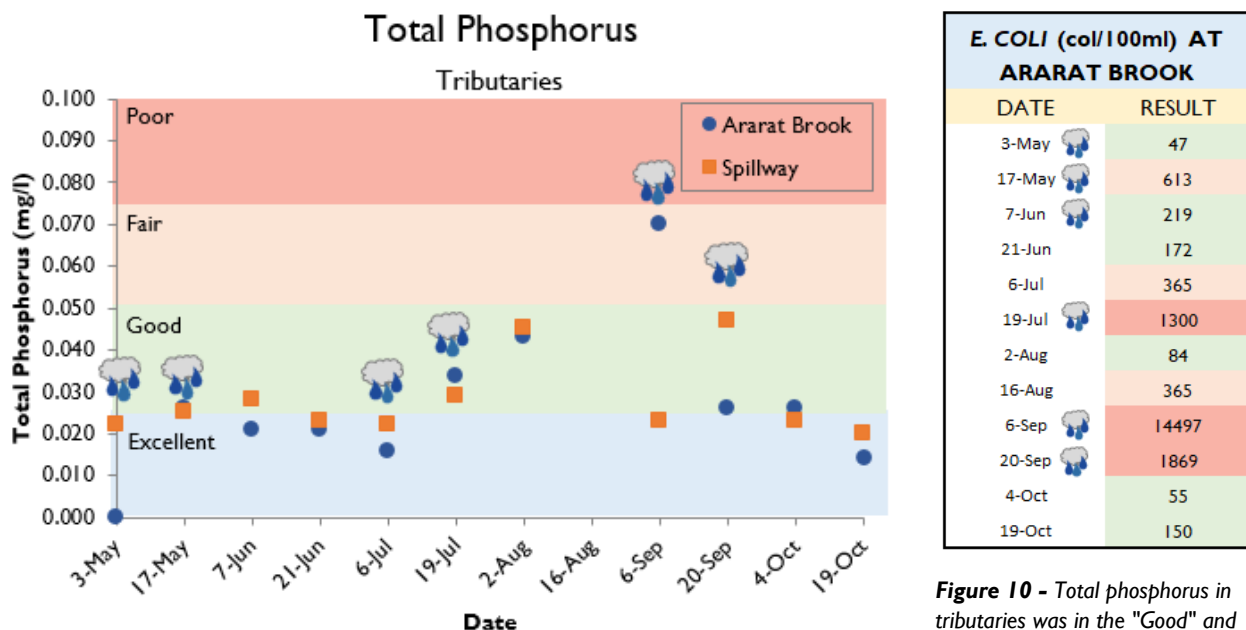


Figure 9 - Total phosphorus in tributaries was in the "Good" and "Excellent" categories all season except for one date where it was considered "Fair" in Ararat Brook.

E. COLI (col/100ml) AT ARARAT BROOK	
DATE	RESULT
3-May	47
17-May	613
7-Jun	219
21-Jun	172
6-Jul	365
19-Jul	1300
2-Aug	84
16-Aug	365
6-Sep	14497
20-Sep	1869
4-Oct	55
19-Oct	150

Figure 10 - Total phosphorus in tributaries was in the "Good" and "Excellent" categories all season except for one date where it was considered "fair" in Ararat Brook.

NO₃ results in the lake outlet, similar to in-lake results, were consistently low. However, as seen in the past, higher NO₃ results were observed in Ararat Brook, ranging from 0.460 mg/l to 0.888 mg/l. TSS results in the tributary Ararat Brook and the lake outlet were in a similar range, between undetectable to 13.0 mg/l. The highest TSS result of the season was 13.0 mg/l in Ararat Brook and is considered “Good”.

Invasive Aquatic Plants and Animals

Plants and animals are vital parts of any lake ecosystem. Plants provide food, shelter and oxygen to other aquatic organisms. Their uptake of nutrients reduces the likelihood of algal blooms, and their root systems stabilize sediments. Animals play invaluable roles in food webs and their removal can disrupt the ecology of a system. An invasive plant or animal is an organism that is not native to the region and outcompetes local flora and fauna. The absence of natural constraints, like predators or environmental limitations, allows invasive plants and animals to reproduce at a rapid rate. When invasive aquatic plants and animals become too numerous or dominant, they can overtake all available space, disrupting local ecosystems and making recreation more difficult. Invasive organisms can arrive by hitching a ride on boats, pets, or boots to get to a new location. Some are released with good intentions as a beautiful addition to a landscape or sport fishing opportunity. Professional surveys and visual inspections from Lakes and Ponds Program staff were used to make management decisions regarding invasive species.

Invasive Aquatic Plants and Animals at Indian Lake. Historically, Indian Lake has hosted several species of nuisance plants, including European Naiad (*Najas minor*), Eurasian Milfoil (*Myriophyllum spicatum*), *Elodea*, Thinleaf Pondweed (*Potamogeton pusillus*), and Common Reed (*Phragmites australis*). As the management of cyanobacteria has increased water clarity, increased light penetration to sediments may have escalated the prevalence of invasive and nuisance aquatic plants in the lake. Previously, these plants were controlled with an entirely chemical-free management plan, combining multiple approaches. This included an annual winter drawdown, in which the water level was reduced by 5-6 feet exposing invasive aquatic plants to the elements, as well as dive teams which aimed to remove the plants by the roots. However, these efforts were not sufficient to keep the plants under control. This prompted the Lakes and Ponds Program to take more proactive measures. In 2021, the systemic herbicide ProcellaCOR was applied to the lake, immediately eradicating the Eurasian Milfoil and killing its root systems.

In 2022, the Milfoil did not return, and an end of season survey found no trace of it or any other invasive aquatic vegetation in Indian Lake. The only invasive plant that was found were several stands of *Phragmites*, which had previously been brought to our attention by residents. This plant grows along the water’s edge in shallow areas and has the potential to crowd out native plants, shallow the water, and increase sedimentation. L&P had treated for this plant with the herbicide glyphosate in the past, and will redouble efforts to control it in 2023. Additionally, during site visits, L&P staff identified two individual water chestnut (*Trapa natans*) plants and immediately removed them. More plants were not found in subsequent surveys; however, the Lakes and Ponds Program will remain vigilant for water chestnut as infestations can rapidly overtake waterbodies.

Following the 2021 ProcellaCOR treatment, Thinleaf Pondweed, a native but opportunistic plant, took advantage of the newly open water and quickly populated the lake, and grew to nuisance levels. Thinleaf

Pondweed is not affected by ProcellaCor or drawdowns, but it is dense enough to affect recreation and cause ecological damage. Overgrowth of Thinleaf Pondweed in 2022 was treated with Reward on 15-Aug, which successfully managed the population.

Survey results from 2022 confirm what we had already known; that the ProcellaCOR treatment of 2021 was highly effective and essentially eradicated the Milfoil, which eliminated the need for the drawdowns to continue. Because eliminating the drawdown was a change for residents, in the winter of 2021-2022, a 3 foot drawdown was implemented to allow for this adjustment while reducing stress on the lake ecosystem. During the winter of 2022-2023, no drawdown was enacted.

Industrial Contaminants

As a post-industrial urban center, legacy pollutants, and emerging contaminants of concern from industrial processes may be present in Worcester’s recreational waters. These contaminants may cause negative health and environmental effects. Every three years, L&P tests for a range of these compounds on both a wet and dry weather event in our lakes. In 2022, L&P tested for 74 volatile organic compounds (VOCs), 72 semi volatile organic compounds (SVOCs), 9 polychlorinated biphenyls (PCBs), petroleum hydrocarbons (TPH), 23 perfluoroalkyl substances (PFAS), 21 pesticides, 10 herbicides, and 22 heavy metals. Detected parameters are shown below. To see a full list of contaminants tested for, contact greenworcester@worcesterma.gov.

Table 3 – Eleven metals were detected in 2019 and 2022. These metals are naturally occurring in New England soils and are not present in quantities that could affect human health. “ND” signifies that the compound’s concentration was not detected by the lab.

Parameter	Wet Result	Dry Result	Wet Result	Unit
	9/20/2022	10/19/2022	6/18/2019	
Metals				
Aluminum, Total	0.0304	0.0497	0.0742	mg/l
Arsenic, Total	0.00170	0.00106	0.00191	mg/l
Barium, Total	0.01971	0.01762	0.01761	mg/l
Calcium, Total	15.8	15.2	20.8	mg/l
Copper, Total	0.00217	0.00174	0.00127	mg/l
Iron, Total	0.102	0.115	0.175	mg/l
Magnesium, Total	2.45	2.31	2.55	mg/l
Manganese, Total	0.04518	0.03348	0.1007	mg/l
Potassium, Total	2.70	2.68	2.71	mg/l
Sodium, Total	58.8	67.3	70.8	mg/l
Zinc, Total	0.01199	0.01542	ND	mg/l

Industrial Contaminants at Indian Lake. All results for VOCs, SVOCs, PCBs, TPH, pesticides, and herbicides were below reporting limits, indicating an extremely low to no concentration. Eleven metals were detected including aluminum, arsenic, barium, calcium, copper, iron, magnesium, manganese, potassium, sodium, and zinc. Overall, metal results were similar to or decreased from 2019 testing (see Table 3). PFAS

is a class of emerging contaminants of concern, however, there are no regulations on PFAS for recreational waterways. There are drinking water regulations for six species of PFAS. The PFAS drinking water limit (also known as an MCL) is total of 20 ng/l, as a sum of the 6 regulated species. The combined total of regulated PFAS species in Indian Lake on each sampling day was 8.95 and 8.85 ng/l (see *Table 4*) which is below the drinking water standard. As drinking water standards are generally much stricter than those of recreational waterways, we can assume that PFAS is not a concern for recreational users of Indian Lake.

Table 4 – Several PFAS compounds were detected at Indian Lake in 2019 and 2022. The totals of regulated compounds were very low and not of concern for recreational contact. “ND” signifies that the compound’s concentration was not detected by the lab. “NT” signified that the compound was not tested for, as the analysis was not yet available.

Parameter	Wet Result	Dry Result	Wet Result	Unit
Non-Regulated Perfluorinated Alkyl Acids				
	9/20/2022	7/19/2022	6/18/2019	
Perfluorobutanoic Acid (PFBA)	2.44	1.82	NT	ng/l
Perfluoropentanoic Acid (PFPeA)	2.96	3.21	NT	ng/l
Perfluorobutanesulfonic Acid (PFBS)	2.31	2.41	2.22	ng/l
Perfluorohexanoic Acid (PFHxA)	2.68	2.53	NT	ng/l
Regulated Perfluorinated Alkyl Acids				
	9/20/2022	7/19/2022	6/18/2019	
Perfluoroheptanoic Acid (PFHpA)	2.22	2.07	ND	ng/l
Perfluorooctanoic Acid (PFOA)	4.24	4.17	5.73	ng/l
Perfluorooctanesulfonic Acid (PFOS)	2.49	2.61	3.05	ng/l
Total Regulated	8.95	8.85	8.78	ng/l

Litter

Litter, or inappropriately disposed waste, is harmful to the ecological, 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.

Litter at Indian Lake. Litter is a difficult parameter to measure in a quantitative way, although litter has been determined to be a concern for lake water quality and recreational enjoyment at Indian Lake. A study at Morgan Park in 2021 found that, of the categories examined, “small items”, “tobacco products”, and “food packaging and containers” were the most prominent classes of litter present. See *Figure 11* for the relative rankings of the different classes of litter examined. While trash receptacles are left out by the City, they are often overturned or not used. While litter was not formally qualified in 2022, the Lakes and Ponds Program is attempting to combat this challenge with collaborations with local organizations and an educational campaign, which you can read more about in the following section.

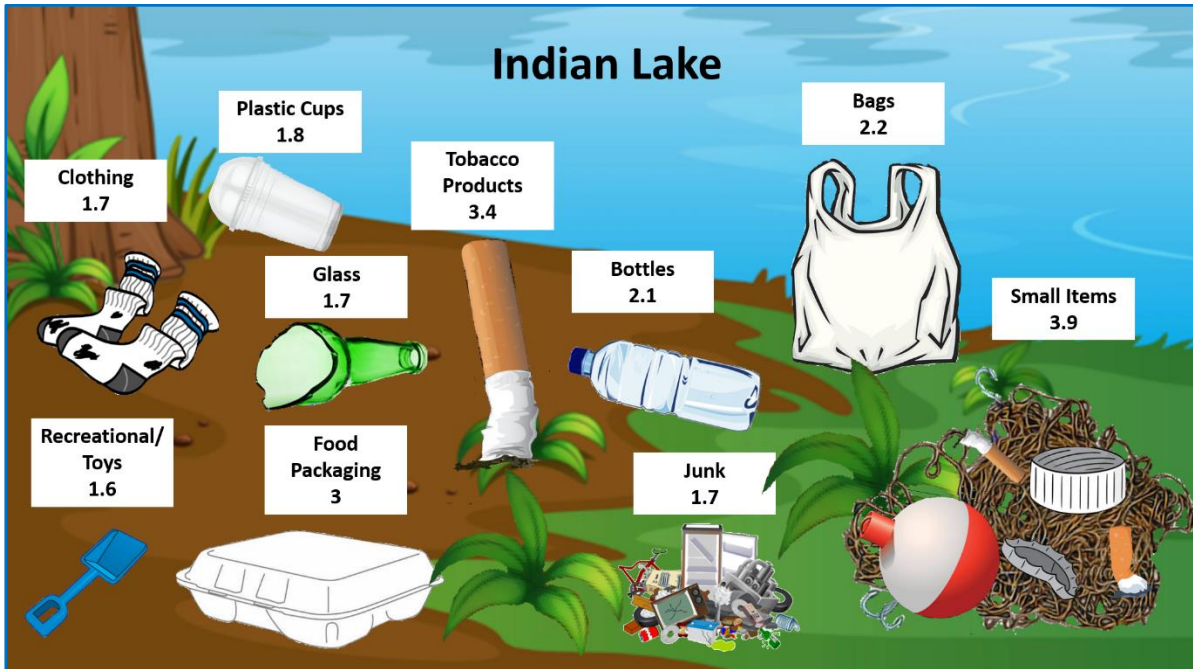


Figure 11 - The relative abundance of different categories of litter in 2021. A rating of 1 indicates lowest abundance, and 5 is the highest.

Ongoing Projects

Boat Decontamination Stations

The Lakes and Ponds Program is committed to monitoring and managing the invasive aquatic plants that can obstruct our waterways. However, the best way to curb invasive aquatic plants' effect on our lake ecosystems is to keep them out of the lakes in the first place. The most common way invasive aquatic plants are spread is the accidental introduction through hitchhikers on boats and trailers. In many cases, even a small piece of a plant can re-root and start growing in a waterbody. In the fall of 2022, the Lakes and Ponds Program was able to utilize funds from the American Rescue Plan Act (ARPA) to install solar powered boat decontamination stations at Indian Lake and Coes Reservoir (see *Figure 12*). These stations are free to use and contain instructions on best practices for intercepting invasive aquatic plants before they can take root in our waterbodies. There are blowers and grabbers to remove weeds in hard-to-reach places, brushes to scrub algae off the sides of boats and tools to drain and dry bilge water. To help spread the word on the stations, L&P created a "Blue Space Minute" called [Boat Cleaning Stations](#) that is available on the City of Worcester YouTube channel.



Figure 12 - Solar powered boat decontamination stations were installed at Indian Lake and Coes Reservoir to enable lake goers to decontaminate their watercraft before and after use to avoid transporting invasive plants to the lakes.

Goose Fencing

In 2021, the Lakes and Ponds Program implemented a Goose Fencing Pilot Project that aimed to reduce the number of beach closures at Coes Reservoir and Indian Lake by humanely keeping geese away from the beach (see *Figure 13*). Geese usually enter the beach from the water and are not good at getting over low fences. They are uncomfortable when there are barriers between the beach and the water because the water is their escape route from land predators. After erecting a small fence between the shore and water during the evening hours, L&P found the use of the beach by the geese was significantly reduced, and beach closures also seemed to be reduced. In 2022, the Lakes and Ponds Program improved the construction of the fencing using higher quality materials and making installation easier to increase usage during the summer. Unfortunately, lack of staffing at Clason Beach meant the fence was only utilized at Shore Park Beach. At times, implementation was inhibited by technical issues, but thankfully the dry season reduced the effect of goose droppings on water quality. L&P plans to continue to improve the fence design and implement it at Indian Lake's beaches in 2023.



Figure 13 – Goose fencing has proven to be an effective strategy for managing fecal bacteria at Indian Lake.

Continuous Monitoring

Since 2021, the Lakes and Ponds Program has installed solar powered continuous monitoring buoys at Lake Quinsigamond. These buoys contain probes that track the cyanobacteria indicators phycocyanin and chlorophyll, as well as turbidity and temperature, and remotely upload them to an online database where data can be viewed in real time. Late in the summer of 2022, a probe was deployed in the northern cove of Indian Lake, adjacent to the inflow of Ararat Brook and Shore Park (see *Figure 14*). The data from this probe will be used to aid in determining water quality in the cove and efficacy of the Alum Dosing Station that will be coming online in the spring of 2023.



Figure 14 – A continuous monitoring buoy was deployed to track cyanobacteria indicators in the northern cove of Indian Lake.

State of the Lake

In 2022, Indian Lake once again receives an overall rating of “Good”. There were no lake closures due to cyanobacteria threshold exceedances nor beach closures for fecal bacteria exceedances, and results indicated low levels of each. Despite drought conditions, water temperatures were considered “Good” and dissolved oxygen was rated “Excellent”. Secchi clarity was slightly higher than the expected range for Indian Lake, though still low enough to be rated as “Fair”. Nutrients were in the “Good” range. Invasive aquatic plant surveys indicate that the management plan for invasive plants has been effective. While a combination of the open niche and higher water clarity lead to increased density of the nuisance native plant Thinleaf Pondweed, an lake treatment in August successfully reduced it.

Plan for 2023

Water Quality Monitoring

In 2023, the Lakes and Ponds Program plans to continue to monitor Indian Lake in order to track changes in water quality and implement its cyanobacteria and invasive aquatic plant management plans. L&P will continue to contract cyanobacteria enumerations to better understand cyanobacteria population dynamics and inform management and public health decisions. L&P will also pay particular attention to pH in 2023, as high and widely fluctuating pH can indicate conditions that are favorable for cyanobacteria and stressful for other aquatic life. An additional sampling plan will be developed and implemented as the Alum Dosing Station comes online. This plan will aim to quantify the concentration of phosphorus before and after the addition of the compound during storm events. The intention is to guide dosing requirements for Ararat Brook to ensure that the project is attaining its intended goal of removing phosphorus before it enters the lake. As litter in the Morgan and Shore Park areas continues to pose a challenge, L&P will monitor litter quality and quantity throughout the park.

24 Hour Dissolved Oxygen Study. In previous years, fish kills have been observed at Indian Lake during periods of high water temperature. While in 2022 temperatures were not as high as in previous years, if future readings suggest it is necessary, the Lakes and Ponds Program will carry out a 24 hour dissolved oxygen study. Generally, during the day, there is still a net positive concentration of oxygen in the water due to photosynthesis by plants and algae. However, at night, when the sun goes down and photosynthesis stops, oxygen is still required for respiration and none is being produced. This leads to a decrease in the amount of oxygen in the water throughout the night. On really hot nights, when there was less oxygen to begin with, it could deplete it entirely, leading to suffocation of small fish. While current data suggests that this diurnal cycle is occurring in Indian lake on the hottest of days, in the shallowest of water, the Lakes and Ponds Program plans on confirming it next year by taking oxygen readings throughout the night.

Lake Management

Alum Dosing Station. Ararat Brook is the major tributary to Indian Lake, and has many storm drain outfalls that carry stormwater containing phosphorus into Indian Lake. The renewed influx of phosphorus every time it rains is in part why lake-wide aluminum sulfate (“alum”) treatments are only temporarily effective

at reducing lake phosphorus concentrations. However, feasibility studies have determined that by applying alum in small doses to the mouth of the brook, phosphorus will be immobilized before it enters the lake, effectively reducing the average lake phosphorus concentration while decreasing the total amount of alum used, saving money in the long term. The result would be a reduced likelihood of a cyanobacteria bloom occurring, as well as significantly increased lake water clarity, increasing safety and making the lake more attractive for recreation. In 2021, an Alum Dosing Station was permitted, and the engineering design phase of the project was completed. In 2022, the properties where the station is being constructed was acquired as two separate donations from Bancroft School and the Universalist Church and site preparations were completed. As of the beginning of 2023, construction of the station is underway, with the goal of being calibrated and put into use by spring of this year (see *Figure 15*). The hope is that this station will eliminate the need for in-lake aluminum sulfate treatments, while increasing water clarity and decreasing the likelihood of cyanobacteria blooms.



Figure 15 – Polyaluminum Chloride, or “Alum”, is a chemical that immobilizes phosphorus on sediments in the water column.

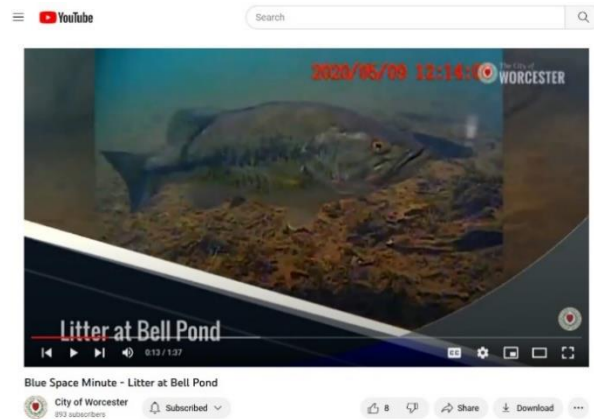


Figure 16 – The “Blue Space Minute” debuted an episode on Litter in 2022 on the City of Worcester YouTube Channel.

Education and Outreach

Litter. The Lakes and Ponds Program will work with its partners, including the Department of Public Works & Parks, and Worcester Green Corps, to use our data to create litter reduction strategies. L&P will also try to build pride around Indian Lake with videos and signage related to its high-quality water, including the re-release of the “Blue Space Minute” Episode on Litter, which debuted in April of 2022.