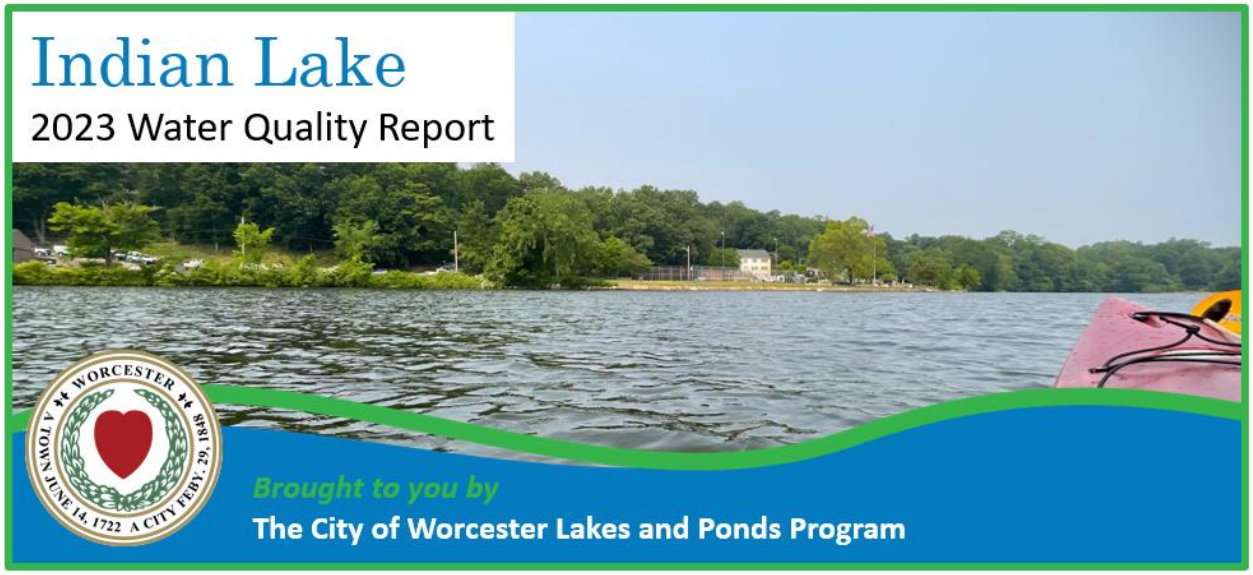
Indian Lake

2023 Water Quality Report



Brought to you by

The City of Worcester Lakes and Ponds Program

Summary

The following report is presented by the City of Worcester Department of Sustainability and Resilience (DSR), Lakes and Ponds Program (L&P). It details the program's water quality monitoring results, management activities and outreach efforts at Indian Lake in 2023. The "State of the Lake" will be rated "Excellent", "Good", "Fair", or "Poor" based on the results' implications on water quality and recreational value. This report will also outline projects and opportunities the City of Worcester's Lakes and Ponds Program (L&P) intends to implement at Indian Lake in 2024.

As an urban waterbody, Indian Lake feels many of the pressures of the city. Indian faces challenges including lake closures due to cyanobacteria and fecal bacteria, high nutrient levels, low water clarity, and invasive aquatic plants. However, management by community groups, and more recently, the City of Worcester Lakes and Ponds Program, has led to water quality that supports a healthy ecosystem and a wide variety of recreational opportunities. ***In 2023, Indian Lake received a score of "Good"***. Continue reading to learn more about this rating and L&P's work at Indian Lake.

Background

Originally a natural 100-acre lake called North Pond, Indian Lake was dammed and expanded in the 1800s to 220 acres in order to supply water to the Blackstone Canal until its closure in 1848. More recently, the construction of I-190 reduced 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 (*See Figure 1*). I-190 borders the lake on its 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 south into Salisbury Pond. Sears Island is

residentially populated and is 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 northeastern 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. 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.

Figure 1 – *View of Indian Lake from Morgan Park*

The following report details the results of a collection of water quality monitoring programs in 2023, as well as the exciting projects and opportunities the City of Worcester's Lakes and Ponds Program will implement in 2024.

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 restrict recreation. However, management by community groups and the Lakes and Ponds Program has led to fewer and shorter lake closures in recent years.

In 2022, water quality continued to be rated as "Good". L&P's management plans continued to be effective at keeping the lake open and safe for recreation. There were no lake closures due to either cyanobacteria or fecal bacteria in 2022. The generally higher clarity in the lake may have promoted the growth of native plants to nuisance levels, prompting further treatment. There were no sightings of the invasive Eurasian Milfoil in the end-of season plant survey. Monitoring for industrial and emerging contaminants did not reveal results in concentrations that would concern recreational users.

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 have been required to avoid cyanobacteria blooms and keep the lake safe for recreation.

In 2023, L&P began the use of a novel nutrient management strategy, an Alum Dosing Station at the lake's main inlet (*See Figure 2*). As the major tributary to Indian Lake, Ararat Brook has many storm drain outfalls that carry stormwater containing phosphorus into Indian Lake. The station applies small amounts of polyaluminum chloride (similar to alum) to the mouth of the brook in small doses when it rains, immobilizing phosphorous before it enters the lake. This method aims to reduce the average lake phosphorus concentration while decreasing the total amount of alum used, saving money in the long term.

Figure 2– *In 2023, an "Alum Dosing Station" came on line at the lake's main inlet, Ararat Brook. The station applies small amounts of the chemical, polyaluminum chloride to the mouth of the brook in small doses when it rains immobilizing phosphorous before it enters the lake.*

As construction delays on the Alum Dosing Station limited treatment of spring rainstorms, L&P contracted an additional aluminum sulfate treatment on 31-May. When the Alum Dosing Station came online in early June, it applied polyaluminum chloride during rain events and continued operation until mid-November. As weather conditions and data suggested an elevated bloom risk in late summer, L&P contracted a second preventative copper sulfate treatment on 17-Aug. Despite an unusually wet season, L&P's management was effective in avoiding recreational restrictions due to cyanobacteria bloom conditions.

Since Indian Lake was effectively treated with the systemic herbicide ProcellaCOR in 2021, the invasive aquatic plant Eurasian Milfoil has not regrown or required additional treatment. However, in 2021 the absence of milfoil gave the opportunistic native plant Thinleaf Pondweed a chance to grow rapidly, overtaking the southern portion of the lake. As in past seasons, the Lakes and Ponds Program treated it in early June with the herbicide diquat dibromide (trade name: Reward) to maintain navigability and recreational access.

Sampling Analysis and Overview

Sampling from multiple locations within a waterbody and its watershed leads to better understanding of the water that enters the lake, how it is transformed within, and the water leaving the lake. To account for these changes over space and time, L&P samples at sites in tributaries, at the surface and bottom of mid-lake sites, and the outlet.

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 insight into where certain impairments in the lake originate. Outlets are the major exits for water in the lake. Most of the L&P program water quality parameters are measured at the major natural tributaries and outlets of the lakes.

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 3)*. At the in-lake locations, probe measurements and water samples were collected one foot below the surface of the water ("surface") and two 2 feet from 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 (NH_3), and nitrate (NO_3) on a monthly basis. Altogether, there were 12 sampling events. Although Worcester experienced its second wettest summer on record in 2023, only two of the sampling days were considered "wet weather" with 24-hour rainfall totals exceeding 0.25 inches. Those days include 16-Aug (0.35 in), and 19-Sept (1.44 in). Results from wet weather days are denoted with the symbol in the figures.

Samples were for cyanobacteria cell density were collected by a contractor as needed. Additionally, Worcester Department of Inspectional Services tested for *E. coli* as an indicator of 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 3 – *Aerial view of Indian Lake and approximate sampling locations.*

Quality Assurance/Quality Control

The Lakes and Ponds Program uses Quality Assurance/Quality Control (QAQC) checks to ensure that our data are representative of local conditions and meet precision and accuracy standards. QAQC check results identify data that need to be flagged and/or censored before they are shared and can highlight issues that affect data quality. When data fail to meet acceptable criteria for these checks, they are 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 through direct contact with animal waste, runoff during rainstorms from the shoreline and impervious surfaces like paved roadways, 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 collects 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 are above the recreational threshold of 235 cfu/100 mL. In past seasons L&P has collected samples for *E. coli* at the surface of certain in-lake sites to assess *E. coli* conditions in open water. As in-lake *E. coli* results never indicated concern, L&P ceased collecting them in 2023. However, L&P continues to collect *E. coli* samples at select tributaries, and beach testing by Inspectional Services continues.

Fecal Bacteria at Indian Lake. In 2023, Shore Park Beach was closed for two days, 3-Jul to 5-Jul, due to fecal bacteria exceedances. Results from beach testing conducted by Inspectional Services ranged between <4 and >20,000 CFU/100mL, with only one result exceeding the recreational limit *(see Table 1).* In 2023, L&P rates Indian lake as "Good" for fecal bacteria because although *E. coli* generally did not affect recreation, Shore Park Beach was closed for two days.

E. coli results at Ararat Brook were less consistent than those at the beaches, often exhibiting higher concentrations of bacteria during rain events (see *Table 2*). Results ranged from undetected to 816 MPN/100 mL. The highest result was recorded on a wet weather day on 19-Sep.

ARARAT BROOK	
DATE	RESULT
2-May	579.43
16-May	488.4
6-Jun	<1
21-Jun	85.74
5-Jul	307.59
18-Jul	140.12
1-Aug	111.9
16-Aug	686.67
6-Sep	201.42
19-Sep	816.41
3-Oct	42.57
17-Oct	<100

	SHORE PARK BEACH	CLASON BEACH
DATE	RESULT	RESULT
26-Jun	<4	80
3-Jul	>20,000	148
5-Jul	20	N/A
10-Jul	44	<4
17-Jul	40	40
24-Jul	12	8
31-Jul	8	24
7-Aug	<4	<4
14-Aug	<4	68
21-Aug	28	12

Excellent	*Good*
Fair	*Poor*

Red Text = Beach Closure

Tables 1 & 2 *Shore Park Beach was closed for two days, 3-Jul to 5-Jul due to fecal bacteria exceedances. E. coli results from Ararat Brook ranged between <1 and 816 MPN/100mL, with most results in the ranges considered "good" and "fair".*

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 to 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 are 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 are taken on a monthly basis and submitted to a lab for analysis.

Water Clarity at Indian Lake. Between 6-Jun and 5-Jul, Secchi depth readings were high compared to past results at Indian Lake ranging between 6.75 ft and 10.75 ft, indicating clearer water (*see Figure 4*). From mid-July through September, readings ranged between 4.5 ft and 5.25 ft, closer to past observations for summertime in Indian Lake. Secchi depth was in the range considered "Poor" on two occasions late in the season 19-Sep (3.75 ft), and 17-Oct (2.75 ft). This late season drop in clarity is expected based on past program monitoring results.

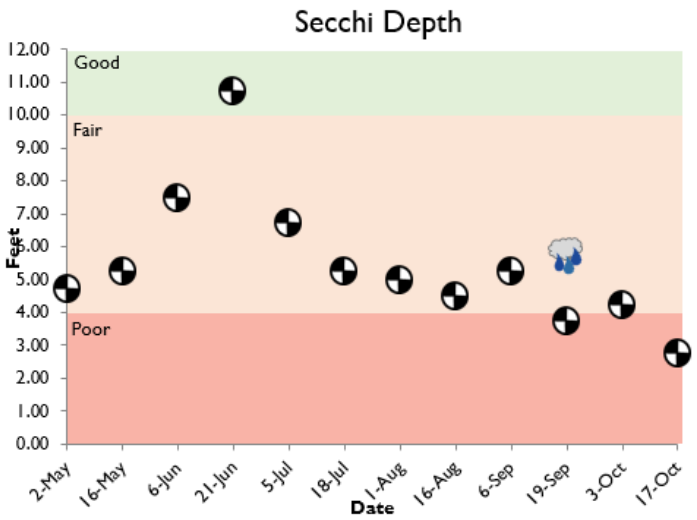


Figure 4 - *Secchi depth was considered "fair" for most of the season with some values in the "good" and "fair" categories. Depths ranged from 2.75-10.75 feet.*

At both in-lake sites, surface TSS results ranged between 1.5 mg/L and 8.9 mg/L, remaining in the range considered "Excellent" during all sampling events. These results were comparable to those in years past. All but one bottom TSS result from the Northern Site fell below 10 mg/L. As expected, TSS increased as Secchi depth decreased at Indian Lake. L&P rates water clarity at Indian Lake as "Fair" in 2023.

TSS results in Ararat Brook and the lake outlet were in a similar range, between undetectable to 10 mg/L. TSS results from Ararat Brook were generally low, indicating clearer water. Results from the spillway were more similar to the in-lake surface results than those of Ararat Brook.

Temperature

Water temperature is important to 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 oxygen, nutrients, and organic matter. Temperature was measured with a thermometer on a handheld probe at the water's surface at all sites and at the bottom for in-lake sites. To form a more complete picture of how temperature changes through the water column, depth profiles were created by taking measurements at 1-ft increments through the water column.

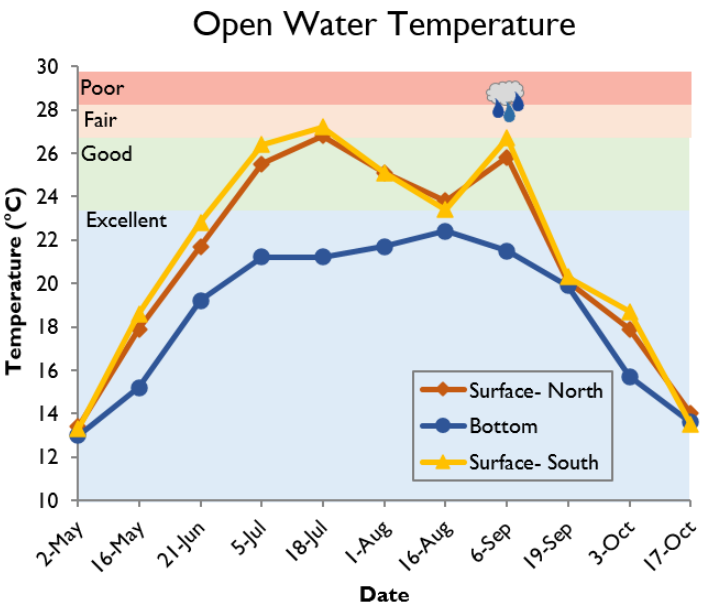


Figure 5 - *Surface water temperature remained in the "excellent" and "good" categories for most of the 2023 season, with one instance considered "fair" at both sites. Bottom temperature was considered "excellent" all year.*

Temperature at Indian Lake. Surface temperatures at the Northern and Southern Sites were similar to each other throughout the season, ranging between 13.4°C and 26.8°C, following expected seasonal variation (*see Figure 5*). Surface temperature readings rose at all sites from the beginning of the season to late summer, reached a maximum temperature on 18-Jul and fell for the rest of the season except for 6-Sep. As expected, bottom temperature at the Northern Site was lower than the surface, ranging between 13.0°C and 22.4° C.

To determine the extent of warming throughout the entire water column, depth profiles were taken at each site (see *Appendix*). Temperature was consistent throughout the water column all season, with a maximum difference between surface and bottom of only 0.4°C. This suggests that mixing throughout the water column is not impeded by thermal stratification. Therefore L&P rates temperature at Indian Lake as "Good" for 2023.

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, or 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, or hypoxic conditions, 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. To form a more complete picture of how DO changes through the water column, depth profiles were created by taking measurements at 1-ft increments through the water column.

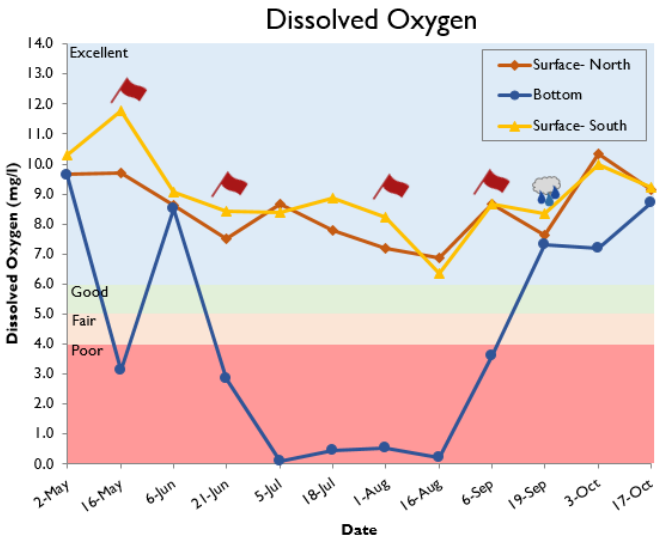


Figure 6 *- Dissolved Oxygen was considered "excellent" at the surface throughout the season. Bottom dissolved oxygen reached the "poor" category in May, June, July, and August.*

Dissolved Oxygen at Indian Lake. Surface DO in the Northern and Southern sites was high throughout the season; consistently in the range considered "Excellent" (*see Figure 6*). As seen in past years, bottom DO at the Northern Site was in the "Poor" range for 7 of 12 readings. All but one bottom reading between 16-May and 6-Sep reported DO below 4 mg/L, or in the range considered "Poor".

As observed from the depth profiles created, the water column was uniformly oxygenated during the first sampling session (see Appendix). Beginning in the end of June, DO concentration began to drop below 4 mg/L, the lower avoidance limit for fish, in the deepest reaches of the water column. From July through early September, a clear oxycline was observed in which water above 8 ft was fully oxygenated, and water below was anoxic. By the end of September, the water column was fully oxygenated to the end of the season. Though anoxic conditions were observed on the bottom of the lake, a large portion of the water remained fully oxygenated, and no fish kills were observed. Despite the presence of an oxycline during summer months, the top 9 ft of the water column always had suitable oxygen for aquatic life. L&P ranks DO at Indian Lake in 2023 as "Good".

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 are taken at the water's surface and two feet from the bottom.

pH at Indian Lake.

In 2023, pH at the Surface of Indian Lake had a wide range of results. At the Northern site, surface pH ranged between 7.35 and 8.69 with the highest reading taken on 16-May. Surface pH in the Southern site had an even wider range of 7.33 to 9.85. After an alum treatment on 6-June, pH readings fell closer to the neutral range at both surface sites. As seen in past years, surface pH readings were often higher at the Southern site than the Northern site. Bottom pH at the Northern site stayed more consistent through the season, ranging from 6.85 to 7.55. Indian Lake often exhibits the most basic water of any lake in the program. As basic conditions can encourage cyanobacteria growth, L&P will continue to pay close attention to pH readings in Indian Lake.

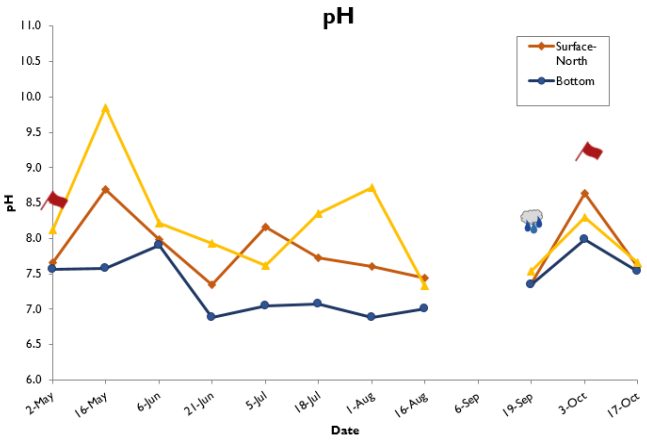


Figure 7 - *Surface pH was consistently higher than bottom pH and fluctuated throughout the season.*

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, phosphorus 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 collects samples for several compounds and submits them to an external lab for analysis. To measure N, samples are collected for Nitrate (NO_3) and Ammonia (NH_3) at all sites monthly. To measure P, samples are collected for total phosphorus (TP) twice a month at all sites, and total dissolved phosphorus (TDP) twice a month at all bottom sites. TDP is analyzed to understand how much P is dissolved in the water and available for use by aquatic organisms.

Nutrients at Indian Lake In 2024, Total Phosphorous results at the in-lake sites were generally lower compared to past years. At the Northern Site, surface results ranged from undetected to 0.027 mg/L, although all but one result was at or below 0.025 mg/L, or in the range considered "Excellent". At the Northern Site, most bottom TP results ranged from 0.015 to 0.025 mg/L and were therefore considered "Excellent". However, there were several outlier concentrations ranging from 0.046 mg/L to 0.052 mg/L. These high results were from 16-Aug and 6-Sep. All but one sample at this site contained undetectable concentrations of Soluble Phosphorus, with the one detected result falling in the "Excellent" range.

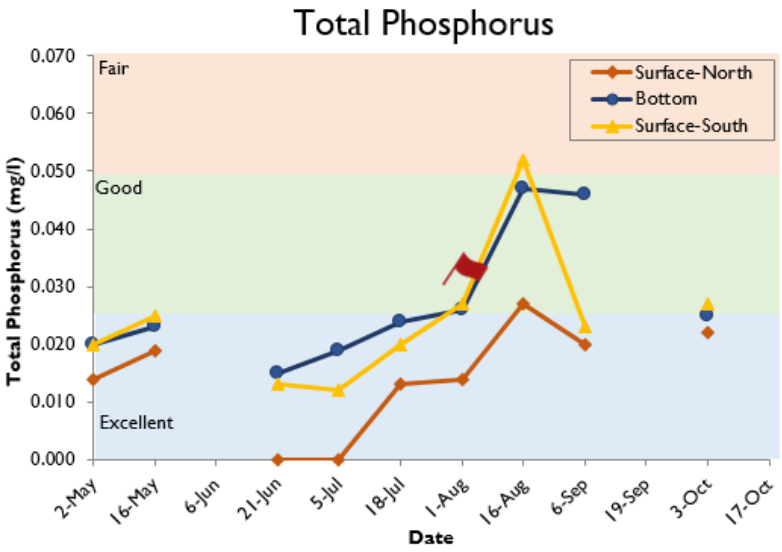


Figure 8 - *Total phosphorus was categorized as "excellent", "good", and "fair". Total phosphorus at the surface-north and bottom sites was generally lower than the surface-south site.*

In Indian Lake's primary tributary, Ararat Brook, results ranged from undetected to 0.026 mg/L. All but one result fell in the range considered "Excellent". By chance no samples were collected during the first flush of a heavy rain event, a situation that is often linked to high phosphorous results. Results at the lake outlet closely resembled the in-lake and tributary results.

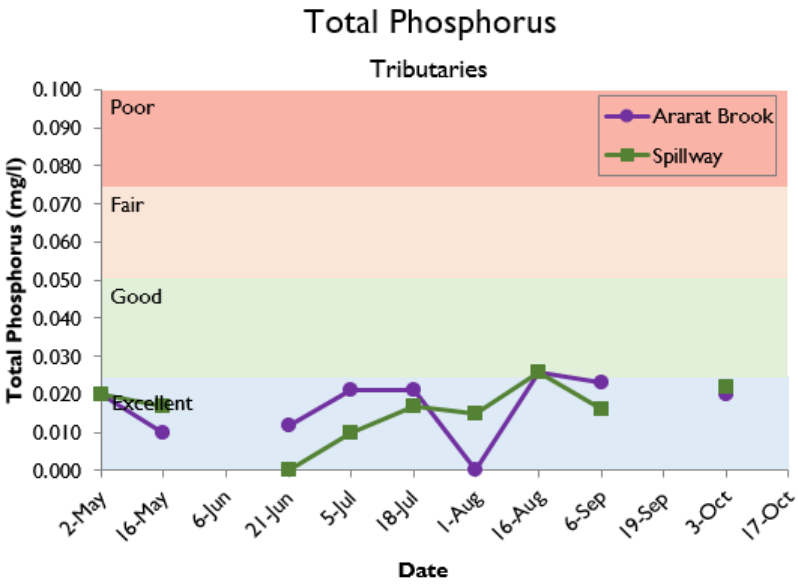


Figure 9 - *Total phosphorus in Ararat Brook was in the "excellent" category for the majority of the season.*

As in past years, NO_3 results were low at all in-lake sites. All but five results were undetectable, and those detected were below 0.6 mg/L; in the range considered "Excellent". Results were similar in the lake outlet. As seen in the past, higher NO_3 results were observed in Ararat Brook inlet, ranging from 0.562 mg/L to 0.882 mg/L. These results were in the range considered "Good."

As in past years, NH_3 results were low at all in-lake surface sites, with all results in the range considered "Excellent". Results at the Northern bottom site ranged from undetected to 0.332 mg/L, with one result in the range considered "Fair". NH_3 results in Ararat Brook and the lake outlet were consistently in the

range considered “Excellent”. L&P rates nutrients in 2023 at Indian Lake as “Good” because active management is required to reduce nutrient concentration and therefore cyanobacteria bloom risk.

Cyanobacteria

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

To understand the abundance of cyanobacteria and make decisions regarding lake management and safe access, L&P contracts samples for cyanobacteria cell counts on a weekly basis at Indian Lake to determine bloom risk. When results are above the recreational threshold of 70,000 cells/mL, the waterbody must be closed to recreation until cell counts fall. During cyanobacteria blooms L&P also contracts samples for cyanotoxins to establish whether they are present in concentrations that could be harmful. When possible, L&P uses preventative lake treatments, such as algaecide, to stop blooms from occurring before cell counts 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 algaecides and flocculants. In 2023, L&P utilized a novel nutrient management strategy, an

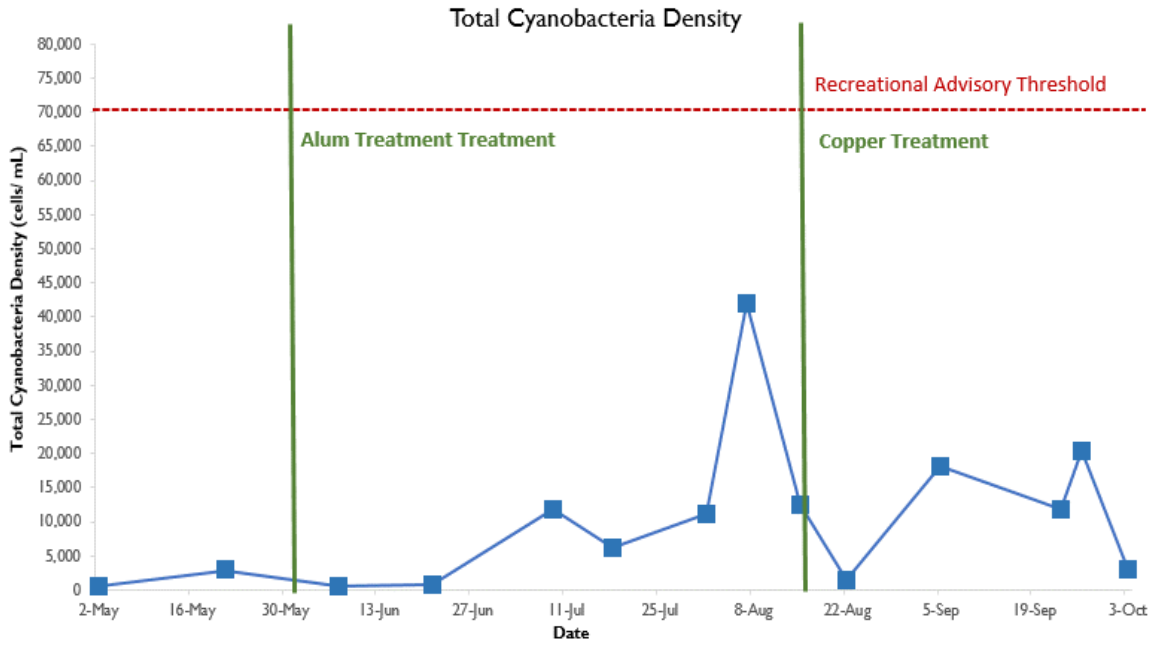


Figure 10 – *Cyanobacteria density at Indian Lake remained well below the recreational threshold of 70,000 cells/ml all season.*

alum dosing station at the inflow of Indian Lake's main tributary Ararat Brook. As construction delays limited treatment of spring rainstorms, L&P contracted an additional aluminum sulfate treatment on 31-May. When the alum dosing station came online in early June, it began adding polyaluminum chloride to the lake during rain events. Results from weekly testing contracted by L&P in 2023 ranged between 529 and 41,896 cells/mL of cyanobacteria, never crossing the recreational advisory threshold of 70,000 cells/mL (see *Figure 8*). Cell counts remained far below the advisory threshold for much of the spring and early summer. However, a result of 41,896 cells/mL on 7-Aug prompted L&P to contract a copper sulfate treatment to avoid cyanobacteria bloom conditions and keep Indian Lake open for recreation. Cell counts fell drastically after the treatment, although results received after the treatment indicated that cyanobacteria results had dropped to 12,441 cells/mL naturally before the treatment was carried out. Compared to previous years, results from 2023 showed slower growth of cyanobacteria populations and no disruption of recreational activities due to blooms. L&P rates cyanobacteria as "Good" in 2023.

Invasive Aquatic Plants and Animals

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 at new locations by hitching a ride on boats, pets, or boots. 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 are 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 and invasive 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 to expose invasive aquatic plants to the elements, as well as dive teams which removed 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 informal surveys did not identify 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 plans to continue efforts to control it in 2024.

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 2023 was treated with the herbicide, Reward on 9-Jun, which reduced density, easing recreation.

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. Because most industrial contaminants are legacy pollutants, contamination levels are not expected to change much year to year. 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. No results of concern were detected. See the 2022 Indian Lake Water Quality Report or contact greenworcester@worcesterma.gov for more information.

State of the Lake

Overall, water quality at Indian Lake continued to be rated as "Good" in 2023. Despite high rainfall totals, L&P's management plans were effective at keeping the lake open and safe for recreation. There were no lake closures due to cyanobacteria, and only one beach closure due to fecal bacteria exceedances. With results indicating a relatively mild summer, L&P rated temperature at Indian Lake as "Good". Secchi clarity was slightly higher than the expected range for Indian Lake, though still low enough to be rated as "Fair". Despite limited oxygen reduction at the bottom during summer months, the top 9 ft of the water column always had suitable oxygen for aquatic life leading to a rating of "Good". Although most surface phosphorous results were in ranges considered "Excellent", L&P rates nutrients in 2023 at Indian Lake as "Good" because active management is required to reduce nutrient concentration and therefore cyanobacteria bloom risk. There were no sightings of invasive Eurasian Milfoil in an informal plant survey.

Ongoing Projects and Plan for 2024

Water Quality Monitoring

In 2024, the Lakes and Ponds Program plans to continue to monitor Indian Lake 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 continue to pay particular attention to pH in 2024, as high and widely fluctuating pH can indicate conditions that are favorable for cyanobacteria and stressful for other aquatic life. Additional sampling to evaluate the effectiveness of the alum dosing station and improve its calibration will continue in 2024. This plan will aim to quantify the concentration of phosphorus before and after the addition of the compound during storm events. This will guide dosing

requirements and ensure that the project is attaining its intended goal of removing phosphorus before it enters the lake.

Since 2021, the Lakes and Ponds Program has installed solar powered continuous monitoring buoys at Lake Quinsigamond. These buoys use probes to track the cyanobacteria indicators phycocyanin and chlorophyll, as well as turbidity and temperature, and upload real-time data to an online dashboard. 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 as operation continues in 2024.

Figure 11 – *A continuous monitoring buoy was deployed to track cyanobacteria indicators in the northern cove of Indian Lake.*

Lake Management

Alum Dosing Station. In 2023, L&P began the use of the newly constructed alum dosing station, a system aimed at immobilizing phosphorous containing sediments as they enter Indian Lake. The intended result is to reduce the likelihood of lake-closing cyanobacteria blooms and to improve lake water clarity, increasing safety and making the lake more attractive for recreation. Ararat Brook is the major tributary to Indian Lake, and has many storm drain outfalls that carry stormwater containing phosphorus into the lake. The renewed influx of phosphorus with each rainstorm is in part of why lake-wide aluminum sulfate ("alum") treatments have been only temporarily effective at reducing lake phosphorus concentrations. The alum dosing station utilizes polyaluminum chloride (PAC), a compound similar to alum, that is best suited for this location and application method. The station selectively doses PAC during rainstorms, when phosphorous input from Ararat Brook is greatest, efficiently treating nutrients at their source.

During the first season of its use, L&P worked with a contractor to evaluate performance and determine operation practices that optimize phosphorous reduction and system efficiency. Monitoring results showed consistent phosphorous reduction following PAC application and determined optimal dosing rates. In 2024, L&P will continue to hone operational procedures and monitor performance. It will likely take several years to understand the full potential impacts of this system, however, initial results are encouraging.

Figure 12 – *The Alum Dosing Station came online in early June of 2023. Results from the first year of operation are encouraging.*

This project was made possible by advocacy from the Indian Lake Watershed Association (ILWA) and other community partners, and land donations from Bancroft School and the Unitarian Universalist Church.

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 the impact of invasive aquatic plants 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 though 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 utilized 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 13 *- 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 lifeguards erected 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 2023, lack of staffing at Clason Beach meant that fencing was only implemented at Shore Park Beach. L&P plans to continue the use of goose fencing at Indian Lake's beaches in 2024 as lifeguard staffing allows.

Figure 14 – *Goose fencing has proven to be an effective strategy for managing fecal bacteria at Indian Lake.*

Education and Outreach

Text Message Alert System. In 2023, the Lakes and Ponds Program launched a text message alert system allowing residents to sign up to receive up-to-date information on lake access to guide upcoming visits. Text messages will alert residents when a beach is closed for fecal bacteria exceedances, or if a boat ramp is closed because a lake is receiving an invasive aquatic plant treatment. Especially since many lakegoers use public transportation to access waterbodies, L&P aims to provide a resource that can help to guide plans before people begin travel. The Lakes and Ponds Program will continue to work with DCR, Inspectional Services, and the Parks Department to establish a flow of information to keep the system up to date.

Litter. Inappropriately disposed waste is harmful to the ecological, aesthetic, and recreational value of lakes and ponds. In 2024, DSR will begin work on a Zero Waste Master Plan that will provide a comprehensive strategy for understanding and mitigating the impact of waste in our community. Lakes and Ponds Program will collaborate with DSR staff on ways to reduce impact of waste and litter in our lakes and ponds.

To learn more about Lakes and Ponds Program offerings, please see WorcesterMA.gov/bluespace.

Appendix: Depth Profiles