Background

About 90 acres in size, Coes Reservoir is located between the Columbus Park and Webster Square neighborhoods of western Worcester. It is 16 feet deep at the deepest point, which is located in the southern portion of the reservoir. Coes Reservoir was created when Tatnuck Brook was dammed in the mid 1800's in order to supply water power to the Coes Knife Factory. It is located at the end of a chain of mill ponds along Tatnuck Brook, which extends south from Holden.

Coes Reservoir is bordered on the west side by Mill Street, a highly trafficked roadway. The City of Worcester owns parkland around the southern and eastern portion of the waterbody, including a public beach, a universal access park, and walking trails. Under construction now are a boardwalk and fishing pier, as well as a kayak boat launch at the Mill Street Beach. Coes Reservoir therefore is a fantastic recreational resource, serving as a venue for swimming, fishing, boating, and walking.

Water Quality Summary

As an urban lake, Coes Reservoir feels many of the pressures of the city. However, management by community groups, and more recently, the Lakes and Ponds Program, has meant that the waterbody has enjoyed water quality that has been consistently rated as "good" for recreation and wildlife. In 2020, this continued to be the case. While the reservoir was created for industrial uses, monitoring has not revealed any industrial or emerging contaminants in the water column that would concern recreational users. While invasive aquatic plants continue to be a challenge at Coes Reservoir, the adaptable management plan has been effective at keeping the reservoir generally free of weeds, at least in the lower portion. While the lake does suffer from higher than ideal concentrations of phosphorus, which may lead to lower water clarity and possible cyanobacteria blooms, a cyanobacteria monitoring plan is in place that has been successfully kept algal toxins from

Figure A **-** Goose fencing was developed and installed during off-hours at the beach, reducing goose congregation and possibly contributing to fewer beach closures for fecal bacteria in 2021.

being produced. The most concerning finding in 2020 was the increase in beach closures caused by the fecal bacteria indicator, *E. coli*. In 2021, steps were taken to reduce this risk. Overall, these efforts were successful and in 2021 the State of the Lake remains "good". The lake had no closures for cyanobacteria blooms, and the number of beach closures for fecal bacteria was reduced and only occurred after major storms.

Management Summary

Coes Reservoir has had management plans for cyanobacteria and invasive aquatic plants for several years now. Additionally, in 2021 a plan was implemented to deal with the increased number of closures due to *E. coli* bacteria that were witnessed in 2020. Following monitoring data aimed at assessing the risk of cyanobacteria blooms, there were two treatments of algaecide applied to the surface of Coes Reservoir, one in July and one in September. Together, these treatments kept cyanobacteria densities safe for recreation and wildlife. To address the three invasive aquatic plants presently found at Coes, including water chestnut, fanwort, and Eurasian milfoil, the Lakes and Ponds Program used a combination of physical removal and herbicide strategies. It should be noted that in 2019 a successful systemic herbicide treatment significantly reduced the fanwort and milfoil density through 2020, and in 2021 minimal intervention was necessary to control grow-back. To address the ongoing water chestnut concern, two rounds of the herbicide Clearcast were applied in June and July, and hand pulling was performed in September. Together, these activities were successful in reducing the density of the invasive plant during the season. Unfortunately, due to its unique reproductive strategy, it will be many more years before the water chestnut will be completely eradicated. Following high *E. coli* readings in 2020 and a suspected relation to goose activity, goose fencing was developed and installed during off-hours at the beach. This ultimately reduced goose congregation on the beach and may have contributed to fewer beach closures for fecal bacteria in 2021 (see *Figure A*).

Sampling Analysis and Overview

Coes Reservoir was visited semimonthly in 2021 from May through November and sampled at four locations: The major aboveground tributary, Tatnuck Brook; the two deepest parts of the reservoir (the northern is about 13 feet deep and the southern is about 15 feet deep); and the outlet at the spillway located in the southern part of the reservoir (see *Figure B*). Parameters evaluated included: Secchi transparency, temperature, dissolved oxygen, pH, total phosphorus, total dissolved phosphorus, *E. coli*, phycocyanin, and litter. Samples analyzed for total suspended solids, ammonia, and nitrate were collected on a monthly basis. Altogether, there were 14 sampling events. For 12 of these events, there had been no rainfall 24 hours prior to data collection. However, on 7/8 there was 0.32 inches of rain in the previous 24 hours to sampling, and on 8/19 there was 3.05 inches of rain. These days are categorized as "wet weather" sampling events.

Figure B **-** Coes Reservoir map and approximate sampling locations.

In addition to Lakes and Ponds Program sampling, volunteers from the Worcester Cyanobacteria Monitoring Collaborative took samples for phycocyanin and particle counts in preparation for monthly meetings on 5/22, 6/19, 7/17, 8/21, 9/25 and 10/26. The City of Worcester Department of Inspectional

Services tested the Binienda Beach for *E. coli* as an indicator for harmful bacteria on at least a weekly basis during the summer months.

Raw data are displayed and explained below. 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 Protections SMART Monitoring Watershed Report Card Criteria. While the report will refer to previous data collected by the program, one must be cautious in comparing data sets of this nature over a five year period.

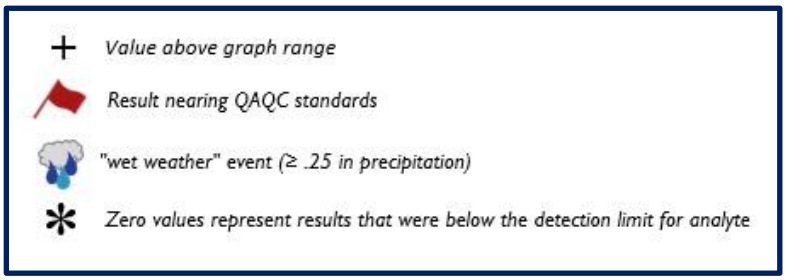

Figure C - Data points with QAQC abnormalities or other notable attributes are marked on figures with these symbols.

Quality Assurance/Quality Control

To have confidence that the data that were collected are representative of local conditions, Quality Assurance/Quality Control (QAQC) checks were employed along at all steps of the sampling and analysis process to verify the validity of the data. Duplicate samples, or two measurements or samples taken in a row, were compared to ensure precision. Matrix spikes compared results to known benchmarks to ensure they were close to their true value. Blanks were samples of pure water that were submitted as samples to the lab to test the equipment, technique, and the lab analysis. All checks were carried out randomly to ensure that each parameter received robust review. 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 (see *Figure C*).

Fecal 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. While most strains are harmless, some can make you very sick. These bacteria can come 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, and improper application of manure on land. 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 results are too high, the city is required to close the beach until readings return to safe levels. The Lakes and Ponds Program also samples for *E. coli* semimonthly at one in-lake site to understand it's prevalence in the middle of the lake. Samples are collected from the water's surface and sent to an external lab for analysis.

Bacteria at Coes Reservoir. Overall, there were many fewer beach closures due to *E. coli* at the beach at Coes Reservoir this year. In 2021, the beach was only closed for 4 days, compared to 13 in 2020. The 4 day closure this July was associated with two wet weather events. Apart from these days, results from beach sampling were in the "good" or "excellent" categories. Coes Reservoir Beach was one of two sites designated for a goose fencing pilot project, which may have contributed to these results. Results from open water bacteria samples were all in the "excellent" and "good" categories, never coming close to the recreational limit. Overall, Coes Reservoir has improved over 2020 in regards to fecal bacteria.

OPEN WATER E.COLI RESULTS		BEACH E.COLI RESULTS	
DATE	RESULT	DATE	RESULT
6-May	5	28-Jun	28
20-May	6	6-Jul	24
3-Jun	7	12-Jul	180
17-Jun	20	19-Jul	556
8-Jul	91	20-Jul	252
21-Jul	40	21-Jul	76
5-Aug	7	22-Jul	20
19-Aug	16	23-Jul	4
9-Sep	13	26-Jul	12
7-Oct	10	2-Aug	20
4-Nov	11	9-Aug	56
19-Nov	2	16-Aug	32
		23-Aug	48
		30-Aug	44

Excellent	*Good*	**Beach closure**
Fair	*Poor*	

Results in colonies/100 ml

Table 1 – In 2021, Coes' beach was closed for four days, compared to 13 in 2020. Open water bacteria results fell in the "excellent" and "good" categories.

Water Clarity

Water clarity, or the level of transparency of water, is an important measure of water quality. Algae, microscopic organisms, eroded particles, and re-suspended bottom sediments are factors that interfere with light penetration and reduce water transparency. Water clarity is important for a variety of reasons in a lake. Clear water allows light to penetrate to greater depths and encourages the growth of aquatic plants, which provide food, shelter, and oxygen to aquatic organisms. Conversely, turbid water, or water filled with particles, will warm up faster as it absorbs heat from sunlight. This causes oxygen concentration to fall because warm water can hold less oxygen than cool water. Finally, clear waters are pleasant to the eye, and generally safer for recreational contact. 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. TSS is a measure of the dry weight of

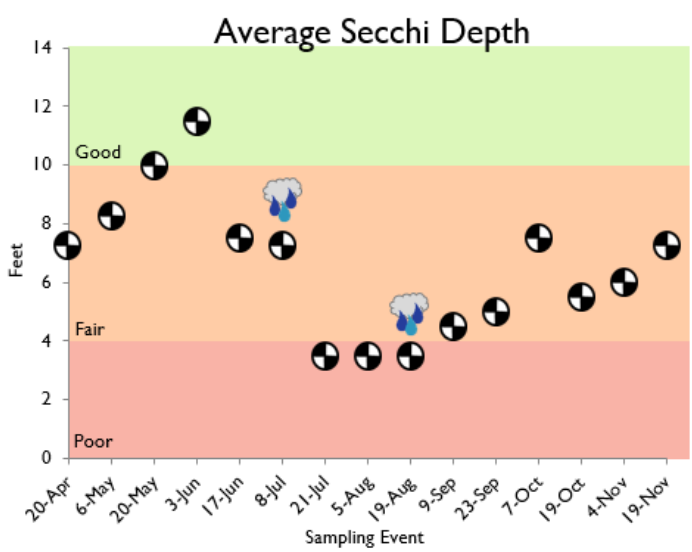

Figure D – Secchi depth decreased after May through August, but only increased into the "fair" category again before the season ended in November.

suspended particles in a given amount of water. TSS samples are taken on a monthly basis and submitted to a lab for analysis. This year the Lakes and Ponds Program used samples collected by the Worcester Cyanobacteria Monitoring Collaborative (WCMC) to help assess clarity by conducting particle counts on a tool called the FlowCam Cyano. The FlowCam takes microscopic pictures of the particles in a sample, counts them and allows users to catalog classifications. This aids in understanding what may be impeding clarity and determining next steps for management.

Water clarity at Coes Reservoir. At Coes Reservoir, Secchi depth was rated as "fair" to "good" in the beginning of the season, with a maximum clarity of 12 feet in early June (see *Figure D*). As the season went on, Secchi fell from "fair" to "poor", only increasing again at the end of September. Clarity did not reach a rating of "good" again for the rest of the season. Compared to previous years, clarity was lower than average at Coes Reservoir.

Temperature/Stratification

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. Water temperature also affects the speed of chemical reactions in addition to how much oxygen can be held in the water. The extent to which water circulates through a lake affects the ability of that water to support aquatic life by mixing oxygen and nutrients up and down the water column. Because the density of water changes with temperature, variations in temperature can cause cold water to settle in a layer on the bottom while warm water stays on top, resulting in stratification. While a natural process, stratification can prevent the replenishing of oxygen on the bottom layers of the lake, and the rise of sediment nutrients to the top, which may be detrimental to lake health.

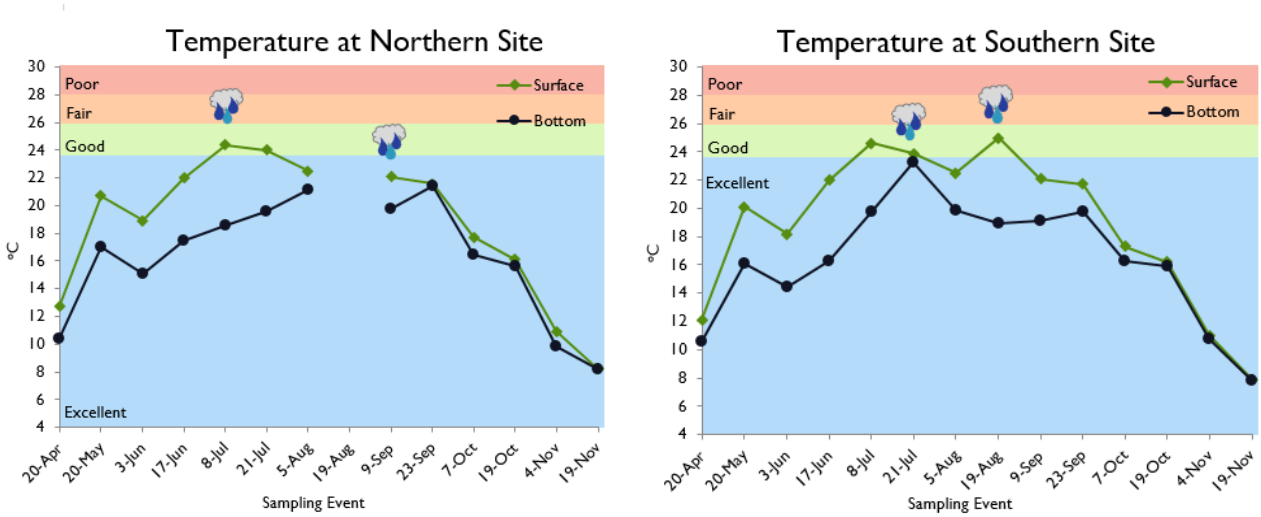

Figure E – *Temperature stayed in the "excellent" category for the majority of the season at the surface and bottom at both sampling sites.*

Temperature at Coes Reservoir. Temperatures at Coes Reservoir stayed in the "excellent" category at the bottom for the entire season. The surface fared similarly, only dipping into the "good" category 2 or 3 times in July and August (see *Figure E*). This is a noticeable improvement from 2020, when the surface temperature was an average 0.9 degrees higher. It is possible that the cooler, rainier summer dampened water temperatures. Surface and bottom temperatures at the two in-lake sites were very similar, suggesting that water was well mixed.

Dissolved Oxygen

Oxygen in the water is essential to aquatic life, just like it is for life on land. Because algae, plants, fish, and other aquatic organisms require a certain amount of oxygen to survive, dissolved oxygen (DO) is an important indicator of water quality. It is a highly variable parameter with daily and seasonal variation. DO concentration can be affected by temperature, pressure, rate of photosynthesis, and respiration by aquatic life, decomposition, aeration, and diffusion. Systems experiencing nutrient loading can suffer from low DO due to increased algal growth and excessive decomposition of organic material. This can lead to fish kills and other ecological issues. DO was measured using a Galvanic DO sensor on a handheld probe at the water's surface, and two feet from the bottom in the in-lake locations.

Dissolved Oxygen at Coes Reservoir. In 2021, DO at the surface of the Reservoir was rated as "excellent" at both in-lake locations, all season long (see *Figure F*). At the bottom, DO began to decline in early June, with bottom DO concentration rated as "poor" between July and the end of September, with the exception of one event at the southern site. Most bottom measurements in this time period were close to 0 mg/l, or anoxic. These results are in line with results from previous years. In past years, depth profiles showed decreasing DO in July and August, approaching the bottom of the lake. However, concentrations did not fall below 4mg/l until a depth of around 9 feet, leaving plenty of the lake with enough DO for aquatic life. However, to ensure that this remains the case, additional profiles will be performed at Coes Reservoir in 2022.

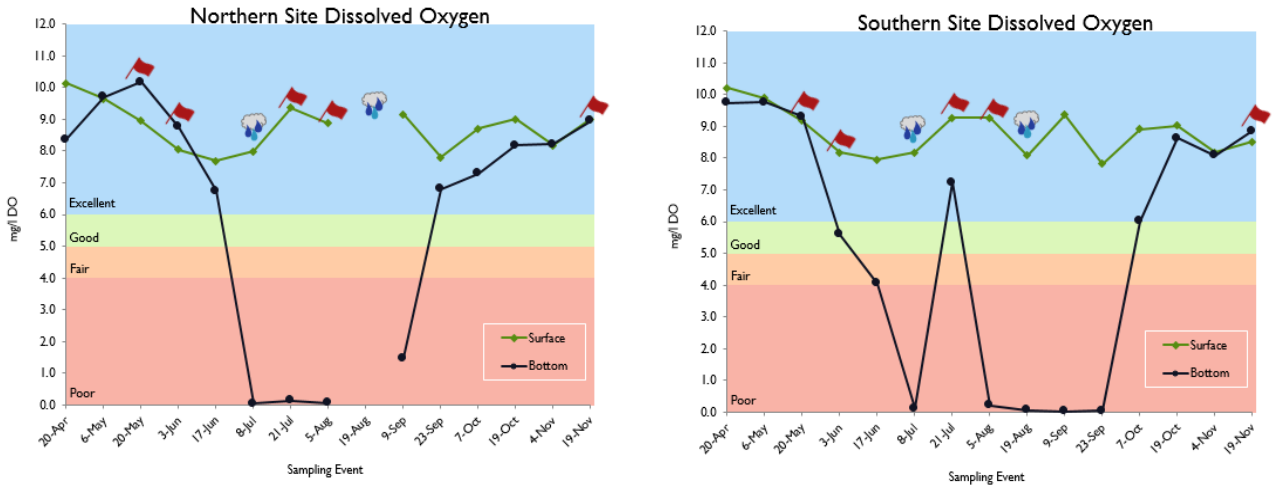

Figure F – Surface DO stayed in the "excellent" category all season at both sampling locations. Readings at the bottom of the lake were very low between July and September.

pH

pH is a measure of the number of hydrogen ions (H^+) in a substance. The more H^+ that are present, the more acidic the solution. On a scale of 0-14 units, 7 is a neutral pH. As you increase from 7, the solution is more basic, and as you decrease, it becomes more acidic. In waterbodies, pH can change due to respiration and photosynthesis by aquatic organisms. A pH that is too high or low can have implications on the health of aquatic organisms. For example, a high pH can also promote chemical reactions that release phosphorus from lake sediments. Like DO, pH can vary throughout the day and season. Healthy lakes in this area have a pH between 6.5 and 8.5. A low pH can be the result of external forces like acid

rain. pH is monitored using an ion-selective electrode (ISE) pH sensor on a handheld monitoring probe. These readings are taken at the water's surface and two feet from the bottom in the open water locations.

pH at Coes Reservoir. This year at Coes, pH ranged between 6.6 and 7.8, which falls within a healthy range for lakes in this region (see *Figure G*). As expected, surface pH tended to be higher than bottom pH. The difference between the surface and bottom readings was smallest in the beginning and the end of the season. During the months of June through August, bottom pH decreased compared to the surface, which follows the observation of low DO during this time period. It is common for high rates of decomposition on the lake bottom to result in increased dissolved CO_2, lowering the pH. In general pH at Coes Reservoir is in a normal range and is not a hindrance to aquatic life or recreation.

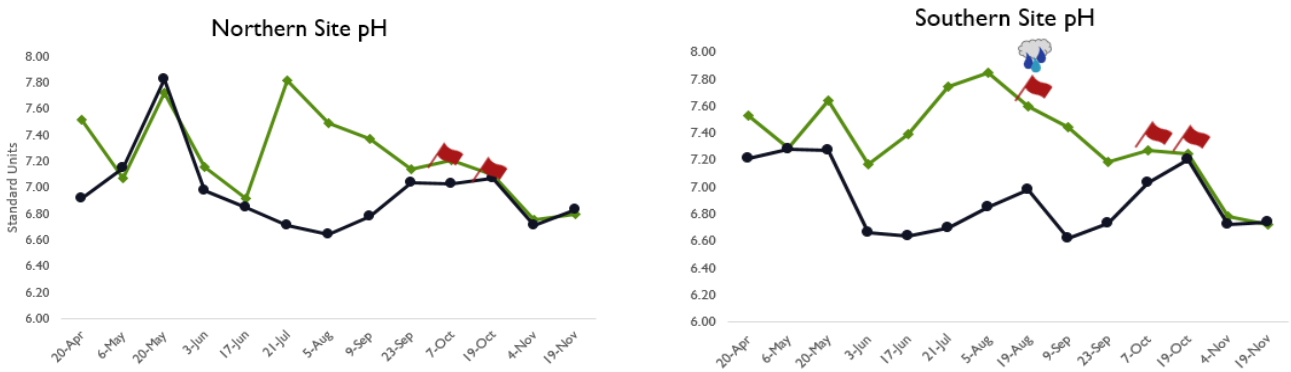

Figure G – pH was generally lower in the deep vs shallow parts of the reservoir, however all results were in the expected range and safe range.

Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), are food sources for aquatic plants and algae. Although aquatic plants and algae are the basis of the food chain, and necessary for a healthy lake ecosystem, an overabundance of nutrients can lead to issues such as harmful algal blooms and excessive plant growth. Overgrowth of these organisms can lead to conditions where oxygen is depleted in the water column, potentially causing fish kills. These nutrients have many known sources in urban lakes including fertilizers, pet and goose waste, illicit sewer connections, and runoff that washes over land and into the storm sewer 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. Nutrients are measured in our lakes by collecting a variety of samples and submitting them to an external lab for analysis. N takes several forms in water bodies, including nitrate (NO_3) and ammonia (NH_3). To measure N, samples are collected for NO_3 and NH_3 at all sites monthly. For phosphorus, samples are collected bi-weekly for total phosphorus (TP) at all sites and total dissolved phosphorus (TDP) at all bottom locations (not displayed). Measuring TDP allows us to understand how much total phosphorus is in a form that can be easily absorbed by plants and algae.

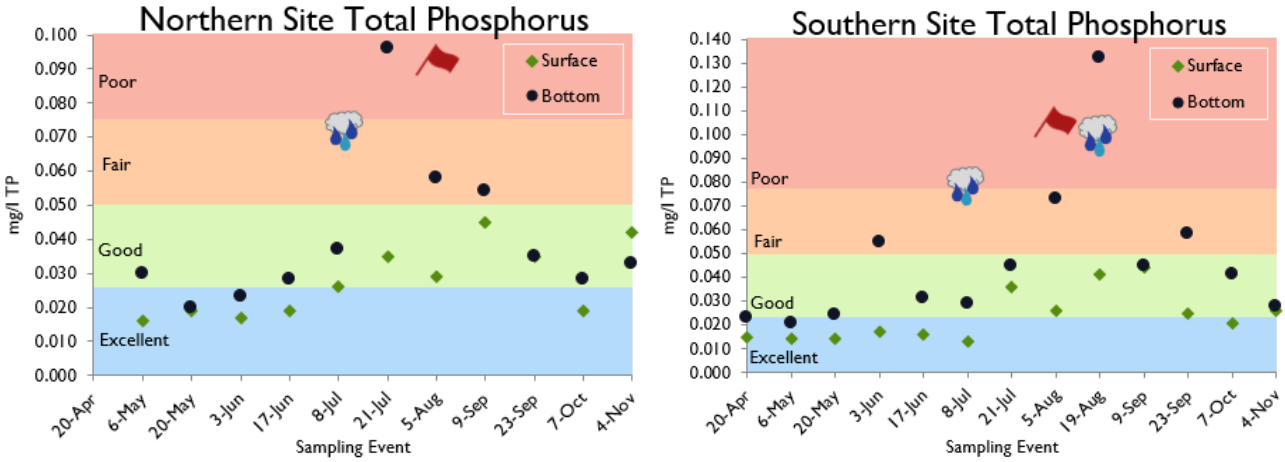

Figure H – Total Phosphorous stayed in the "excellent" and "good" categories at the surface at both sites but strayed into the "fair" category at the bottom.

Nutrients at Coes Reservoir. While TP was in the "excellent" category at the surface in the beginning of the season, concentrations began to rise into the "good" category in mid-July (see *Figure H*). This is generally in line with what has occurred at Coes over the past few years. TP at the bottom increased to the "fair" category in August, but readings returned to the "good" category by the end of the season. There were also results in the "poor" category on 7/21 and 8/19. Although this trend was generally mirrored between the northern and southern sampling sites, the southern site experienced more bottom sample results in the "fair" category over the course of the season. The increase of the TP concentration as the season went on may have put Coes at higher risk for cyanobacteria blooms.

Ammonia in mg/l	North Site		South Site	
	Surface	Bottom	Surface	Bottom
20-May	ND	ND	ND	ND
17-Jun	ND	ND	ND	ND
21-Jul	ND	0.267	ND	0.248
19-Aug			ND	0.789
23-Sep	0.075	0.396	ND	0.310
19-Oct	0.081	0.111	0.080	0.102
19-Nov	0.192	0.190	0.197	0.183

Figure I – Most NH_3 results were below the detection limit. At the southern site, there were elevated results at the bottom.

Generally, nitrate concentrations were low at all sites, with all results below 1 mg/L, which is indicative of an unpolluted waterbody. Surface results for ammonia were also in the "excellent" category throughout the season in all locations save one "good" result in November (see *Figure I*). At the bottom of the lake, ammonia was less consistent, with higher results in August and September.

Cyanobacteria

Cyanobacteria are naturally occurring microorganisms in aquatic ecosystems. These organisms are bacteria that use sunlight, N, and P in a similar way to algae. While they are present in small numbers in healthy ecosystems, under warm, high-nutrient conditions they can reproduce quickly, causing a bloom.

Cyanobacteria blooms, in addition to being unsightly and smelly, 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 understand cyanobacteria dynamics in our lakes and ponds.

The MA Department of Public Health has advisory thresholds for cyanobacteria, and if the density of cyanobacteria cells is too high, a waterbody must be closed for recreation. During the summer months, as the potential for blooms increases, the Lakes and Ponds Program contracts an environmental consultant to perform cell enumerations, or cell counts, of cyanobacteria to determine if there is a public health risk and inform management.

Cyanobacteria at Coes Reservoir. There were no closures due to cyanobacteria exceedances at Coes Reservoir in 2021. Cyanobacteria cell counts remained low in the early season, beginning to increase in early July (see *Figure J*). A preventative algaecide treatment was conducted on 7/22, which brought the density down at the end of July. Previously, one treatment was enough to keep densities low at Coes for the rest of the season. However, as the 2021 season progressed, the cell count increased again in late August, and a second treatment was conducted for 9/16. 2021 was the first year that two treatments have been applied in the same year at Coes. After the second treatment, the cell count fell and did not rise again for the remainder of the season.

WCMC

Photo Credit: Stephanie Tam

The Worcester Cyanobacteria Monitoring Collaborative (WCMC) is a group of community science volunteers that is working to better understand the diversity and abundance of algae and cyanobacteria in local lakes and ponds. Volunteers collect data monthly between spring and fall at 22 waterbodies in and around Worcester, including Coes Reservoir. Samples are collected for pigment analysis, particle counts and qualitative analysis under a microscope. In the future, this program aims to provide robust quantitative data to local government and community members to assist in making public health and lake management decisions. To learn more about the program, you can visit WoprcesterMA.gov/WCMC.

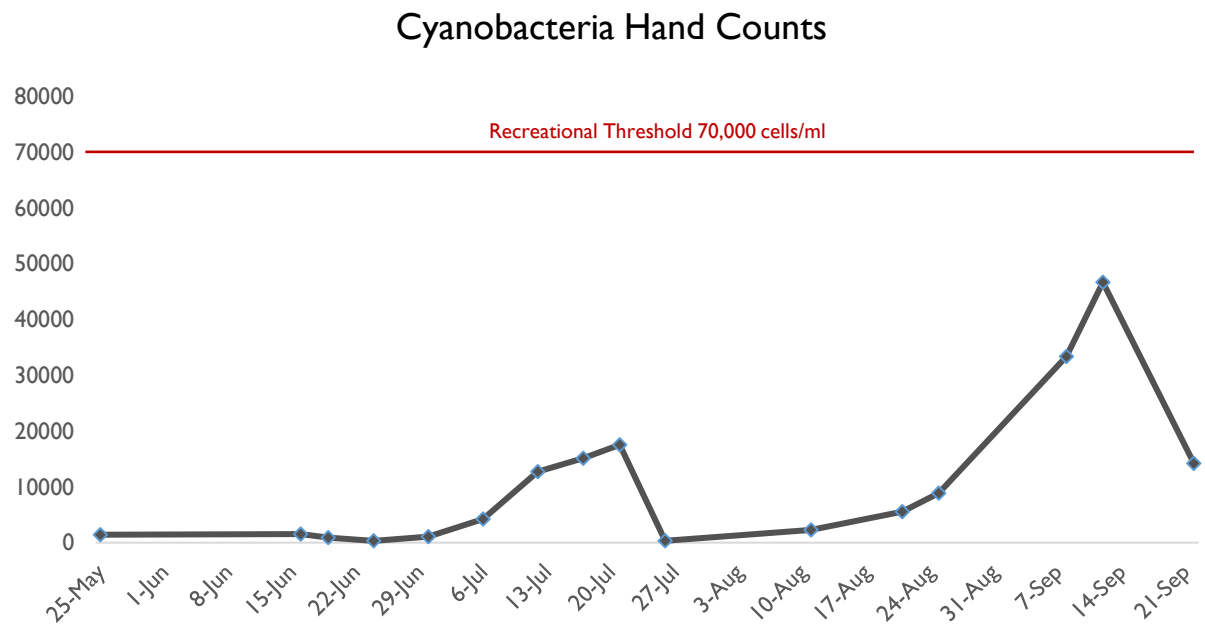

Figure J – Cyanobacteria counts peaked in late August and fell after the treatment on 9/16. They rose again in September and required a second treatment in September.

Invasive Aquatic Plants and Animals

Native aquatic plants and animals are vital parts of any lake ecosystem. Native 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. Native 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, or did not originally come from the area. These plants and animals can 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 rapid rate. When aquatic plants and animals become too numerous, they can reduce people's ability to enjoy our lakes and ponds, as well as crowd out local species. Invasive organisms can arrive by hitching a ride on boats, pets, or boots to get from place to place. 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.

Figure K – Northern end of Coes Reservoir before and after treatment for invasive water chestnut.

Invasive aquatic organisms at Coes Reservoir. Coes Reservoir is managed for three invasive aquatic plants: water chestnut (*Trapa natans*), fanwort (*Cabomba caroliniana*), and Eurasian milfoil (*Microphyllum spicatum*). Over the years, the Lakes and Ponds Program has continued to refine its plan for each of them based on present conditions. At the end of 2020, the disbursal of aquatic plants was mapped in order to track progress and more effectively manage them in coming years (see *Figure L*).

Figure L – *Aquatic invasive plant coverage at the end of the season in 2020.*

All treatments are approved by the Worcester Conservation Commission and applied by licensed professionals. In 2019, the systemic herbicide fluridone (trade name: Sonar) was used to address both the Eurasian milfoil and fanwort. As a systemic herbicide, the herbicide killed the milfoil at the root, which means that affected plants were not expected to grow back the following year. The treatment was successful and very little was present in the 2020 end-of season survey. In 2021, those patches were

treated with the contact herbicide diquat dibromide (trade name: Reward) so remaining plants would not reproduce.

Previously, the invasive aquatic plant water chestnut, which is found primarily in the northern portion of the reservoir, was managed using a mechanical harvester, which acts similarly to a floating lawn mower, cutting back and removing the floating vegetation before it matures to a reproductive state. Unfortunately, the size of the infestation and geography of the reservoir makes it difficult to eradicate all plants with this method. In 2021, the contact herbicide Imazomox (trade name Clearcast) was applied on 6/18 and 7/21 and greatly reduced the density of water chestnut (see *Figure K*). A hand pull was conducted on 9/13 by Lakes and Ponds Program staff to address the remaining patches of water chestnut outside of the main treatment area. Unfortunately, the reproductive strategy of the water chestnut means that it will need to continue to be managed over the next 5-7 years before the infestation in eradicated. But, overall, while present, invasive aquatic plants are being successfully managed at Coes Reservoir.

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.

Figure M – *Litter on Binienda Beach.*

Litter is a difficult parameter to measure in a quantitative way. This past year, the Lakes and Ponds Program was privileged to work with several students from WPI to develop a tool to track and quantify litter at our public spaces. The students determined a classification system that used two sets of metrics: One that included overall condition of the beach for various aspects of usability, and one that characterized the litter itself.

There were five categories that were used for judging "*Overall Conditions*", including cleanup effort, aesthetic, safety, litter density, and impact on the functionality of the site. Each one of these categories receives a score from 1-5. The final score therefore ranges between 5 (the best) and 25 (the worst). The

second portion of the clarification includes "*Litter Characterization*", which compares the different types of litter found that day, and includes things like bottles, glass, tobacco products, textiles, and other things commonly found in public spaces.

Litter at Coes Reservoir. Litter was characterized at Binienda Beach on Mill Street. Through the sampling season, the beach scored an average of 2 in each of the categories "Clean-up effort", "At a glance", "Safety", "Litter density", and "Impact/functionality". This indicates that litter was present but conditions were not severe and cleanup would not be extremely difficult. Relative abundance of the different types of litter were also noted. Of the litter categories assessed, "small items", "tobacco products", and "food packaging and containers" usually scored 3 or higher, while the rest scored 2 or below. Before September, it was often observed that litter had gathered in the reeds along the shore, but this was not as common later in the season. A large accumulation of trash was observed on the southern side of the beach as the season went on. The hope is that this information can help to guide management decisions.

Overall Litter Conditions

Date	Clean Up Effort	At a glance	Safety	Litter Density	Impact/Functionality	Matrix Score
6/17	2	2	2	2	2	10
7/8	2	2	2	2	2	10
7/21	2	2	2	2	2	10
8/5	2	2	2	2	2	10
9/9	2	2	2	3	2	11
9/23	2	2	2	2	2	10
10/7	2	2	2	2	2	10
10/19	2	2	2	2	2	10
11/4	3	2	3	3	2	13

Table 2 **—**The beach at Coes Reservoir generally scored 2 for Overall Litter Condition, indicating that litter was present but not severe.

Litter Characterization

Date	Bottles	Plastic cups	Glass	Bags	Food packaging	Tobacco products	Recreational/toys	Textiles/clothing	Junk	Small items
6/17	2	1	2	1	3	4	3	3	2	4
7/8	3	2	2	3	4	3	3	2	2	4
7/21	2	1	1	3	4	3	2	2	1	5
8/5	2	2	1	1	3	3	3	2	1	4
9/9	4	1	2	2	4	4	1	2	1	4
9/23	3	2	2	2	3	3	2	1	1	4
10/7	2	3	2	2	2	3	2	3	3	3
10/19	2	3	2	3	3		1	3	2	3
11/4	2	2	2	3	2	3	2	3	3	3

Table 3 **–** Of the litter categories, "small items", "tobacco products", "bags" and "food packaging and containers" scored highest.

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 or outfall 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 are measured at the major natural tributaries and outlets of the lakes in the Lakes and Ponds Water Quality Monitoring Program.

Tributaries at Coes Reservoir. At Coes Reservoir, the major natural tributary is Tatnuck Brook, which enters the pond from the north. The major outlet of the reservoir is the spillway, located on the southern end. Tatnuck Brook is considered a Coldwater Fisheries Resource (CFR), which means that it is a stream in which reproducing coldwater fish have been found. Tatnuck Brook, therefore, has higher standards for temperature than many local urban waterbodies. Over the 2021 sampling season, the brook had a maximum temperature of 22 degrees on July 8, and was in the "fair" temperature range for 5 of the 14 sampling events (see *Figure N*). As water from Tatnuck Brook enters Coes Reservoir, it slows down and is more exposed to the sun and air, warming it up. On average, the water leaving the Coes Reservoir spillway is 2.4 degrees higher than when it enters.

Dissolved oxygen generally stayed in the "excellent" and "good" categories all season in both locations. The spillway had slightly higher DO readings from May through October but with Tatnuck Brook surpassing the spillway concentrations through the end of the year.

Total phosphorous was also in the "excellent" and "good" categories for most of the season with one "fair" and one "poor" reading in Tatnuck Brook. Tatnuck Brook had slightly higher phosphorus results than the spillway between May and July but they were roughly equal for the rest of the season.

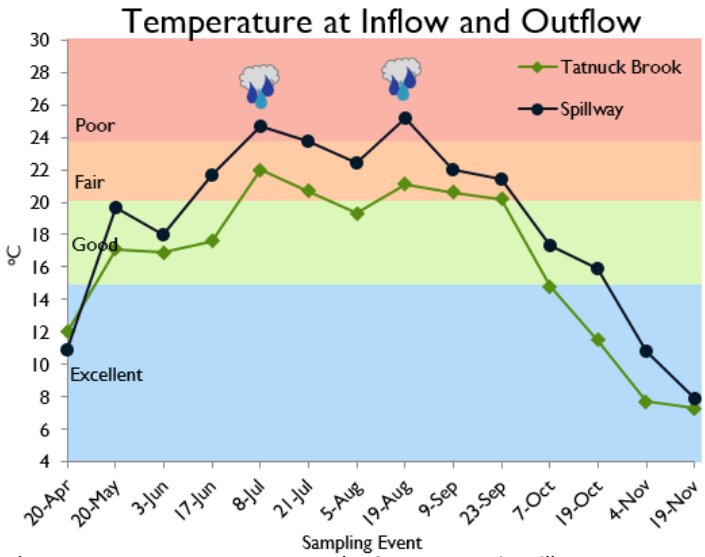

Figure N – *Water temperature at the Coes Reservoir spillway was on average 2.4 degrees higher than when it entered.*

Ongoing Projects

Goose Fencing Pilot Project In 2020, Coes Reservoir beach was closed for 13 days due to high concentrations of the fecal bacteria indicator, *E. coli*. Further examination of the beach area during this revealed that geese that were leaving large amounts of droppings on the shore and in the shallow water. In 2021, the Lakes and Ponds Program implemented a pilot project that aimed to reduce the number of beach closures by keeping geese away from the beach in a humane way while not inconveniencing beach users. Geese usually enter the beach from the water, and are not good and getting over even low barriers. Additionally, they do not like barriers between the beach and the water, as the water is their escape route from land predators. After erecting a small fence between the shore and water during the evening hours, use of the beach by the geese was significantly reduced. In 2022, the Lakes and Ponds Program intends to improve the constriction of the fencing using higher quality materials and make installation easier so as to increase usage during the summer.

State of the Lake

In 2021, Coes Reservoir once again receives a score of "good". There were water quality improvements over 2020 in terms of temperature, with healthier ranges on the surface as well as on the bottom of the reservoir. Additionally, beach closures due to fecal bacteria were also reduced from 13 to 4 days. While invasive aquatic plants do exist in the waterbody, they are being successfully managed and are not hindering recreation. Nutrient levels are not ideal, but the cyanobacteria management and response plan

has kept dangerous cyanobacteria blooms at bay. Finally, in 2021, steps have been taken to classify and quantify litter, and Coes Reservoir beach, providing a baseline for future measurement.

Plan for 2022

Water Quality Monitoring at Coes Reservoir

In 2022, the Lakes and Ponds Program will continue to monitor Coes Reservoir in order to track changes in water quality and implement its cyanobacteria and invasive aquatic plant management plans. In addition to the standard parameters taken every month, one to two rounds of sampling for industrial contaminants will be collected. Those samples will cover contaminants one may expect to find in a post-industrial city, as well as emerging contaminants of concern. These parameters, including heavy metals, PCBs, PFAS, and others, were last sampled at Coes Reservoir in 2019. At that time, none of the results were of concern, though PFAS concentrations were surprisingly higher in Coes Reservoir than other locations. In the coming year, results for these parameters will be examined in particular to ensure that there are no new threats to Coes Reservoir. Additionally, more samples will be taken for cyanobacteria pigment analysis in order to better understand the formation of blooms at Coes Reservoir.

Water Quality Monitoring Up Tatnuck Brook

Coes Reservoir is one of the last of a chain of lakes along Tatnuck Brook, which stretches down from Holden through western Worcester. Other lakes on the brook include Cooks Pond, Patch Reservoir, Patch Pond, and Coes Pond. Previously, consistent water quality monitoring has been restricted to Coes Reservoir due to funding and staffing constraints. However, this year, the Lakes and Ponds Program is excited to be working with Worcester State University to expand sampling into Patch Reservoir and Cooks Pond. Researchers and students from WSU received a grant to use Lakes and Ponds methodologies to collect samples in these waterbodies on the same days as the Lakes and Ponds Program does in Coes Reservoir in 2022. This allows for the ability to compare results apples to apples to better understand water quality dynamics and create more informed management plans for these waterbodies in the years to come.

Litter Tracking and Management

The Lakes and Ponds Program plans to continue to refine its new Litter Tracking Tool to better understand patterns in litter and trash at Coes Reservoir. In addition, the Lakes and Ponds Program will work with its partners, including the Department of Public Works & Parks, and Worcester Green Corps, to use this data to develop litter reduction strategies.

Invasive Aquatic Plant Management

In 2022, the Lakes and Ponds Program plans to continue administering the invasive aquatic plant management plan at Coes Reservoir similar to how it was enacted in 2021. The use of herbicides and physical hand pulling of the water chestnut will continue, as well as spot treatments of the Eurasian milfoil. At the end of the 2022 season, an aquatic plant survey will be performed to map progress and inform the management plan for 2023.