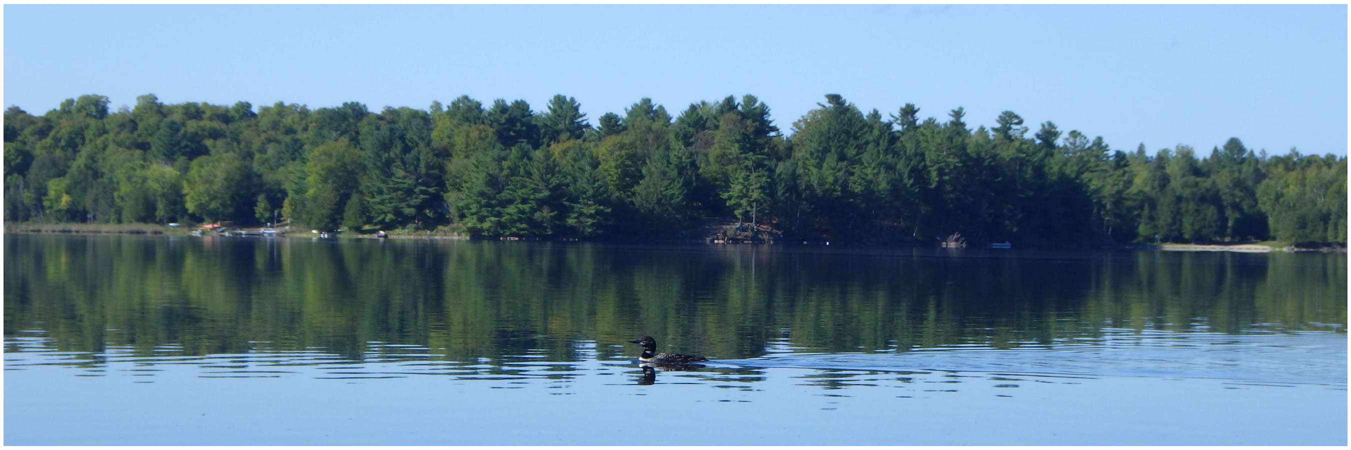


Integrated Monitoring Report
2018 Season

Upper Mississippi and Indian River Subwatersheds

Mississippi Valley Conservation Authority

Table of Contents

<u>Cover photos</u>
Top: Loon on Clayton Lake, 2018.
Bottom: Ready to launch on Pine Lake, 2018.

Executive Summary

The purpose of this integrated monitoring report is to present an overview of the monitoring that MVCA undertook during the 2018 season. As such, the emphasis of this report is on lake monitoring results but also includes water levels and flow, snow pack, and stream monitoring data. Each subwatershed within the Mississippi Valley is part of a five year rotation for this more indepth results analysis. This strategy will provide readers with a more holistic understanding of each of the subwatersheds. The Upper Mississippi and Indian River watersheds were the focus for 2018. Additionally, two lakes along the main stem of the Mississippi River and one auxiliary lake were sampled in 2018.

The most significant factor affecting the lakes and streams in the summer of 2018 was dry conditions. Water levels were high in the spring due to an above average flood event with peak flows on May 2nd, and then there was a lack of precipitation. MVCA issued a Level 1 Low Water Condition Statement on July 1st which was in place until December 3rd.

Aside from the atypical values at the end of August for Malcolm Lake, the lakes in the Upper Mississippi and Indian River subwatersheds maintained their previous trends for each of the monitoring parameters. Kashwakamak, McCauseland, Mosque and Pine Lakes all maintained summer thermal stratification with sufficient temperature and dissolved oxygen levels to support native cold water fish species.

Through the stream monitoring program, 21 sites were targeted in 2018 for fish and benthic community assessment. Six of these sites were found to support cold water fish species. MVCA was able to confirm the presence of cold water fish species in two sites where the fish were initially discovered in 2017 (Mosquito Creek and Donnelly Creek).

This report emphasizes the value of the combined monitoring conducted through MVCA's Water Management, Lake Monitoring, and Stream Monitoring programs. It also highlights some gaps in these programs. While MVCA has tried to address a few of these deficiencies with revisions to monitoring protocols, a lack of baseline stream data still remains an issue. Focusing on filling these sampling gaps will allow the MVCA to provide a better understanding of the ecological variety and environmental trends to stakeholders, which will assist in future decision-making.

Introduction

The Lake Monitoring Program (Formerly called the Watershed Watch program) was initiated at the Mississippi Valley Conservation Authority (MVCA) in 1998 in partnership with the Mississippi Valley Lake Stewardship Network. The goal of the program is to accumulate reliable environmental data on the lakes within the watershed. Despite various adjustments to the protocol throughout the years, the program has remained a fundamental part of MVCA's monitoring schedule. It continues to provide valuable baseline data while promoting stewardship of these important features.

The main goal of the lake monitoring program is to collect environmental data and monitor trends on the lakes of the Mississippi Valley watershed. Ideally the program would sample every lake annually. However, due to the large number of lakes within the MVCA area a rotational sampling program is undertaken with the goal to collect baseline data and to monitor general trends. MVCA collects relatively simple data on parameters that are easy to repeat and which provide a broad idea of potential changes in water quality. The data MVCA collects is insufficient on its own for environmental impact studies that may need to be conducted on a lake due to development projects etc. If lake stewards are interested in more detailed yearly assessments of their lake, they should consider the Lake Partner Program (LPP) which is coordinated through the Dorset Environmental Science Centre. Relying on volunteer effort, this program provides an excellent framework and equipment for yearly data collection. It is also an excellent means to promote awareness and ownership of lake health.

Accompanying the lake monitoring program, is MVCA's stream monitoring program. This program collects valuable information on stream temperature as well as fish and benthic communities of the watershed's many tributaries. It follows Ontario Stream Assessment Protocol (OSAP) methods to conduct stream site identifications, electrofishing, benthic surveys, and temperature monitoring at various sites throughout the year. In 2018, MVCA sampled 21 stream sites focusing on representing the two target subwatersheds, as well as surveying select sites representing the seven other Mississippi River subwatersheds.

The goal of MVCA's fish data collection is largely to determine the presence or absence of cold or cool water species. These species are indicators of the thermal regime of a stream as they require very specific conditions to thrive. Changes in their abundance may indicate habitat trends. MVCA has also been monitoring the water temperature at select sites to confirm the potential thermal habitat available as well as tracking thermal trends between years for climate change analysis.

Benthic macroinvertebrate data collection is also used as a means to determine water quality in our wadeable streams. Benthic macroinvertebrates are the small, yet visible, insects that live along the stream bottom for some or all of their life cycle. Different classes of benthic invertebrates vary widely in their tolerance of environmental stressors (eg. dissolved oxygen levels) and so an analysis of the community composition can be very telling of the health of a particular stream when combined with other habitat characteristic data. Benthic samples are collected in the fall and processed throughout the winter and spring. As such, results from 2018 will not be available for this report.

Water Quantity Monitoring

Summary

Three types of water quantity monitoring occurred in the Upper Mississippi and Indian River subwatersheds in 2018; snow pack, water levels, and water flow. Figure 1 and 2 portray the locations of the gauges used to collect level and flow data, the locations of snow courses where snow pack water content is measured, and the locations of the lake monitoring sites in both the Upper Mississippi and Indian River subwatersheds.

A late season spring runoff from rainfall produced an above average peak for the lower portion of the watershed. Flows at Appleton peaked on May 2, 2018. The August rain was approximately 150 cm less than average rainfall and warmer than normal summer conditions lead to a level one minor drought declaration being issued on July 1st. This condition persisted through the remainder of the summer and into the fall. Conditions finally returned to normal in November and the declaration was terminated on December 3rd.

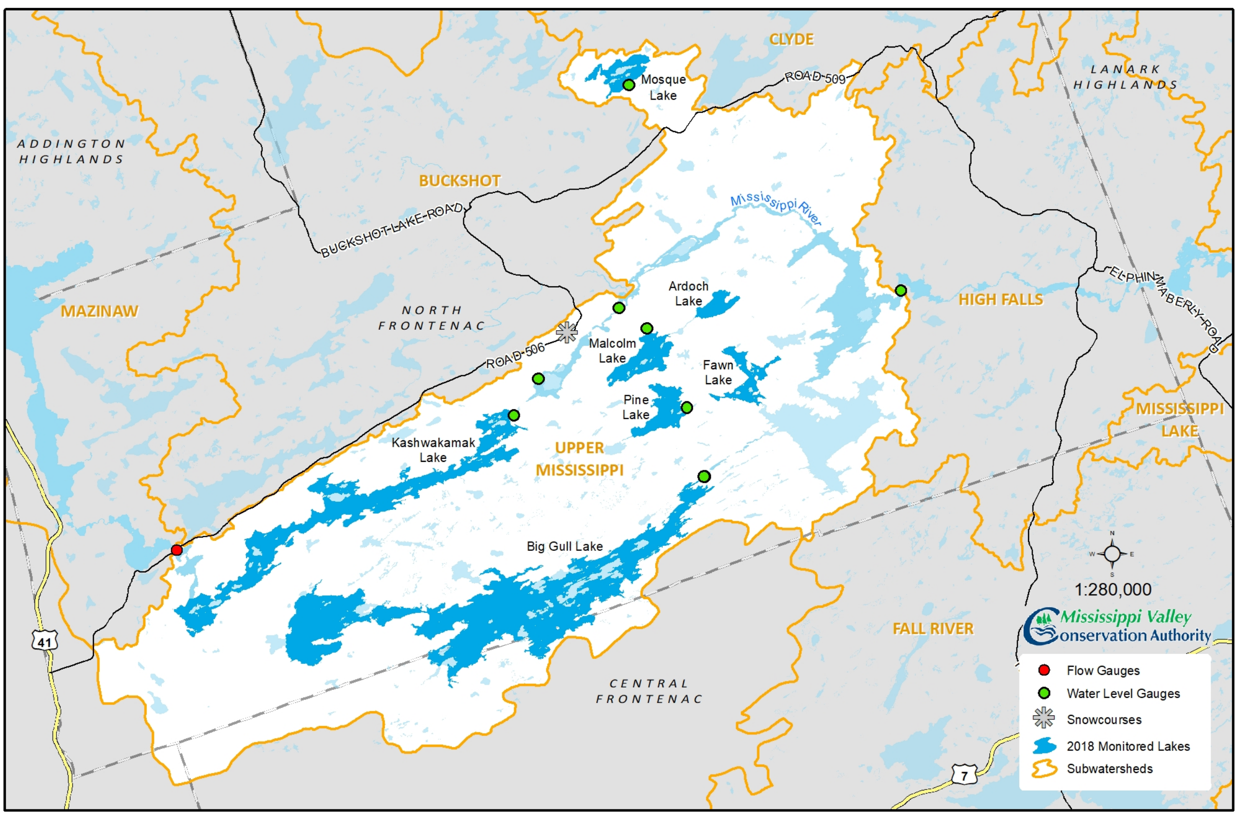


Figure 1: The various water quantity monitoring sites in the Upper Mississippi subwatershed, plus the lakes monitored in 2018.

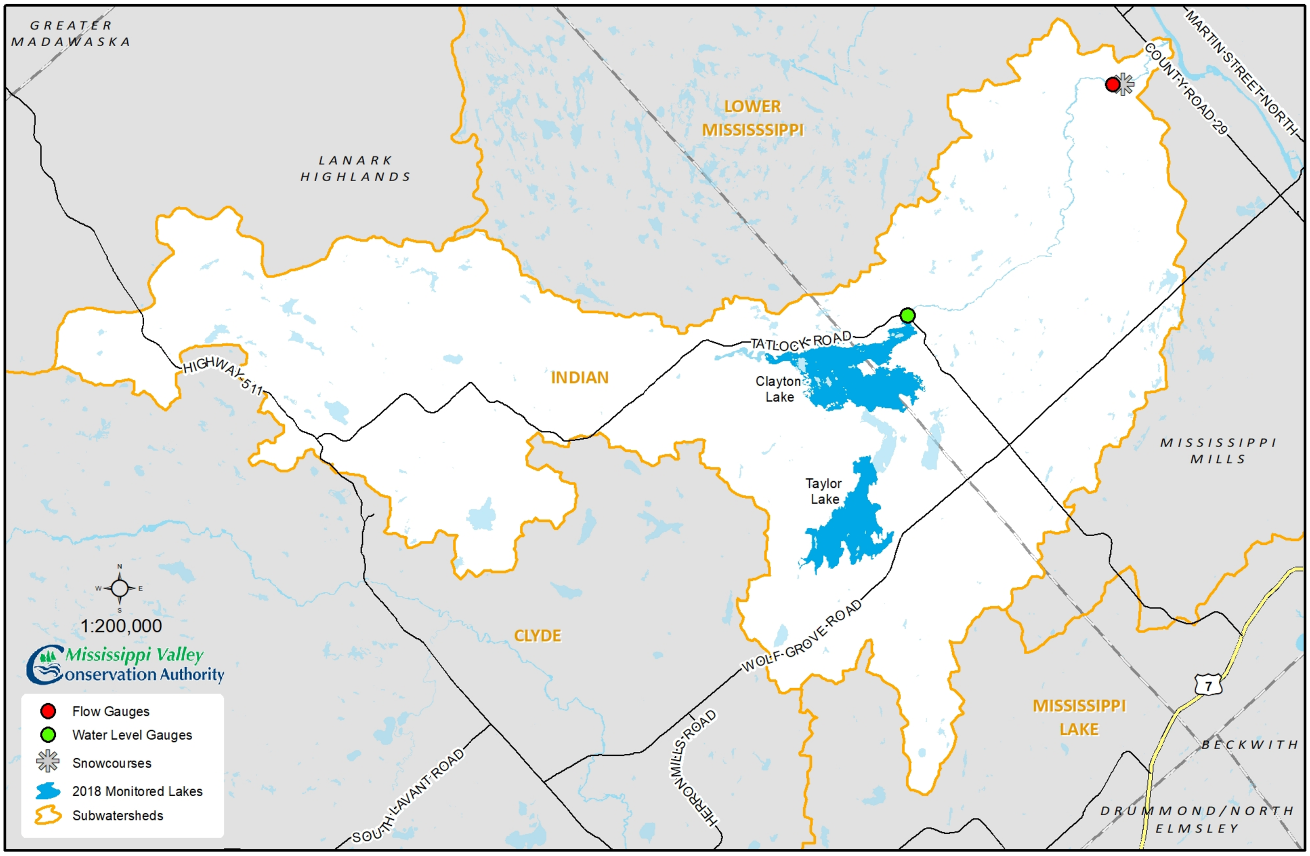


Figure 2: The various water quantity monitoring sites in the Indian River subwatershed, plus the lake monitoring sites for 2018.

The stream flow and rain gauge station on the Indian River, near Blakeney

Snow Pack

Snow pack is measured at 16 sites within the MVCA's jurisdiction. The data collected with this program provides MVCA with information on the expected spring runoff for that year. This assists in decisions related to dam operations and flood forecasting. These water management efforts are critical to minimizing flood damage, maintaining flows and water levels for fish and wildlife, and meeting the target levels for summer recreational activities. There is one snow course in the Upper Mississippi subwatershed at Arodch, and one in the Indian River subwatershed at Blakeney. The snow pack results for 2018 can be seen in Figures 3 and 4.

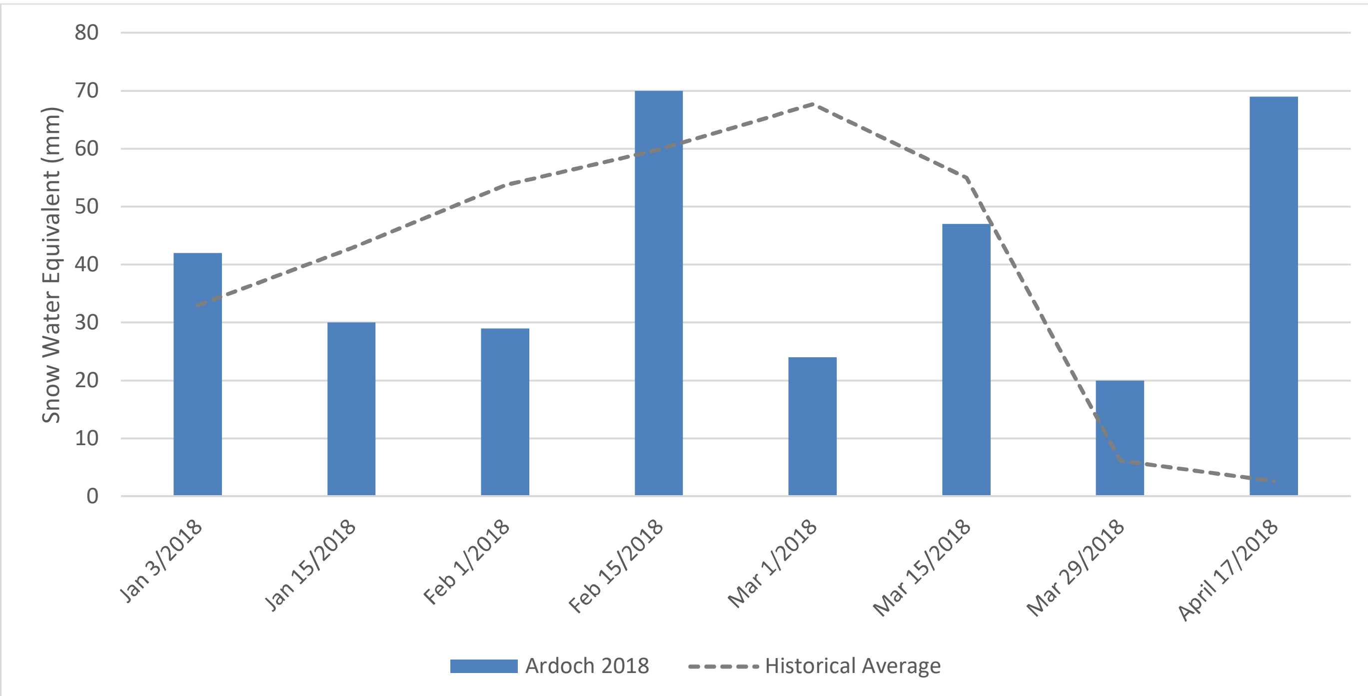


Figure 3: 2018 Upper Mississippi subwatershed snow water equivalent levels vs. historical averages sampled at the Ardoch snow course station.

Measuring snow depth and equivalent water content at the Ardoch snow course

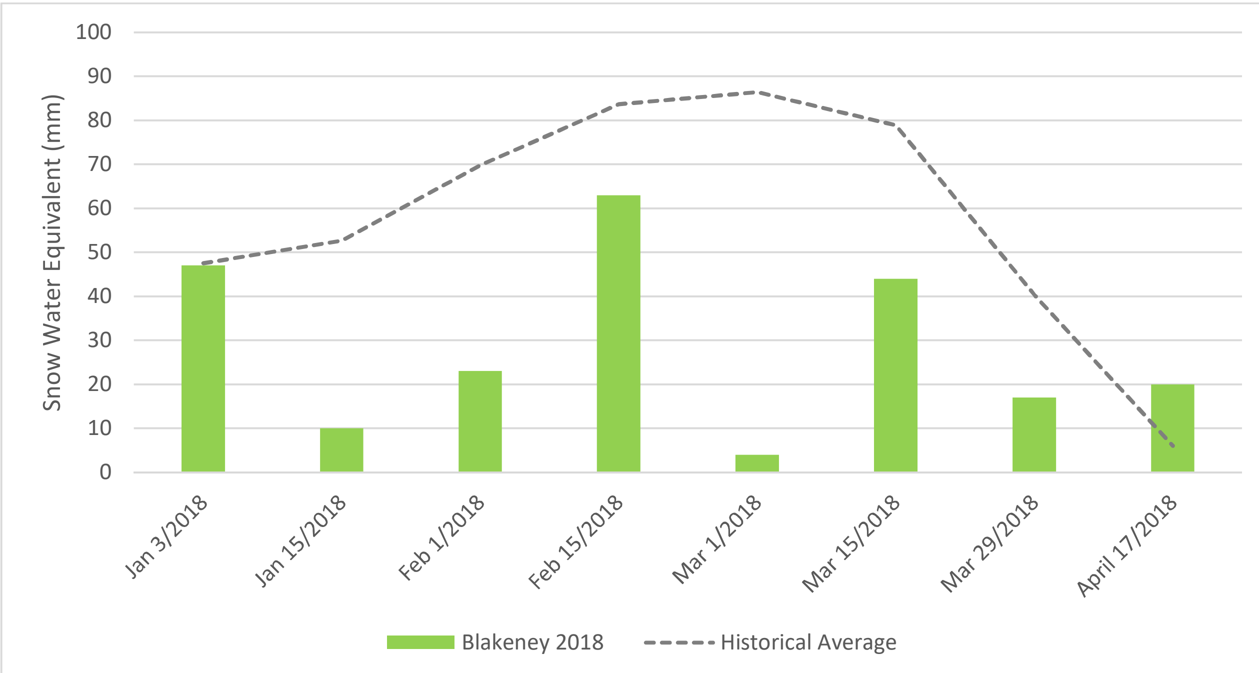


Figure 4: 2018 Indian River subwatershed snow water equivalent levels vs. historical averages sampled at the Blakeney snow course station.

It is evident that with the exception of an event in early to mid-February the Ardoch snow course, and thus the Upper Mississippi Subwatershed, was below average in snow water content. The area was then nearly clear of snow at the end of March but an early April event brought the snow pack up to above average levels by April 17th. The snow course in the Indian River subwatershed at Blakeney showed a similar trend, with all but the April survey showing low snow water equivalent levels. Although the April 17th level was brought up with the early April event there was not as much snow accumulation at Blakeney as there was at Ardoch.

The spring melt as well as the rain events after the April 17th high snow pack readings resulted in an above average spring flood season with peak flows occurring on May 2nd, 2018.

Stream Flow and Precipitation

Precipitation gauges are located with streamflow gauge station sites across the watershed. These gauges informs us of the conditions which influence water levels on the Mississippi River. This report will focus on 2018 data for the stream flow and rain gauge station at Myers Cave (just upstream of Kashwakamak Lake) and the stream flow and rain gauge station for the Indian River subwatershed at Blakeney. The daily total rainfall and the daily mean flows at these two gauge stations can be seen below in Figure 5 and Figure 6.

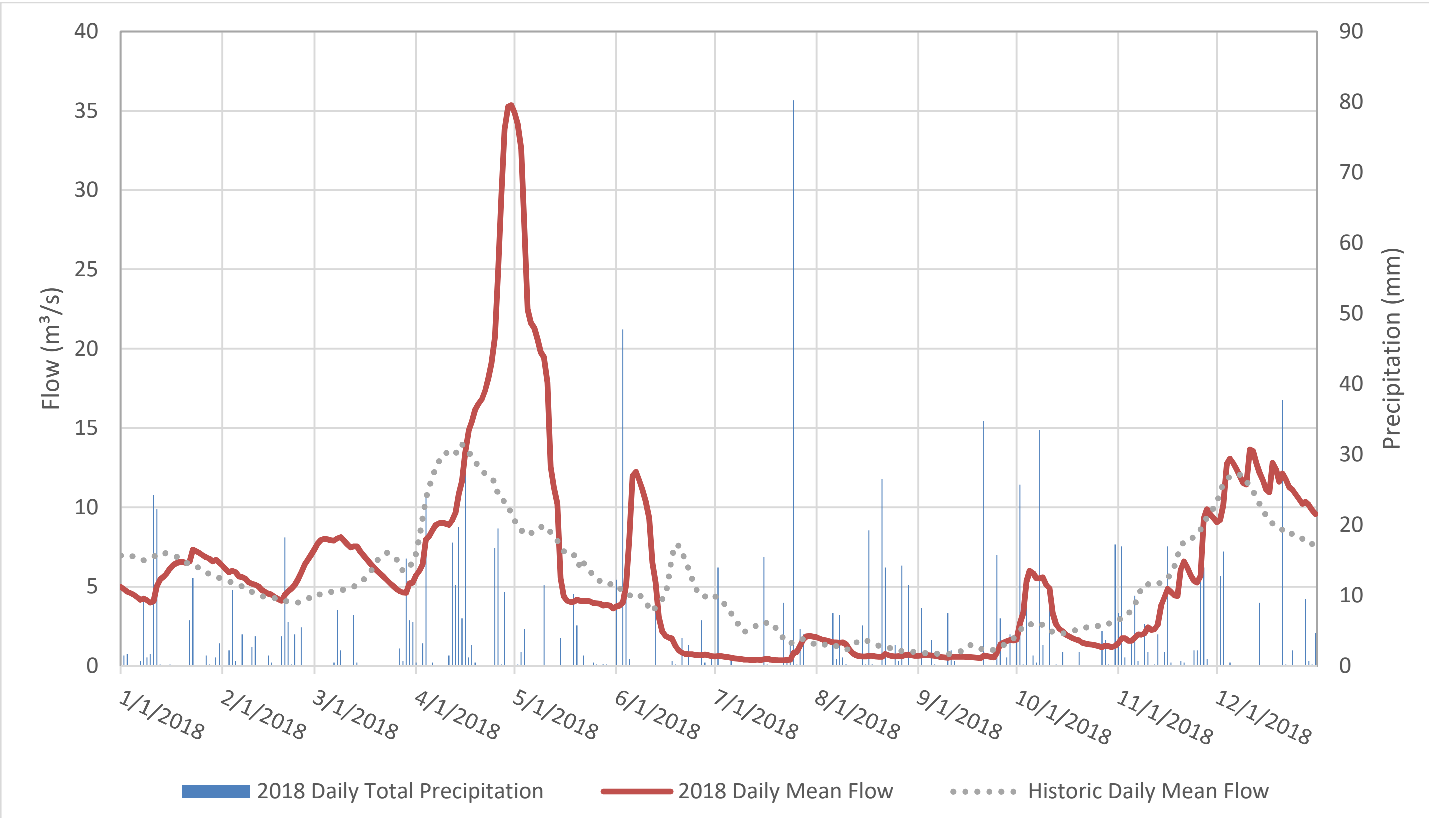
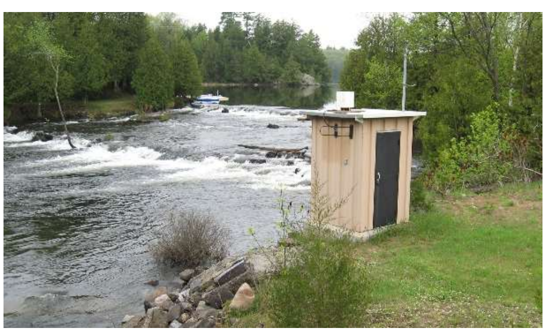


Figure 5: Daily total precipitation and daily mean water flows at the Myer's Cave gauge station for 2018 compared to the historic daily mean flows for the site.

Figures 5 and 6 show peak flows occurred on May 2nd and April 29th respectively during a higher than average spring flood season. The flows then reduced and MVCA issued a Level 1 Low Water Condition Statement on July 1st, indicating that the watershed was experiencing drought conditions. The low flow conditions lasted until December when the Level 1 Low Water Condition Statement was lifted.



The stream flow and rain gauge station at Myer's Cave

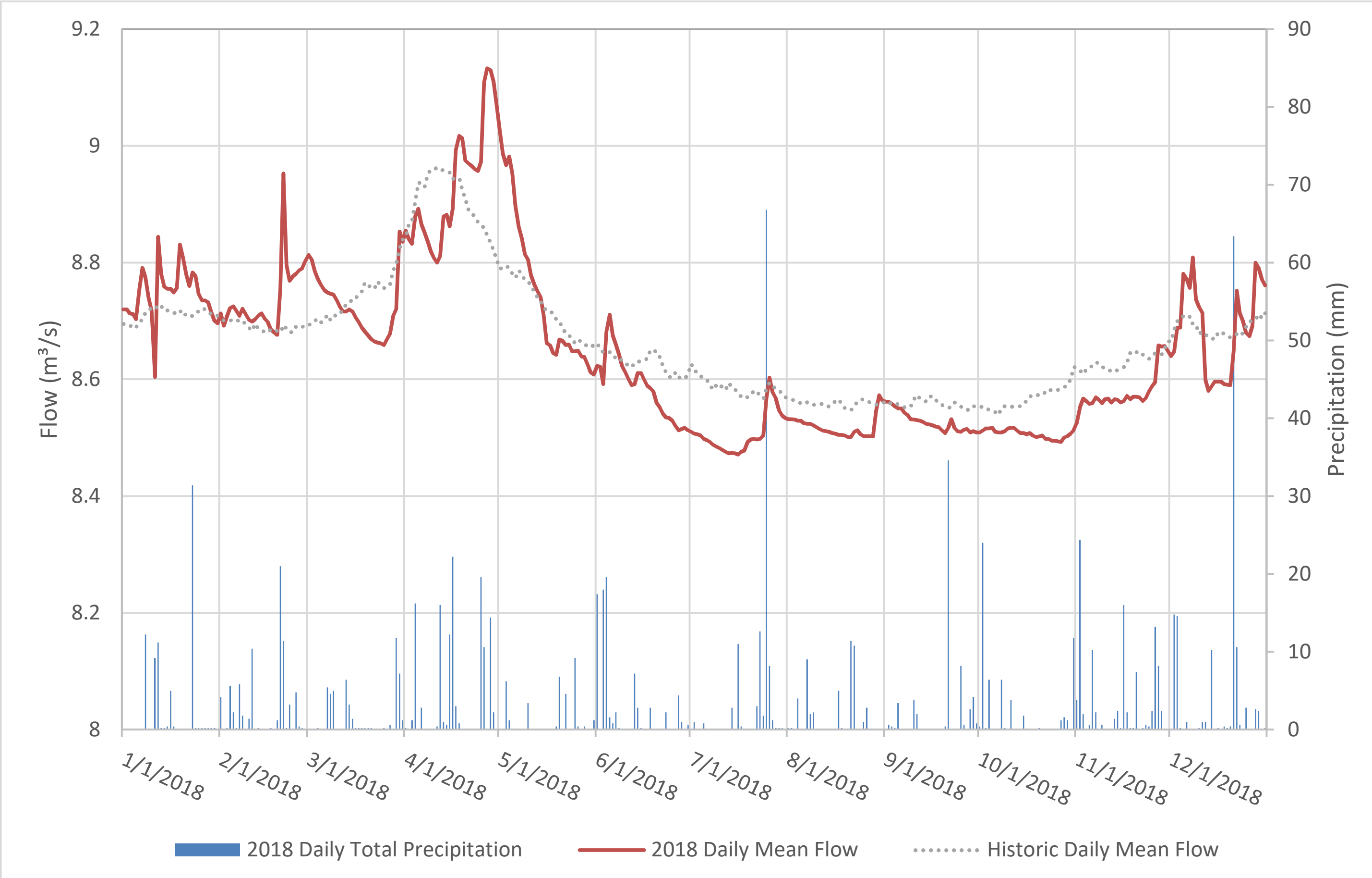


Figure 6: Daily total precipitation and daily mean water flows at the Blakeney gauge station for 2018 compared to the historic daily mean flows for the site.

Both Figure 5 and 6 show a large number of precipitation events occurring throughout the year. However, when the data is looked at more closely, Myer's Cave recorded precipitation on 165 days and 45% of those events contributed 10 mm or less of rain to the area at the upstream end of Kashwakamak Lake. The Indian River subwatershed had similar summer conditions with 187 days of precipitation and 82% of them contributing 10 mm or less of rain to this subwatershed. Further differences in the regional rain contributions to the Mississippi Valley can be seen in the largest rainfall event of 2018, which happened on July 25th. The gauge at Myer's Cave received 80.25 mm of rain, whereas the gauge at Blakeney received 66.8 mm of rain.

Due to the hot dry summer season experienced in 2018, the rain that did fall infiltrated into the soil leaving little surface runoff to contribute to the stream water levels or flows.

Lake Water Levels

Water levels are measured from gauges installed at many MVCA owned and/or operated dams and gauge stations around the watershed. There are water level gauges on the dams at the outlets of Kashwakamak Lake (Figure 7) and Big Gull Lake (Figure 8). Mississippi Valley does not manage a lake level gauge within the Indian River subwatershed.

MVCA operates 18 dams throughout the watershed. Water levels in seven of the lakes monitored in 2018 are managed by dams. Ardoch, Fawn, and Taylor lakes do not have a dam at their outlet however, their water levels are influenced by a dam structure at the next lake downstream. Due to the wet spring, both Kashwakamak and Big Gull lakes were able to stay near their optimal water level and well within their targeted operating ranges for the summer recreational season despite the drought conditions experienced between July and December.

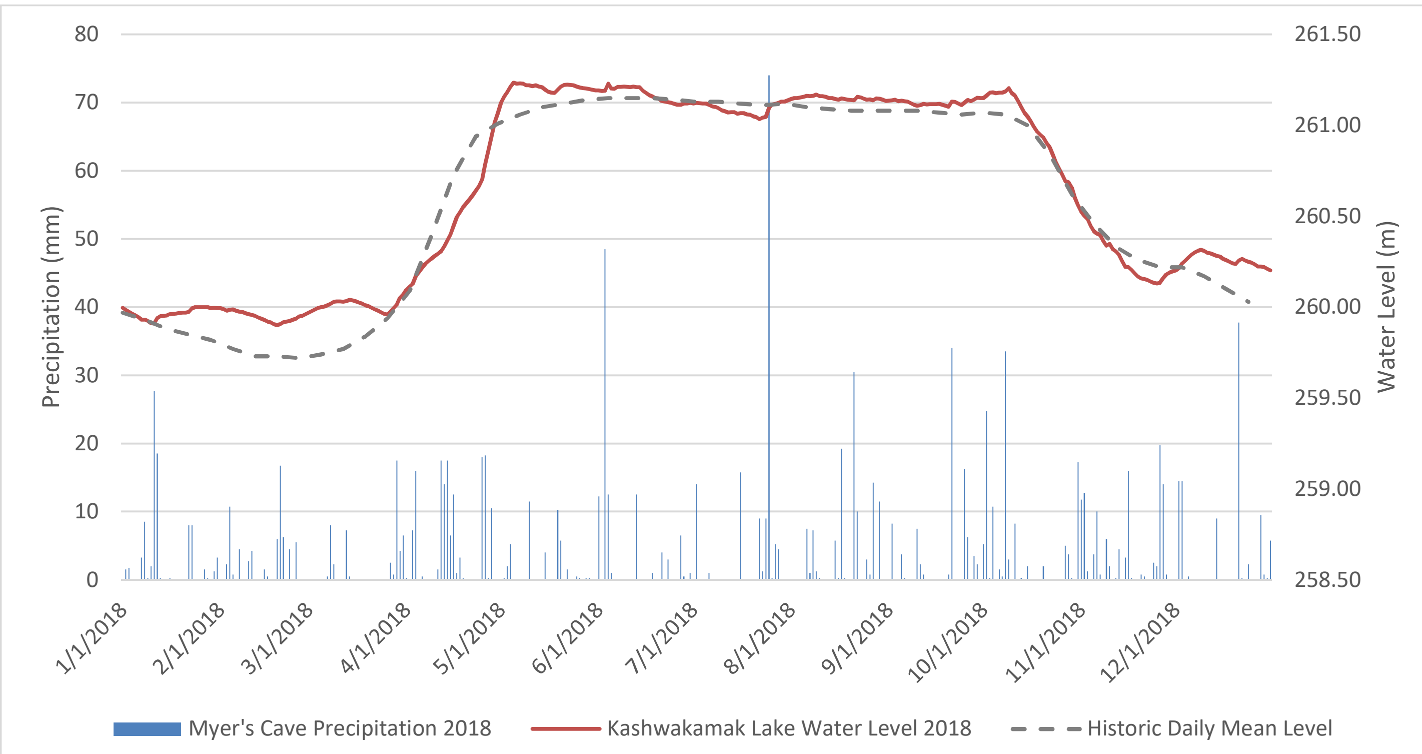


Figure 7: 2018 and historic water levels on Kashwakamak Lake as they compare to the 2018 daily total precipitation at Myer's Cave.

The dam at the outlet of Kashwakamak Lake and the automated lake level gauge

The staff gauge at the Kashwakamak Lake dam

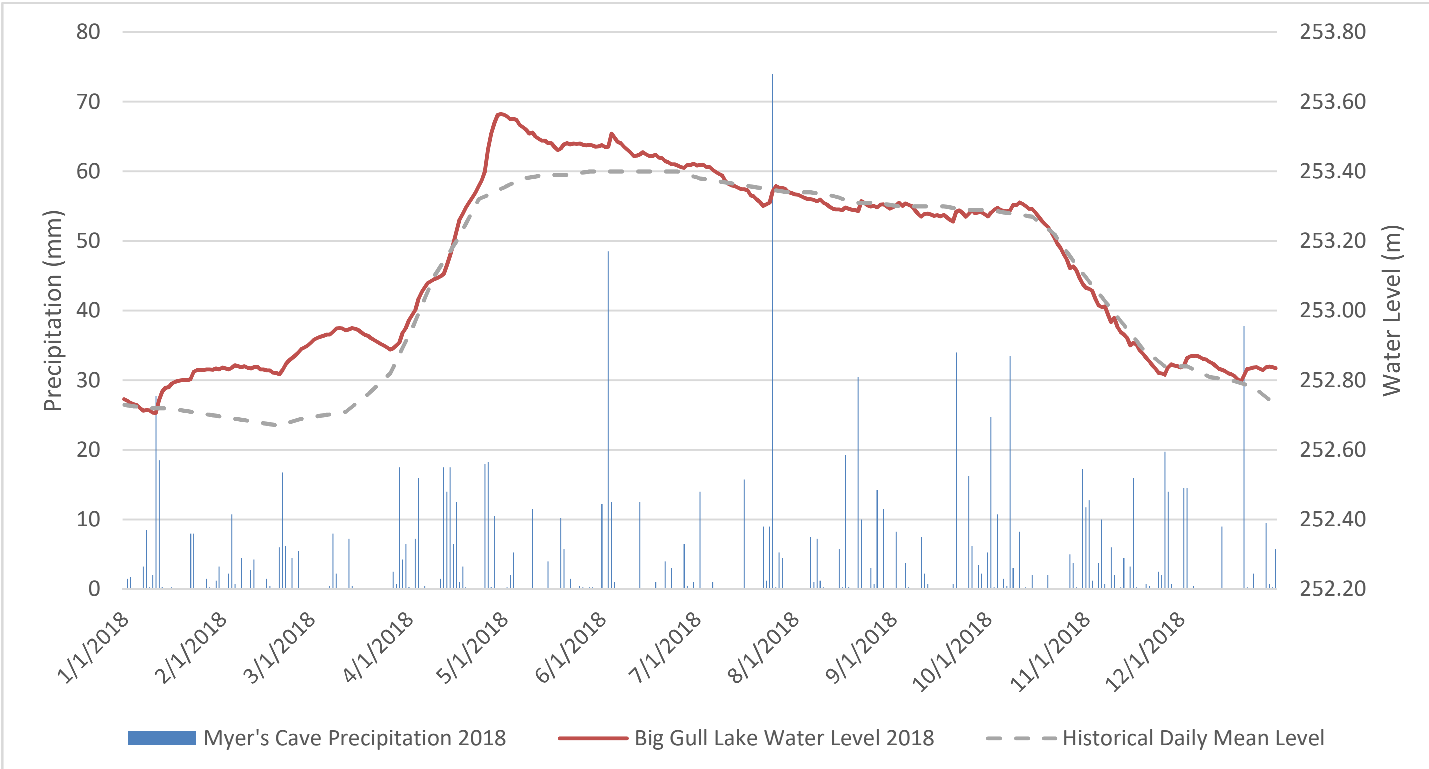


Figure 8: 2018 and historic water levels on Big Gull Lake as they compare to the 2018 daily total precipitation at Myer's Cave.

The dam at the outlet of Big Gull

Lake Monitoring Program

In 2018, the sampling focus was on the Upper Mississippi subwatershed, located in the northwest portion of the watershed from Myers Cave to the outlet of Crotch Lake, and the Indian River subwatershed, which is east of Highway 511 and flows into the Mississippi River north of Almonte. Figure 9 below indicates the lake sites where sampling occurred.

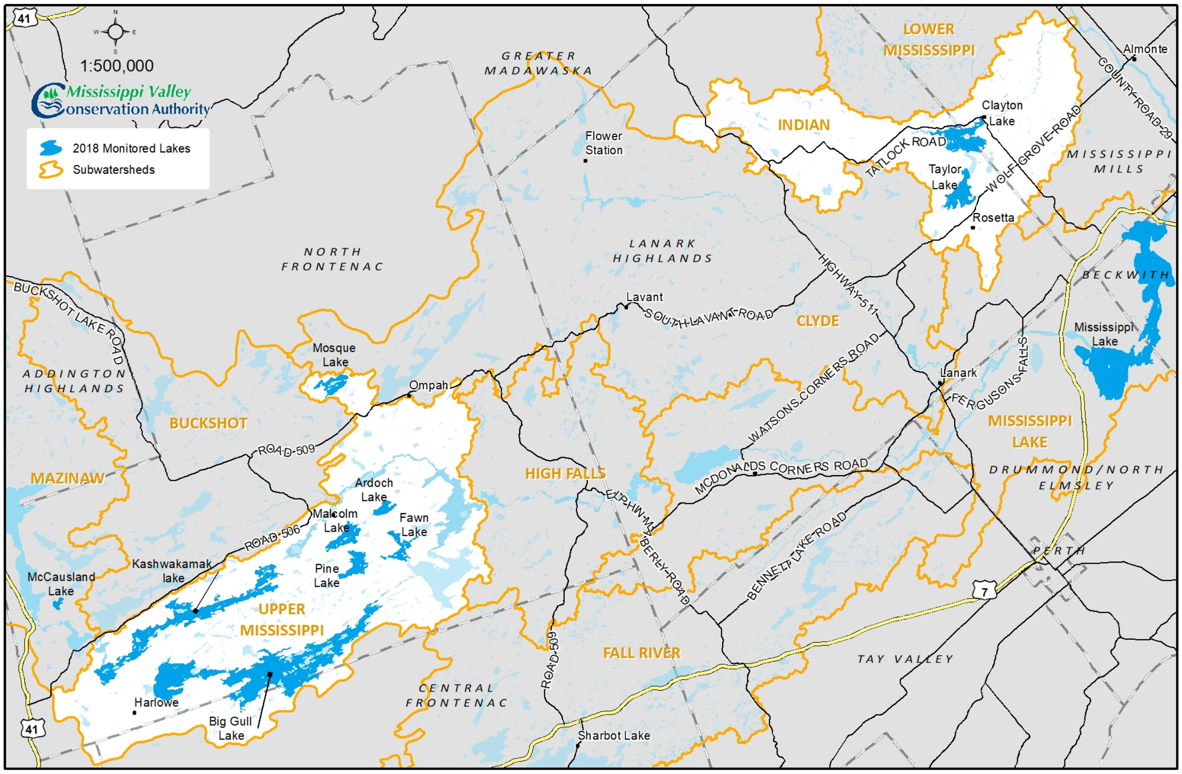


Figure 9: Lake monitoring locations for the 2018 sampling season.

In total, two lakes were sampled representing the main Mississippi River, six were sampled in the Upper Mississippi subwatershed, two in the Indian River subwatershed, and one auxiliary lake for a total of eleven lakes sampled in 2018. Table 1 lists the lakes sampled along with their subwatershed. The main Mississippi River lakes were Kashwakamak Lake which receives water from the Mazinaw Subwatershed, and Mississippi Lake, which is the last lake the Mississippi River flows through.

Table 1: Lakes sampled in 2018.

Mississippi Main Stem	Upper Mississippi Subwatershed	Indian River Subwatershed	Auxiliary Lakes
Kashwakamak Lake	Ardoch Lake	Clayton Lake	McCauseland Lake
Mississippi Lake	Big Gull Lake	Taylor Lake	
	Fawn Lake		
	Malcolm Lake		
	Mosque Lake		
	Pine Lake		

Results Summary

Overall, the lakes sampled in 2018 maintained historic trends for total phosphorus levels, secchi depth, pH and trophic status. The main result of interest this year was that two euphotic zone samples exceeded the Provincial Water Quality Objective for total phosphorus (20 µg/L):

- Ardoch Lake (56 µg/L Aug 31, 2018)
- Malcolm Lake (24 µg/L Aug 31, 2018)

It is possible that the rain events that occurred between August 25 and August 29th (total rainfall amount of 29.5 mm) resulted in the higher nutrient concentrations found in these lakes. It is also possible that there may have been a sampling or processing error. The lakes will continue to be sampled as part of the regular rotation to determine if these peak values are one-off events or part of a larger trend.

Samples taken 1 m off the bottom (TPB) of Mosque Lake's south and west basins returned high total phosphorus concentrations for all three sample dates in 2018 (South Basin ranged 31-308 µg/L, West Basin ranged 32-234 µg/L), while the samples from the north basin were much lower (6-12 µg/L). When high values occur, the possibility of a sampling error is considered. Lake sediment has extremely high levels of phosphorus, and even small amounts in the sample will cause a large spike in the result. While reviewing sample results from past years, the TPB samples in these basins is often higher than 30 µg/L, so there may be other factors influencing these results. This trend is similar to one noticed on Dalhousie Lake where there is an increased potential for some of the sediments to be free floating in the water above the lake bed resulting in collection within the near bottom water sample. MVCA will continue to monitor for these unique occurrences in the data.

Appendix A includes the 2018 water temperature and dissolved oxygen charts for each lake's sampling point.

Preparing to filter a bottom sample

Lake Monitoring Indicators and Methodology

The Lake Monitoring Program (formerly the Watershed Watch program) tests for numerous water quality parameters. These parameters are selected for their relative simplicity of collection, reproducibility, and ability to contribute to trophic status determination. These parameters are further described below.

Total Phosphorus

Phosphorus is an essential nutrient for all living organisms as it plays a role in numerous aspects of biological metabolism. It is also the limiting nutrient in biological activity and therefore when phosphorus levels get too high there tends to be adverse effects such as algae blooms. Phosphorus can be found naturally in the environment, as well as in many man-made products such as soaps, detergents, fertilizers and septic waste. Total phosphorus is measured in micrograms per litre (µg/L).

As part of the Lake Monitoring program, two types of total phosphorus levels are measured at each sampling location: euphotic zone phosphorus and bottom phosphorus. The euphotic zone is defined as twice the Secchi depth and is the depth to which light can reach and influence plant growth.

Kemmerer Bottle

The bottom phosphorus sample is collected at approximately 1 meter off the bottom of the lake, at sites that have a depth greater than the euphotic zone, using a device called a Kemmerer Bottle. The bottle is sent down to the appropriate depth with both ends open, then a weight on the rope is dropped, causing both ends to close and sealing the sample water in the bottle; providing a discrete volume of water from the appropriate depth.

Total phosphorus levels provide an accepted standard to characterize a lake's trophic status following the general guidelines seen in Table 2 below. It should be noted that while these numbers provide an idea of a lake's trophic status, lakes naturally progress over time from oligotrophic to eutrophic, so an 'ideal' trophic status does not exist. Furthermore, natural variation can cause a great deal of change from year to year and even within years, so it is important to look at larger trends rather than one or two exceptional years.

Table 2: Interpreting total phosphorus results.

Total Phosphorus Level	Lake Trophic Status
< 10 µg/L	Oligotrophic – unenriched, few nutrients
10.1 – 19.9 µg/L	Mesotrophic – moderately enriched, some nutrients
> 20 µg/L	Eutrophic – enriched, higher levels of nutrients

The Provincial Water Quality Objective (PWQO) for phosphorus in lakes is 20 µg/L (*Water Management, Policies and Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy. MOE. 1994*). The goal is to keep phosphorus below this level in order to maintain aquatic health and the recreational value of our lakes.

Secchi Depth

Secchi depth is a measure of water clarity and is collected using a Secchi disc. The Secchi disc is a black and white disc that is lowered into the water on the shady side of the boat to the point where it can no longer be seen. The greater your Secchi depth, the clearer your lake is. The Secchi depth also helps determine the euphotic zone (the depth of water through which light is able to penetrate). Secchi depth can be influenced by the concentration of algae or the presence of other suspended materials in the water. Often a decrease in Secchi depth occurs in unison with an increase in phosphorus. The following guideline shown in Table 3 is used to determine your lake's nutrient status according to Secchi depth.

Secchi disc

Table 3: Interpreting Secchi disc results.

Secchi Depth	Lake Nutrient Status
> 5 meters	Oligotrophic – unenriched, few nutrients
3.0 – 4.9 meters	Mesotrophic – moderately enriched, some nutrients
< 3.0 meters	Eutrophic – enriched, higher levels of nutrients

pH

The pH scale is a logarithmic measure of the concentration of hydrogen ions in solution. It is a measure of the acidity of a solution and ranges from 0 to 14. A pH of 7 is considered neutral, while values above 7 are basic, and values below 7 are acidic. The logarithmic scale means that a change from pH 7 to pH 8 is a ten-fold decrease in the concentration of hydrogen ions in solution.

The acidity of a water body affects all chemical reactions within the water. Even small changes in pH can have a large influence on the solubility of some nutrients, including phosphorus, which in turn can influence plant growth. The PWQO for pH in lakes is 6.5 – 8.5, which ensures optimal conditions for most aquatic species.

Calcium

Calcium in lakes is a measure of the levels of Ca^{2+}, Mg^{2+} and HCO_3^- ions in the water. Higher levels of these ions classify the water as 'hard' water, and lower levels 'soft' water. This can be measured various ways but is usually done either as the concentration of free calcium ions (Ca^{2+}) (mg/L) or, because most hard water ions stem from calcium carbonate, as calcium hardness as $CaCO_3$ (mg/L). For this program, MVCA measures Calcium Hardness (in mg/L as $CaCO_3$) in the field then the result is multiplied by 0.4 to determine the concentration of Ca^{2+} freely available in the water. Ca^{2+} in freshwater usually falls within the range of 4 to 100 mg/L.

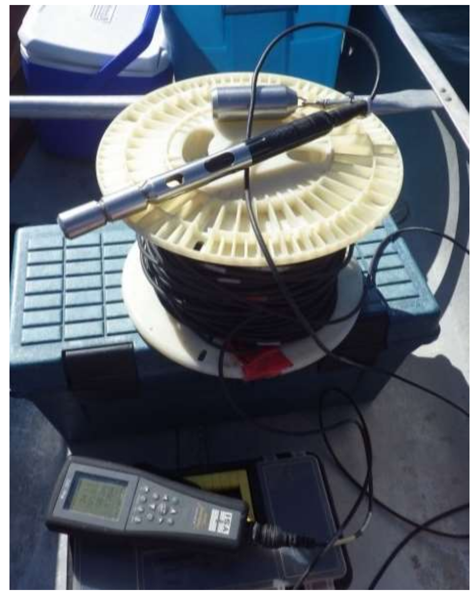
Calcium enters a lake largely through the mineral weathering of rocks (especially marbles and limestones). It is then either used by aquatic organisms for bones or shells or as a component in the cell walls of aquatic plants, and eventually deposits into the sediment of the lake. Because of its importance in shell/body coverings, calcium has been shown to influence zooplankton (small planktonic invertebrates) communities, which are an important food source for many baitfish species. Higher calcium levels are also required for zebra mussels to thrive.

Dissolved Oxygen

Adequate dissolved oxygen (D.O.) levels are essential to all aquatic life, including fish, invertebrates and bacteria. Many factors can influence dissolved oxygen concentrations in a lake but two key factors are lake stratification (water temperature) and the amount of phytoplankton (microscopic algae) biomass produced in the lake.

Lake stratification is the separation of the lake into three layers: the epilimnion (top layer), metalimnion (middle layer) and the hypolimnion (bottom layer). Stratification is caused by changes in water temperature with depth, and occurs from late spring to early fall.

D.O. is at its lowest during the late summer and early fall as water in the hypolimnion cannot recharge its oxygen concentrations since it is isolated from the atmosphere by the epilimnion and thermocline (the steep temperature gradient between the warm sunlight epilimnion water and the cooler hypolimnion water below). Also during the fall the phytoplankton that are active during the summer months begin to die and settle to the bottom of the lake. The bacteria that then decompose the phytoplankton consume large amounts of oxygen, further depleting stores in the hypolimnion. The low levels of D.O. in the bottom depths of a lake decrease the amount of critical habitat available for cool water fish species to thrive.



Optical Dissolved Oxygen Probe

Dissolved oxygen is measured using an Optical Dissolved Oxygen Probe. This instrument, pictured above, is lowered through the water at one meter intervals, where it takes both temperature and D.O. readings. This creates a dissolved oxygen profile where changes in temperature and D.O. can be recorded as depth increases. Table 4 shows the optimal temperature/D.O. combinations for cold, cool, and warm water fish habitat. Results from the D.O. and water temperature profiles for each of the 2018 lake monitoring sites are available in the Appendix A.

Table 4: Optimal conditions for different fish habitat.

	Dissolved Oxygen		Temperature
Cold Optimal	>6 mg/L	AND	<10 °C
Cool Optimal	>4 mg/L	AND	<15.5 °C
Warm Optimal	>4 mg/L	AND	<25 °C

Source: Coker, G.A., Portt, C.B., & Minns, C.K.(2001). Morphological and Ecological Characteristics of Canadian Freshwater Fishes. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2554.

Main Mississippi River Lakes

Kashwakamak Lake

Kashwakamak Lake is a large cold water lake in North Frontenac that is on the main line of the Mississippi River, between the villages of Myer's Cave and Ardoch. It has a maximum depth of 22 meters. MVCA has now monitored it through five ice free seasons and it has consistently had low to moderate total phosphorus results, with an average in the oligotrophic range. The 2018 season is no different with the majority of the samples near or within the oligotrophic range with low total phosphorus concentrations and moderate Secchi depth measurements (Table 5, Figure 10).

Table 5: 2018 sampling summary for Kashwakamak Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)	pH	Calcium (Ca2+) (mg/L)
East Basin	05/30/2018	2.5	2	<2	8.17	24
East Basin	07/05/2018	4.0	14	7	7.40	
East Basin	09/06/2018	3.5	9	11	n/a	
West Basin	05/30/2018	3.0	3	2	8.10	16
West Basin	07/05/2018	4.5	9	6	7.32	
West Basin	09/06/2018	4.0	7	16	7.89	

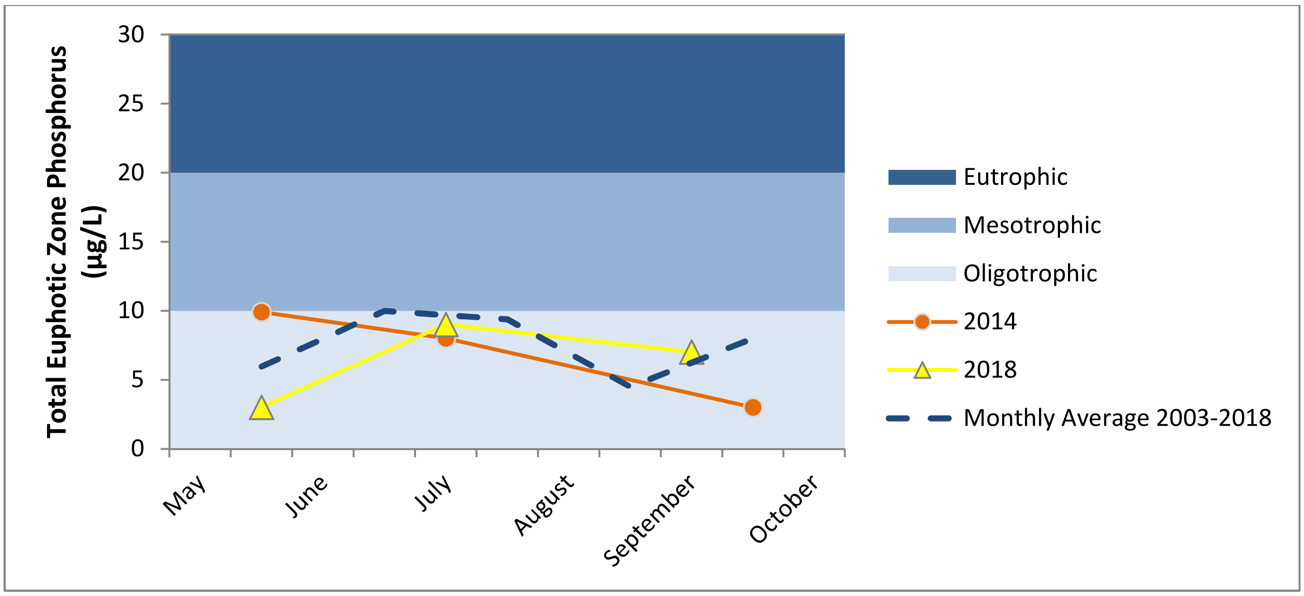


Figure 10: Total euphotic zone phosphorus results for the deepest sampling point in the West Basin of Kashwakamak Lake compared to a monthly average of the results for this site.

Kashwakamak Lake maintains optimal and critical cold water fish habitat throughout the ice free season, with a 12 m deep zone of suitable cold water habitat persisting into the fall (Appendix A).

Mississippi Lake

Mississippi Lake is a large warm water lake in Lanark County. It is the most downstream lake directly on the Mississippi River system and its outlet is at the town of Carleton Place. It has a maximum depth of 9 meters. MVCA began monitoring Mississippi Lake in 2002, and has now monitored it through 14 ice free seasons. A summary of the results from the 2018 survey are found below in Table 6.

Figure 11 illustrates the total phosphorus results from 2018 compared to the results from 2016 and 2017 sampling results as well as the monthly average total phosphorus results from all 14 seasons of sampling at the deepest point near Burnt Island. The average line extends into the eutrophic zone due to an extreme result collected in June of 2002. With that aside, the trend for the lake is within the mesotrophic range and the 2018 results maintain this trend.

Table 6: 2018 sampling summary for Mississippi Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)*	pH	Calcium (Ca2+) (mg/L)
Inlet	05/08/2018	3.3	7	8	n/a	16
Inlet	07/11/2018	5.3	9		7.37	
Inlet	08/29/2018	4.0	12		8.28	
Burnt Island	05/08/2018	3.5	10	9	n/a	24
Burnt Island	07/11/2018	4.0	17		7.15	
Burnt Island	08/29/2018	3.0	13		7.86	
Pretties Island	05/08/2018	3.3	10	7	7.05	48
Pretties Island	07/11/2018	4.3	16		7.18	
Pretties Island	08/29/2018	2.5	13		7.89	
Outlet	05/08/2018	3.0	7	n/a	7.00	40
Outlet	07/11/2018	2.3	15		7.53	
Outlet	08/29/2018	2.0	10		8.12	

*Total Phosphorus samples are only taken from 1 m off the bottom of the lake if the euphotic zone does not extend to the bottom.

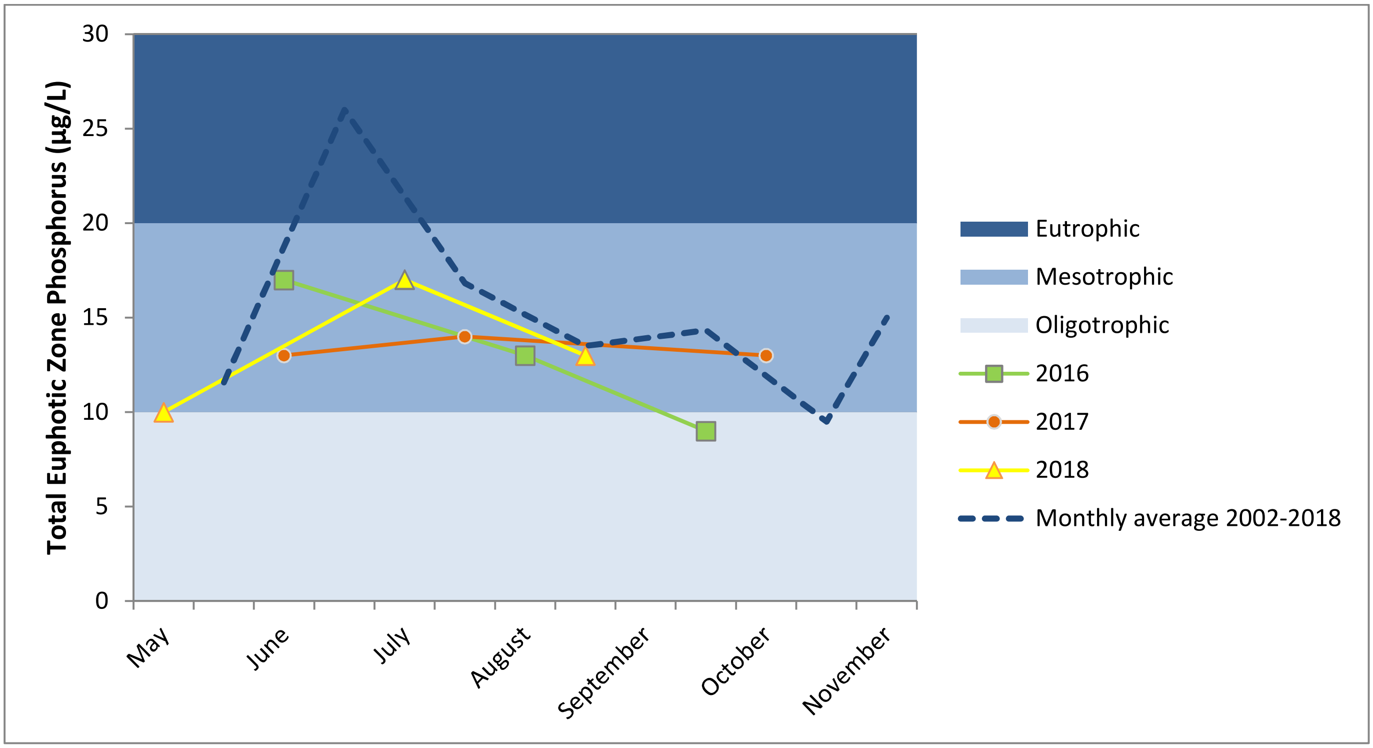
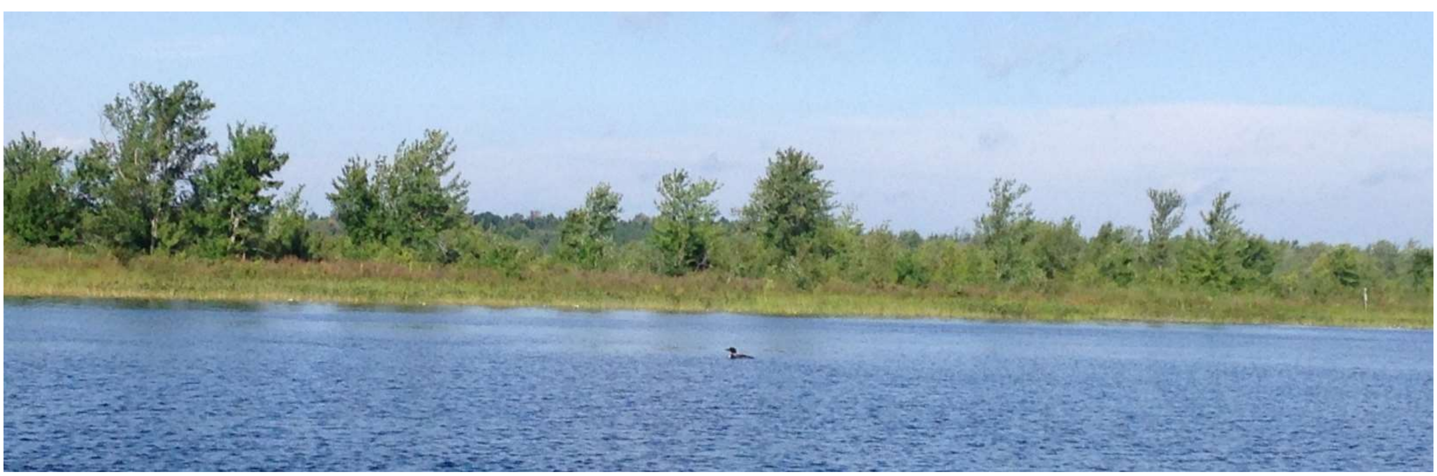


Figure 11: Total euphotic zone phosphorus results for the deepest sampling point in Mississippi Lake at Burnt Island, as compared to a monthly average for this site.

The water temperature and dissolved oxygen profile data from the 2018 sampling events are available in Appendix A.



Upper Mississippi Subwatershed Lakes

Ardoch Lake

Ardoch Lake is a small headwaters lake that flows into Malcolm Lake, in North Frontenac. It has a maximum depth of 17.4 meters. MVCA has now monitored this lake through seven ice free seasons and it has consistently had a moderate total phosphorus results. Figure 12 shows that there were early season results over 20 µg/L in 2014, which were likely a result of spring runoff event bringing nutrients into the lake. The 2018 results (Table 7) were fairly low total phosphorus concentrations in the spring and mid-summer, but the late season result is uncharacteristically high at 56 µg/L. At this time is it not clear what caused this result to be so high. The lake will continue to be monitored to assess if this result is due to a sampling error or if something else might be occurring in this area.

Table 7: 2018 sampling summary for Ardoch Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	05/11/2018	5.5	8	11	n/a	48
Main Basin	07/03/2018	4.3	7	30	n/a	
Main Basin	08/31/2018	4.5	56	22	7.97	

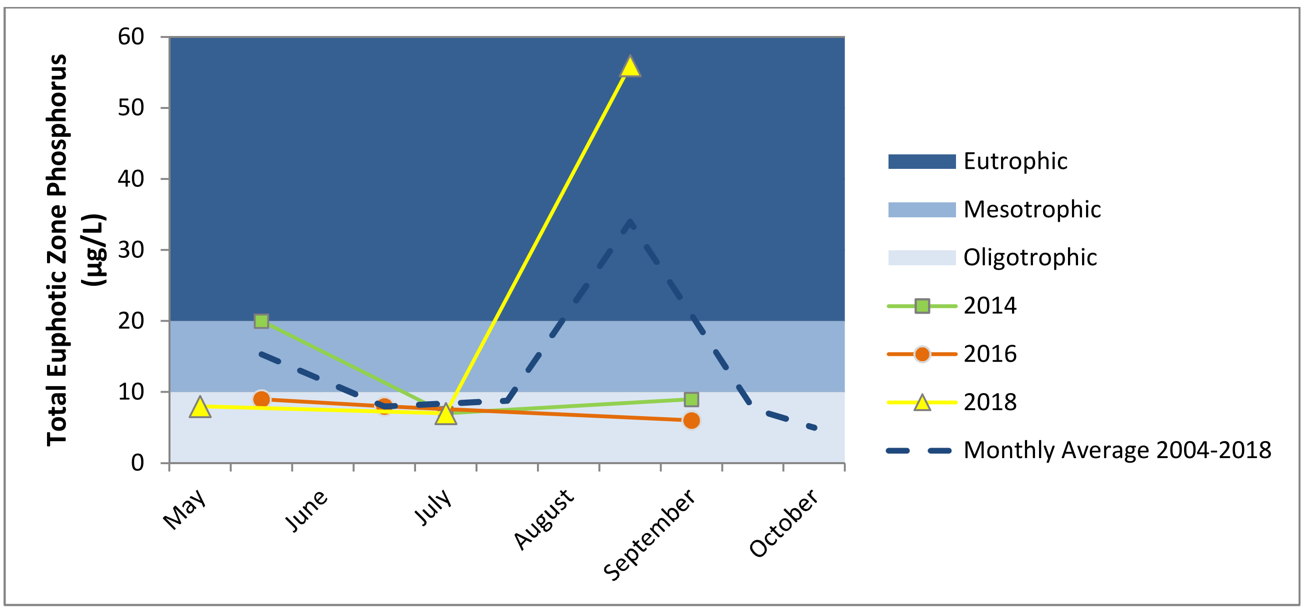


Figure 12: Total euphotic zone phosphorus results for Ardoch Lake as compared to a monthly average for this site.

Ardoch Lake maintains optimal and critical cold water fish habitat throughout the ice free season. This cold water habitat becomes constricted to a zone of water that is four meters deep by fall (Appendix A). Despite the presence of suitable habitat, MVCA has no record of the lake supporting cold water sport fish species.

Big Gull Lake

Big Gull Lake is a large cold water lake in North Frontenac that flows into the south basin Crotch Lake. It has a maximum depth of 26 meters. The 2018 results (Table 8) returned fairly low and consistent total phosphorus concentrations and shallow to moderate Secchi depth measurements. MVCA has now monitored Big Gull through four ice free seasons and it has consistently had a low to moderate total phosphorus results, with an average in the oligotrophic range. 2018 data supports this classification. Figure 13 shows the 2018 results in comparison to the previous visit in 2014 and the average results from the sampling efforts between 2004 and 2018.

Table 8: 2018 sampling summary for Big Gull Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)	pH	Calcium (Ca2+) (mg/L)
East Basin	05/23/2018	2.8	8	8	8.02	16
East Basin	07/04/2018	3.3	13	10	7.53	
East Basin	09/04/2018	3.3	7	7	8.18	
Main Basin	05/23/2018	2.0	6	11	8.05	16
Main Basin	07/04/2018	3.3	8	7	7.62	
Main Basin	09/04/2018	3.5	7	12	n/a	
West Basin	05/23/2018	3.5	8	n/a	7.86	16
West Basin	07/04/2018	2.5	10	n/a	7.49	
West Basin	09/04/2018	3.0	11	n/a	8.10	

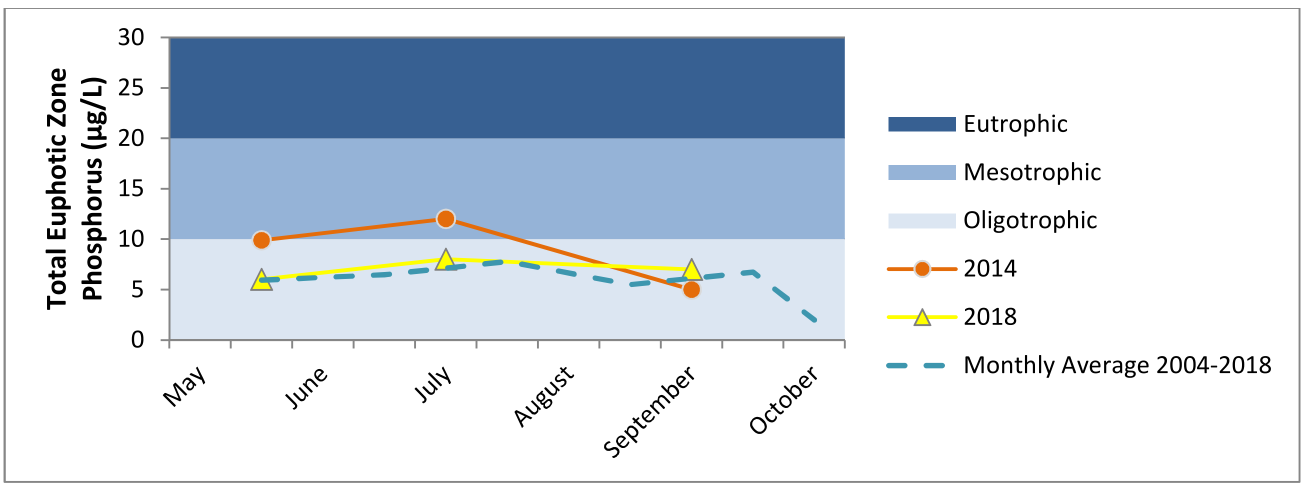


Figure 13: Total euphotic zone phosphorus results for the deepest sampling point at the Main Basin of Big Gull as compared to the monthly average for this site.

The east and the main basins of Big Gull Lake have optimal cold water fish habitat in the spring and summer seasons. These conditions became constricted by the Autumn of 2018 (Appendix A). This is similar to previous years where the main basin supports a narrow zone of cold water habitat into the fall. Big Gull is known to support a warm water fishery as well as cold water fish species such as lake whitefish. These fish are slightly more tolerant to warm water temperatures than the lake trout that were historically found in Big Gull.

Fawn Lake

Fawn Lake is a small warm water lake in North Frontenac that flows into the south basin of Crotch Lake. It has a maximum depth of 9 meters. The 2018 results showed consistent low total phosphorus concentrations and moderate Secchi depth measurements (Table 9). Figure 14 shows the results from the sampling efforts in 2018 as compared to the previous visit in 2014 and the monthly average Total Phosphorus results over all the sample years between 2000 and 2018. MVCA has now monitored Fawn Lake through five ice free seasons and the lake has averaged in the mesotrophic range with late season results for 2000 and 2005 greater than the PWQO of 20 µg/L. These previous high values are influencing the average shown in Figure 14.

In both 2014 and 2018 a sample was not taken in the late summer/early fall season. This is due to the water draw down efforts on Crotch Lake reducing the water levels in the channel to Fawn Lake to a point where it becomes impassable and Fawn Lake is no longer accessible.

The water temperature and dissolved oxygen profile data from the 2018 sampling events are available in Appendix A.

Table 9: 2018 sampling summary for Fawn Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	05/24/2018	4.3	8	7.89	16
Main Basin	07/06/2018	4.0	8	7.32	

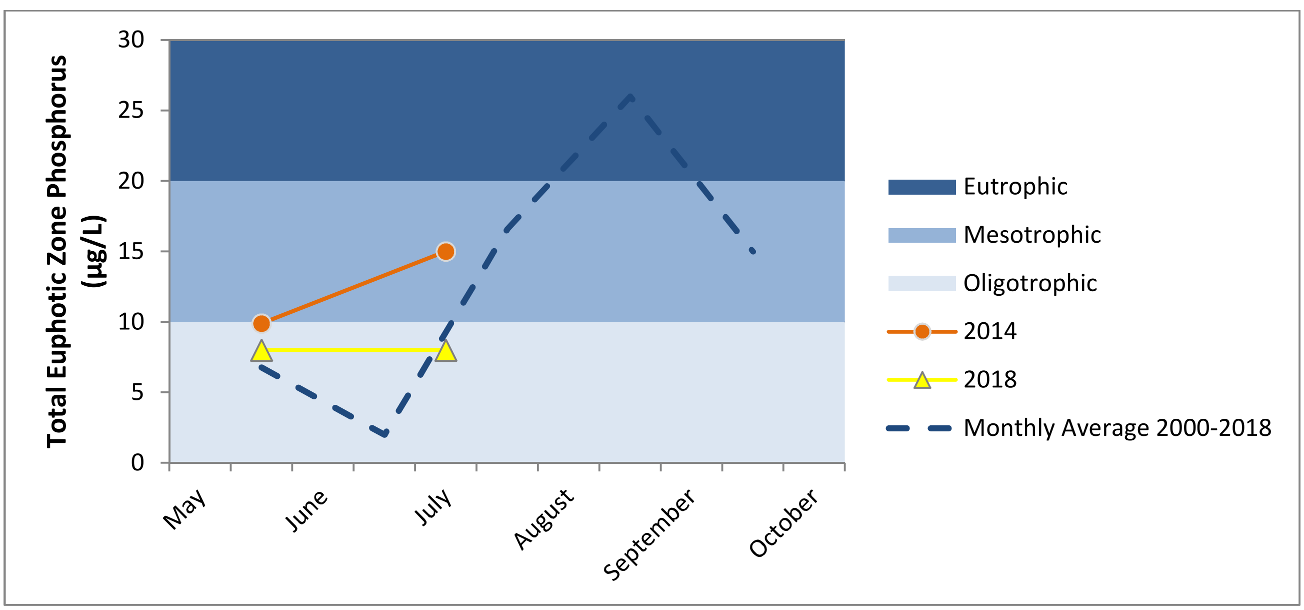


Figure 14: Total euphotic zone phosphorus results for Fawn Lake as compared to the monthly average for this site.

Malcolm Lake

Malcolm Lake is a shallow warm water lake in North Frontenac that flows into the Mississippi River at the village of Ardoch. It has a maximum depth of 4.6 meters. The 2018 data (Table 10) shows an increase in the total phosphorus and a slight decrease in the Secchi depth measurements as the year progressed. MVCA has now monitored Malcolm Lake through four ice free seasons and with the exception of an extreme value collected in 2009, it has averaged a mesotrophic status. Figure 15 shows the results from 2018 which are compared to the results from 2014 and a monthly average of all the results between 2004 and 2018. In Figure 15 a downward trend of total phosphorus concentrations occurs over the 2014 season. Then in an opposite trend, 2018 started low and then rose to a concentration of 24 µg/L by the end of August. Although this late season sample result is just above the PWQO for total phosphorus of 20 µg/L, the 2018 results are within the average results for this lake. The lake will continue to be monitored to assess if this result is due to a sampling error or another factor.

Table 10: 2018 sampling summary for Malcolm Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	05/11/2018	4.0	5	n/a	32
Main Basin	07/03/2018	3.5	13	n/a	
Main Basin	08/31/2018	3.5	24	7.94	

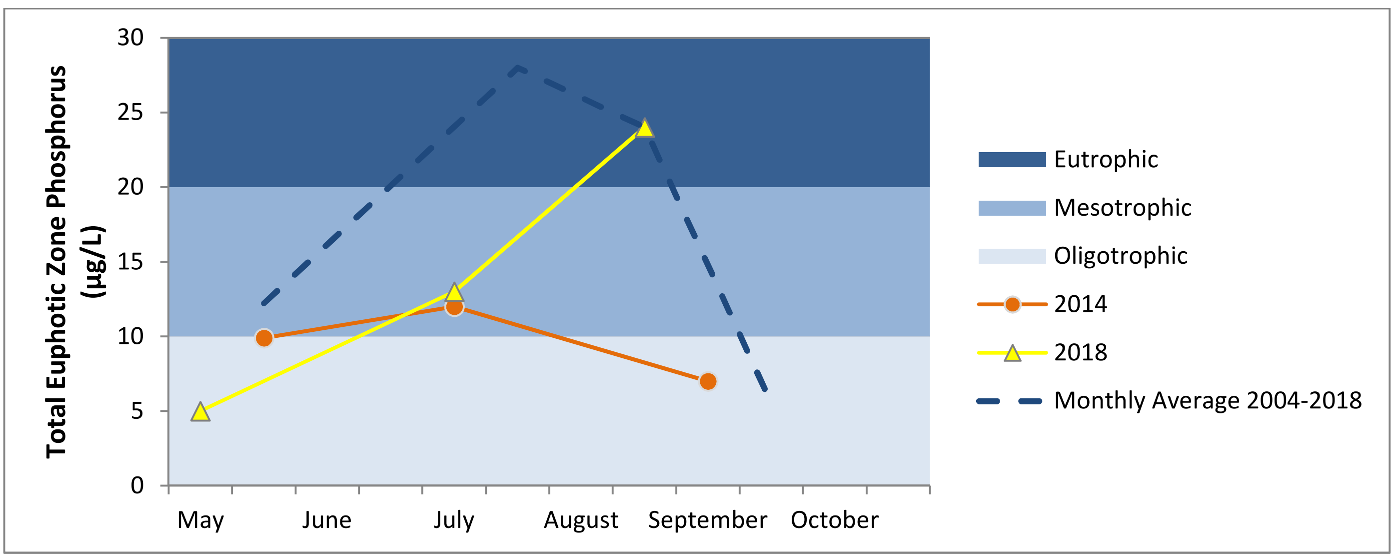


Figure 15: Total euphotic zone phosphorus results for Malcolm Lake as compared to the monthly average for this site.

The water temperature and dissolved oxygen profile data from the 2018 sampling events are available in Appendix A.

Mosque Lake

Mosque Lake is a cold water lake in North Frontenac that flows into Conn's Creek, which outlets into the Mississippi River south of Ompah. It has a maximum depth of 34 meters. The 2018 data (Table 11) shows low to moderate levels of total phosphorus and moderate to deep Secchi depth measurements throughout the lake. MVCA has now monitored it through five ice free seasons and with the exception of inconsistent data from 2000, it has maintained a low to moderate total phosphorus results. Results from 2018 are compared to results from 2014 and a monthly average of all the results between 2000 and 2018. The 2018 season maintains the low to moderate total phosphorus results with the lake starting the ice free season with an undetectable level of total phosphorus (< 2 µg/L), and then rising into the mesotrophic range over the summer (Figure 16).

Mosque Lake maintains optimal and critical cold water fish habitat throughout the ice free season (Appendix A).

Table 11: 2018 sampling summary for Mosque Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)	pH	Calcium (Ca2+) (mg/L)
North Basin	06/07/2018	4.5	< 2	6	7.75	16
North Basin	07/18/2018	5.0	7	5	7.45	
North Basin	08/27/2018	4.0	10	12	8.13	
South Basin	06/07/2018	5.5	<2	31	7.82	24
South Basin	07/18/2018	4.5	11	59	7.46	
South Basin	08/27/2018	4.5	18	308	7.69	
West Basin	06/07/2018	4.0	2	32	7.82	16
West Basin	07/18/2018	3.5	12	133	7.28	
West Basin	08/27/2018	3.5	9	234	8.00	

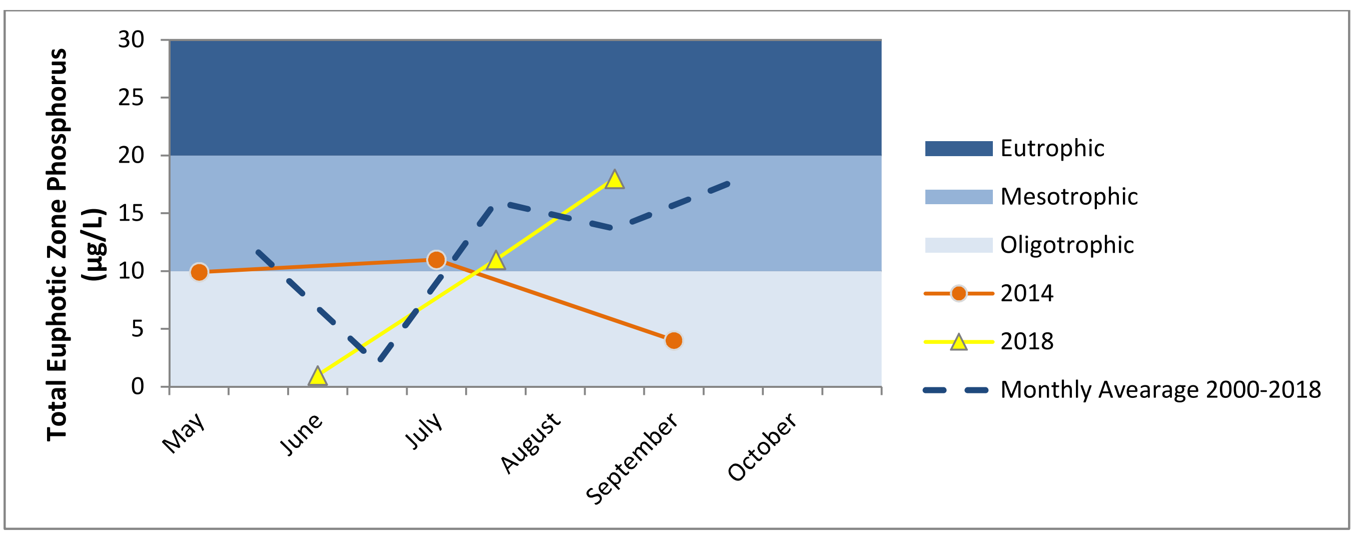


Figure 16: Total euphotic zone phosphorus results for Mosque Lake South Basin as it is the deepest sampling point, as compared to a monthly average for this site.

Pine Lake

Pine Lake is a small cold water lake in North Frontenac that flows into the south basin of Crotch Lake. It has a maximum depth of 17.7 meters. The 2018 data show low total phosphorus concentrations and moderate Secchi depth measurements (Table 12). Results from 2018 as well as 2014 and a monthly average of all the results between 2004 and 2018 are shown in Figure 17. MVCA has now monitored Pine Lake through four ice free seasons and it consistently has a low total phosphorus results. 2018 is no different with the lake starting the ice free season with a moderate level of total phosphorus then dropping into the oligotrophic range for the remainder of the season.

Pine Lake maintains optimal and critical cold water fish habitat throughout the ice free season (Appendix A).

Table 12: 2018 sampling summary for Pine Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	05/14/2018	3.3	12	9	n/a	16
Main Basin	07/10/2018	4.3	5	15	7.50	
Main Basin	09/05/2018	5.0	9	17	8.31	

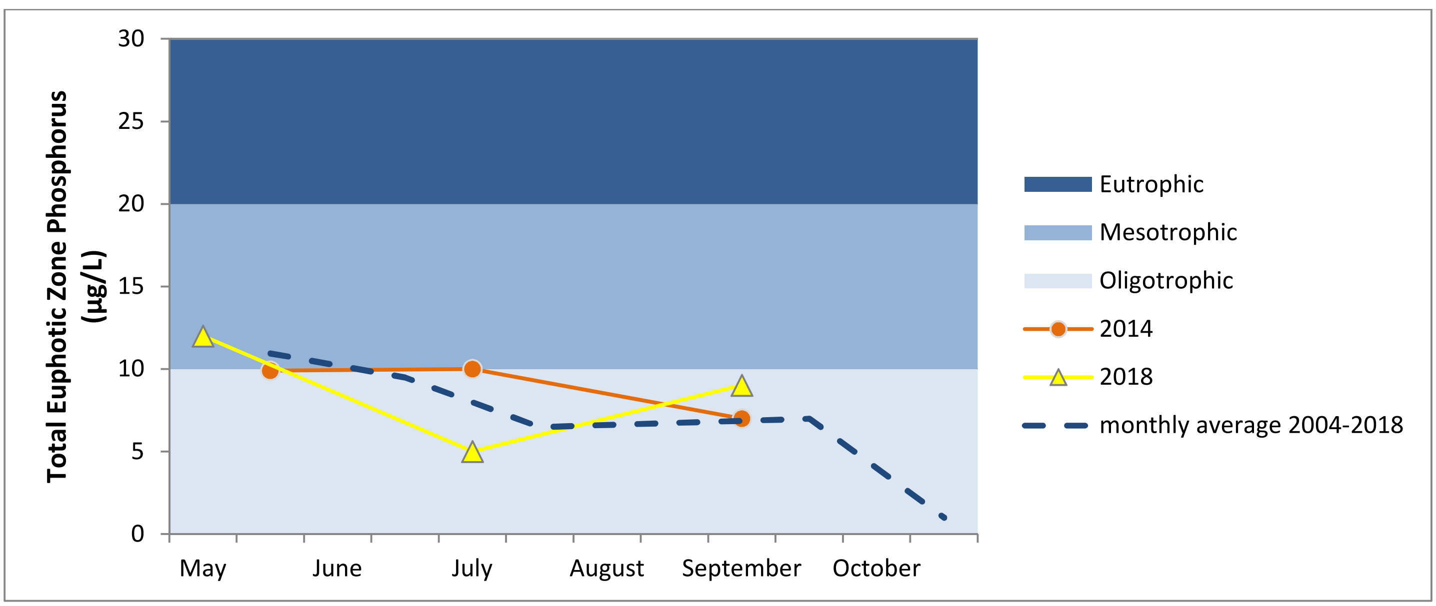


Figure 17: Total euphotic zone phosphorus results for the Pine Lake Main Basin, as compared to a monthly average for this site.

Indian River Subwatershed Lakes

Clayton Lake

Clayton Lake is a warm water lake in Lanark Highlands and Mississippi Mills that flows into the Indian River at the village of Clayton. It has a maximum depth of 10 meters. Clayton and Taylor Lakes are unique in the MVCA jurisdiction due to their large shoreline wetland ecosystem which has been classified as a Provincially Significant Wetland.

Table 13 summarizes the 2018 results which show moderate levels of total phosphorus concentrations and Secchi depth measurements. MVCA has now monitored Clayton Lake through four ice free seasons and it has consistently had moderate total phosphorus results. Results from 2018 as well as 2012 and a monthly average of all the results between 2002 and 2018 are shown in Figure 18. In 2012 the spring started out with higher total phosphorus than usual but then it returned to a mesotrophic range. In 2018 the lake remained mesotrophic, and experienced an increase of total phosphorus throughout the late summer into September.

The water temperature and dissolved oxygen profile data from the 2018 sampling events are available in Appendix A.

Table 13: 2018 sampling summary for Clayton Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	06/06/2018	4.0	16	7.93	48
Main Basin	07/12/2018	3.5	11	7.49	
Main Basin	09/13/2018	4.0	20	8.15	

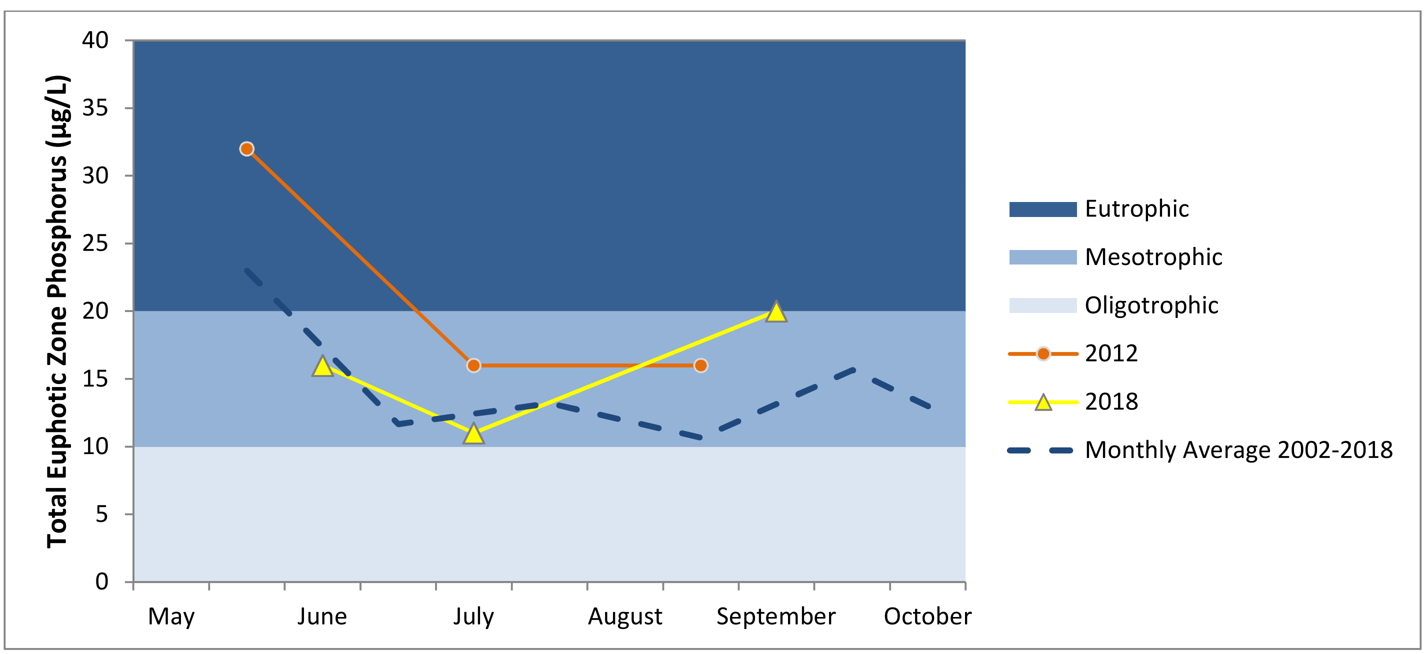


Figure 18: Total euphotic zone phosphorus results for the Main Basin of Clayton Lake, as compared to a monthly average for this site.

Taylor Lake

Taylor Lake is a small shallow warm water lake in Lanark Highlands that flows into Clayton Lake from the south. It has a maximum depth of 3 meters. Clayton and Taylor Lakes are unique in the MVCA jurisdiction due to their large shoreline wetland ecosystem which has been classified as a Provincially Significant Wetland.

Table 14 summarizes the 2018 results which show low total phosphorus concentrations and, considering the lake is only 3 meters deep, good levels of light penetration in the Secchi depth measurements. Results from 2018 and 2012 as well as a monthly average of all the results between 2002 and 2018 are shown in Figure 19. Taylor Lake has had an overall moderate total phosphorus result. There have been exceptions to this overtime, however the average trend for total phosphorus concentrations has maintained a mesotrophic (or moderate) classification. In 2018 the lake's total phosphorus concentrations started rather low and rose to the mesotrophic range, which is similar to the results from the previous sampling in 2012.

The water temperature and dissolved oxygen profile data from the 2018 sampling events are available in Appendix A.

Table 14: 2018 sampling summary for Taylor Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	06/06/2018	3.0	4	7.98	40
Main Basin	07/12/2018	2.5	9	7.80	
Main Basin	09/13/2018	2.7	12	8.02	

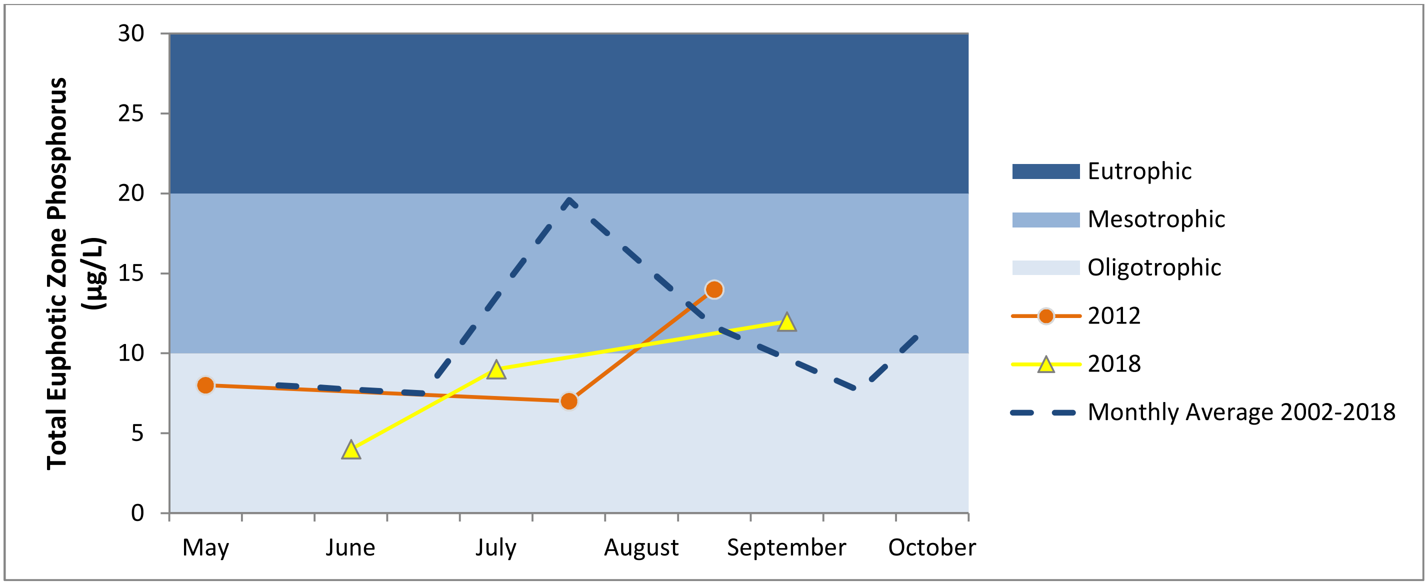


Figure 19: Total euphotic zone phosphorus results for the Main Basin of Taylor Lake, as compared to a monthly average for this site.

Auxiliary Lake

McCauseland Lake

McCauseland Lake is a small cold water lake in North Frontenac that flows into Mazinaw Lake. It has a maximum depth of 24 meters. The 2018 results (table 15) show low total phosphorus concentrations and deep Secchi depth measurements. MVCA has now monitored it through five ice free seasons (3 of which included total phosphorus sampling). It has consistently had low total phosphorus results within the oligotrophic range. The 2018 season returned two of the lowest total phosphorus concentrations recorded for that time of year. Results from 2018 are compared to the results from 2013 and a monthly average of all the results between 2008 and 2018 in Figure 20.

McCausleand Lake maintains optimal and critical cold water fish habitat throughout the ice free season (Appendix A).

Table 15: 2018 sampling summary for McCauseland Lake.

Site	Date	Secchi Depth (m)	Total P – Euphotic Zone (µg/L)	Total P – Bottom Sample (µg/L)	pH	Calcium (Ca2+) (mg/L)
Main Basin	05/18/2018	5.5	7	6	7.63	8
Main Basin	07/17/2018	6.5	3	12	7.53	
Main Basin	08/28/2018	5.5	6	39	7.86	

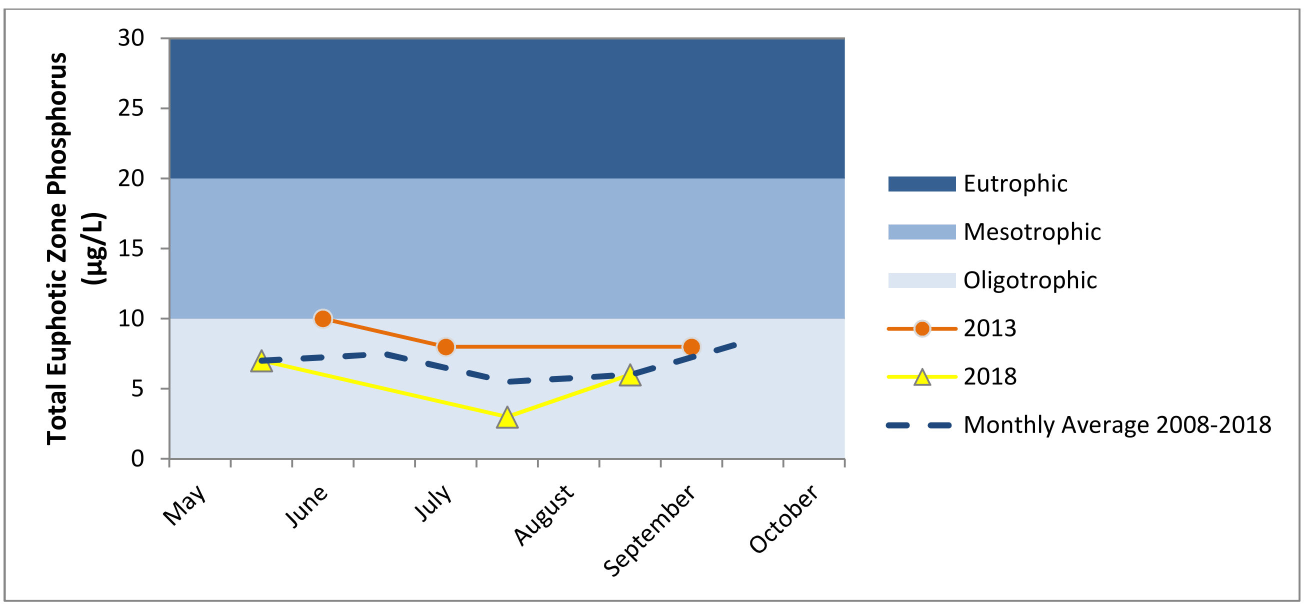


Figure 20: Total euphotic zone phosphorus results for the main basin of McCauseland Lake, as compared to a monthly average for this site.

Stream Monitoring Program

Summary

The highlight of stream sampling in 2018 was confirmation of the presence of brook trout in five streams. It was also beneficial to increase sampling efforts in the Upper Mississippi and Indian River subwatersheds to help expand MVCA's knowledge of those areas.

Brook Trout

Due to limitations in the various sampling protocols, the extent of time they take to perform, the season in which they are undertaken and equipment availability it is not possible to sample every monitoring site with all three techniques (fish community, benthic community and thermal classification) in the same year. Table 16 summarizes the stream monitoring protocols MVCA performed in 2018, and Figure 21 illustrates the locations of these sites across the watershed.

Table 16: A summary of the Mississippi River watershed stream sites sampled in 2018 along with their thermal classification results. The subwatersheds in light blue are the focus of this report.

Subwatershed	Stream Name	Electrofished	Benthic Samples Collected	2018 Thermal Classification
Buckshot Creek	Buckshot Tributary	Yes		
Clyde River	Easton's Creek - 006	Yes	Yes	Cool-Warm
Fall River	Bolton Creek	Yes		Warm
Fall River	Limekiln Creek	Yes		
Fall River	Sharbot Creek	Yes		
High Falls	Black Creek	Yes	Yes	Cool-Warm
High Falls	Mosquito Creek	Yes	Yes	Cool
Indian River	Indian River - 003	Yes		
Indian River	Indian River - 004	Yes	Yes	
Indian River	Indian River - 008			Result not available
Indian River	Indian River - 07B	Yes	Yes	
Indian River	Union Hall Creek	Yes	Yes	
Lower Mississippi	Cartwright's Creek	Yes		Cool
Lower Mississippi	Wolfe Grove Creek	Yes		Cool-Warm
Mazinaw	Donnelly Creek	Yes	Yes	Cold-Cool
Mississippi Lake	Campbell's Creek	Yes		
Mississippi Lake	Long Sault Creek	Yes		Cool
Mississippi Lake	Paul's Creek	Yes		Cool-Warm
Upper Mississippi	Burt's Creek	Yes	Yes	
Upper Mississippi	Conn's Creek	Yes	Yes	Cool
Upper Mississippi	Gull Creek			Cool
Upper Mississippi	Unnamed Tributary	Yes	Yes	

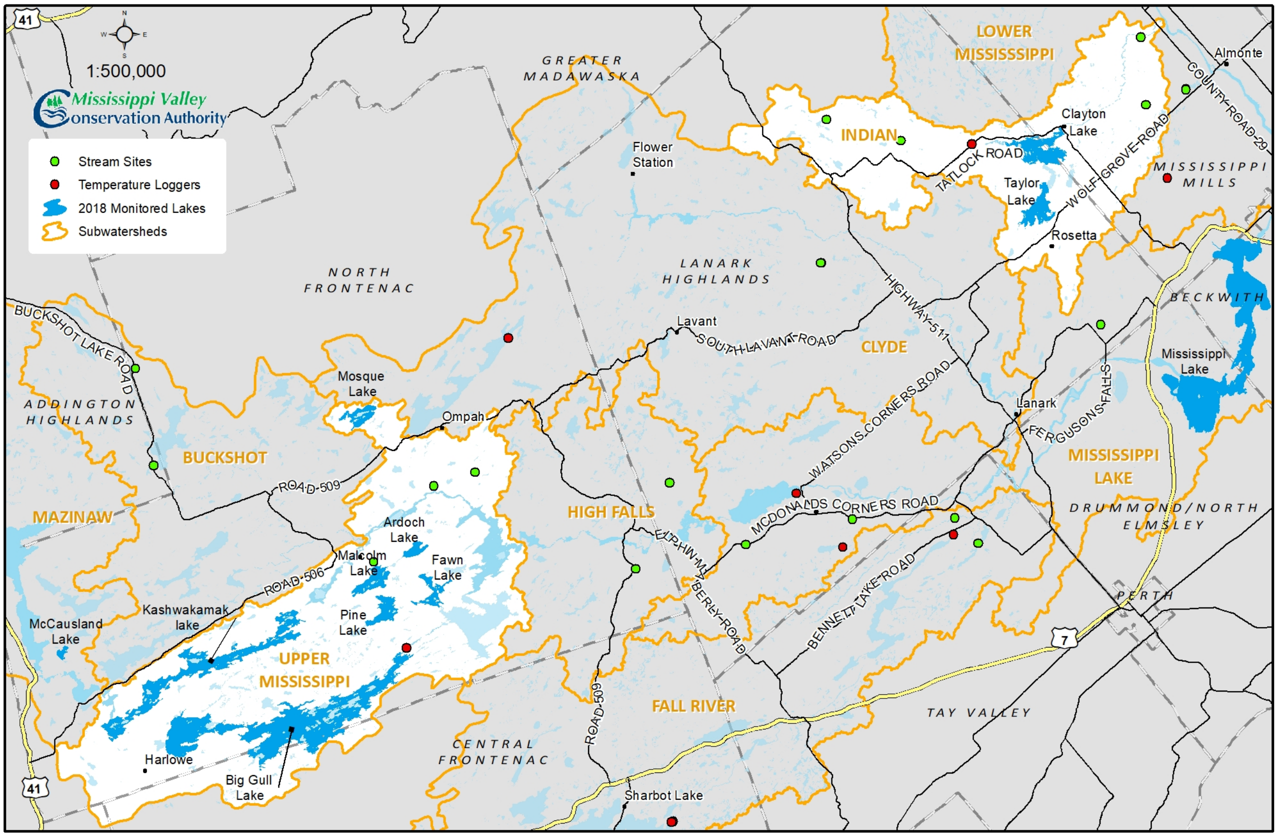


Figure 21: 2018 stream sampling site distribution.

Fish Community Monitoring

MVCA uses a sampling technique called electrofishing to safely and temporarily stun the fish by passing an electrical current through the water. This allows the crew to net, identify and measure the fish and then they are released back into the water.

Twenty stream sites within the Mississippi River's subwatersheds were electrofished in 2018. Sites were chosen in order to learn more about the tributaries in the Upper Mississippi and Indian River subwatersheds, as well as to check on sites known to be cool water streams. Refer to Table 16 for the complete list of the stream sites sampled. Coldwater fish species were found at six sites. MVCA has continued to successfully capture burbot in Bolton Creek and was able to repeat the capturing of brook trout in Donnelly Creek, Mosquito Creek, Long Sault Creek, and Paul's Creek. Mottled Sculpin were captured by MVCA in Wolf Grove Creek in both 2015 and in 2018 despite the temperature logger showing the creek to have warm and cool-warm water habitat respectively. This indicates that there might be springs or other thermal refuge available to this cool water fish.

Crew performing an electrofishing survey in the Indian River

In 2017 a cool water fish species (spottail shiner) was captured in Limekiln Creek so the site was resampled in 2018. This species was not collected in 2018, but the site has continued to support other cool water species such as the Iowa Darter. This site will continue to be monitoring as part of the sampling rotation to account for annual variations in species abundances and to document habitat characteristics.


Benthic Sampling

Benthic Community Monitoring

While benthic samples were collected at 10 stream sites during the fall of 2018, the processing of these samples is completed in the lab over the winter and into the following summer. Therefore, at the time of publishing this report MVCA does not have an analysis of the results available. Refer to Table 16 for a complete list of the stream sites sampled.

Temperature Monitoring

Temperature loggers were launched at 12 of the stream sites with the intent to continue monitoring known cold to cool water streams for potential variations in available thermal habitat due to changes in annual climate. For example, in 2017 the electrofishing surveys found two previously unknown populations of Brook Trout. In 2018 temperature loggers were launched at these sites to determine their thermal classification and found that one was a cold-cool habitat, and the other was a cool habitat.

Many factors can influence fluctuations in stream temperature, including springs, tributaries, precipitation runoff, discharge pipes and stream shading from riparian vegetation. Water temperature is used along with the maximum air temperature (using the revised Stoneman and Jones method by Cindy Chu *et al, 2009*) to classify a watercourse as either cold, cold-cool, cool, cool-warm, or warm water. Refer to Table 16 for a summary of the thermal classification results from the 2018 season.

The 2018 season started with an above average flood event. However, by July 1st water levels were low and the Mississippi Valley was in a Level 1 drought until December. Analysis of the temperature logger data indicates that the warm, dry conditions influenced the in stream water temperatures. For example the data collected from Bolton Creek and Paul's Creek in 2018 was warm enough that the thermal classification received was one category warmer than the classification they each received in 2017. This highlights the need for continued monitoring at these stations to determine if this fluctuation is a trend or part of a normal variation in the stream temperature due to the climatic conditions experienced in 2018.


Deploying a temperature logger

Only one logger was deployed in the Indian River subwatershed in 2018. Due to the low water conditions experienced during the summer, the logger was out of the water during the time range required to do the habitat classification. It is MVCA's intent to revisit the Indian River subwatershed and deploy temperature loggers in other locations that will be more drought tolerant.

Shoreline Stewardship

MVCA's Tree Planting Programs

Shoreline tree planting is an effective way to protect water quality, combat erosion, clean the water, and create healthy habitat for fish, birds, pollinators and other wildlife. To help with this, MVCA has two programs that distribute native species of trees and shrubs to waterfront properties within the watershed.

MVCA administers a small scale shoreline planting program where MVCA staff perform a site visit then work with the property owners to design a shoreline planting plan that will suit their property's needs. MVCA then orders, delivers and installs the plants according to the agreed upon plan. In 2018, this program resulted in 243 trees and shrubs being planted across 10 properties.

For the past two years MVCA has been working with a select number of lake associations on a rotational basis to pilot a free tree event, where property owners from the lakes monitored in the MVCA watershed are offered up to 15 shoreline plant species per property. In 2018, MVCA partnered with the Kashwakamak Lake Association and the Big Gull Lake East End Cottage Association to distribute 1266 plants to 97 properties. Due to the continued successful uptake of this program within the lake community, Palmerston Lake and Silver Lake have been selected for 2019.

Lake Planning

2018 Activity Summary

MVCA has a mandated role to address natural hazard issues, such as flooding and erosion in the review of planning applications under the Planning Act. Additionally, in an advisory role, applications are reviewed within the context of natural heritage values such as wetlands, wildlife and fish habitat; as well as water quality and quantity. MVCA also administers Ontario Regulation 153/06. The purpose of this regulation is to prevent loss of life and property due to flooding and erosion, and to conserve and enhance natural resources. In MVCA regulated areas (floodplains and shorelines), permission is required from MVCA for development, interference with wetlands, and alterations to shorelines and watercourses.

In 2018 MVCA planning and regulations staff reviewed 43 permit applications on the lakes monitored. This represents 28% of the permits issues in 2018.

Having reliable information about the health of a lake is essential for providing appropriate and effective recommendations on development applications. Data from the lake monitoring program assists MVCA in making such recommendations. It also serves to encourage and assist shoreline residents, both seasonal and permanent, to become personal stewards of their lake by taking an active role in restoring and enhancing their shoreline. Stewardship projects that aid water quality include temporarily storing water (eg. rain barrels), directing runoff away from the lake (eg. installing properly working eavestroughs), creating or enhancing surfaces to allow more water to infiltrate rather than run off along the surface (eg. rain gardens), and planting trees and shrubs along the shoreline. All of these initiatives protect and enhance water quality.

Appendix A: Water Temperature and Dissolved Oxygen Profile Details

The results from the 2018 temperature and dissolved oxygen profiles from all the lake sampling events are found below in alphabetical order. For the lakes with appropriate cool to cold water conditions, a colour code has been applied to the table representing optimal cold water habitat conditions (in blue) and the fringe vital conditions for survival (in pink) as defined in Table A-1. Some of the warm water lakes may be shown to have these conditions periodically but they do not last throughout the season and thus they only support a warm water fishery.

Table A-2 summarizes the thermal classifications for the lakes sampled in 2018. Some of the cold water lakes no longer support certain cold water fish species (such as lake trout) due to historical stocking activities or water level management efforts.

Table A-1: Optimal and vital habitat conditions for cold water fish species such as trout.

	Optimal Habitat for Cold Water Fisheries (Trout) = DO > 6 mg/L at < 10°C
	Vital Habitat for Cold Water Fisheries (Trout) = DO > 4 mg/L at < 15.5°C

Table A-2: List of cold water and warm water lakes monitored in 2018.

Cold to Cool Water Lakes	**Warm Water Lakes**
Big Gull Lake	Ardoch lake
Kashwakamak Lake	Clayton Lake
McCauseland Lake	Fawn Lake
Mosque Lake	Malcolm Lake
Pine Lake	Mississippi Lake
	Taylor Lake

Ardoch Lake

Main Basin

	May 11/2017		July 3/2017		August 31/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	11.10	11.50	25.90	8.91	22.70	8.78
1	11.40	11.36	25.60	8.97	22.70	8.77
2	11.40	11.33	25.40	9.08	22.70	8.75
3	11.30	11.31	24.90	8.66	22.70	8.73
4	11.30	11.28	22.70	9.88	22.70	8.71
5	9.90	11.47	20.40	11.19	22.70	8.69
6	8.70	11.41	14.90	12.45	16.70	12.42
7	7.30	10.65	12.30	12.10	12.70	11.45
8	6.60	9.00	10.40	11.60	11.00	9.66
9	6.30	8.07	8.60	9.85	9.40	6.98
10	6.20	7.61	7.80	8.73	8.50	4.92
11	6.10	7.44	7.40	6.68	7.90	1.64
12	6.00	7.16	6.90	3.32	7.60	0.56
13	6.00	7.04	6.70	1.50	7.40	0.28
14	5.90	6.91	6.60	0.75		
15			6.60	0.55		

Big Gull Lake

Big Gull: West Basin

	May 23/2017		July 4/2017		Sept 4/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	19.10	9.55	29.10	8.52	25.20	9.08
1	18.70	9.61	28.00	8.69	24.50	9.11
2	18.50	9.61	27.30	8.77	24.10	9.05
3	17.70	9.35	26.30	8.15	24.00	9.09
4	16.90	9.38	24.30	7.07		
5			23.70	6.81		

Big Gull: Main Basin

	May 23/2017		July 4/2017		Sept 4/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	15.80	11.21	27.80	8.83	23.90	8.84
1	15.50	11.26	26.50	9.07	23.40	8.86
2	15.30	11.26	25.40	9.35	23.20	8.85
3	13.90	11.32	24.50	9.45	23.00	8.82
4	13.70	11.21	26.60	9.21	23.00	8.78
5	12.90	11.03	21.80	9.20	22.90	8.72
6	12.30	10.83	18.20	7.21	22.50	8.21
7	10.50	10.49	15.40	6.35	20.80	6.14
8	9.00	10.21	12.50	6.32	17.00	2.53
9	8.50	10.27	11.60	6.40	13.50	2.42
10	8.10	10.11	10.40	6.68	11.40	2.64
11	7.70	9.94	9.70	7.00	10.40	2.46
12	7.60	9.95	8.90	7.26	9.90	3.02
13	7.40	9.95	8.70	7.38	9.70	3.46
14	7.20	9.92	8.40	7.34	9.30	3.99
15	7.10	9.88	8.10	7.04	8.80	4.22
16	6.80	9.34	7.90	7.14	8.40	4.00
17	6.80	9.24	7.70	7.27	8.20	3.89
18	6.70	9.14	7.50	7.03	7.90	2.99
19	6.70	9.00	7.30	6.58	7.70	1.96
20	6.40	8.72	7.10	5.75	7.50	2.01
21	6.40	8.52	7.00	5.56	7.40	1.82

Big Gull: East Basin

	May 23/2017		July 4/2017		Sept 4/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	16.40	11.10	27.70	8.81	24.50	8.74
1	16.00	11.14	27.70	8.86	23.90	8.77
2	15.20	11.19	26.50	9.00	23.60	8.79
3	15.00	12.22	25.80	9.14	23.50	8.79
4	14.90	11.19	24.00	9.13	23.40	8.73
5	13.40	11.07	20.30	8.43	23.40	8.67
6	11.50	10.60	18.60	7.46	23.30	8.50
7	9.50	10.17	14.30	6.18	22.60	7.78
8	8.60	9.89	12.10	5.66	16.80	2.58
9	8.20	9.63	10.90	5.61	12.10	1.84
10	8.10	9.52	10.20	5.66	10.90	1.63
11	7.90	9.31	9.60	5.69	10.40	1.65
12	7.60	9.20	9.50	5.70	10.00	1.80
13	7.40	9.19	9.40	5.68	10.00	1.74
14	7.40	9.19	9.20	5.68	10.00	1.75
15			9.10	5.62	9.90	1.74
16			9.00	5.49	9.80	1.87
17			8.80	5.60	9.40	2.02
18			8.70	5.74	9.20	2.06

Clayton Lake

Main Basin

	June 6/2017		July 12/2017		Sept 13/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	18.80	8.60	25.00	9.74	20.70	8.67
1	18.80	8.56	25.10	9.70	20.20	8.68
2	18.80	8.45	24.90	9.66	20.10	8.63
3	18.80	8.41	24.90	9.46	19.90	9.44
4	18.60	8.09	24.70	9.14	19.80	8.00
5	18.60	7.73	24.10	8.03	19.50	7.43
6	17.00	4.55	19.00	0.03	19.40	0.31
7	14.70	0.70	16.70	-0.10		
8			14.60	-0.16		

Fawn Lake

Main Basin

	May 24/2017		July 6/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	19.90	10.84	26.70	9.73
1	18.70	10.78	27.10	9.61
2	18.20	10.96	27.20	9.54
3	17.40	11.00	19.30	7.62
4	11.20	13.20	14.50	8.11
5	8.40	10.12	11.10	6.23
6	6.70	7.43	8.10	3.38
7	6.10	5.35	7.10	0.93
8	5.50	2.97	6.50	0.26
9			6.00	0.30

Kashwakamak Lake

Kashwakamak Lake: East Basin

	May 30/2017		July 5/2017		Sept 6/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	21.60	11.69	27.90	9.93	24.00	8.74
1	21.10	11.76	27.70	9.94	24.10	8.69
2	20.60	11.88	26.90	10.31	24.20	8.68
3	19.40	12.15	25.60	10.40	24.10	8.68
4	16.60	12.78	23.90	10.45	24.10	8.68
5	14.50	12.82	22.40	10.35	24.00	8.65
6	12.80	12.73	18.90	11.12	23.40	8.60
7	11.70	12.16	14.30	13.13	19.90	9.11
8	9.40	11.97	11.10	13.56	13.20	10.71
9	8.10	11.73	8.80	12.37	10.80	10.87
10	7.40	11.47	7.90	11.18	8.50	9.40
11	7.10	11.33	7.60	10.72	8.00	8.45
12	7.00	11.07	7.40	10.41	7.70	8.37
13	6.70	11.01	7.10	10.13	7.50	7.22
14	6.60	10.90	7.00	9.96	7.40	6.97
15	6.50	10.81	6.90	9.84	7.20	6.35
16	6.40	10.75	6.80	9.68	7.10	6.35
17	6.30	10.43	6.70	9.46	7.00	6.29
18	6.30	10.40	6.60	9.23	6.90	5.63
19	6.20	10.41	6.50	8.47	6.80	5.03
20	6.20	10.26	6.30	8.12		
21	6.10	9.56	6.30	7.50		
22	5.90	8.14	6.20	5.17		

Kashwakamak Lake: West Basin

	May 30/2017		July 5/2017		Sept 6/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	22.50	11.22	28.00	10.12	23.90	8.80
1	22.10	11.29	27.20	10.17	24.00	8.77
2	21.30	11.42	26.20	10.44	23.90	8.78
3	20.70	11.71	25.50	10.47	23.80	8.77
4	17.80	11.99	23.90	10.62	23.60	8.75
5	15.10	12.90	21.40	10.28	23.60	8.72
6	12.40	12.17	17.60	11.54	23.30	8.30
7	10.30	11.89	14.70	12.86	22.80	8.20
8	8.70	11.25	12.30	13.31	19.80	8.10
9	7.70	10.62	9.90	10.80	13.50	8.07
10	7.20	10.15	8.50	9.73	9.20	5.75
11	6.70	9.65	7.90	8.60	8.20	4.23
12			7.50	7.92	7.90	0.30
13			7.30	7.20		

Malcolm Lake

Main Basin

	May 11/2017		July 3/2017		August 31/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	15.40	10.85	28.20	8.14	22.80	9.08
1	15.40	10.84	26.90	8.77	22.80	9.06
2	15.20	10.94	26.20	9.04	22.80	9.10
3	15.10	11.04	26.00	9.05	22.70	9.12
4					22.60	9.22
5					22.70	0.52

McCauseland Lake

Main Basin

	May 18/2017		July 17/2017		August 28/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	15.30	11.46	25.90	9.62	23.40	8.82
1	15.30	11.46	25.80	9.67	23.30	8.84
2	15.30	11.43	25.70	9.68	23.30	8.83
3	15.30	11.40	25.40	9.57	23.30	8.79
4	11.20	12.26	24.80	10.17	23.30	8.78
5	9.60	12.23	21.00	14.30	23.20	8.78
6	7.90	12.00	16.00	14.35	20.90	12.03
7	6.90	11.80	12.60	14.17	15.70	12.30
8	6.40	11.48	10.70	14.01	12.30	12.49
9	5.70	10.95	9.30	13.50	10.30	12.38
10	5.30	10.25	7.70	12.93	8.30	10.35
11	5.00	9.82	6.90	11.40	7.10	9.17
12	4.90	9.49	6.20	10.10	6.30	7.91
13	4.80	9.02	5.70	8.74	5.70	7.13
14	4.60	8.45	5.30	8.17	5.40	6.40
15	4.50	8.17	5.10	7.36	5.20	5.83
16	4.40	7.87	4.90	6.77	5.00	5.24
17	4.40	7.56	4.70	6.16	4.80	4.67
18	4.40	7.38	4.60	5.73	4.70	4.26
19	4.30	7.19	4.50	5.46	4.60	3.69
20	4.30	6.99	4.50	5.16	4.50	3.12
21	4.30	6.73	4.40	4.26	4.50	2.18
22	4.20	6.18	4.40	3.22	4.50	1.08
23	4.20	5.89	4.40	1.87	4.40	0.05
24	4.20	5.75	4.40	0.83	4.40	0.04
25			4.30	0.03		

Mississippi Lake

Mississippi Lake: Inlet

	May 08/2017		July 11/2017		August 29/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	14.00	9.52	26.00	8.61	24.70	8.43
1	13.90	9.55	26.10	8.58	24.50	8.44
2	13.80	9.54	26.00	8.54	24.40	8.37
3	13.70	9.51	25.50	8.19	24.40	8.40
4	13.70	9.47	23.80	5.80	24.40	8.34
5	13.70	9.45	22.20	4.57	23.40	6.26
6	13.70	9.40	20.10	1.99	21.80	3.05
7	13.60	9.40	18.80	0.30		
8			17.20	0.07		

Mississippi Lake: Burnt Island

	May 08/2017		July 11/2017		August 29/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	14.10	10.33	24.30	9.88	24.10	8.95
1	14.00	10.31	24.30	8.02	24.30	8.98
2	13.90	10.30	24.20	7.95	24.00	8.89
3	13.70	10.28	24.20	7.87	24.00	8.98
4	13.60	10.26	24.10	7.84	24.00	8.95
5	13.50	10.21	24.10	7.73	24.00	8.86
6	12.10	10.24	24.00	7.35	24.00	8.85
7	12.70	10.22	23.80	6.43	23.90	8.10
8	12.50	10.19	23.70	6.04		
9	19.20	10.12	23.60	5.77		

Mississippi Lake: Pretties Island

	May 08/2017		July 11/2017		August 29/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	12.90	10.63	25.20	8.06	25.00	9.03
1	12.70	10.66	25.10	8.10	24.50	9.11
2	12.60	10.64	24.90	7.97	24.40	9.07
3	12.50	10.60	24.80	7.92	24.30	8.99
4	12.40	10.55	24.70	7.82	24.30	8.93
5	12.20	10.50	24.60	7.62	24.20	8.24
6	12.10	10.46	24.60	7.60		
7			24.60	7.62		

Mississippi Lake: Outlet

	May 08/2017		July 11/2017		August 29/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	13.60	10.74	25.20	8.83	24.70	9.48
1	13.40	10.74	24.80	9.09	24.60	9.50
2	13.30	10.73			24.50	9.96

Mosque Lake

Mosque Lake: North Basin

	June 7/2017		July 18/2017		August 27/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	17.40	9.92	25.20	8.97	22.80	7.44
1	17.50	9.91	25.30	8.95	22.90	7.43
2	17.50	9.89	25.30	8.91	23.00	7.41
3	17.50	9.85	25.10	8.89	23.00	7.37
4	17.50	9.82	24.50	8.80	23.00	7.35
5	13.60	10.74	21.20	11.18	22.70	7.22
6	11.20	10.70	15.30	13.02	20.40	8.91
7	9.50	10.35	11.90	13.34	15.20	9.25
8	8.40	10.00	9.30	12.90	11.40	9.16
9	7.30	9.15	8.10	12.00	9.70	8.30
10	6.70	8.50	7.00	9.05	8.20	7.19
11	6.40	8.06	6.40	5.94	7.00	3.32
12	6.10	7.53	6.10	5.30	6.30	3.04
13	5.90	7.35	5.90	5.11	5.90	2.97
14	5.70	7.10	5.70	4.64	5.80	2.36
15	5.60	6.90	5.60	4.28	5.70	1.61
16	5.50	6.66			5.60	0.82
17	5.40	6.37			5.50	0.35
18	5.30	5.90			5.40	0.06
19	5.20	4.43				

Mosque Lake: South Basin

	June 7/2017		July 18/2017		August 27/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	17.70	9.79	24.70	8.90	22.70	7.32
1	17.70	9.77	24.80	8.88	22.70	7.31
2	17.70	9.77	24.80	8.85	22.70	7.29
3	17.60	9.74	24.80	8.79	22.70	7.28
4	17.50	9.70	24.70	8.75	22.60	7.22
5	13.60	11.17	21.60	10.81	22.60	7.18
6	10.50	10.87	14.40	13.99	20.20	8.97
7	8.60	10.37	11.10	13.52	14.50	10.24
8	7.70	9.50	9.30	12.59	10.80	8.87
9	7.20	9.01	8.50	11.90	9.10	8.50
10	6.70	8.53	7.60	11.14	7.80	8.14
11	6.00	8.13	6.80	8.71	7.00	6.22
12	5.70	8.03	6.30	7.75	6.30	5.02
13	5.30	7.70	5.80	7.18	5.80	4.39
14	5.00	7.28	5.50	6.23	5.40	4.13
15	4.80	6.89	5.20	6.21	5.10	4.09
16	4.70	6.73	5.00	6.11	4.90	4.10
17	4.50	6.44	4.80	5.79	4.60	4.14
18	4.40	6.25	4.60	5.59	4.40	4.08
19	4.40	6.03	4.50	5.36	4.30	3.73
20	4.40	5.93	4.40	5.00	4.30	3.00
21			4.40	4.71	4.30	2.81
22			4.30	4.33	4.30	2.27
23			4.30	3.78	4.30	1.58
24			4.30	3.32	4.30	0.84
25			4.30	3.54	4.30	0.28
26			4.30	2.77	4.30	0.05
27			4.20	1.70	4.30	0.11
28			4.20	0.81	4.30	0.13
29			4.20	0.24	4.30	0.15
30			4.20	0.04		
31			4.20	0.20		

Mosque Lake: West Basin

	June 7/2017		July 18/2017		August 27/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	17.70	9.82	24.50	9.08	22.80	7.33
1	17.70	9.87	24.80	8.97	22.80	7.32
2	17.70	9.76	24.80	8.92	22.80	7.31
3	17.70	9.76	24.50	9.13	22.80	7.27
4	14.80	13.75	23.80	9.41	22.70	7.17
5	10.30	14.37	18.10	13.32	21.60	7.32
6	8.10	13.80	11.70	14.09	15.10	7.50
7	6.60	9.59	9.10	11.30	10.00	4.40
8	5.50	5.45	7.40	6.12	8.00	0.20
9	5.20	2.25	6.20	1.70	6.60	0.04
10	4.90	0.95	5.50	0.47	6.00	0.02
11	4.80	0.18	5.40	0.18	5.50	0.05
12	4.70	0.10	5.30	0.03	5.30	0.07
13	4.60	0.18	5.20	0.04	5.10	0.09
14	4.60	0.22	5.00	0.12	5.00	0.10
15	4.50	0.23	4.80	0.16	4.90	0.11
16	4.50	0.25	4.70	0.20	4.80	0.12
17	4.50	0.28				

Pine Lake

Main Basin

	May 14/2017		July 10/2017		Sept 5/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	13.80	12.10	25.10	8.75	24.20	8.75
1	13.50	12.20	25.00	8.73	24.00	8.80
2	12.40	12.43	24.80	8.75	23.70	8.83
3	11.40	12.53	24.70	8.72	23.40	8.70
4	10.60	12.31	24.50	8.72	23.30	8.62
5	10.10	12.13	21.00	9.12	22.90	8.44
6	9.30	11.76	14.50	8.73	20.60	7.54
7	8.20	11.41	11.30	9.07	13.70	7.55
8	7.70	11.25	9.30	9.57	10.70	7.33
9	7.40	11.12	8.30	9.51	9.10	9.33
10	7.20	11.00	7.90	11.17	8.10	7.08
11	7.00	10.81	7.50	8.65	7.70	4.55
12	6.90	10.68	7.20	6.71	7.30	2.92
13	6.70	10.58	7.00	5.50	7.10	1.30
14	6.60	10.33	6.90	4.57	7.00	0.60
15	6.60	10.20	6.80	2.73	6.80	0.25
16	6.50	9.90	6.70	1.29	6.80	0.15

Taylor Lake

Main Basin

	June 6/2017		July 12/2017		Sept 13/2017	
Depth (m)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)	Temp (°C)	D.O. (mg/L)
0.1	18.70	8.98	25.50	10.72	21.20	9.09
1	18.70	8.94	25.20	10.77	19.50	9.29
2	18.60	8.82			19.20	9.34
3	18.60	7.2				