2019 KAHSHE AND BASS LAKE STEWARD REPORT

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ABSTRACT

The findings of all environmental water quality monitoring for both Kahshe and Bass Lakes in 2019 have been summarized and compared to acceptable water quality and aquatic health benchmarks for over 40 different chemical and physical parameters. Historical trends in water quality over more than 35 years also have been presented and discussed. As in 2018, the report has focused on nutrient loading and climate-related factors associated with the potential for harmful algal bloom development. Know The Lake – Help Protect The Lake

KAHSHE LAKE RATEPAYERS' ASSOCIATION - MAY 2020

2019 KAHSHE AND BASS LAKE STEWARD REPORT

TABLE OF CONTENTS

Executive Summary

2019 Kahshe and Bass Lake Steward Report

A comprehensive review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes has now been completed and presented in annual Lake Steward Reports from 2012 through 2019. These documents as well as Executive Summaries are posted on the new **Lake Health** tab of the KLRA web-site: https://kahshelake.ca/Water-Quality. This report summarizes the findings from sampling and analysis of both Kahshe and Bass Lakes in 2019. The sampling programs include those of two agencies: The District Municipality of Muskoka (DMM) and the Ontario Ministry of Environment, Conservation and Parks (MOECP). In the latter, the Lake Stewards of Ontario carry out the water sampling and clarity measurements and the MOEC analyzes the samples and coordinates the data reporting.

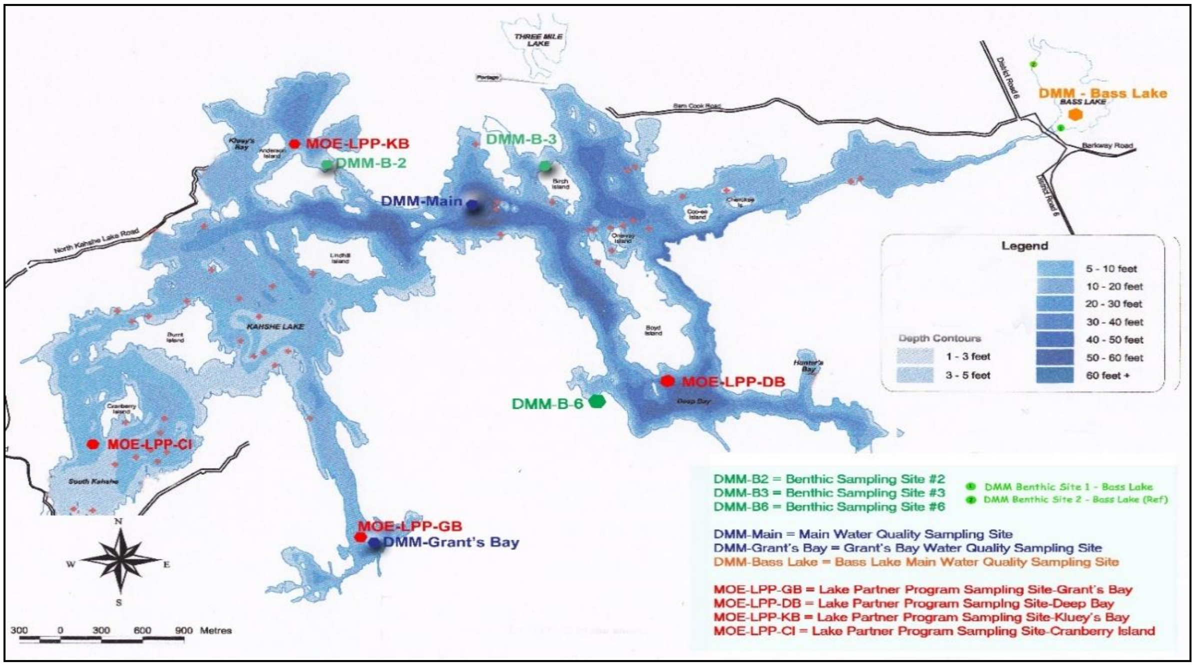
As in 2018, this report has been structured to address the following issues/areas of potential concern for both lakes with emphasis on the development of harmful algal blooms.

- Nutrients, Water Clarity, Temperature and Algal Growth
- Calcium Depletion
- Lake Acidification
- Metals and Other Chemicals
- Dissolved Oxygen
- Benthic Health (not undertaken in 2019)

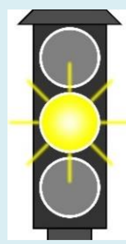
Before any discussion of the above main areas of interest, it's important to understand how climatic factors in 2019 compared with other years, as it is now well documented that we live in a time of changing climate conditions and these atmospheric changes can impact several water quality findings.

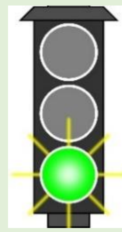
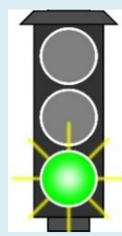
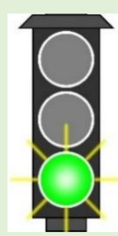
The information on weather and water/ice conditions confirmed that 2019 was generally similar to the 30 year climatic normals, with the only pronounced variation being a much wetter April and warmer and dryer July. As the noticeably lower levels of precipitation in July coincided with slightly above normal temperatures, this likely contributed to the warmer lake water experienced towards the end of July and early August. Ice-out on Kahshe occurred around April 26, which was a few days earlier than in 2018. Ice-out records for Deep Bay also have been recorded dating back to 1987, and this record shows no clear trend towards an earlier or later ice-out.

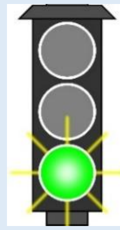
The map below shows the locations of all sampling sites for both DMM and MOECP (abbreviated to MOE) sampling programs, while the summary table that follows provides brief information on each of the six issues.

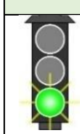


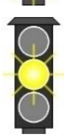
Summary of 2019 Findings for Kahshe and Bass Lakes

Issue	Why It's Important	Level of Concern*	Comments
Nutrients, Water Clarity, Temperature and Algal Growth	❑ Total P and Nitrogen are indicators of water quality degradation and increase the potential for algal blooms. ❑ The other factor associated with algal blooms is increasing water temperature ❑ The DMM's total P benchmark is set to preserve water quality via a background approach. ❑ Natural tea colour of water complicates the relationship between water clarity and water quality findings.	 Kahshe & Bass	❑ 2019 results for Kahshe Lake show total P levels below Threshold and Background. ❑ In Bass Lake, the 2019 sampling results also were well below the existing Threshold level and marginally below the Background level. ❑ No upward or downward trend in total phosphorus in either lake has been detected in almost 40 years of monitoring. ❑ In the case of nitrogen, the levels are in a normal range and no trend has been detected in either lake. ❑ As in 2018, water temperature in the upper layers of both lakes was higher than in previous years and reflected a warmer air temperature that was documented. ❑ To date, there has been no confirmed evidence of a harmful blue-green algal bloom in either Kahshe or Bass Lakes. However, because of the documented presence of this type of algal bloom in several nearby Muskoka lakes in both 2018 and 2019, and the fact that in

Issue	Why It's Important	Level of Concern*	Comments
			several cases, their total phosphorus levels were lower than those in Kahshe and Bass Lakes, we must remain vigilant about maintaining or reducing nutrient loading. This may help us avoid an algal bloom as we experience warmer water associated with climate change.
Calcium Depletion	❑ Calcium is naturally occurring in soils and rocks and is essential component of aquatic food chain. ❑ There was enhanced leaching from soil to lakes due to acid rain impacts in 1970s & 80s. ❑ Many Muskoka lakes show a decline in calcium and are now at lower end of the growth limiting threshold for some aquatic species.	 Kahshe & Bass	❑ Not a shoreline development or concern regarding algal blooms. ❑ No upward or downward trend over almost 15 years has been detected. ❑ Calcium in Kahshe and Bass Lake is currently above the growth limiting threshold for some sensitive zooplankton species (which is good), but the margin of safety is small, so we need to keep monitoring.
Lake Acidification (pH)	❑ In mid to late 1900s, sulphur and other acid gasses from the Sudbury basin plus transboundary air flows from the U.S. acidified many lakes. ❑ Most lakes in Muskoka have recovered following emission controls.	 Kahshe & Bass	❑ The Ontario objective is to keep pH of lake water between 6.5 and 8.5. ❑ Kahshe and Bass Lakes are currently at the lower end of the optimum pH range (6.5) and generally above the level of 6.0 where impacts to sensitive aquatic species might be encountered. ❑ No upward or downward trend over almost 15 years has been detected. ❑ However, both lakes have a low buffering capacity - are less able to neutralize acid inputs than lakes with a higher buffering capacity - so we need to continue monitoring.
All Other Chemicals	❑ DMM samples and analyzes Kahshe and Bass Lake for over 30 different metals, nutrients and other chemicals. ❑ This report analyzes them relative to chronic toxicity benchmarks and charts them all since monitoring began in early 2000s.	 Kahshe & Bass	❑ All 30 metals and other parameters have been compared to chronic toxicity benchmarks from Ontario, Canada and the U.S. EPA. ❑ Sampling of both lakes in 2019 confirmed that most are well below aquatic thresholds for survival. ❑ A few historical exceedances are likely due to analytical problems early in the program. ❑ For cadmium and silver, the laboratory detection limits need to be improved,

Issue	Why It's Important	Level of Concern*	Comments
			as the non-detect (MDL) levels are close to or higher than the aquatic benchmarks.
Dissolved Oxygen (DO)	❑ Oxygen is essential for all aquatic organisms. ❑ It enters surface water from the air and is transferred down to lower depth waters via spring and fall water turnover. ❑ Levels in the bottom waters deplete during the summer and can become anoxic and impact aquatic survival and also release P from sediments.	Kahshe & Bass 	❑ The PWQO for DO in warm water lakes is 5 mg/L. ❑ The DO levels in mid and lower layers of water in both lakes often drop below the desirable PWQO benchmark. ❑ However, neither Kahshe nor Bass Lake is considered anoxic, and the lower DO levels are limited to late summer and fall and are unlikely to impact aquatic organisms.
Benthic Monitoring	❑ The study of benthic organisms living in the bottom sediment is undertaken as an early warning activity for water quality impairment. ❑ The population of benthic organisms can detect very subtle changes due to alteration in species richness and in the survival or decline of groups of species that respond differently to impaired water quality.		❑ Not evaluated in 2019.

 Green = Normal and Not a Concern

 Amber = Flagged for continued monitoring and caution as margin of safety is low

In conclusion, based on the foregoing summary of the environmental monitoring of Kahshe and Bass Lakes, no major environmental water quality issues have been identified. However, given the documented occurrence of harmful blue-green algae blooms at several lakes in the Muskoka area in 2018 and 2019 and the finding that half of these lakes had nutrient (phosphorus) levels similar to or even lower than those in Kahshe and Bass Lakes, continued vigilance in terms of nutrient loading is imperative as we face the reality of warmer water associated with a changing climate. Each of us can do our part by:

- managing our septic systems properly and having tanks pumped out and inspected regularly;

- avoiding the use of any chemical fertilizers or pesticides for lawns, flowers or cultivated vegetation in areas close to the shore;
- minimizing near-shore removal or management of native species and ensuring that any shoreline disturbance does not result in soil runoff to the lake; and,
- avoiding the use of any cleaners containing phosphorus/phosphates at the cottage and in particular on boats or docks near the water.

While not related to water quality *per se*, desirable lake stewardship also involves:

- taking precautions if moving boats to or from other lakes to avoid introducing invasive aquatic species; and,
- avoiding the planting or re-location of non-native invasive plant species to your lake property.

1.0 Kahshe Lake Stewardship Mandate

As a standing member of the Kahshe Lake Conservation Committee, the roles and responsibilities of the Lake Steward include:

- Educating the residents and other users of Kahshe and Bass Lakes on how to **preserve** and **improve** the quality of both lakes and their shorelines.
- Monitoring the water quality of both lakes and keeping the association members up to date on the results of all analytical and biological monitoring programs.

In accordance with this mandate, a comprehensive review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes has now been completed and presented in annual Lake Steward Reports from 2012 through 2019. These documents as well as Executive Summaries are posted on the new **Lake Health** tab of the KLRA web-site https://kahshelake.ca/Water-Quality. Prior to 2012, a few Lake Steward reports were located in a review of the historical KLRA file retention system. However, this was prior to development of the KLRA web site, and as such, these reports are not currently on-line.

Before moving on to discuss the chemical and biological monitoring since 2012, it is important to discuss another water quality parameter that is **not** being routinely monitored in either lake or at the public beaches by any organization - coliform contamination. If you are drinking water from the lake – **which is strongly not recommended** - and want to ensure that your filtering system is functioning properly, you can submit a sample of water to the Simcoe Muskoka Health Unit for coliform analysis. The contact info is:

- 2-5 Pineridge Gate, Gravenhurst, ON, P1P 1Z3. PHONE: 705-684-9090, FAX: 705-684-9887.

Anyone who suspects that a neighbouring septic system is in need of pumping or improved management can also take a sample from the lake and submit it to the Simcoe Muskoka Health Unit. If this is something you would rather not do, then you should inform the Building Department at the Town of Gravenhurst of your concern and follow-up with them to determine if action is/was/will be undertaken.

Given the importance of and responsibility for maintaining fully functional septic systems and keeping the coliform levels as low as possible, the following information has been extracted from a Good Neighbour Resource Hand book article which was updated in 2014 by the KLRA's Conservation Committee.

Your septic system is a sewage treatment facility that requires careful attention to design, construction, operation and maintenance. **As a property owner, this is your responsibility.** In Ontario, the specifications for construction and maintenance of sewage systems with a flow of less than 10,000 litres per day are regulated under the *Ontario Building Code*, and municipalities are responsible for the inspection and approval of all septic installations. For Kahshe and Bass Lakes, the Building Department of the Town of Gravenhurst is the agency with this responsibility. In addition to permitting the installation of septic systems, the Town operates a septic re-inspection program as follows:

- the re-inspection on Kahshe Lake is carried out every 5 years;
- it consists of a trained student visiting most (but not always all) properties and carrying out a visual

inspection of the tank and bed;

- if the visual inspection finds the tank and bed in good condition, they leave a note to inform the property owner and send a follow-up letter;
- if there are visual signs of failure of the leaching bed, they leave a notice and the Building Department follows up with a letter requiring a pump-out and system inspection with a receipt from a licensed pumper to confirm that it has been carried out;
- if the visual signs point to a serious failure, the Building Department issues a stop order until evidence is provided that the problem has been corrected.

Unfortunately, there is no systematic process for re-inspections based on permits or on re-inspection findings. However, cottage owners are encouraged to report any suspected problems to the Building Department so they can follow up with an inspection of the system.

The KLRA has been asked on a number of occasions to include coliform monitoring as part of the chemical and biological sampling programs carried out by DMM and the Lake Steward. As the Lake Steward, it has and continues to be my position that:

- I am not qualified as a medical or public health volunteer to interpret or advise on the findings from this type of sampling program.
- My understanding is that coliform concentrations are highly variable, which would make any predictive type of notification regarding use of the water for consumption or swimming virtually impossible.
- Given the length of time it would take to collect, submit and receive the results from this type of monitoring program, any potential benefit would be limited, as any detrimental health effects would already have taken place by the time the results were received.

Based on the above, I have no plans to undertake this type of monitoring program going forward; however, if there is interest in this type of program, and someone with the appropriate qualifications is identified or retained by the Board to conduct this type of assessment, I would be pleased to discuss how this could be incorporated into the Lake Steward mandate if the Board of the KLRA wished to proceed in this direction.

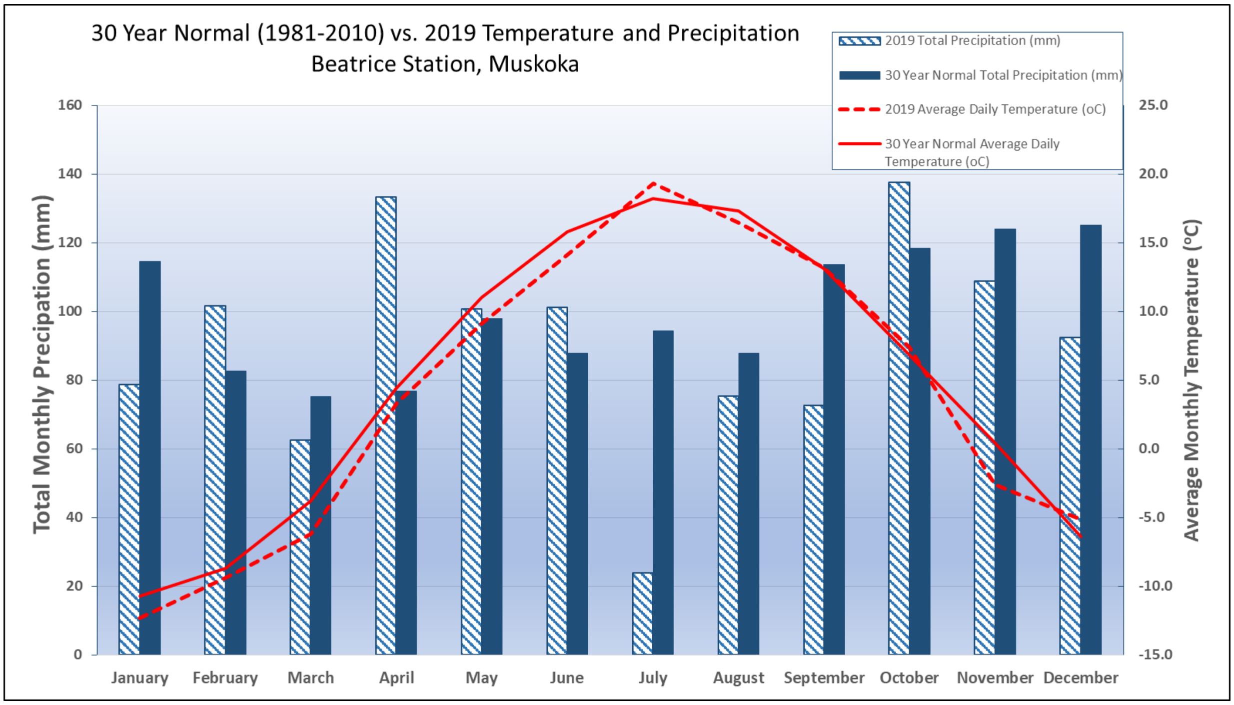
1.0 Overview of Climatic Factors and Water/Ice Conditions

In order to better understand the chemical and physical data that have been collected and their relationship (if any) to weather conditions, this year's report again includes an overview of several climatological factors that have the potential to influence the lake monitoring findings. This attempts to answer the question: How normal were temperature, rainfall and ice-out conditions compared to past years?

Air Temperature and Precipitation

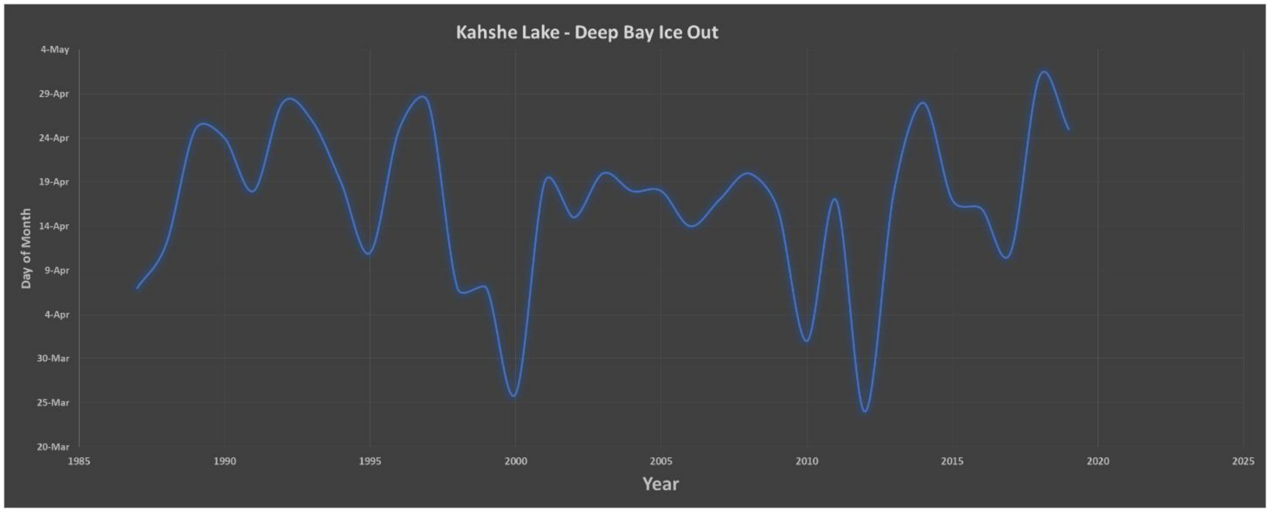
Air temperature and rainfall records from the Beatrice weather monitoring station in 2019 and earlier years were evaluated. The chart below shows the average monthly air temperature and total monthly precipitation (rain + snow) for the entire 2019 year. These results are then compared to the 30 year (1981-2010) normal monthly temperature and precipitation.

This comparison demonstrates that air temperatures in 2019 were generally a few degrees cooler in the spring up to mid-June, slightly higher in July and similar to the normal for the fall. It was also noted that total precipitation data for the spring months of April, and to a lesser extent May and June were well above normal, while those for July, August and September were below normal. In the case of the months with lower than normal precipitation, only July, with a very prominent below normal level of precipitation, coincided with slightly higher than normal air temperatures. As this combination could have elevated surface water temperature, it is discussed in greater detail later in this report.



Ice-Out Times

While there is no DMM or MOECP record for ice-out times on Kahshe or Bass Lakes, the 2016 Lake Steward report did present the findings of a publicly generated data base of ice-out times for Muskoka Lakes (Rosseau and Joseph) dating back 125 years. This information was updated to include 2018 in the 2018 Lake Steward report; however, evidence for ice-out in Muskoka Lakes for 2019 was not located. However, from my own observations, ice-out in the western area of Kahshe Lake (vicinity of Denne's Marina) took place around April 26, a slightly later date than in some previous years. A record of ice-out tracking for Deep Bay has now been identified, thanks to the efforts of Rod Cronin, with back-up assistance from Michael Wayling. This record has been kept annually since 1987, and records ice-out as the date that Deep Bay is navigably free of ice. A plot of this data is shown below, and clearly demonstrates that there has been no trend towards earlier or later ice-out conditions in this part of the lake.



Source: R. Cronin and M. Wayling, 2020.

Climatic Factors and Ice Condition Summary

To better understand the chemical and physical data that have been collected, this year's report includes an overview of the climatological factors that have the potential to influence lake conditions. The information on weather and ice conditions confirmed that 2019 was generally similar to the 30 year climatic normals, with the only pronounced variation being a much wetter April and warmer and dryer July. As the noticeably lower levels of precipitation in July coincided with slightly above normal temperatures, this may have contributed to the warmer lake water experienced towards the end of July and early August. Ice-out on Kahshe occurred around April 26, which was a few days earlier than in 2018 and similar to the recorded ice-out date of May 4 for Muskoka lakes. Ice-out records for Deep Bay also have been recorded dating back to 1987, and this record shows no clear trend in either direction.

2.0 Overview of Environmental Monitoring

Kahshe and Bass Lakes are being monitored for water quality and biological functioning parameters under two main initiatives as outlined below:

Lake Partner Program (LPP) – MOECP – Kahshe Lake Only

This program is operated by the Ontario Ministry of the Environment, Conservation and Parks (MOECP) through the Dorset Environmental Science Centre. Under this program, water sampling and measurement of water clarity on Kahshe Lake is conducted by the Lake Steward every year. The program consists of the following activities:

- **Water clarity measurements**

  Clarity of the water is measured every two weeks during the ice-free period at three locations using a Secchi disc, and these findings are forwarded to the MOECP for compilation and comparison with other lakes in Ontario.

- **Water quality testing**

  Water is sampled from the same three locations on Kahshe Lake in May each year and sent to the MOECP where it is analyzed for total phosphorous and calcium.

Lake System Health Program (DMM) – Kahshe and Bass Lakes

This program is one of several components of a larger Muskoka Water Strategy which is operated by The District Municipality of Muskoka (DMM), with support from the Muskoka Watershed Council (MWC), the MOECP and several other participating agencies.

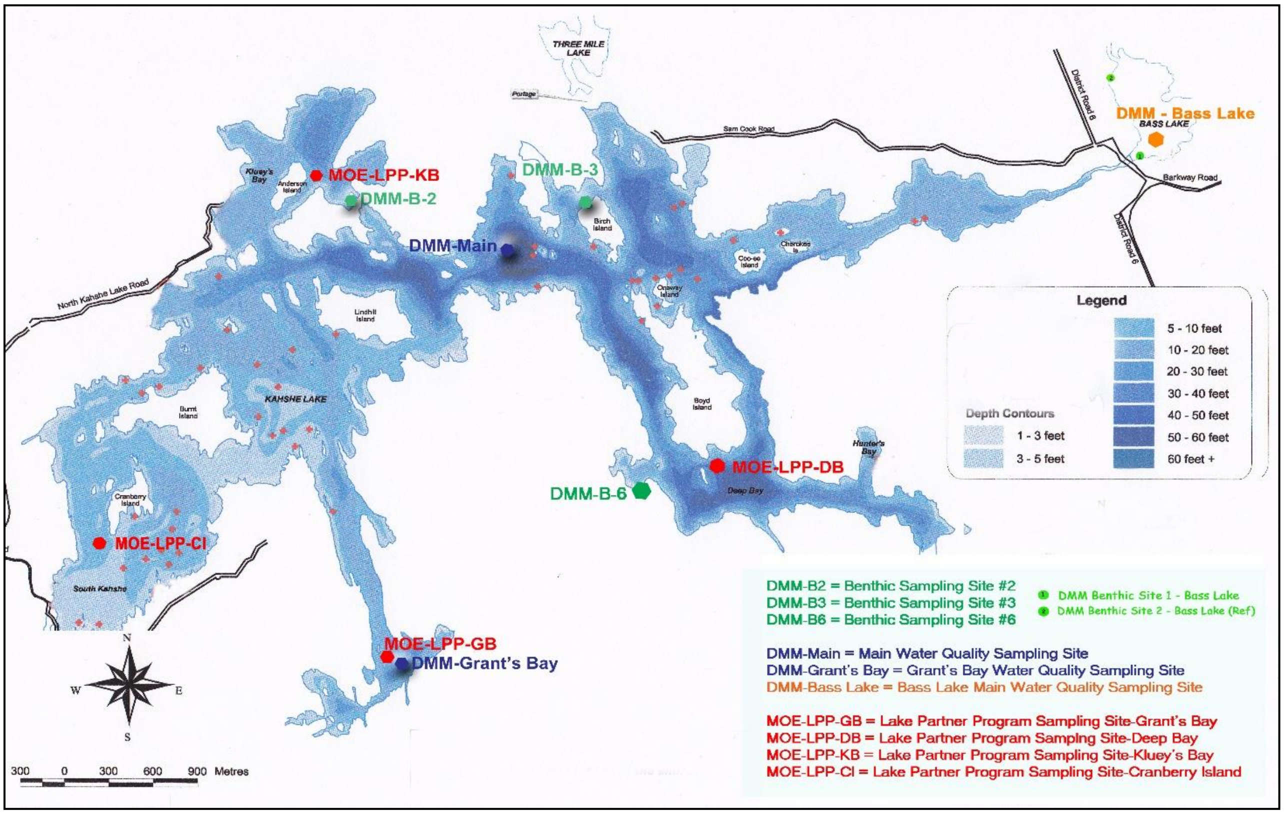
The monitoring program consists of 193 sampling sites on 164 lakes on a rotational basis. The program was designed to deliver a monitoring program which would establish a long-term record of key water quality parameters so that trends in water quality and lake system health could be identified and appropriate management decisions taken to protect lake water quality. For Kahshe and Bass Lakes, the DMM program consists of the following activities which have been conducted every second year for Kahshe Lake and every third year for Bass Lake:

- Water sample collection for total phosphorus and a suite of other physical and chemical parameters in May/June (2 sites in Kahshe Lake and 1 site in Bass Lake);
- Secchi disc depth measurements collected in May/June and August (2 sites in Kahshe Lake and one site in Bass Lake);
- Temperature and dissolved oxygen at increasing water depths taken in May/June and August (2 sites in Kahshe Lake and 1 site in Bass Lake);
- Benthic invertebrate sampling at one of three sites in Kahshe Lake in August each year from 2004 through 2007 and 2011 through 2015 and in Bass Lake in 2016, 2017 and 2018.

Since the DMM program had not been carried out on Kahshe Lake in 2018, sampling was carried out in 2019. Although sampling in 2019 in Bass Lake would not normally have been carried out, it was conducted to further assess water quality, as Bass Lake had been identified as a ‘transitional lake’ as part of the DMM's review of its water quality model in 2016. Benthic assessment was not carried out on either Kahshe or Bass Lake in 2019; however, Figure 1 continues to show the benthic monitoring sites in both lakes to ensure that these locations can be identified if future benthic assessment is conducted.

The locations of water sampling and benthic monitoring on both lakes have been shown on Figure 1 below.

Figure 1: Map Showing 2019 MOECP and DMM Sampling Locations on Kahshe and Bass Lakes



3.0 Results of Monitoring on Kahshe and Bass Lakes

In this report, the results have been presented in several sections to focus on the main parameters of concern to the health of our lakes. Because both the DMM and the MOECP include sampling of some of the same parameters, this report also compares the findings from each agency. The main components of this report will address the following main areas of interest in terms of water quality:

- Nutrients, Water Clarity, Temperature and Algal Growth
- Calcium Depletion
- Lake Acidification
- Metals and Other Chemicals
- Dissolved Oxygen

3.1 Nutrients, Water Clarity, Temperature and Algal Growth

Harmful algal blooms are a global water quality issue and are the result of ongoing nutrient (nitrogen and phosphorus) loading from watersheds (Downing et al., 2001; Elmgren, 2001; Conley et al., 2009; Smith and Schindler, 2009; Brookes and Carey, 2011; and Paerl et al., 2011) and a changing climate, resulting in warmer temperatures and stronger stratification (Jöhnk et al., 2008; Wagner and Adrian, 2011; Carey et al., 2012; and Posch et al., 2012). Adding to the complexity of algal bloom development is the fact that these organisms also can play a role in both nitrogen and phosphorus cycling within the water column through the seasons (U.S. EPA, 2008) and in the fixation of nitrogen from the atmosphere. In these and other roles, micronutrients such as iron, molybdenum and copper also are involved and can affect the development of a bloom.

The most harmful, blue-green algae, are actually cyanobacteria. They are primitive microscopic organisms that have inhabited the earth for over 2 billion years. They are bacteria, but have features in common with algae. Although often blue-green in colour, they can range from olive-green to red. Blue-green algae occur naturally in a wide variety of environments including ponds, rivers, lakes and streams. For more information on these organisms and their impacts on lakes in Ontario and other areas, refer to fact sheets published by the Ontario Environment Ministry (2014) and Municipal Affairs and Environment, Newfoundland and Labrador (2019).

Why are we concerned about the development of blue-green algal blooms? Because blue-green algal blooms can produce toxins that pose a health risk to both humans and animals (Hudnell, 2008). The blooms also negatively affect the appearance and aesthetic qualities of the lake and this is likely to impact property values.

The severity of symptoms and the level of risk to health depend on how you are exposed to blue-green algal toxins. Human health effects from contact with these toxins may include:

- itchy, irritated eyes and skin from direct contact through activities such as swimming and water skiing; and,
- flu-like symptoms, such as headache, fever, diarrhea, abdominal pain, nausea and vomiting if large amounts of impacted water are ingested.

To give a better idea of the potential impact of a blue-green algal bloom, a copy of the Health Unit's 2018 advisory to the property owners on nearby Leonard Lake where a blue-green algal bloom was confirmed in 2018 has been shown below:

- The health unit advises residents and businesses not to drink the water from this lake and to take the following precautions:
- do not use the lake water for drinking or for food preparation including breastmilk substitute (infant formula), even if it is treated or boiled;
- do not cook with the lake water because food may absorb toxins from the water;
- do not allow pets or livestock to drink or swim in the water where an algae bloom is visible; and,
- do not eat the liver, kidneys and other organs of fish caught in the lake and be cautious about eating fish caught in water where blue-green algae blooms occur.

Based on the foregoing discussion, the most obvious question is how can the potential for harmful algal blooms development be minimized? There are essentially two main drivers in the formation of harmful algal blooms - nutrient enrichment and warming waters. The first is within our control while the second is weather related and associated with a changing climate. In the case of nutrient enrichment, the main causal factors in algal growth are phosphorus and nitrogen. For lakes like ours, which have no immediate inputs from industrial, municipal or agricultural operations, nitrogen and phosphorus enters primarily in these ways:

- septic system effluents
- lawn and garden fertilization
- land-clearing/disturbance and soil runoff to the water
- atmospheric inputs (mainly nitrogen via rainfall and dust)
- aquatic and semi-aquatic wildlife activity, and
- re-suspension of minerals from rock/sediments as part of phosphorus and nitrogen cycling.

Those sources that are within our control are highlighted in yellow above.

The main focus of water quality monitoring in Muskoka and Ontario by both the DMM and the LPP has been to track the quality of the water in terms of its total phosphorus levels. This in turn has served as a driver of shoreline management and property development strategies. However, emerging research shows that nitrogen is more involved in harmful algal growth than originally thought (Great Lakes Commission, 2017).

While nutrient enrichment is important, it is not the only factor involved in the promotion of harmful algal growth. Blue-green algae thrive in areas where the water is shallow, slow moving and warm, but they may also be present in deeper, cooler water. Accordingly, this section has been structured to examine the three main causal factors (excluding light which is essential for photosynthesis) in the development of harmful algal growth: **phosphorus, nitrogen and water temperature**.

The analysis in this section also includes water clarity, as although it’s more a symptom of nutrient enrichment and degraded water quality than a fundamental driver of algal growth, it can provide an early warning for lake water conditions that are susceptible to algal growth.

Phosphorus

In the 1960s and 70s, many North American rivers and lakes were experiencing rapid declines in water quality. Industrial and municipal effluents were stimulating the growth of algae and other aquatic plants (termed ‘eutrophication’) leading to unsightly mats of green sludge, oxygen depletion, massive die-offs of fish and other aquatic life, and problems with the taste and odour of municipal drinking water.

The public, industry, and all levels of government agreed that something had to be done. However, there was disagreement over the most effective course of regulatory action because at the time, scientists and policymakers were still debating which nutrients were most responsible for eutrophication.

In the late 1960s and early 70s, David Schindler, a Canadian limnologist oversaw a number of whole-lake experiments designed to determine which nutrient (out of nitrogen and phosphorus) was primarily responsible for eutrophication. His studies clearly demonstrated that phosphorus was the main contributor.

As a result of that work and other studies, the main focus of the lake monitoring programs in Ontario has been on measuring total phosphorus concentrations and linking the findings to management strategies. In Muskoka, the DMM evaluates the responsiveness of lakes in Muskoka to input and mobility of phosphorus as it enters the lake from human and natural sources. As demonstrated in previous reports, both Kahshe and Bass Lakes are considered moderate in terms of their sensitivity to phosphorus. This sensitivity rating also factors into the setting of a total phosphorus threshold for lakes in Muskoka based on limiting the elevation of total phosphorous above a pre-determined background value. This threshold value is set equal to the pre-determined background concentration plus an additional 50%. For example, the pre-determined background concentration of total phosphorus in Kahshe Lake is 9.5 µg/L. This results in a threshold concentration of 14.2 µg/L (i.e. [50% of 9.5] + 9.5 = 14.2). The background concentration in Bass Lake was determined to be 20.6 µg/L, resulting in a calculated threshold level of 30.9 µg/L.

If the lake's measured and modelled phosphorus concentrations over a 10-year period are greater than its threshold value, then the lake is considered "over threshold" and actions may be initiated to reduce the amount of phosphorus entering the lake from its watershed. As noted in last year's report, neither Kahshe nor Bass Lakes have 10-year averages greater than threshold. However, the DMM has now completed their review of the water quality model that has been used to set threshold levels. In a 2016 letter to property owners of lakes affected by this review, the DMM state:

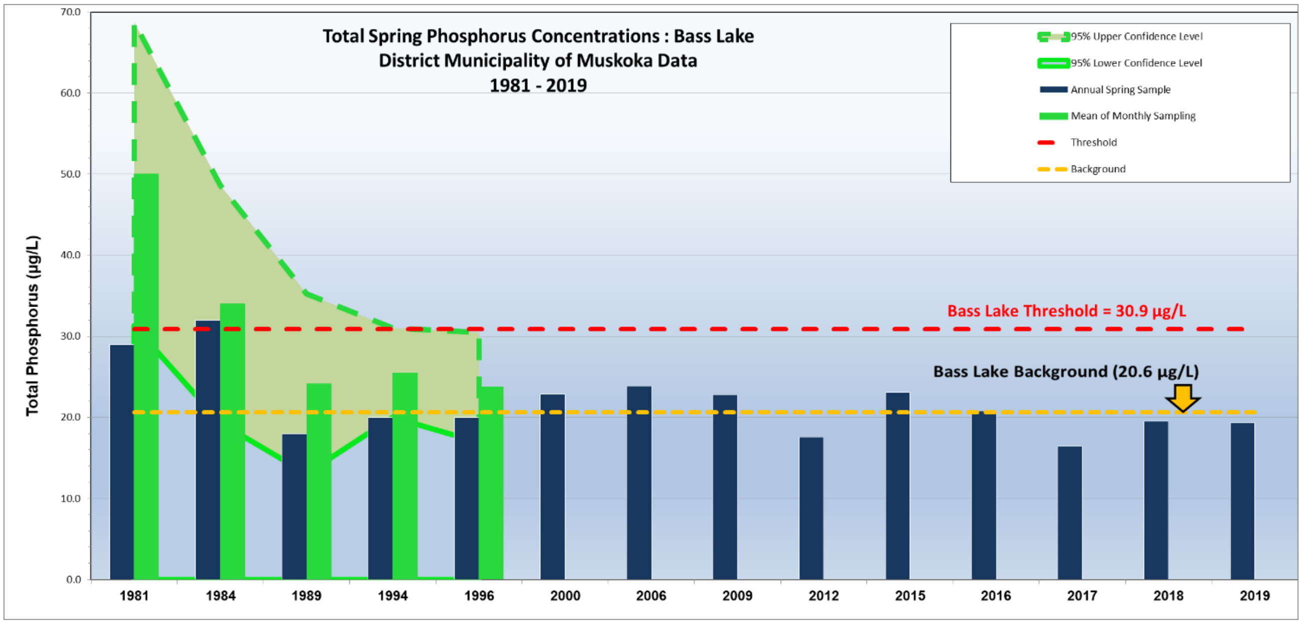
"The results of the review suggest the need for an updated approach governing development or redevelopment on lakes which reflects scientific advances in the last decade, in recognition that the existing model was too narrowly focused and had some limitations when used to evaluate an individual lake. While any change to planning policy would require an official plan amendment and significant public consultation, the policy direction suggested by the results of the Water Quality Model review recognizes that all lakes should be afforded a high degree of protection through implementation of a set of "Standard" Best Management Practices (BMPs) for all new development or redevelopment of shoreline lots. In addition, the science tells us that certain lakes have been flagged as requiring additional study and potentially a higher level of protection. These "transitional" lakes are identified on the basis of one or more of three "management flags":

- *Total Phosphorus concentrations greater than 20 micrograms/litre,*
- *A rising trend in Total Phosphorus; and/ or*
- *Documented occurrence of a blue-green algal bloom.*

Bass Lake and six other lakes across the District (including Ada (ML), Barron's (GB), Brandy (ML), Bruce (ML), Stewart (ML/GB) and Three Mile (ML) Lakes) are currently affected by these management flags."

Bass Lake was flagged only because it met one of the three conditions, that being a total phosphorus concentration greater than 20 µg/L. Because of that, the DMM undertook additional sampling of Bass Lake in 2016 even though sampling wasn't due to be carried out until 2018. The special sampling of Bass Lake continued in 2017, 2018 and 2019.

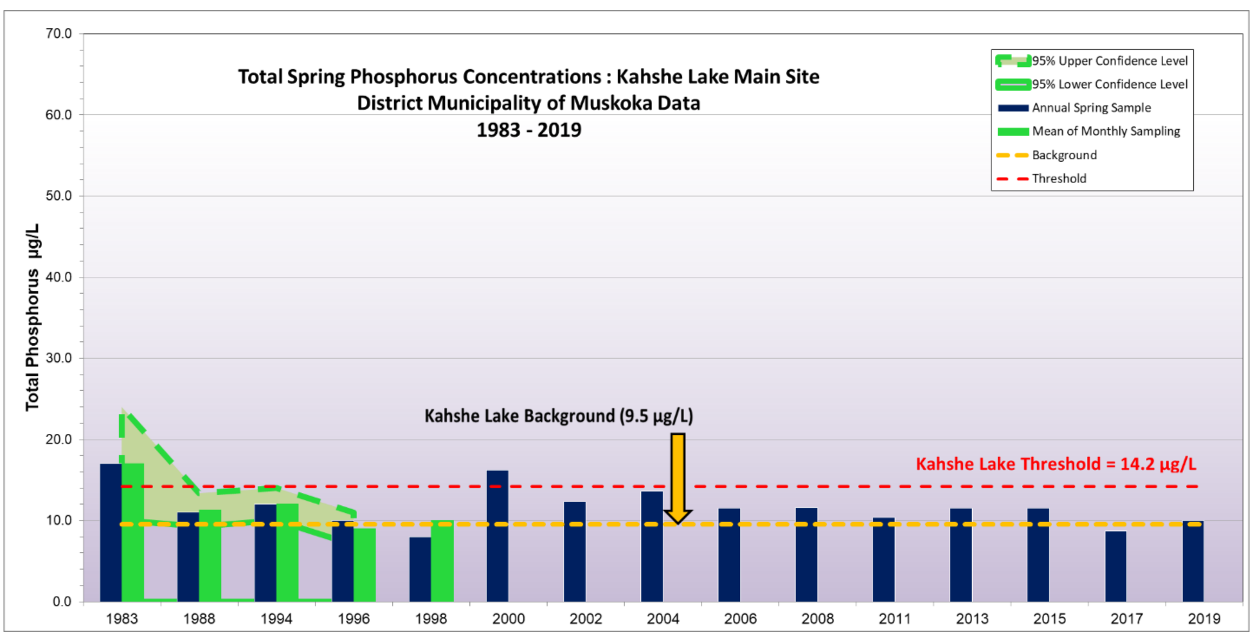
The Bass Lake total spring phosphorus results for 2019 as well as those of the past 37 years are shown below:



These findings can summarized as follows:

- There has been no detectable trend in total phosphorus concentrations over the past 37 years.
- The total phosphorus level in 2019 of 19.3 µg/L was well below the DMM's existing Threshold Level, marginally below both the Background Level and below the concentration of 20 µg/L that triggered the special 'Transitional Lake' status by DMM in 2016.

The 2019 total spring phosphorus concentrations as well as the results for the previous 35 years for Kahshe Lake are shown below. Note that for comparison purposes, the same concentration scale has been used.

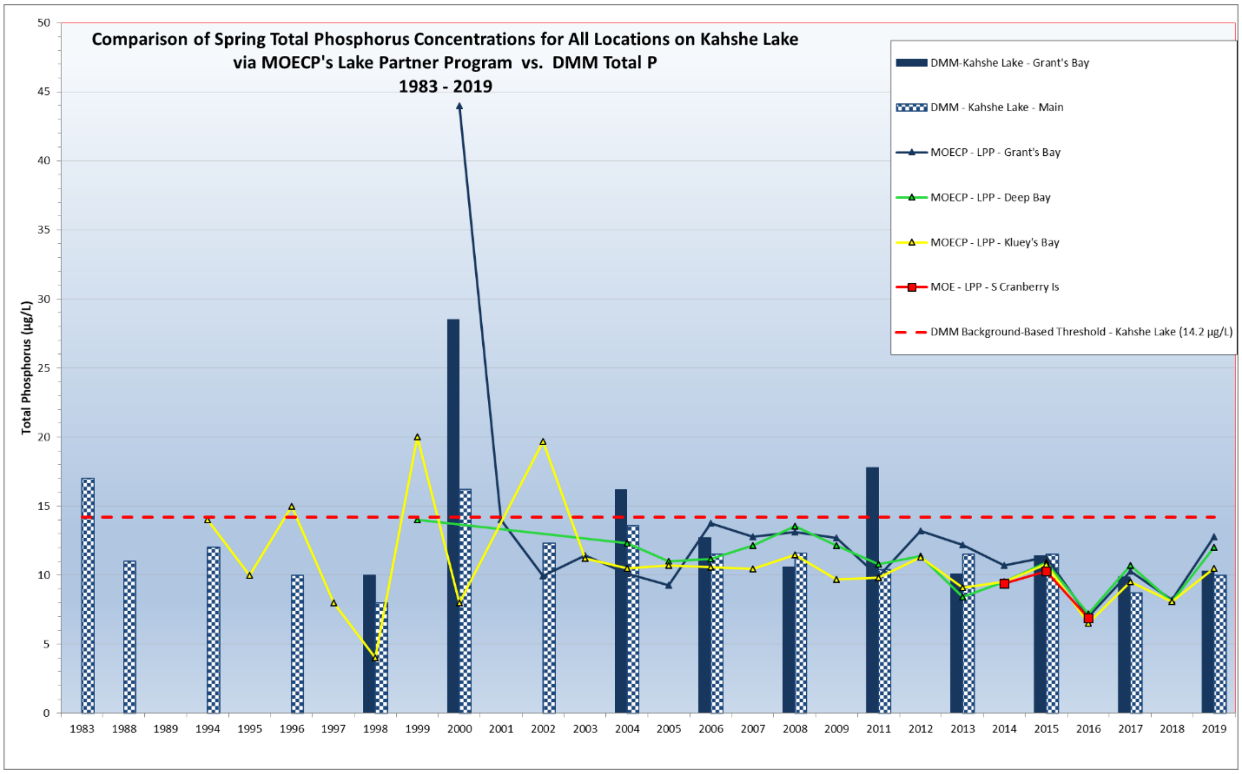


These findings can summarized as follows:

- There has been no detectable trend in total phosphorus concentrations over the past 36 years.

- The total phosphorus level in 2019 of 10.0 µg/L (Main Site) was well below the DMM's existing Threshold and Background Levels. The concentration in Grant's Bay (10.3 µg/L) was similar and also below Background and Threshold Levels.

As noted above, Kahshe Lake also was sampled and analyzed for total spring phosphorus under the Lake Partner Program (LPP). The chart below shows the total phosphorus levels at the three LPP sampling sites in Kahshe Lake for 2019. The historical findings dating back to 1994 for the LPP program and to 1983 for the DMM results also are presented for trend analysis.



This comparison confirms that:

- The 2019 results demonstrate a continued low level of total phosphorus (12.8, 12.0 and 10.5 µg/L) which is below both the Threshold value of 14.2 µg/L and only marginally above the pre-established background concentration of 9.5 µg/L.
- Sampling of the three different areas of Kahshe Lake under the LPP has yielded similar results to those from the DMM sampling program for as long as the sampling by both agencies has been conducted.
- There has been no detectable upward or downward trend in total phosphorus concentrations over the past 35 years.

Nitrogen

In a recently published document (Great Lakes Commission, 2017) on the role of nitrogen in the formation of harmful algal blooms, the current knowledge was summarized and is further discussed below. While this work was focussed on algal blooms in Lake Erie, the findings appear applicable to smaller freshwater bodies such as Kahshe and Bass Lakes.

Based on their work, nitrogen dynamics in aquatic systems was found to play a role in understanding both algal biomass trends (i.e. the size/extent of bloom development) and potential toxicity. For example, nitrogen additions can increase both biomass and toxin production in algal blooms, but at different rates depending on the form of nitrogen. (Harke et al., 2016).

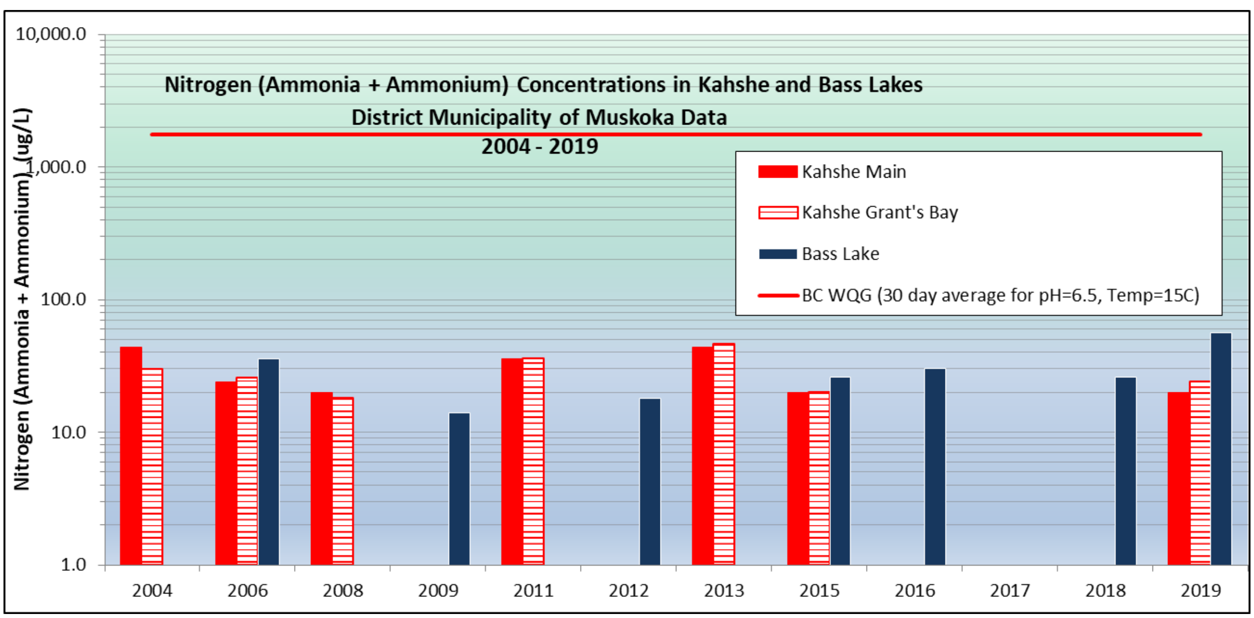
In water, nitrogen occurs in several different dissolved forms. These forms influence communities of algae and cyanobacteria in different ways, based largely on their abilities to convert the different nitrogen forms into biomass and compete with other organisms. Regardless of the form, cyanobacteria must convert nitrogen to ammonium (NH_4^+) within the cell before they can use it for biomass or toxin production. Ammonium is also the easiest nitrogen form for primary producers to acquire and transport into the cell. Nitrate and nitrite (NO_3^- /NO_2^-) must be actively transported into the cell and then converted to ammonium, which, in turn, requires energy and micronutrients, such as iron. The differences in nitrogen bioavailability for algal growth are summarized in decreasing below:

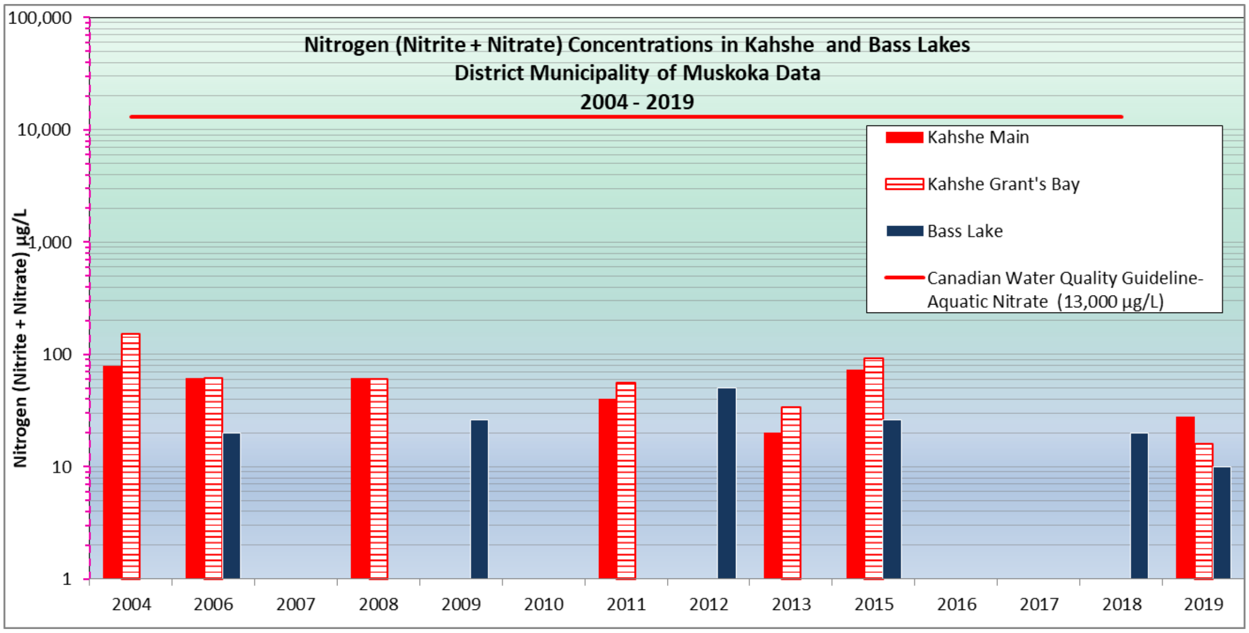
Ammonium	Urea	Nitrite	Nitrate	Atmospheric Nitrogen
Most Bioavailable →				Least Bioavailable

(adapted from Harke et al. 2016 as presented in Great Lakes Commission, 2017)

As noted earlier, the primary sources of nitrogen to inland lakes like ours would be from septic system discharge and soil erosion and leachate migration from fertilized lawns/gardens. Residue from bird and aquatic animal feces, plant decay (leaves, aquatic weeds) and to a lesser extent from atmospheric deposition also contribute.

The nitrogen monitoring results for the two forms of nitrogen that are analyzed by DMM have been charted below. The DMM also report Total Kjeldahl Nitrogen, but no reference to how this form of nitrogen plays a role in algal growth has been found.





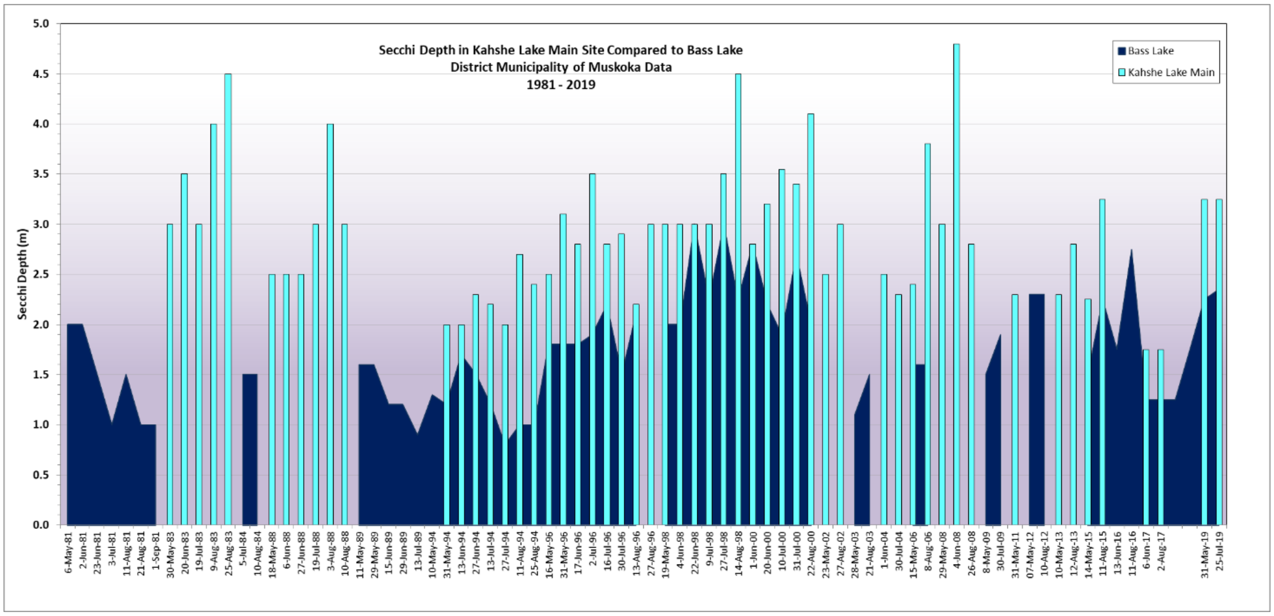
The results of this analysis have been summarized below.

- No evidence of a concentration trend in either of the two analyzed forms of nitrogen has been detected in Bass or Kahshe Lakes over the years dating back to 2004.
- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive species.
- No algal growth benchmarks for either form of nitrogen have been located, as the linkage between phosphorus, nitrogen and water temperature is too complex to set individual nutrient benchmarks.

Water Clarity

While the linkage between total phosphorus concentrations and water clarity are typically weak in tea coloured waters where clarity also is impacted by dissolved organic carbon (DOC), both sampling programs have monitored clarity via the Secchi disc method for as long as we have data on total phosphorus.

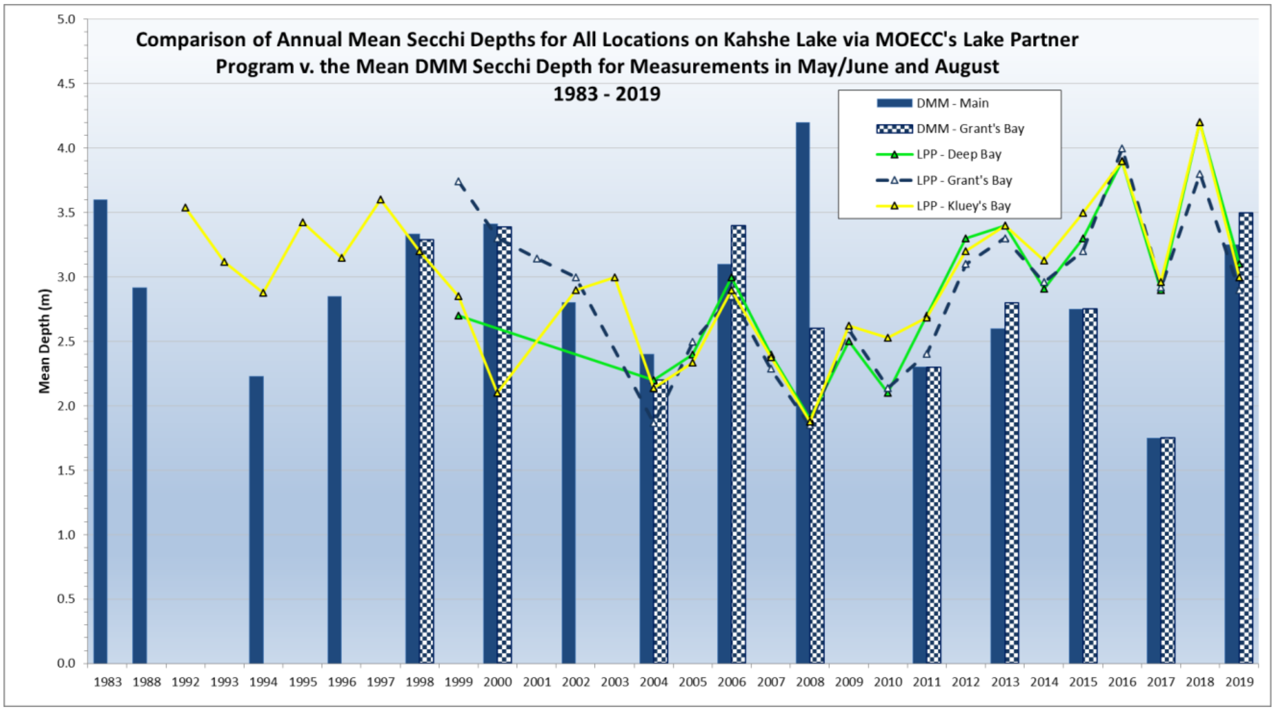
The DMM’s 2019 water clarity levels for both lakes have been compared with the historical results dating back to 1980s in the chart that follows.



In this comparison, Bass Lake is represented by the dark blue columns while the Secchi disc data from the Main Site on Kahshe Lake are shown via the light blue columns. The findings from this comparison are summarized below:

- Water clarity in Bass Lake in 2019 was slightly better than in 2018, but generally similar to historical measurements dating back to 1981.
- Water clarity in Kahshe Lake in 2019 was slightly better than in 2017 but generally similar to historical measurements dating back to 1983.
- Water clarity is noticeably better in Kahshe Lake than in Bass Lake, most likely due to the more tea coloured nature of Bass Lake - as confirmed by slightly higher Dissolved Organic Carbon [DOC] levels in Bass Lake vs. Kahshe Lake.

To further explore the clarity in Kahshe Lake, the Lake Partner data for water clarity at the three sampling sites in Kahshe Lake also were evaluated and compared to the Secchi disc measurements taken by the DMM in 2019 and earlier. The findings are shown below.



As noted in the previous 2018 Lake Steward Report, water clarity in Kahshe Lake was noticeably lower in 2017 based on the DMM measurements. However, water clarity in Kahshe Lake as measured under the Lake Partner Program (bi-monthly by the Lake Steward) was noted to be better than the results from DMM commencing in 2013 and continuing through 2017. The findings for 2019 confirm an upward trend in water clarity, and in 2019, the clarity as measured by DMM was slightly better than the corresponding clarity measurements taken under the LPP.

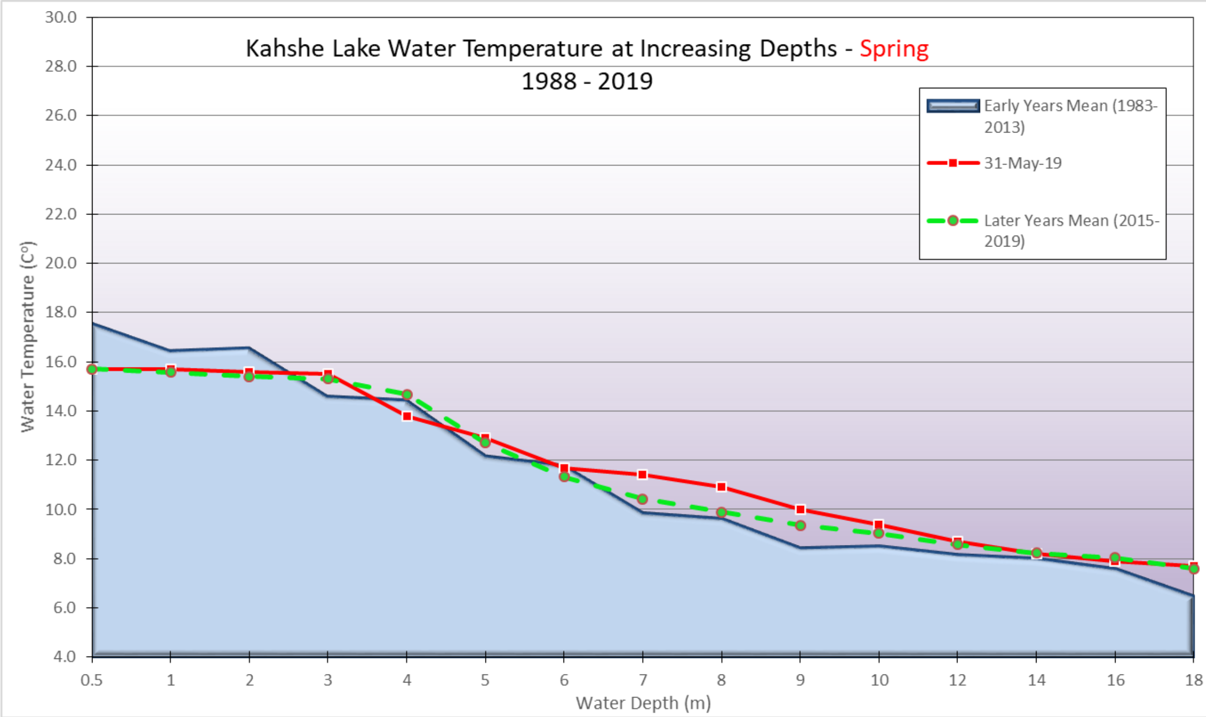
Water Temperature

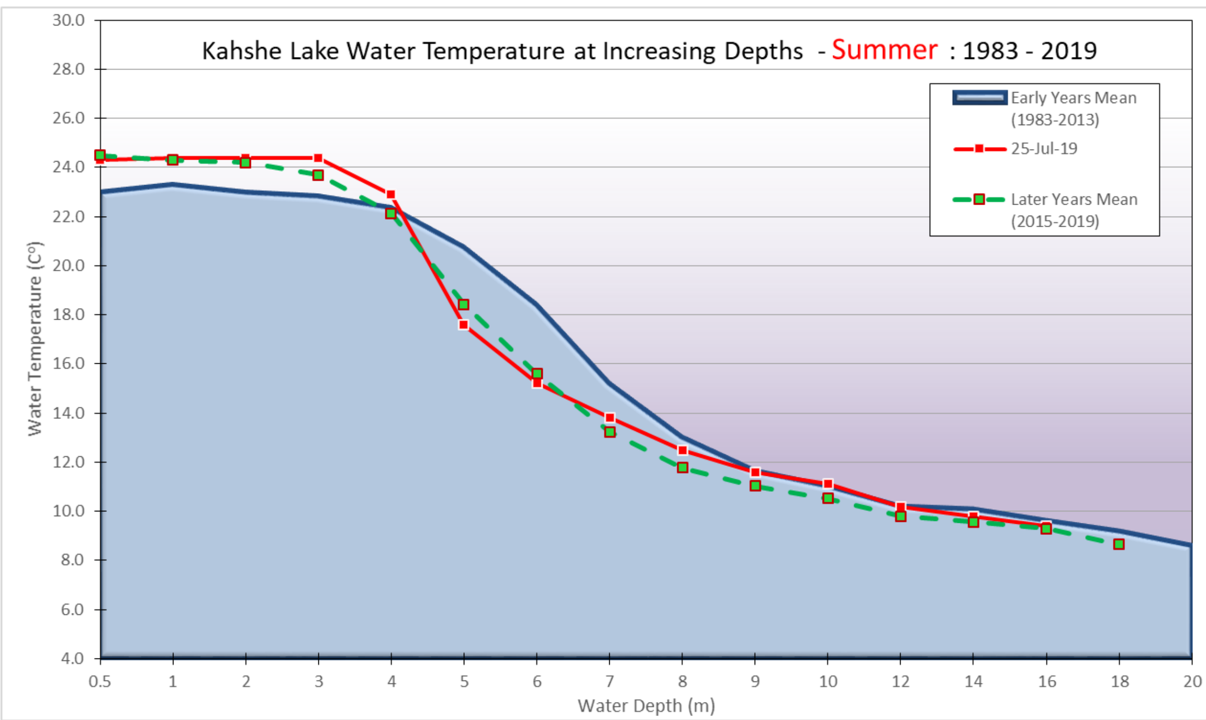
Another parameter that is involved in algal bloom development is water temperature, as warm water increases the rate of photosynthesis and promotes algal growth. Water temperature is important for several other reasons:

- It affects the solubility of oxygen in water.
- It affects the metabolic rates, life cycles and the sensitivity of all aquatic organisms to parasites and disease.
- It factors into the classification of a lake as a cold or warm water body (both Kahshe and Bass are considered warm water lakes – i.e. not a Lake Trout Lake).

The DMM water temperature readings at increasing depths in both Kahshe and Bass Lake data dating back to 1988 have been plotted in the four charts below. In an attempt to explore any trends in water temperature, the 2019 results have been compared with historical means grouped over two time periods:

- The early years (1983-2013)
- The later years (2015-2019)

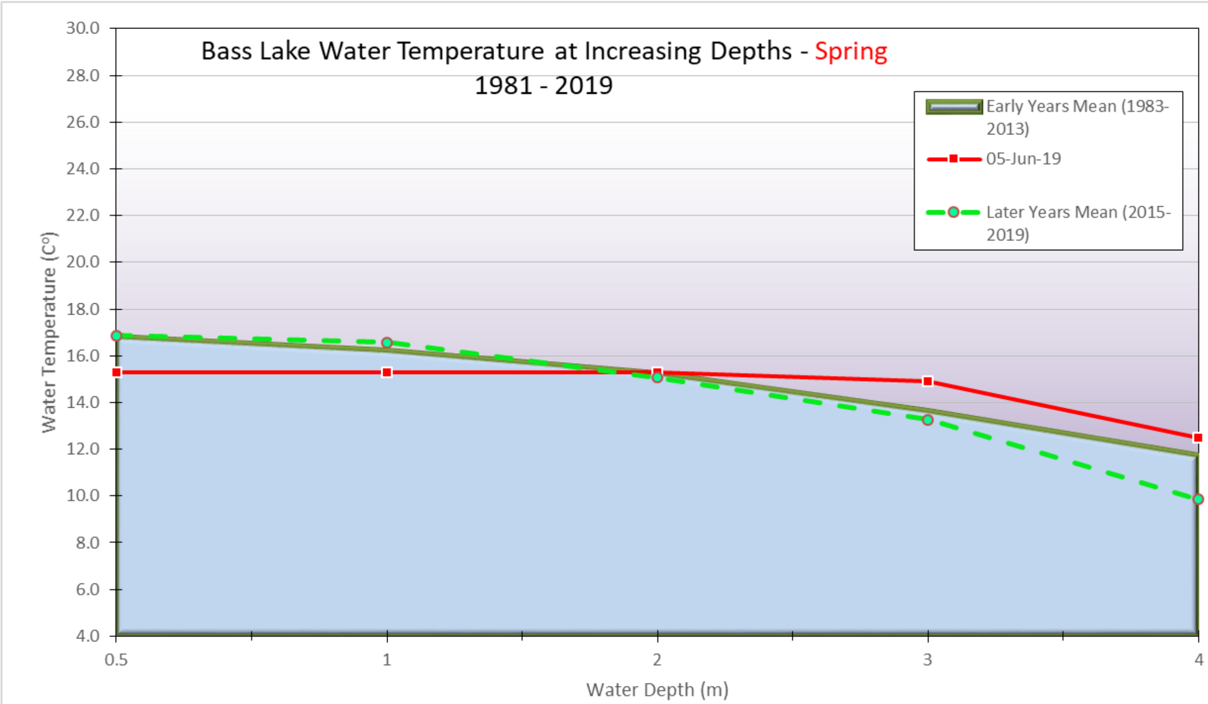


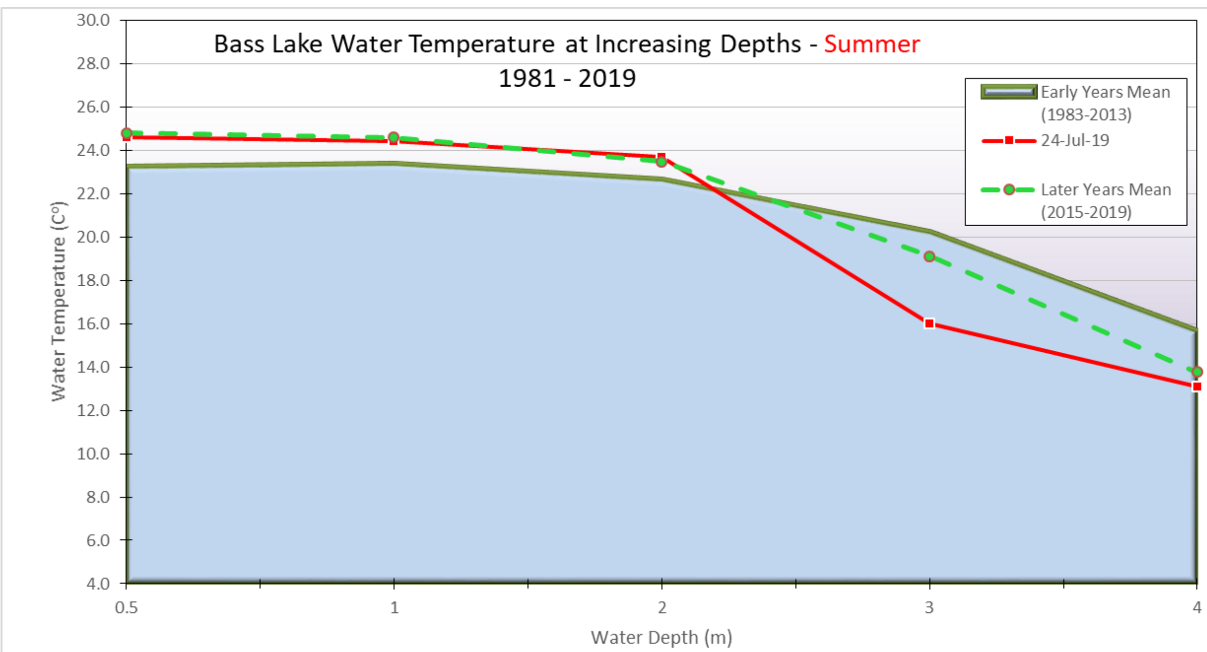


It is apparent from the above two charts that:

- Water temperature in the spring of 2019 in Kahshe Lake was a little cooler than in the early years within the top 2m and similar to the later year means at all depths.
- However, by August 2019, the temperature in the top 3-4m was well above the early years mean, similar to the later years mean and below the early years mean from depths of 4-9m.

The water temperature findings for Bass Lake in both Spring and Summer are presented below:





It is apparent from the above two charts for Bass Lake that:

- Water temperature in the spring of 2019 in Bass Lake was similar to both the Early Years and Later Years mean at all depths; and,
- By August 2019, the temperature in the top 2m was slightly above the Early Years mean, and below both the Early and Later year means at depths greater than 2m.

In summary, at appears that in both lakes, the spring temperatures are essentially similar to historical findings, while the summer measurements are showing a possible warming trend for the surface layers and a trend towards a slight cooling of the deeper layers. While the results from a single lake would not have the power to detect statistically significant water temperature changes over these relatively short time periods, increasing temperatures in the range of 1-2°C have been reported using the larger database of all Muskoka lakes (Palmer, 2012).

Algal Growth

As noted in the 2018 report, a small algal bloom was observed at the east end of Kahshe Lake in November 2017 and the MOECP was notified. However, the bloom disappeared very quickly and by the time the Ministry had been notified and an investigation organized, the bloom was no longer present. As such, it was not possible to determine if it was a blue-green algal bloom. No algal blooms were reported in 2018, but there was a localized algal mass reported by an Oak Road cottager in 2019; however, the MOECP investigated and reported that while blue-green algae were present, the mass was not an algal bloom. The MOECP findings as reported to the property owner on Oak Road are shown below:

Small amounts of the following types of algae were observed in the sample, at levels considered too low to contribute to a bloom:

· blue-green algae (specifically Anabaena (aka Dolichospermum))

· diatoms (specifically Synedra, Tabellaria)

· green algae (specifically Staurastrum, unidentified filamentous green algae)

Observations included particles that were not identified as algae: debris, pine pollen.

Based on the foregoing, there has been no documented blue-green algal blooms on either Kahshe or Bass Lakes to date. However, as noted in a recent Krier article, we must remain vigilant in our efforts to minimize nutrient loading to both lakes, as blue-green algal blooms have been documented by the MOECP and investigated by the Simcoe Muskoka District Health Unit in several neighbouring lakes in both 2018 and 2019.

The table below shows the affected lakes and their status with respect to health concerns.

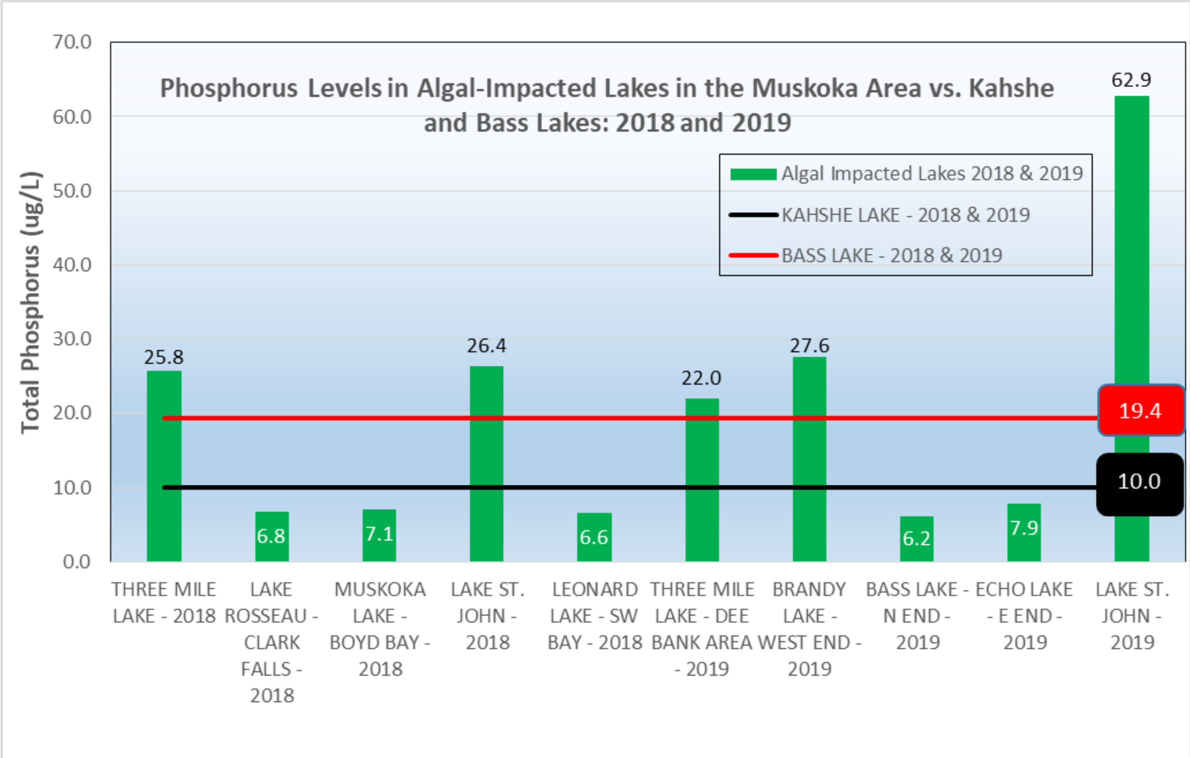
Table 1: List of Blue-Green Algae Impacted Lakes in the Neighbouring Muskoka Area-2018 and 2019

Affected Waterway	Municipality	Date Public Notice Issued	Status
2018			
Three Mile Lake	Muskoka Lakes	July 31, 2018	Lifted June 6, 2019
Lake Rosseau – Clark Falls area	Muskoka Lakes	August 17, 2018	Lifted June 6, 2019
Lake Rosseau - Boyd Bay area	Muskoka Lakes	August 21, 2018	Lifted June 6, 2019

Affected Waterway	Municipality	Date Public Notice Issued	Status
Lake St. John	Ramara	August 31, 2018	Lifted June 6, 2019
Leonard Lake - South West Bay	Muskoka Lakes	September 4, 2018	Lifted June 6, 2019
Lamont Creek	Clearview	September 20, 2018	Lifted June 6, 2019
2019			
Three Mile Lake – Dee Bank area	Muskoka Lakes	August 27, 2019	Lifted December 12, 2019
Brandy Lake – West end	Muskoka Lakes	September 12, 2019	Lifted December 12, 2019
Bass Lake – Northern end	Muskoka Lakes	October 24, 2019	Lifted November 26, 2019
Echo Lake – East end	Lake of Bays	October 11, 2019	Lifted December 12, 2019
Lake St. John	Ramara	October 18, 2019	Lifted December 4, 2019
Lake St. George – South end	Severn	September 9, 2019	Lifted December 4, 2019
MacLean Lake - South end of Geri Bay	Severn	September 26, 2019	Lifted December 4, 2019
MacLean Lake – North end		October 11, 2019	Lifted December 4, 2019

To further explore the relevance of these harmful algal blooms in lakes in the Muskoka and surrounding areas, the MOECP's 2018 and 2019 LPP total phosphorus data for each of the above algal-impacted lakes were examined and compared to the phosphorus levels in Kahshe and Bass Lakes over the same time period. In cases where there was no LPP data, the total phosphorus levels from the DMM investigations were used. Of the 13 impacted lakes, total phosphorus levels for 10 were found. While it must be noted that the phosphorus levels for the above water bodies in 2018 and 2019 may not accurately reflect the water concentrations at the specific location or time each bloom was detected, they do provide a general picture of the concentrations that were documented in the impacted lakes. In the case of larger lakes, with multiple sampling locations, the sites located closest to the general area where the algal bloom was detected were utilized.

The total phosphorus levels in the 10 lakes with data are shown in tabular format in Attachment 1 and the findings have been plotted in the chart below.



As is apparent from the above chart, three of the impacted lakes (Three Mile, St. John and Brandy Lakes) had very high total phosphorus levels, so the presence of an algal bloom in these lakes could not be considered a surprising result. However, five of the impacted lakes (Rosseau, Muskoka, Leonard, Bass and Echo) had total phosphorus levels well below those of both Kahshe and Bass Lakes.

These findings give cause for concern, as this trend towards increasing numbers of harmful algal blooms throughout Muskoka does not appear to be directly associated with increasing levels of nutrient loading and is more likely being driven by warming waters.

As we have no control over climatic impacts, we need to focus on maintaining the lowest possible total phosphorus and nitrogen concentrations, as the threat of a harmful blue-green algal bloom is real and would have devastating impacts on the recreational use of the water for swimming, fishing and consumption.

We can do this by:

- pumping out and having our septic systems (tanks/leaching beds) inspected on a regular basis;
- managing our shorelines to keep them as natural and as vegetated as possible, and;
- avoiding the use of phosphorus or nitrogen fertilizers on any existing lawns, gardens or flower beds in the vicinity of the shoreline.

Will this give us 100% protection from the onset of a blue-green algal bloom? Unfortunately, no; but it will help to minimize the risk.

Nutrients, Water Clarity, Temperature and Algal Growth Summary

The main reason for the total phosphorus, nitrogen, water clarity and temperature monitoring that is conducted by both the DMM and the MOECP is to provide an early warning for both undesirable nutrient enrichment and the potential for harmful algal blooms.

Phosphorus has long been identified as the main concern in terms of water quality and shoreline management due to its major role in algal growth and bloom development. However, more recently, nitrogen also has been identified as a key factor in algal bloom development and it too enters the lake from sources similar to those for phosphorus.

A summary of the findings for the three major input variables and for water clarity that have been evaluated is presented below:

Phosphorus

- In both lakes, there has been no detectable upward or downward trend in total phosphorus concentrations over the past 37 years.
- The total phosphorus data from both the DMM and LPP show some variability, but in general, the findings are similar across the years that samples have been taken.
- Total phosphorus concentrations are almost twice as high in Bass Lake than in Kahshe Lake, but well below the DMM’s existing Threshold Level and at or below the expected Background concentration.

Based on these findings, our efforts to minimize septic leaching bed discharges and to manage our shorelines to reduce disturbance and erosion as well as minimizing fertilizer use on lawns and gardens close to the lake appear to be holding total phosphorus levels stable over the past three decades.

Nitrogen

While recognition of the role of nitrogen in nutrient enrichment and algal growth has not been a focus for as long as phosphorus, there is a growing focus on this nutrient now based on a strong weight of published evidence for its role in promoting algal growth. In water, nitrogen occurs in several different dissolved forms. These forms influence communities of algae and cyanobacteria in different ways, based largely on their abilities to convert the different nitrogen forms into biomass and compete with other organisms. Ammonium is the easiest nitrogen form for primary producers to acquire and transport into the cell. Nitrate and nitrite (NO_3^- /NO_2^-) must be actively transported into the cell and then converted to ammonium, which, in turn, requires energy and micronutrients, such as iron. For these reasons, the monitoring has focussed on the two main forms of nitrogen (Ammonia + Ammonium) and (Nitrite + Nitrate). The 2019 findings are summarized below:

- No evidence of a concentration trend in either form of nitrogen has been detected in Bass or Kahshe Lakes over the years dating back to 2004.
- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive species.
- No algal growth benchmarks for either form of nitrogen have been developed, as the linkage between phosphorus, nitrogen and water temperature is simply too complex to set individual benchmarks.

Based on these findings, as for phosphorus, our efforts to minimize septic leaching bed discharges and to manage our shorelines to reduce disturbance and erosion as well as minimizing fertilizer use on lawns and gardens close to the lake appear to be holding nitrogen levels stable over the period dating back to 2004. Unlike total phosphorus, levels of both forms of nitrogen are similar in Bass and Kahshe Lakes.

Water Temperature

While nutrient enrichment is important, it is not the only factor involved in the promotion of harmful algal growth. Blue-green algae thrive in areas where the water is shallow, slow moving and warm. Water temperature is also important for other reasons, including:

- It affects the solubility of oxygen in water.
- It affects the metabolic rates, life cycles and the sensitivity of all aquatic organisms to parasites and disease.
- It factors into the classification of a lake as a cold or warm water body (both Kahshe and Bass are considered warm water lakes)

In both Kahshe and Bass Lake, water temperature in the spring of 2019 was similar to the historical (1983-2018) averages. However, by August, the temperature in the surface layers of both lakes was well above the historical mean from the early years (1983-2013). This warming of surface layers appears to be consistent with above normal air temperature findings for July of 2019, and in line with the findings published by Palmer (2012) who demonstrated a statistically significant water temperature increase using the full Muskoka lake database.

Water Clarity

As noted earlier, water clarity is not a driving variable in algal growth but rather a symptom of nutrient loading and eutrophication. In both Bass and Kahshe Lakes, this is more complicated as the linkage between water clarity and nutrient loading with phosphorus is masked by the tea coloured waters associated with dissolved organic carbon (DOC). However, notwithstanding these limitations, both sampling programs have monitored clarity via the Secchi disc method for as long as we have data on total phosphorus. The 2019 results are summarized below:

- Water clarity in both Kahshe and Bass Lakes in 2019 was slightly better than in 2017/2018 but generally similar to historical measurements dating back to 1983.
- Water clarity is noticeably better in Kahshe Lake than in Bass Lake, most likely due to the more tea coloured nature of Bass Lake - as confirmed by slightly higher Dissolved Organic Carbon [DOC] levels in Bass Lake vs. Kahshe Lake.

Algal Growth

To date, there have been no documented cases of a blue-green algal bloom in either Kahshe or Bass Lakes. However, the potential for an algal bloom, and in particular, a blue-green algal bloom is real, as blue-green blooms were confirmed on several Muskoka lakes and neighbouring water bodies in both 2018 and 2019. The nearby lakes with documented blue-green algal blooms and associated public health notices from the Simcoe/Muskoka Health Unit in 2019 included:

- Three Mile Lake
- Brandy Lake
- Bass Lake (south of Lake Joseph)

- Echo Lake
- Lake St. John
- Lake St. George
- MacLean Lake

To assess the relevance of these findings to our own lakes, total phosphorus levels in algal-impacted neighbouring lakes in 2018 and 2019 were compared with the corresponding phosphorus levels in Kahshe and Bass Lakes. The main finding from this comparison was that out of 10 impacted lakes with available total phosphorus levels, five had levels well below those found in Kahshe and Bass Lakes. Obviously, this is of concern, as although it is well established that total phosphorus is a driver of algal bloom development, other factors such as nitrogen and water temperature are involved. As we have no control over water temperature, we must remain vigilant about maintaining the lowest total phosphorus and nitrogen concentrations, as the threat of a blue-green algal bloom is real and would have devastating impacts on the recreational use of the water for swimming, fishing and consumption.

We can do this by:

- pumping out and having our septic systems (tanks/leaching beds) inspected on a regular basis;
- managing our shorelines to keep them as natural and as vegetated as possible, and;
- avoiding the use of phosphorus or nitrogen fertilizers on any existing lawns, gardens or flower beds in the vicinity of the shoreline.

As the likelihood of a blue-green algal bloom is exacerbated by increasing lake water temperatures, it is critical that we act responsibly as noted above. Will this give us 100% protection from the onset of a blue-green algal bloom? Unfortunately, no; but it will help to minimize the risk.

3.2 Calcium Depletion

Another chemical of potential concern to the health of our lake is calcium. In this case, the concern is not related to shoreline development, but arises from a Muskoka trend towards decreasing levels of calcium which has been documented in a recent Canada Water Network Research Program in the Muskoka watershed. Why is calcium so important?

Calcium is a nutrient that is required by all living organisms, including very small organisms called zooplankton (e.g. *Daphnia*) that live in the waters of Muskoka lakes and are a key component of the food chain for other aquatic and terrestrial organisms higher up the food chain. The reproduction of these organisms as well as others like mollusks, clams, amphipods and crayfish have been shown to be adversely affected by low levels of calcium in lake waters.

Based on data from over 700 lakes in Ontario, about 35% currently have calcium levels below 1.5 mg/L, which is considered a limiting threshold for the survival of species like *Daphnia*. Other species require more than 1.5 mg/L while others can tolerate levels as low as 0.5 mg/L. One of the implications of reduced calcium is a lowering of biodiversity. Dr. N. Yan explained how this can happen using calcium as an example in response to a Toronto Star article in 2014. He elaborated on a study designed to highlight a fairly fundamental shift from crusty to jelly-clad species as dominants in the plankton, as we move from a higher calcium, phosphorus world in our lakes to a lower calcium, lower phosphorus world.

This has resulted in *Holopedium* taking dominance over *Daphnia*, as it needs 20 times less calcium, and two times less phosphorus than *Daphnia*. It also survives attacks from invertebrate predators better and was already widespread in our lakes. The point of the paper was that it has become more dominant over the last 20-30 years at the expense of its more calcium-needy competitors.

There are a few possible ecological concerns of the change. Yan explained:

1) We are losing biodiversity here, as several species of *Daphnia* are losing out to only one *Holopedium* species;
2) The nutritional value of the large animal plankton is reduced, as *Holopedium* has a much lower mineral content than *Daphnia*. The implications of this should be explored, but are not yet known; and,
3) There may well be less food passed up the food chain to fish in our small lakes where invertebrate predators are actually key steps between plankton and fish, because *Holopedium* is pretty well protected from most invertebrate predators by its jelly coat. When it is eaten, it has lower mineral content.

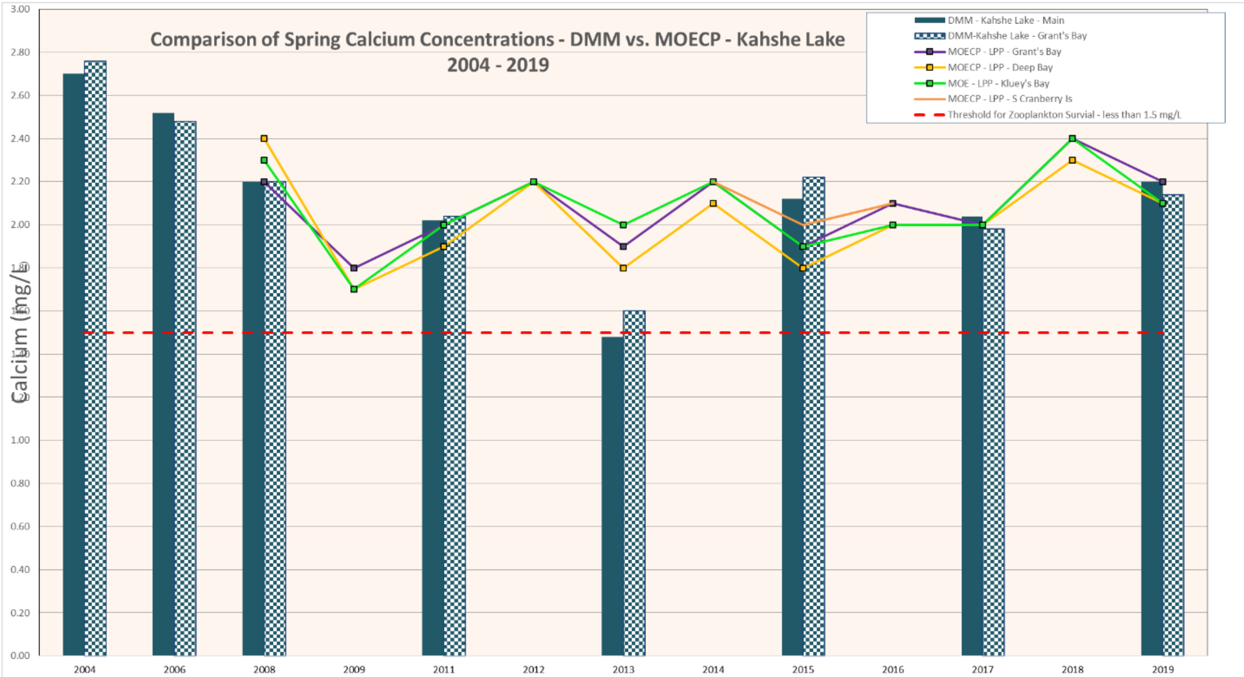
In our Muskoka lakes, the absolute abundance of *Holopedium* has increased by an average of about two fold over the last 20 years, and the relative abundance has increased more, said Yan, while the abundance of five species of *Daphnia* has declined. There are two other, smaller species of *Daphnia* that need less calcium than their congeners, and they are still doing well, but this won't last if calcium continues to fall, he said.

Still, jellification doesn't mean the end to fish in our lakes. The thing to understand, said Yan, is that "the sky is not falling, but it's not quite the same sky as it once was." No doubt ongoing research and monitoring is critical to the health of our lakes. The upside to the attention raised by The Toronto Star's article this week, said Yan is that it highlights how "research in Muskoka is alerting the world to intriguing and fundamental changes that accompany human interventions in the natural world."

Studies have shown that the gradual reduction in calcium levels in watershed soils and the water of lakes and rivers is associated with acidic rainfall, forest harvesting and climate change. In the early days, very acidic rain leached the calcium from soils faster than it could be regenerated via natural weathering of underlying rocks and this resulted in increased levels in the water of some lakes. However, as acid deposition rates were reduced, less calcium is now being leached from watershed soils into lakes, resulting in lower calcium concentrations that are threatening the health of aquatic species. Forest harvesting also has played a role, as the removal of timber and subsequent re-growth of forests following timber harvesting has further diminished the supply of calcium in soils that is available for leaching to lakes. Finally, climate change is also playing a role, as it has in some areas, resulted in decreased water flow within the watershed, resulting in less calcium being exported from watersheds to lakes.

Fortunately, the DMM water sampling program has included calcium since 2004, while the MOECP have been analyzing Kahshe Lake water for calcium since 2008. The chart that follows plots the calcium data for Kahshe Lake by the two sampling programs (DMM and LPP) over this time period. It also shows the 1.5 mg/L threshold for the survival of sensitive species such as *Daphnia*.

As the findings for Bass Lake (2.76 mg/L in 2019) also were above the lower limit of 1.5 mg/L, and show no upward or downward trend since sampling by the DMM began in 2004, they have not been separately charted below, but are presented in a separate chart in Attachment 2.



Based on this information, it can be concluded that:

- Calcium concentrations in both Kahshe and Bass Lakes are above the lower limit that has been set to protect some sensitive zooplankton species.
- Although we don't have an extensive history of calcium monitoring results, the data we do have show no obvious signs of increasing or decreasing concentrations.

Calcium Depletion Summary

Decreasing lake water calcium concentration is an emerging concern for lakes on the Precambrian Shield in Ontario due to its impact on the reproduction and survival of zooplankton and other aquatic species that are important components of the aquatic food chain.

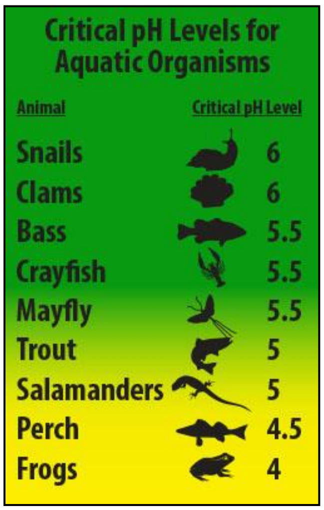
Levels of calcium below the growth limiting threshold range of 1.5 mg/L have not been identified in the sampling of Kahshe or Bass Lakes. However, as the calcium concentrations in both lakes are only marginally above the limiting value and as this threshold would not be protective of all aquatic organisms, continued vigilance is necessary.

3.3 Lake Acidification

Water acidity is measured on a unitless scale referred to as pH. The pH of water is a measure of the hydrogen ion concentration expressed on a scale of 0 to 14, with a pH of 7 being neutral, values below 7 being acidic and above 7 being alkaline. As the hydrogen ion concentration is measured on a logarithmic scale, the change in pH of 1 unit (i.e. from 7.0 to 6.0) represents a 10-fold increase in acidity. Distilled water is considered to be neither acidic nor alkaline, and has a pH of 7.0. However, even in the absence of any man-made acidic gases, the natural levels of carbon dioxide in the atmosphere will react with water to generate carbonic acid, and this will cause rain to have a natural pH of about 5.6.

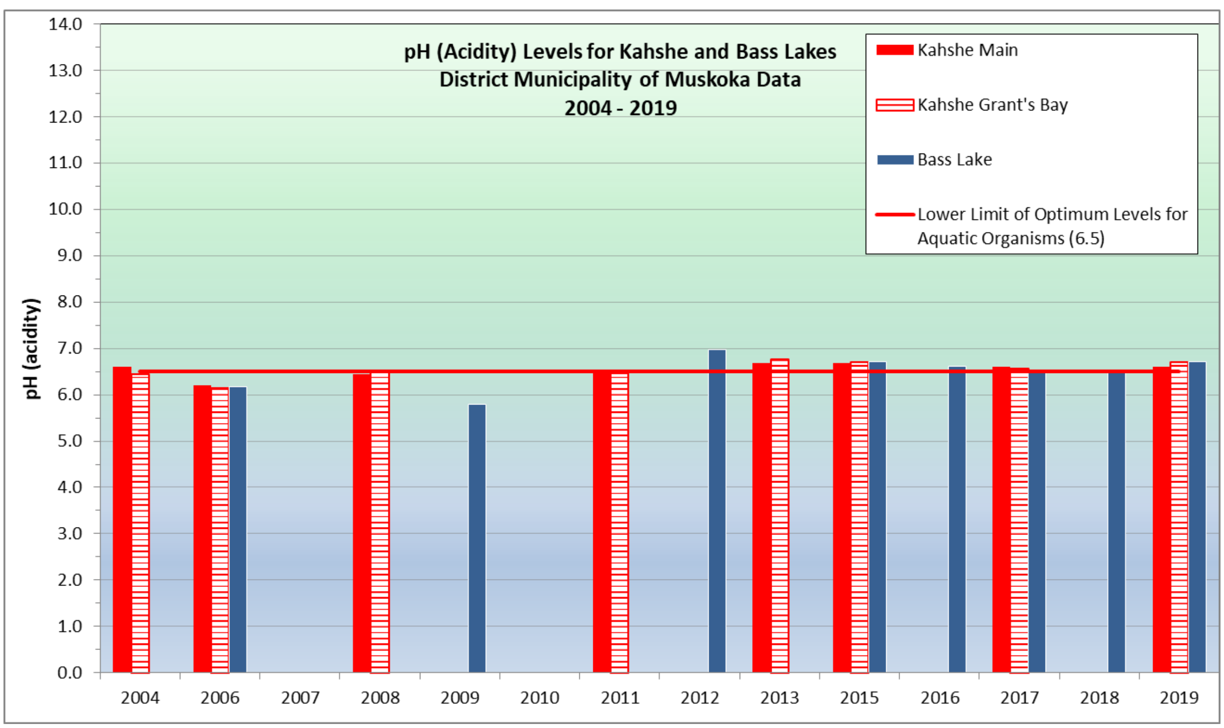
Although source-oriented acid gasses and particulates have contributed significantly to the acidification of lakes in Ontario, particularly around major sulphur sources in the Sudbury basin, there has been noticeable recovery over the last two decades as emission controls were implemented. The ingress of acidic gasses and particulates of nitrogen and sulphur from transboundary air flows into southern Ontario also have been reduced.

The Provincial water quality objective is to keep pH between 6.5 and 8.5, as values above or below those levels can be harmful to some aquatic organisms.



In the green-shaded figure to the left, the pH level at which key organisms may be lost as their environment becomes more acidic has been shown (EPA. 2017; Effects of Acidification on Ecosystems). Some types of plants and animals are able to tolerate acidic waters and moderate amounts of aluminum. Others, however, are acid-sensitive and will be lost as the pH becomes more acidic. Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die. Some acidic lakes have no fish. Even if a species of fish or animal can tolerate moderately acidic water, the animals or plants it eats might not. For example, frogs have a critical pH around 4, but the mayflies they eat are more sensitive and may not survive pH below 5.5.

The chart below shows the pH values for Kahshe and Bass Lakes from 2004 through 2019.



It is apparent from this chart that the pH of Kahshe and Bass Lakes is:

- At or slightly above the lower end of the optimum pH range of 6.5-8.5, which is a good.
- Above the level of 6.0 where impacts to some sensitive aquatic species might be encountered (see EPA species sensitivity picture above), which also is good news.
- Not showing any evidence of either an increase or decrease in acidity over the 13 year period of monitoring.

While the pH findings represents good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification, as the ability of the water to buffer (neutralize) incoming acid via precipitation is low.

Lake Acidification Summary

The waters of Kahshe and Bass Lake have acidity (pH) levels that are within a normal range and above the lower limit of the optimum level where aquatic impacts may begin to be shown. There is also no evidence of an increase or decrease in acidity over the 13 year monitoring period.

While the pH findings represent good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification, as the ability of the water to buffer the acid input is low.

As such, while there is currently no concern, continued monitoring of the acidity is warranted.

3.4 Anions, Cations and Other Chemicals

The DMM has analyzed water samples for a much larger suite of chemical parameters than those that are routinely reported in their year-end report and data sheet summaries. This leaves a large number of chemicals that have been analyzed but which have not been specifically evaluated in terms of their potential impacts on aquatic species.

The full suite of chemicals analyzed via the DMM sampling program in 2019 included: chloride, nitrogen (ammonia + ammonium), nitrogen (nitrite+nitrate), total Kjeldahl nitrogen, sulphate, aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, titanium, vanadium, zinc. In addition, the following additional parameters were added to the suite of chemicals in 2012 and repeated annually since then: antimony, arsenic, boron, selenium, silver, thallium and uranium.

As most of these parameters have not been included in the DMM summary table of additional chemical parameters, this report attempts to do this by comparing the results for all years for which data exist to surface water benchmarks that are available from the MOECP or other regulatory agencies. A brief description of the benchmarks which have been used and what they're designed to protect follows:

- For the anions and cations and other parameters included in the DMM dataset, the findings have been compared to currently available aquatic protection values (APVs) used by the Ontario MOECP (MOE, 2011). These values represent the highest concentration of a contaminant in surface water to which an aquatic community can be exposed indefinitely without resulting in an adverse impact.

- In cases where an MOECP APV was not available, a similar format to the one used by the MOECP in protecting surface water from ground water discharges associated with contaminated sites (*O. Reg.*

153/04 as amended) has been followed. This involved first checking for a U.S. EPA chronic ambient water quality criterion (based on a continuous chronic criterion, (U.S. EPA, 2012; U.S. EPA, 1986));

- If neither of these sources had a value, a Canadian Water Quality Guideline (CCME, 2012), a B.C. Ambient Water Quality Criterion (B.C. 2000; B.C. 2001a and b) or a U.S. EPA Tier-II Secondary Chronic Value (Suter II and Tsao, 1996) has been used.

In all cases, the surface water protection provided via these benchmarks is for long term exposure to concentrations that are considered chronic, as opposed to short-term protection against acute effects.

The charts for all chemicals along with their respective water quality benchmarks have been attached as Attachment 2 and a summary of the findings has been presented in Table 3 below.

Table 3: Summary of Chemical Analysis Results – Kahshe and Bass Lake – 2019

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
Anions	Chloride	MOECP APV	All reported values well below aquatic benchmark and chloride concentrations in Bass Lake are slightly higher than those in Kahshe. Note that the chart uses a logarithmic scale.
	Nitrogen (Ammonia + Ammonium)	BC Water Quality Guideline	All reported values well below aquatic benchmark and concentrations in Bass Lake are slightly higher than those in Kahshe. Note that the chart uses a logarithmic scale.
	Nitrogen (Nitrite + Nitrate)	Canadian Water Quality Guideline	All reported values well below aquatic benchmark and concentrations in Kahshe are slightly higher than those in Bass. Note that the chart uses a logarithmic scale.
	Nitrogen (total Kjeldahl)	None Found	Concentrations in Bass Lake are noticeably higher in Bass Lake than those in Kahshe.
	Sulphate	BC WQC	All reported values well below benchmark
Cations	Aluminum	Interim Canadian WQG	All reported values for Kahshe Lake well below the WQG. Bass Lake values are higher than those from Kahshe Lake and most are close to or marginally above the upper range in the WQG. Note that the CWQG for Al is both pH and DOC dependent. As such, the low end of the range of CWQGs based on the pH and DOC levels has been plotted.
	Barium	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Beryllium	MOECP APV	All reported values well below benchmark
	Cadmium	MOECP APV	The Aquatic Protection Value is exceeded in 2018 and 2019 as well as in two earlier years. The early exceedances are likely a sampling (water filtering) or laboratory quality control issue, as the APV is very close to the detection levels of most laboratories. Similarly, the apparent increase in the 2018 and 2019 levels is due to a change in the Laboratory MDL values which now exceed the APV. As such, the reported exceedances are not measured concentrations, simply

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
			the level of detection by the laboratory. As such, cadmium concentrations warrant continued monitoring, but no aquatic impacts are anticipated.
	Chromium	MOECP APV	All reported values well below benchmark
	Cobalt	MOECP APV	All reported values well below benchmark
	Copper	MOECP APV	One exceedance of the benchmark in 2006, with none since; likely a sampling or laboratory quality control issue.
	Iron	U.S. EPA CCC	All reported values for both lakes are well below benchmark, although results for Bass Lake are noticeably higher than those of Kahshe Lake. This is confirmed in 2019.
	Lead	MOECP APV	Two exceedances of the benchmark in Bass Lake in early years, but none since 2009; likely a sampling or laboratory quality control issue. Note that the chart uses a logarithmic scale.
	Magnesium	U.S. EPA LCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Manganese	BC AWQC	All reported values well below aquatic benchmark and manganese concentrations in Bass Lake are noticeably higher than those in Kahshe.
	Molybdenum	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Nickel	MOECP APV	All reported values well below benchmark
	Potassium	U.S. EPA LCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Silicon	None Found	In most years, including 2019, silicon concentrations in Kahshe Lake are slightly higher than those in Bass Lake. No aquatic protection benchmark was found for comparison.
	Sodium	MOECP APV	All reported values well below aquatic benchmark and concentrations in Bass Lake are noticeably higher than those in Kahshe. Note that the chart uses a logarithmic scale.
	Strontium	U.S. EPA T-II SCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Titanium	None Found	In most years including 2019, titanium concentrations in Bass Lake noticeably higher than those in Kahshe Lake. No aquatic protection benchmark was found for comparison.
	Vanadium	MOECP APV	All reported values well below benchmark
	Zinc	MOECP APV	All reported values well below benchmark
Other Chemicals	Dissolved Organic Carbon	DMM Notes	Although there is no aquatic benchmark, the findings for Bass Lake are noticeably higher than those in Kahshe and also are at or slightly higher than 7 mg//L, which is the Ontario aesthetic objective for recreational use.

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
	Electrical Conductivity	None Found	In most years including 2019, EC concentrations in Bass Lake are slightly higher than those in Kahshe Lake. No aquatic protection benchmark was found for comparison.
	Alkalinity	DMM Notes	Although there is no benchmark, the alkalinity of both Kahshe and Bass Lakes is below 10 mg/L, indicating that both lakes have low buffering capacity and therefore, are potentially susceptible to acidification.
Recently Added Cations	Antimony	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Arsenic	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Boron	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Selenium	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Silver	MOECP APV	All reported values are marginally below the benchmark. This needs to be followed, as the laboratory detection limit is only marginally above the APV. Note that the chart uses a logarithmic scale.
	Thallium	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Uranium	MOECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.

Legend:
[1] Evaluation Benchmarks

- MOECP APV means Ontario Ministry of Environment, Conservation and Parks – Aquatic Protection Value
- EC CWQG means Environment Canada – Canadian Water Quality Guideline
- BC AWQC means British Columbia Ambient Water Quality Criterion
- U.S. EPA CCCC means United States Environmental Protection Agency Continuous Chronic Criterion
- U.S. EPA LCV means United States Environmental Protection Agency Lowest Chronic Value
- U.S. EPA Tier II SCV means United States Environmental Protection Agency Secondary Chronic Value

Although the main goal of the above discussion was to examine the potential of these parameters to impact water quality in terms of aquatic health, the comparison also identified a number of cases where concentrations in Kahshe or Bass Lake were higher than in the other. While the cause of this finding is not immediately apparent, it is interesting given the finding of noticeably higher concentrations of total phosphorus in Bass Lake compared to Kahshe Lake. To explore this further, the following table identifies the parameters which are either slightly or noticeably elevated in one lake compared to the other.

Bass Lake Concentrations Higher than in Kahshe Lake		Kahshe Lake Concentrations Higher than in Bass Lake	
Noticeably	**Slightly**	**Noticeably**	**Slightly**
▪ N-Kjeldahl ▪ Al ▪ Fe	▪ Cl ▪ $N\text{-}NH_4$ ▪ Ca	▪ none	▪ $N\text{-}NO_3$ ▪ Si

Bass Lake Concentrations Higher than in Kahshe Lake		Kahshe Lake Concentrations Higher than in Bass Lake	
Noticeably	**Slightly**	**Noticeably**	**Slightly**
▪ Mn ▪ Na ▪ Ti	▪ EC ▪ DOC		

As noted above, the reason for these differences between the two lakes is unknown. However, they may play a role in the search for causality in the elevated total phosphorus levels in Bass vs. Kahshe Lake.

Anions, Cations and Other Chemical Summary

The analysis of several additional anions, cations and other chemicals by the DMM has identified no pressing issues from an aquatic health aspect. While there were some minor exceedances of chronic (long term) benchmarks established by the MOECP and other agencies to protect aquatic receptors, most of these exceedances were detected in the early years of the sampling program and appear to be related to sampling or laboratory artifacts, as more recent sampling has shown concentrations that are in the expected range for non-impacted surface water bodies in Ontario. In a couple of cases (cadmium and silver), the laboratory detection limits are similar to or slightly below the aquatic protection value, and as a result, the non-detected levels of these substances are either just above or below their respective aquatic benchmarks. Aluminum in Bass Lake also exceeds the aquatic benchmark in several years; however, as noted, the benchmark consists of a range in values and must be evaluated based on the pH and DOC concentrations in lake water. As such, these substances will be followed carefully in future monitoring to ensure that the waters of Kahshe and Bass Lakes are safe from an aquatic perspective.

The other finding from this data set is that there are numerous parameters that, like total phosphorus, are slightly or noticeably higher in Bass Lake compared to Kahshe Lake. There are also a couple of parameters where the opposite (Kahshe higher than Bass) is documented. The reason for these differences in the two lakes is unknown.

3.5 Dissolved Oxygen

Dissolved oxygen (DO) in lake water is important for two main reasons: 1) it is essential for the survival of all aquatic organisms, and 2) a lack of oxygen in the lower layers of the lake (referred to as being anoxic) can cause mobilization of phosphorus from sediments. This is referred to as internal phosphorus loading.

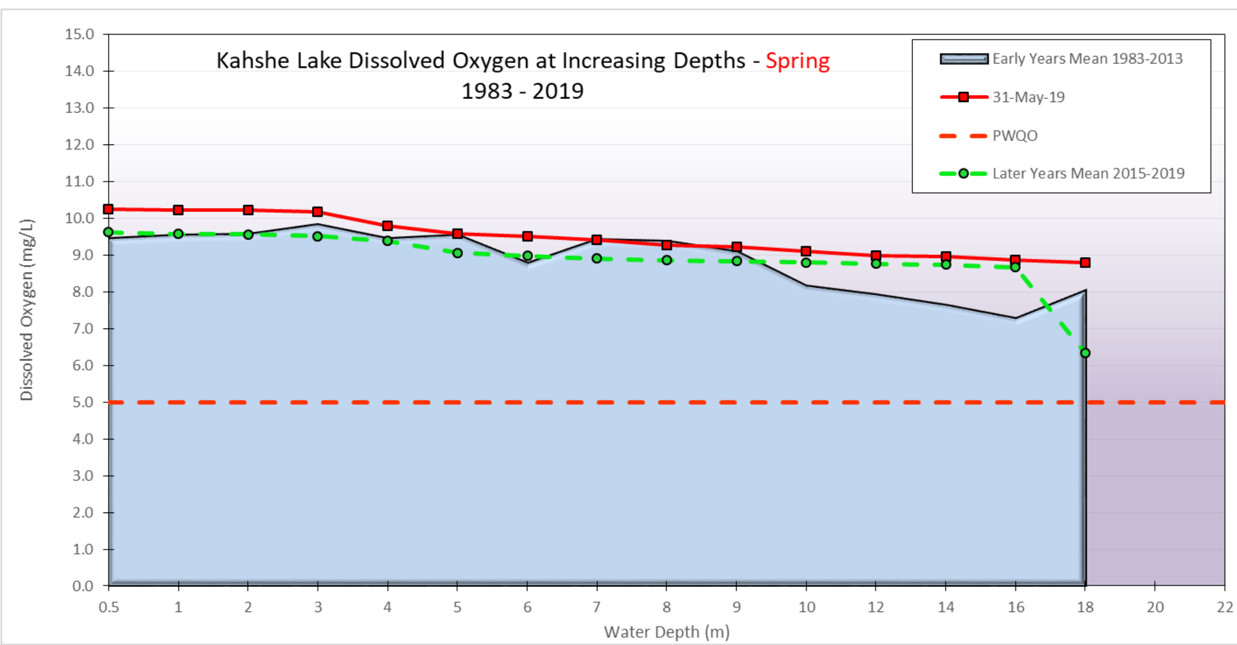
In addition to the consumption of oxygen by fish and other aquatic organisms, the decomposition of organic matter in all layers of the lake consumes oxygen. However, because of the minimal mixing of upper and lower layers of lake water during the ice-free period (referred to as thermal stratification), only the upper layers of water are replenished with oxygen as a result of photosynthesis by aquatic plants, in-bound water from streams and atmospheric oxygen as a result of mixing caused by wind and waves. As such, the gradual depletion of oxygen in the lower layers (hypolimnion) of the lake progresses following spring turnover and these lower waters do not get re-oxygenated until the late fall turnover again takes place.

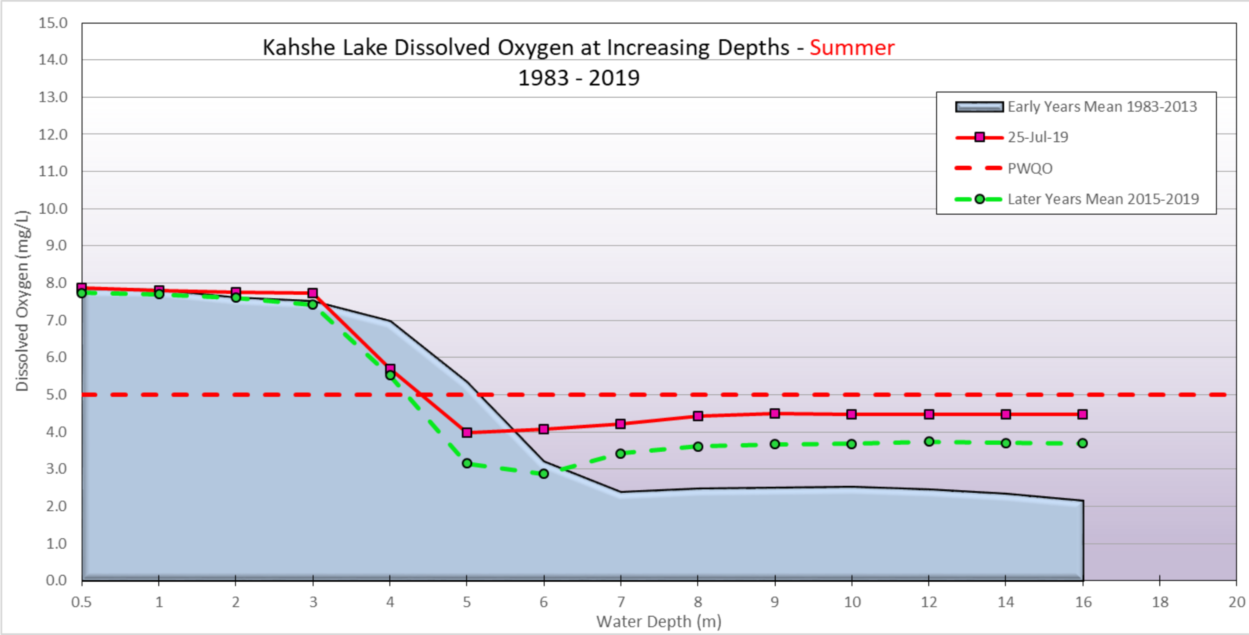
Water temperature also plays a role in the dissolved oxygen cycling process, as warm water becomes saturated at lower concentrations than required for cold water. However, the bottom line is that the colder waters near the bottom of the lake become gradually depleted of oxygen over the ice-free period and can reach levels that will not support aquatic species.

The setting of an aquatic benchmark for DO is typically conducted under both an acute (short term, high concentration) and a chronic (long term, lower concentrations) basis. For chronic exposure, aquatic organism effects include the traditional growth and reproduction impairment, swimming impairment and long term impacts on survival. The low oxygen threshold at which some reaction first becomes apparent is usually referred to as the incipient or critical level. At this level, the organism must extend or adjust its available energies to counteract the influence of hypoxia (oxygen starvation) and/or to move to waters with higher DO levels. Unfortunately, the variability in toxicity symptoms and exposure times challenges the derivation of water quality guidelines for DO, and as a result, the guideline derivation does not follow the standard process.

For warm water lakes like Kahshe and Bass, the Provincial Water Quality Objective (PWQO) and the Canadian Water Quality Guideline (CWQG) are set at 5 and 5.5 mg DO/L, respectively. This report will use the lower of the two, as some other agencies have set DO benchmarks in the 3-4 mg/L range.

To examine the DMM findings for DO, the data have been averaged in a manner similar to what was done with water temperatures. This generated an Early Years Mean (1983-2013) and a Later Years Mean (2015-2019) for all Spring and Summer sampling up to 2019, and these findings for Kahshe Lake are plotted below.

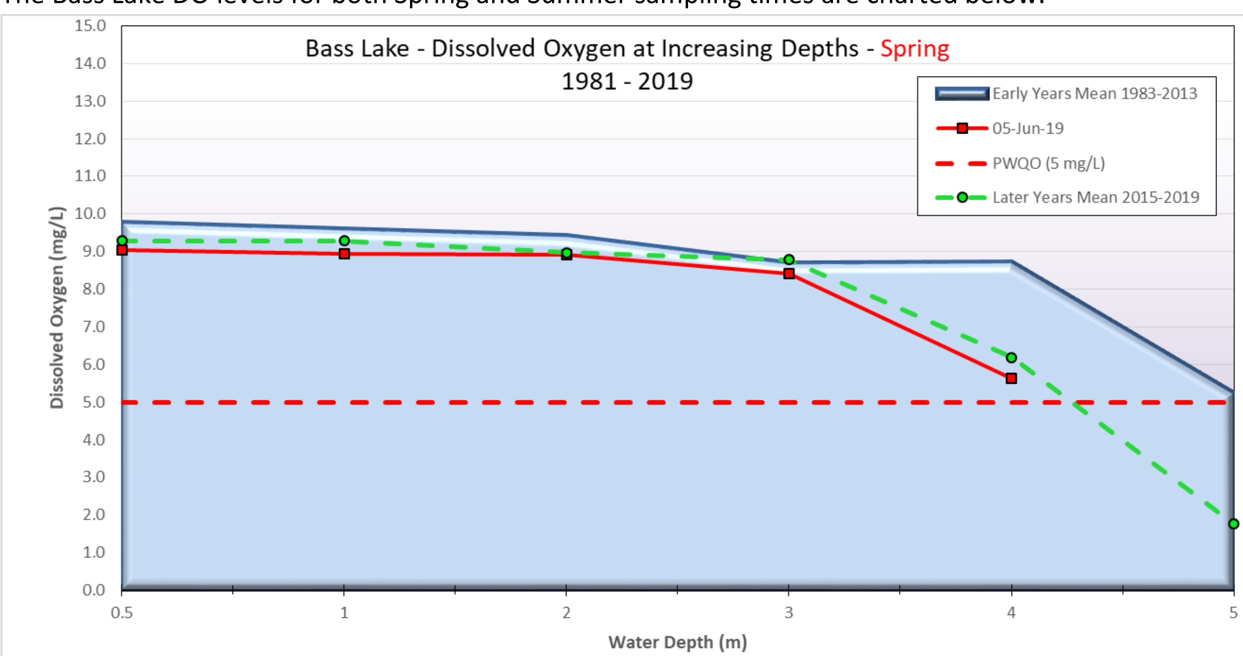


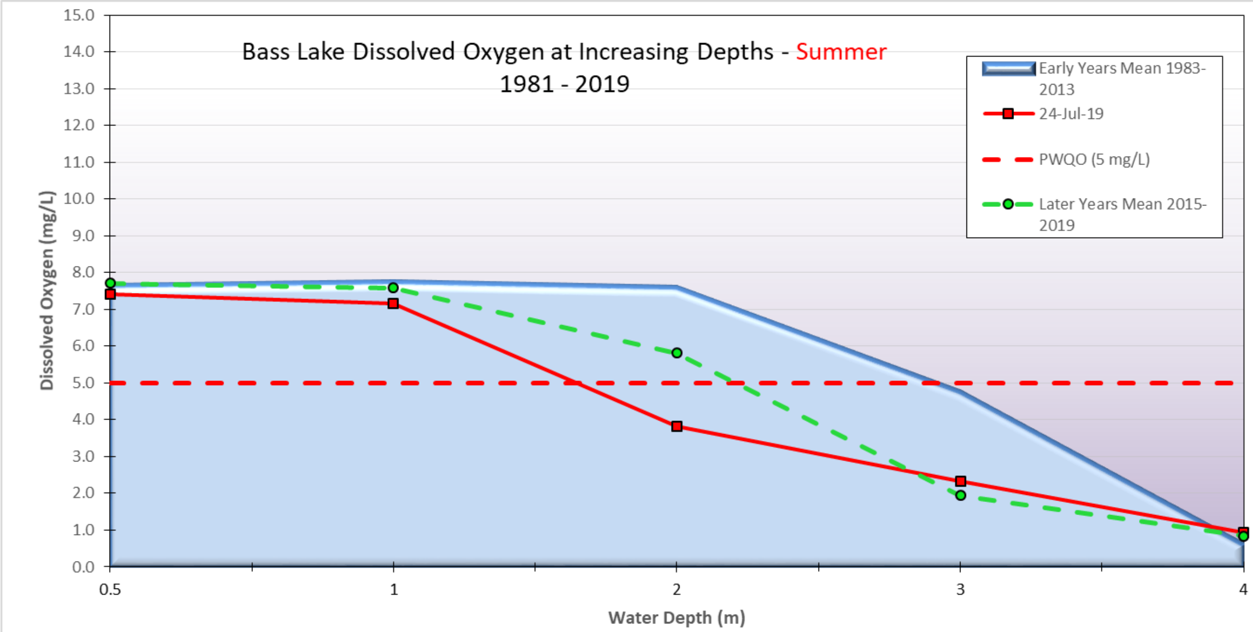


The above two charts for Kahshe Lake have been summarized below:

- As expected, the DO levels in the Spring sampling event reveal only a slight trend to decreasing DO levels with increasing water depth, and in all cases the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixed the water across the depth of the lake.
- However, by late July, the 2019 DO levels are essentially similar to the two sets of historical background mean concentrations down to 3m and then decrease sharply from 3-5m, dropping below the PWQO at depths of 4-5m.
- Interestingly, the DO levels in 2019 and in the Later Years differ from the Early Years mean in that they are noticeably higher than in the Early Years from depths greater than about 6 m.

The Bass Lake DO levels for both Spring and Summer sampling times are charted below.





The above two charts for Bass Lake have been summarized below:

- As for Kahshe Lake, the DO levels in the Spring sampling event reveal only a slight trend to decreasing DO levels with increasing water depth, and in all but the lowest depths, the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixed the water across the depth of the lake, although to a lesser extent in Bass Lake due to its more shallow depth.
- However, by late July, the 2019 DO levels are essentially similar to the two sets of historical background mean concentrations down only to 1m and then decrease gradually from 1m down through the 4m depth of sampling, dropping below the PWQO at depths of just under 2m.
- Interestingly, and in contrast to Kahshe Lake, the DO levels in 2019 and in the Later Years differ from the Early Years mean in that they are noticeably lower than in the Early Years from depths greater than 1m.

Dissolved Oxygen Summary

Dissolved oxygen (DO) in lake water is important for two main reasons:

- It is essential for the survival of all aquatic organisms, and
- A lack of oxygen in the lower layers of the lake (referred to as being anoxic) can cause mobilization (release) of phosphorus from sediments.

Dissolved oxygen is influenced by seasonal changes that factor into lake stratification, the process whereby lake water is turned over in the fall and again following the winter ice melt and then begins to stratify through the spring, summer and fall as water temperature increases at the surface and DO levels decrease with increasing depth.

The DO findings for spring and summer at different water depths in both Kahshe and Bass Lakes for 2019 are summarized below. In the evaluation, the results are compared to the mean results historically, broken into the Early Years (1983-2013) and Later Years (2015-2019).

- In both lakes, the Spring DO levels are relatively stable across all sampling depths, reflecting the action of vertical mixing from the turnover of cold and warm water from the fall through the spring.
- In the much deeper Kahshe Lake, by late July, the 2019 DO levels are essentially similar to the two sets of historical background mean concentrations down to 3m and then decrease sharply from 3-5m, dropping below the PWQO at depths of 4-5m.
- Interestingly, the DO levels in 2019 and in the Later Years differ from the Early Years mean in that they are noticeably higher than in the Early Years from depths greater than about 6m.
- The Bass Lake findings for late July differ from those of Kahshe Lake at depths greater than 1m, likely due to the more shallow nature of the lake.
- While levels below the aquatic benchmark have been identified, this is not believed to represent a significant barrier to fish survival, as these lower levels can be avoided through changes in fish and other aquatic species movement.

3.6 Evaluation of Benthic Monitoring

Monitoring of bottom-dwelling aquatic invertebrate communities which live within the sediment or 'bottom mud' has been carried out at three locations on Kahshe Lake by the DMM since 2003. However, benthic monitoring on Kahshe Lake was suspended in 2016 in order to focus more on Bass Lake due to its classification as a 'Transitional' lake requiring additional assessment due to its elevated total phosphorus levels.

As benthic monitoring of Bass Lake did not take place in 2019, there is no further evaluation of this water quality metric.

4.0 Summary and Conclusions

A comprehensive review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes has now been completed and presented within annual Lake Steward Reports from 2012 through 2018. These documents as well as Executive Summaries each year have been posted on the KLRA web-site: https://kahshelake.ca/Water-Quality.

This report captures the findings from sampling and analysis of both Kahshe and Bass Lakes in 2019.

In an effort to simplify the reporting of a large amount of measurement and analysis data, the report has been structured to address the following issues/areas of potential concern for both Kahshe and Bass Lakes:

- Nutrients, Water Clarity, Temperature and Algal Growth
- Calcium Depletion
- Lake Acidification
- Metals and Other Chemicals
- Dissolved Oxygen

To better understand the chemical and physical data that have been collected, the report includes an overview of the climatological factors that have the potential to influence lake conditions. The information on weather and water/ice conditions confirmed that 2019 was generally similar to the 30 year climatic normals, with the only noticeable variation being a much wetter April and warmer and dryer July. As the lower levels of precipitation in July coincided with slightly above normal temperatures, this may have contributed to the warmer surface lake water experienced towards the end of July and early August. Ice-out on Kahshe occurred around April 26, which was a few days earlier than in 2018. Ice-out records for Deep Bay also have been recorded dating back to 1987, and this record shows no clear trend in either direction.

Nutrients, Water Clarity, Temperature and Algal Growth Summary

The main reason for the total phosphorus, nitrogen, water clarity and temperature monitoring that is conducted by both the DMM and the MOECP is to provide an early warning for both undesirable nutrient enrichment and the potential for harmful algal blooms.

Phosphorus has long been identified as the main concern in terms of water quality and shoreline management due to its major role in algal growth and bloom development. However, more recently, nitrogen also has been identified as a key factor in algal bloom development and it too enters the lake from sources similar to those for phosphorus.

A summary of the findings for the three major input variables and for water clarity that have been evaluated is presented below:

Phosphorus

- In both lakes, there has been no detectable upward or downward trend in total phosphorus concentrations over the past 37 years.
- The total phosphorus data from both the DMM and LPP show some variability, but in general, the findings are similar across the years that samples have been taken.
- Total phosphorus concentrations are almost twice as high in Bass Lake than in Kahshe Lake, but well below the DMM's existing Threshold Level and at or below the expected Background concentration.

Based on these findings, our efforts to minimize septic leaching bed discharges and to manage our shorelines to reduce disturbance and erosion as well as minimizing fertilizer use on lawns and gardens close to the lake appear to be holding total phosphorus levels stable over the past three decades.

Nitrogen

While recognition of the role of nitrogen in nutrient enrichment and algal growth has not been a focus for as long as phosphorus, there is a growing focus on this nutrient now based on a strong weight of published evidence for its role in promoting algal growth. In water, nitrogen occurs in several different dissolved forms. These forms influence communities of algae and cyanobacteria in different ways, based largely on their abilities to convert the different nitrogen forms into biomass and compete with other organisms. Ammonium is the easiest nitrogen form for primary producers to acquire and transport into the cell. Nitrate and nitrite (NO_3^- /NO_2^-) must be actively transported into the cell and then converted to ammonium, which, in turn, requires energy and micronutrients, such as iron. For these reasons, the monitoring has focussed on the two main forms of nitrogen (Ammonia + Ammonium) and (Nitrite + Nitrate). The 2019 findings are summarized below:

- No evidence of a concentration trend in either form of nitrogen has been detected in Kahshe or Bass Lakes over the years dating back to 2004.

- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive species.
- No algal growth benchmarks for either form of nitrogen have been developed, as the linkage between phosphorus, nitrogen and water temperature is simply too complex to set individual benchmarks.

Based on these findings, as for phosphorus, our efforts to minimize septic leaching bed discharges and to manage our shorelines to reduce disturbance and erosion as well as minimizing fertilizer use on lawns and gardens close to the lake appear to be holding nitrogen levels stable over the period dating back to 2004. Unlike total phosphorus, levels of both forms of nitrogen are similar in Bass and Kahshe Lakes.

Water Temperature

While nutrient enrichment is important, it is not the only factor involved in the promotion of harmful algal growth. Blue-green algae thrive in areas where the water is shallow, slow moving and warm. Water temperature is also important for other reasons, including:

- It affects the solubility of oxygen in water.
- It affects the metabolic rates, life cycles and the sensitivity of all aquatic organisms to parasites and disease.
- It factors into the classification of a lake as a cold or warm water body (both Kahshe and Bass are considered warm water lakes)

In both Kahshe and Bass Lake, water temperature in the spring of 2019 was similar to the historical (1983-2018) averages. However, by August, the temperature in the surface layers of both lakes was well above the historical mean from the early years (1983-2013). This warming of surface layers appears to be consistent with above normal air temperature findings for July of 2019, and in line with the findings published by Palmer (2012) who demonstrated a statistically significant water temperature increase using the full Muskoka lake database.

Water Clarity

As noted earlier, water clarity is not a driving variable in algal growth but rather a symptom of nutrient loading and eutrophication. In both Bass and Kahshe Lakes, this is more complicated as the linkage between water clarity and nutrient loading with phosphorus is masked by the tea coloured waters associated with dissolved organic carbon (DOC). However, notwithstanding these limitations, both sampling programs have monitored clarity via the Secchi disc method for as long as we have data on total phosphorus. The 2019 results are summarized below:

- Water clarity in both Kahshe and Bass Lakes in 2019 was slightly better than in 2017/2018 but generally similar to historical measurements dating back to 1983.
- Water clarity is noticeably better in Kahshe Lake than in Bass Lake, most likely due to the more tea coloured nature of Bass Lake - as confirmed by slightly higher Dissolved Organic Carbon [DOC] levels in Bass Lake vs. Kahshe Lake.

Algal Growth

To date, there have been no documented cases of a blue-green algal bloom in either Kahshe or Bass Lakes. However, the potential for an algal bloom, and in particular, a blue-green algal bloom is real, as blue-green blooms were confirmed on several Muskoka lakes and neighbouring water bodies in both

2018 and 2019. The nearby lakes with documented blue-green algal blooms and associated public health notices from the Simcoe/Muskoka Health Unit in 2019 included:

- Three Mile Lake
- Brandy Lake
- Bass Lake (south of Lake Joseph)
- Echo Lake
- Lake St. John
- Lake St. George
- MacLean Lake

To assess the relevance of these findings to our own lakes, total phosphorus levels in algal-impacted neighbouring lakes in 2018 and 2019 were compared with the corresponding phosphorus levels in Kahshe and Bass Lakes. The main finding from this comparison was that out of 10 impacted lakes with available total phosphorus levels, five had levels well below those found in Kahshe and Bass Lakes. Obviously, this is of concern, as although it is well established that total phosphorus is a driver of algal bloom development, other factors such as nitrogen and water temperature are involved. As we have no control over water temperature, we must remain vigilant about maintaining the lowest total phosphorus and nitrogen concentrations, as the threat of a blue-green algal bloom is real and would have devastating impacts on the recreational use of the water for swimming, fishing and consumption.

We can do this by:

- pumping out and having our septic systems (tanks/leaching beds) inspected on a regular basis;
- managing our shorelines to keep them as natural and as vegetated as possible, and;
- avoiding the use of phosphorus or nitrogen fertilizers on any existing lawns, gardens or flower beds in the vicinity of the shoreline.

As the likelihood of a blue-green algal bloom is exacerbated by increasing lake water temperatures, it is critical that we act responsibly as noted above. Will this give us 100% protection from the onset of a blue-green algal bloom? Unfortunately, no; but it will help to minimize the risk.

Calcium Depletion Summary

Decreasing lake water calcium concentration is an emerging concern for lakes on the Precambrian Shield in Ontario due to its impact on the reproduction and survival of zooplankton and other aquatic species that are important components of the aquatic food chain.

Levels of calcium below the growth limiting threshold range of 1.5 mg/L have not been identified in the sampling of Kahshe or Bass Lakes. However, as the calcium concentrations in both lakes are only marginally above the limiting value and as this threshold would not be protective of all aquatic organisms, continued vigilance is necessary.

Lake Acidification Summary

The waters of Kahshe and Bass Lake have acidity (pH) levels that are within a normal range and above the lower limit of the optimum level where aquatic impacts may begin to be shown. There is also no evidence of an increase or decrease in acidity over the 13 year monitoring period.

While the pH findings represent good news, it should also be recognized that the waters of Kahshe and Bass Lakes have low levels of alkalinity, and as such, are more susceptible to acidification, as the ability of the water to buffer the acid input is low.

As such, while there is currently no concern, continued monitoring of the acidity is warranted.

Anions, Cations and Other Chemical Summary

The analysis of several additional anions, cations and other chemicals by the DMM has identified no pressing issues from an aquatic health aspect. While there were some minor exceedances of chronic (long term) benchmarks established by the MOECP and other agencies to protect aquatic receptors, most of these exceedances were detected in the early years of the sampling program and appear to be related to sampling or laboratory artifacts, as more recent sampling has shown concentrations that are in the expected range for non-impacted surface water bodies in Ontario. In a couple of cases (cadmium and silver), the laboratory detection limits are similar to or slightly below the aquatic protection value, and as a result, the non-detected levels of these substances are either just above or below their respective aquatic benchmarks. Aluminum in Bass Lake also exceeds the aquatic benchmark in several years; however, as noted, the benchmark consists of a range in values and must be evaluated based on the pH and DOC concentrations in lake water. As such, these substances will be followed carefully in future monitoring to ensure that the waters of Kahshe and Bass Lakes are safe from an aquatic perspective.

The other finding from this data set is that there are numerous parameters that, like total phosphorus, are slightly or noticeably higher in Bass Lake compared to Kahshe Lake. There are also a couple of parameters where the opposite (Kahshe higher than Bass) is documented. The reason for these

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- It is essential for the survival of all aquatic organisms, and
- A lack of oxygen in the lower layers of the lake (referred to as being anoxic) can cause mobilization (release) of phosphorus from sediments.

Dissolved oxygen is influenced by seasonal changes that factor into lake stratification, the process whereby lake water is turned over in the fall and again following the winter ice melt and then begins to stratify through the spring, summer and fall as water temperature increases at the surface and DO levels decrease with increasing depth.

The DO findings for spring and summer at different water depths in both Kahshe and Bass Lakes for 2019 are summarized below. In the evaluation, the results are compared to the mean results historically, broken into the Early Years (1983-2013) and Later Years (2015-2019).

- In both lakes, the Spring DO levels are relatively stable across all sampling depths, reflecting the action of vertical mixing from the turnover of cold and warm water from the fall through the spring.
- In the much deeper Kahshe Lake, by late July, the 2019 DO levels are essentially similar to the two sets of historical background mean concentrations down to 3m and then decrease sharply from 3-5m, dropping below the PWQO at depths of 4-5m.
- Interestingly, the DO levels in 2019 and in the Later Years differ from the Early Years mean in that they are noticeably higher than in the Early Years from depths greater than about 6m.

- The Bass Lake findings for late July differ from those of Kahshe Lake at depths greater than 1m, likely due to the more shallow nature of the lake.
- While levels below the aquatic benchmark have been identified, this is not believed to represent a significant barrier to fish survival, as these lower levels can be avoided through changes in fish and other aquatic species movement.

Benthic Health Summary

Benthic monitoring of aquatic invertebrates was not conducted in Kahshe or Bass Lakes in 2019.

Conclusion

In conclusion, based on the foregoing summary of the environmental monitoring of Kahshe and Bass Lakes, no major environmental water quality issues have been identified. However, given the documented occurrence of harmful blue-green algae blooms at several lakes in the Muskoka area in 2018 and 2019, and the finding that their nutrient (phosphorus) levels were similar to or even lower than those in Kahshe and Bass Lakes, continued vigilance in terms of nutrient loading is imperative as we face the reality of warmer water associated with a changing climate. Each of us can do our part by:

- managing our septic systems properly and having tanks pumped out and inspected regularly;
- avoiding the use of any chemical fertilizers or pesticides for lawns, flowers or cultivated vegetation in areas close to the shore;
- minimizing near-shore removal or management of native species and ensuring that any shoreline disturbance does not result in soil runoff to the lake; and,
- avoiding the use of any cleaners containing phosphorus/phosphates at the cottage and in particular on boats or docks near the water.

While not related to water quality *per se*, desirable lake stewardship also involves:

- taking precautions if moving boats to or from other lakes to avoid introducing invasive aquatic species; and,
- avoiding the planting or re-location of non-native invasive plant species to your lake property.

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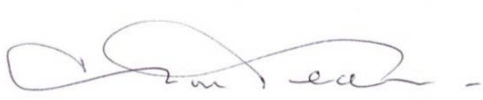


Ron Pearson

Kahshe Lake Steward

Attachments

Attachment 1

Total Phosphorus Results - Bloom-Impacted Lakes with Lake Partner Program Data - 2019

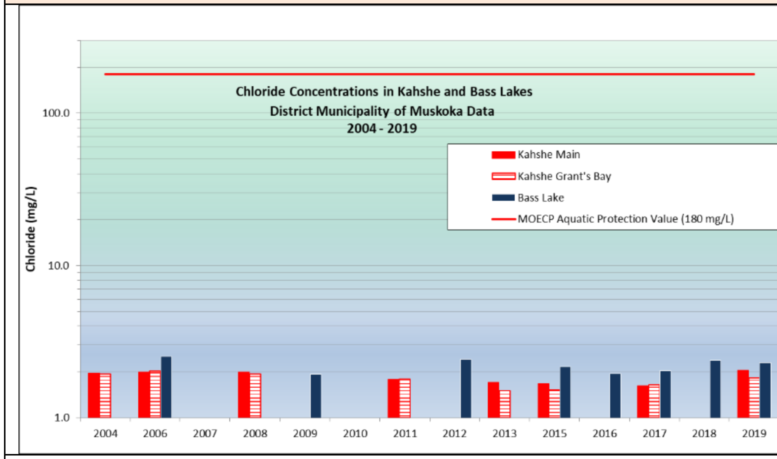
Lake	Township	Location in Lake	Sampling Date	Total Phosphorus (ug/L) TP1	TP2	Average
THREE MILE LAKE	WATT	Deep Spot, South West Bay	8-Jun-19	16.8	18.8	17.8
THREE MILE LAKE	WATT	Deep Spot, South West Bay	2-Jul-19	23.0	24.2	23.6
THREE MILE LAKE	WATT	Deep Spot, South West Bay	9-Aug-19	26.8	26.6	26.7
THREE MILE LAKE	WATT	Deep Spot, South West Bay	16-Sep-19	20.4	19.0	19.7
THREE MILE LAKE	WATT	Deep Spot, South West Bay	11-Oct-19	23.0	21.2	22.1
Average						**22.0**
BRANDY LAKE	WATT	West	6-Jun-19	9.0	5.2	7.1
BRANDY LAKE	WATT	West	23-Jun-19	25.2	21.2	23.2
BRANDY LAKE	WATT	West	26-Jul-19	22.4	23.6	23.0
BRANDY LAKE	WATT	West	23-Aug-19	27.4	27.2	27.3
BRANDY LAKE	WATT	West	20-Sep-19	51.8	38.8	45.3
BRANDY LAKE	WATT	West	3-Nov-19	37.6	41.4	39.5
Average						**27.6**
BASS LAKE	MUSKOKA LAKES	District Municipality of Muskoka*	10 Year Average to 2017			**6.2**
ECHO LAKE	MCLEAN	Mid Lake, deep spot	16-May-19	7.2	8.6	**7.9**
ST. JOHN LAKE	RAMARA	Main Basin-deep spot	11-Aug-19	76.0		76.0
ST. JOHN LAKE	RAMARA	Main Basin-deep spot	14-Sep-19	48.4	49.0	48.7
ST. JOHN LAKE	RAMARA	N end, deep spot	11-Aug-19	80.0		80.0
ST. JOHN LAKE	RAMARA	N end, deep spot	14-Sep-19	55.2	55.2	55.2
ST. JOHN LAKE	RAMARA	S end, deep spot	14-Sep-19	55.4	53.4	54.4
Average						**62.9**
MACLEAN LAKE (BLACK)	MATCHEDASH	Mid Lake, deep spot	29-May-04	32.8	32.7	32.8
MACLEAN LAKE (BLACK)	MATCHEDASH	Mid Lake, deep spot	29-May-05	21.9	21.6	21.8
Average						**27.3**

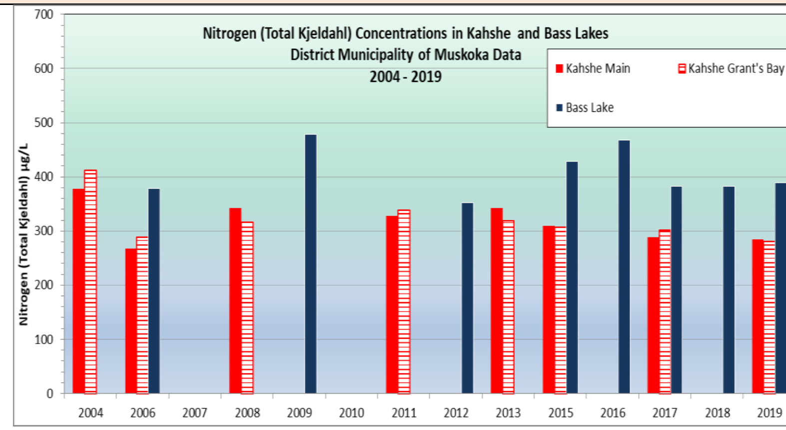
* No LPP data for this lake. Data from District Municipality of Muskoka

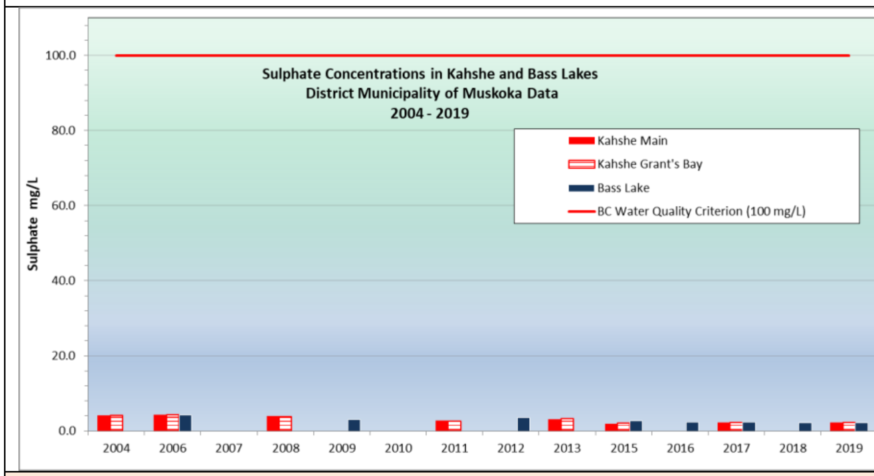
Attachment 2

Charts of Water Chemistry Results from DMM Sampling of Kahshe and Bass Lakes

Anions







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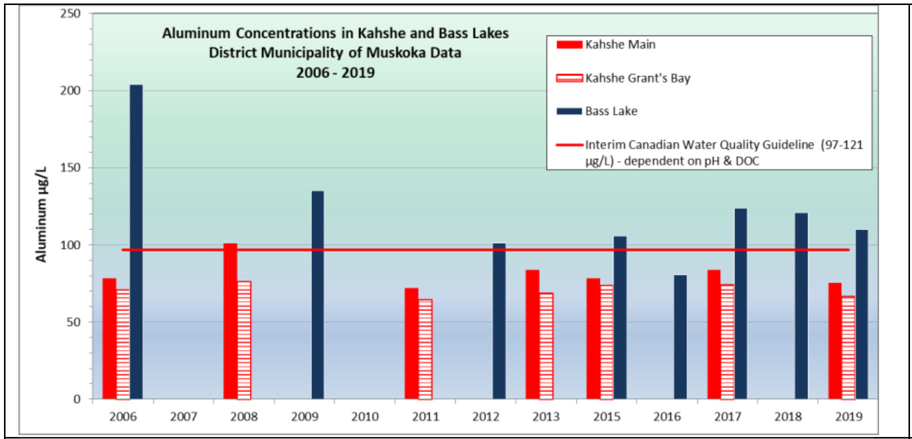
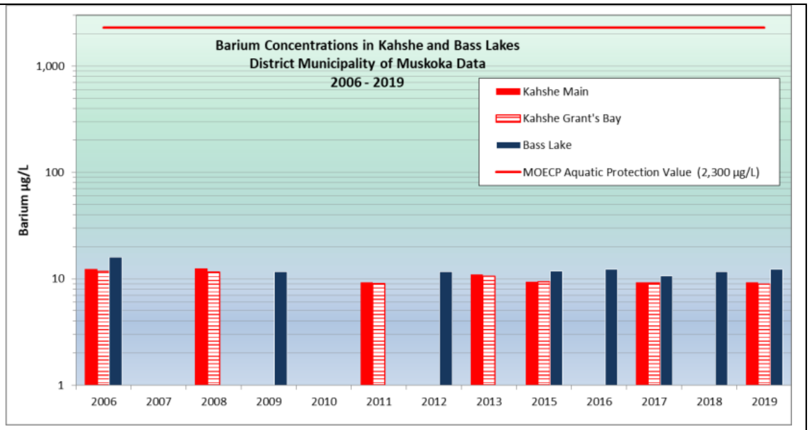

Aluminum Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Interim Canadian Water Quality Guideline (97-121 µg/L) - dependent on pH & DOC
Aluminum µg/L
250
200
150
100
50
0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Barium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (2,300 µg/L)
Barium µg/L
1,000
100
10
1
2006
2007
2008
2009
2010
2011
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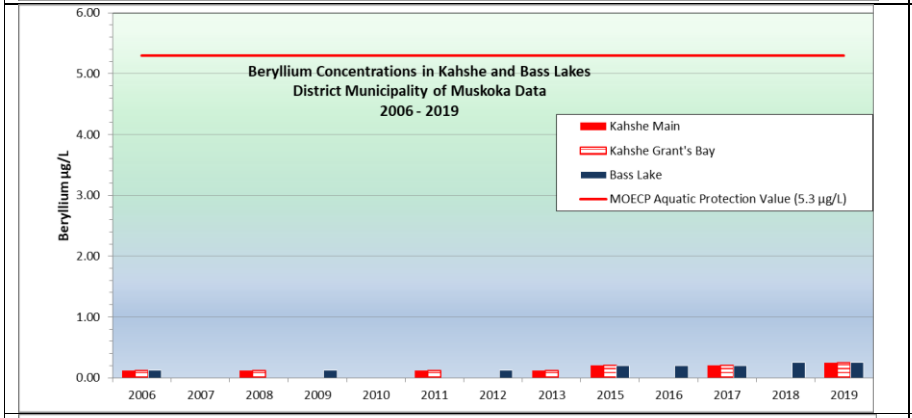
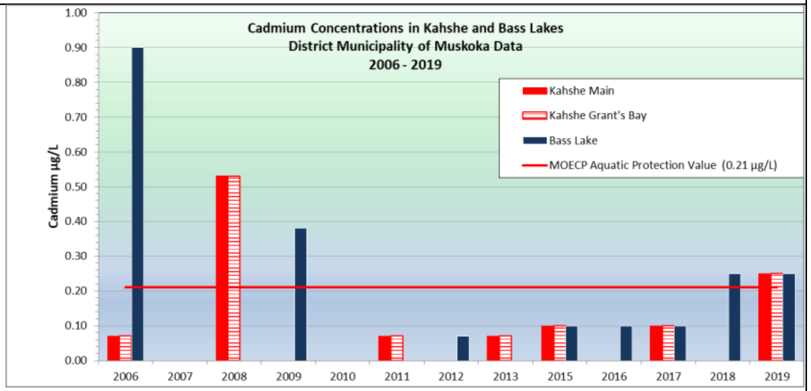
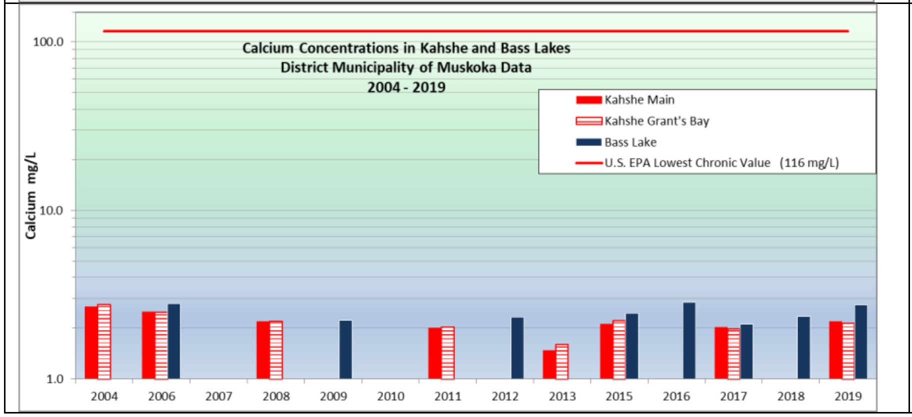
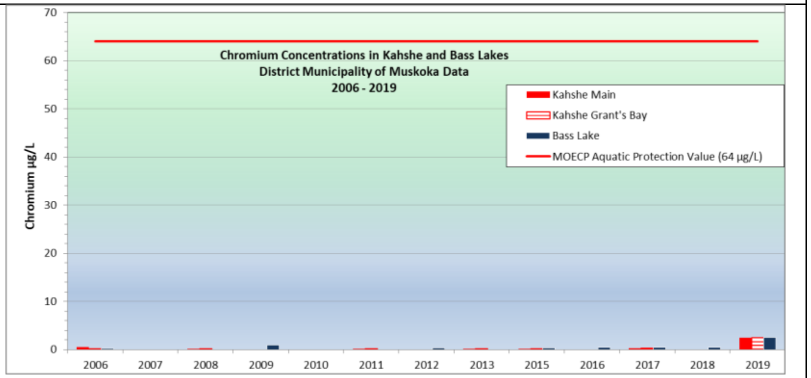
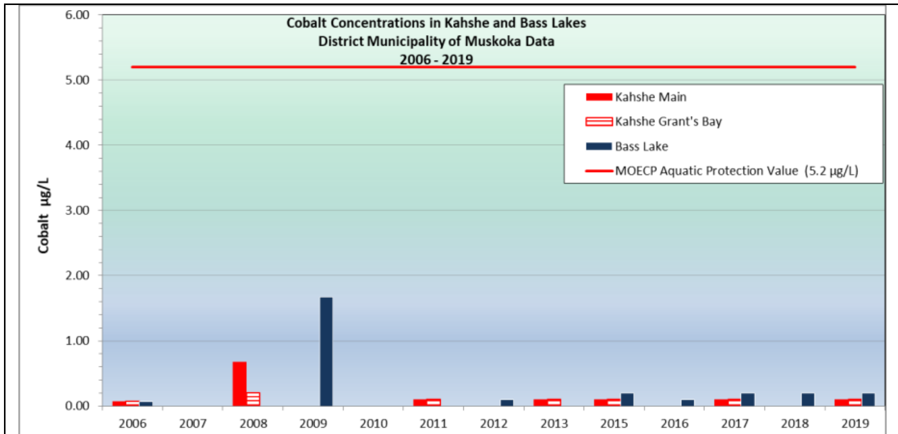
2015
2016
2017
2018
2019


Beryllium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (5.3 µg/L)
Beryllium µg/L
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Cadmium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (0.21 µg/L)
Cadmium µg/L
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Calcium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (116 mg/L)
Calcium mg/L
100.0
10.0
1.0
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Chromium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (64 µg/L)
Chromium µg/L
70
60
50
40
30
20
10
0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Cobalt Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (5.2 µg/L)
Cobalt µg/L
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
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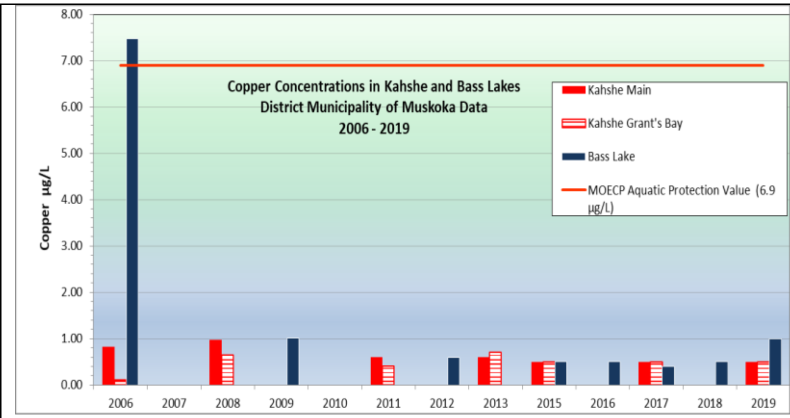
2015
2016
2017
2018
2019


Copper Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (6.9 µg/L)
Copper µg/L
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
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2007
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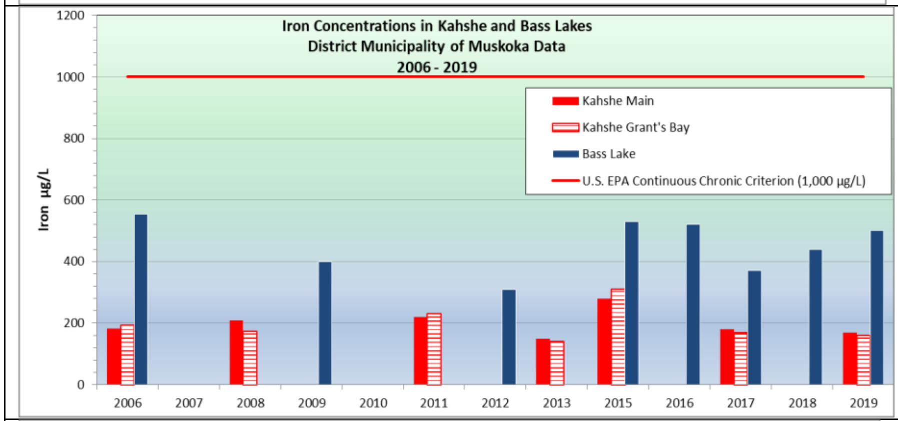
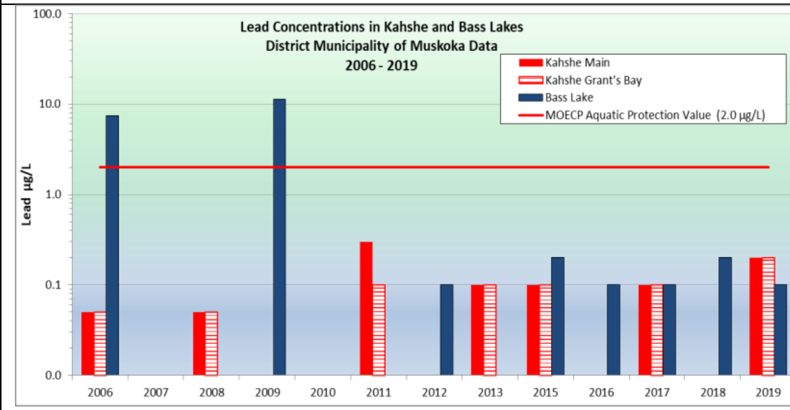
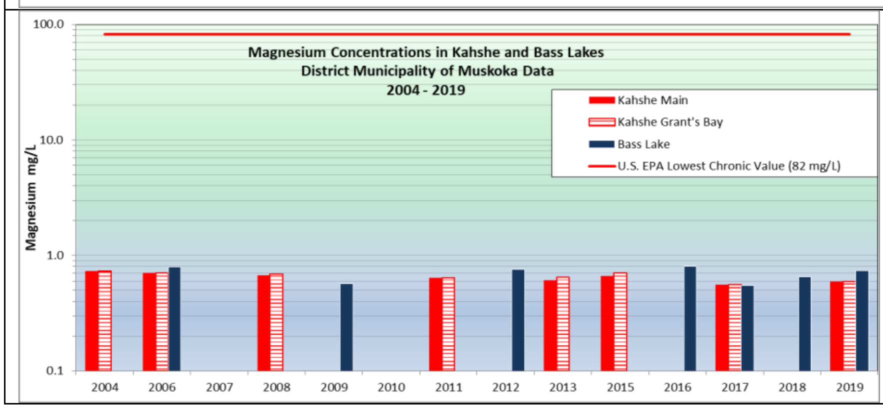
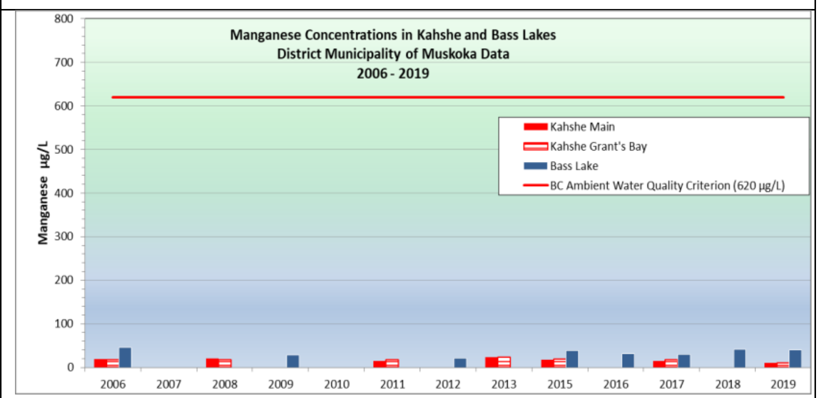
2015
2016
2017
2018
2019


Iron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Continuous Chronic Criterion (1,000 µg/L)
Iron µg/L
1200
1000
800
600
400
200
0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Lead Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (2.0 µg/L)
Lead µg/L
100.0
10.0
1.0
0.1
0.0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Magnesium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (82 mg/L)
Magnesium mg/L
100.0
10.0
1.0
0.1
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019


Manganese Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
BC Ambient Water Quality Criterion (620 µg/L)
Manganese µg/L
800
700
600
500
400
300
200
100
0
2006
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2008
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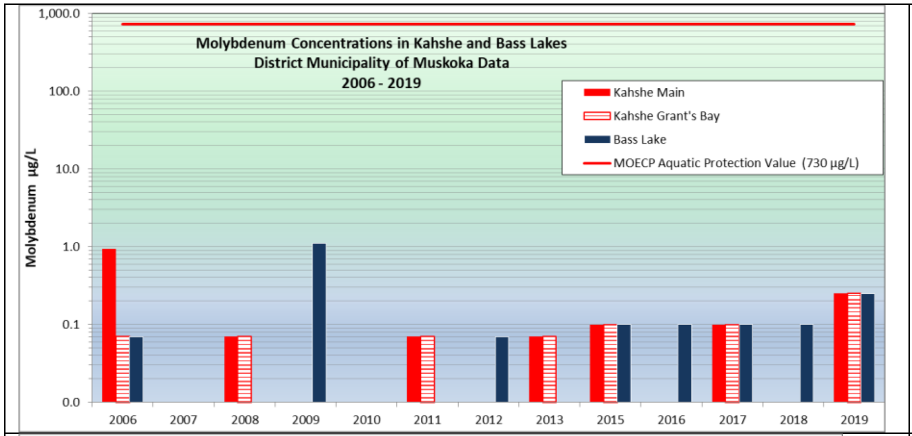
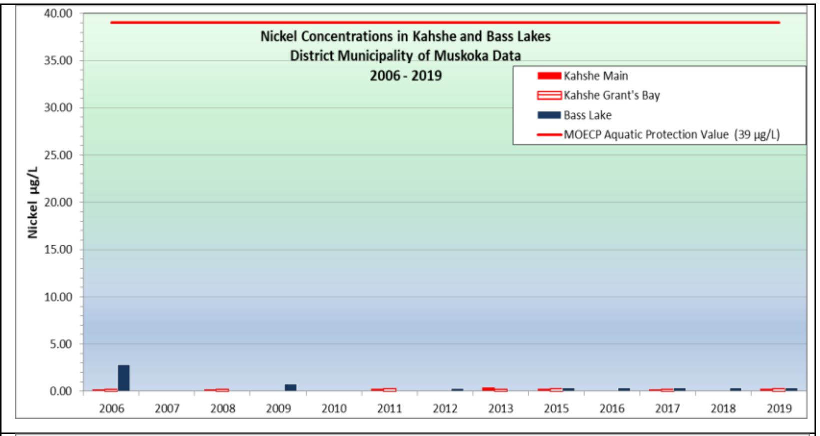
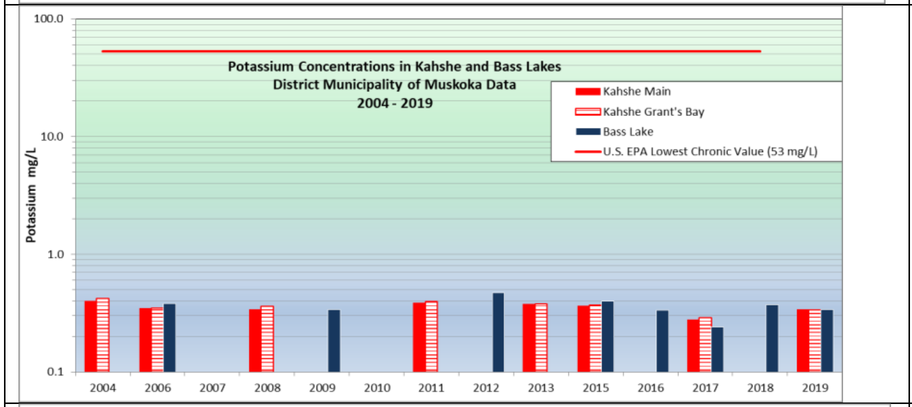
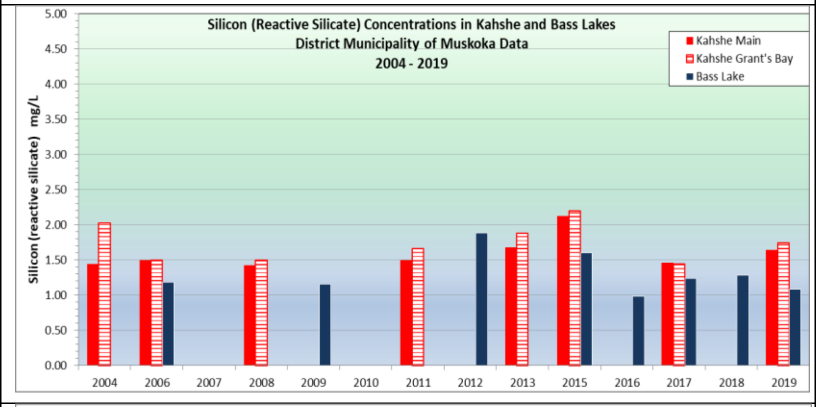
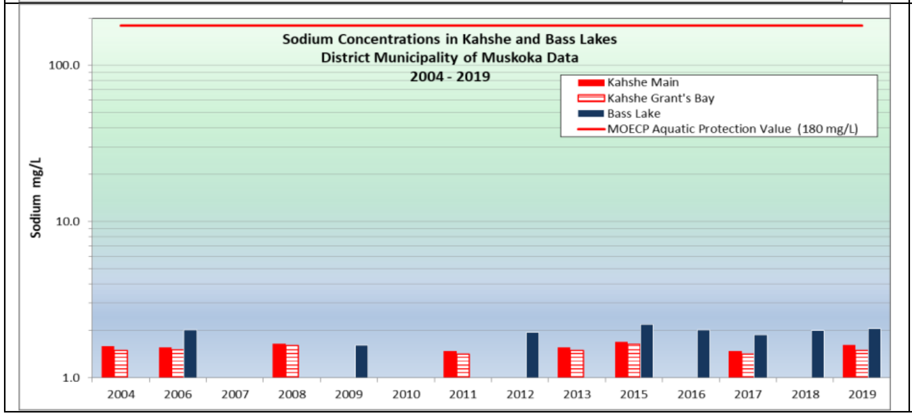
2015
2016
2017
2018
2019

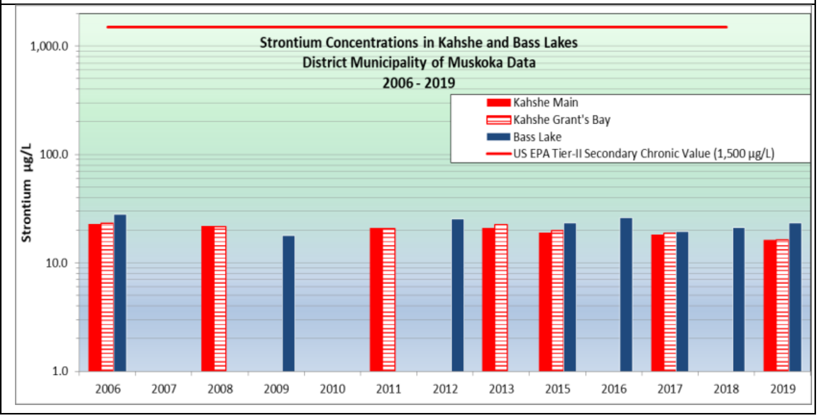

Molybdenum Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (730 µg/L)
Molybdenum µg/L

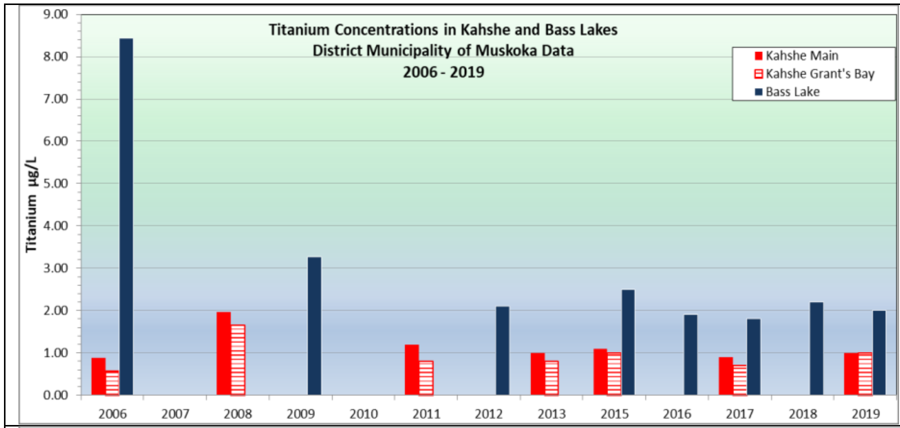

Nickel Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (39 µg/L)
Nickel µg/L

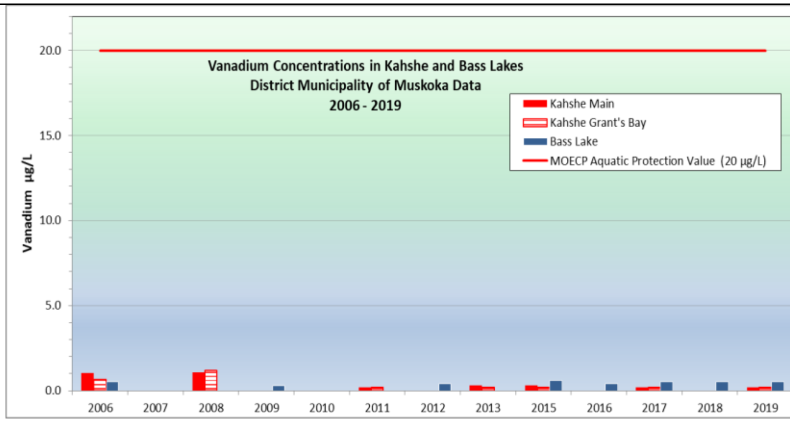

Potassium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (53 mg/L)
Potassium mg/L

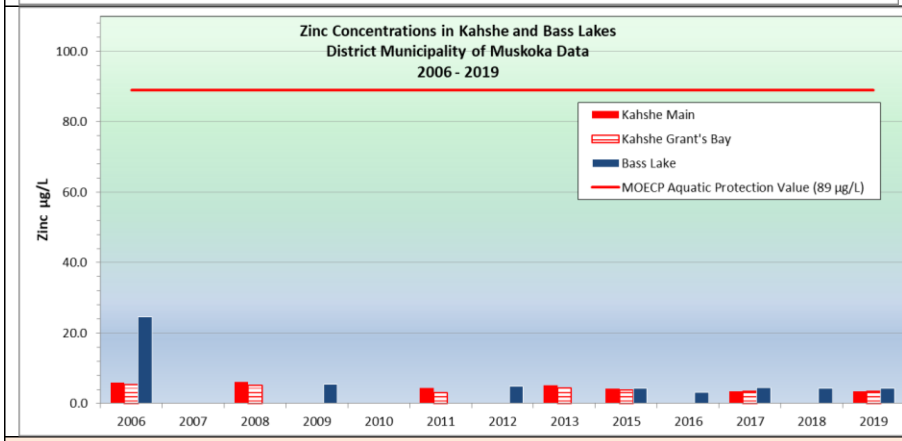

Silicon (Reactive Silicate) Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Silicon (reactive silicate) mg/L


Sodium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (180 mg/L)
Sodium mg/L

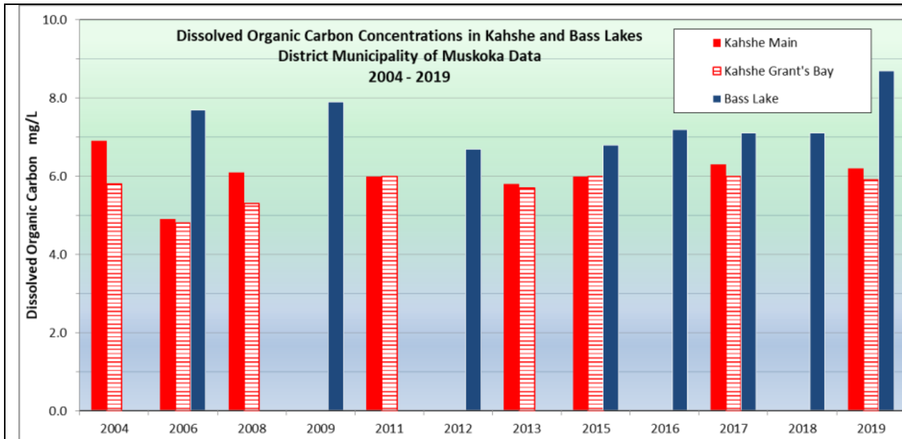

Strontium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
US EPA Tier-II Secondary Chronic Value (1,500 µg/L)
Strontium µg/L

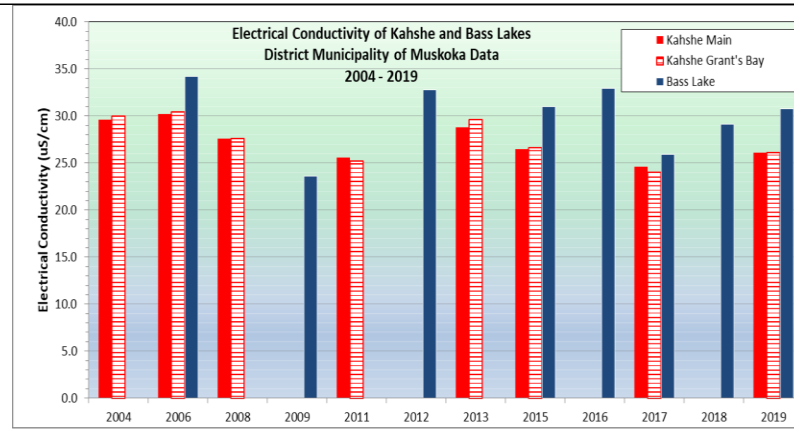


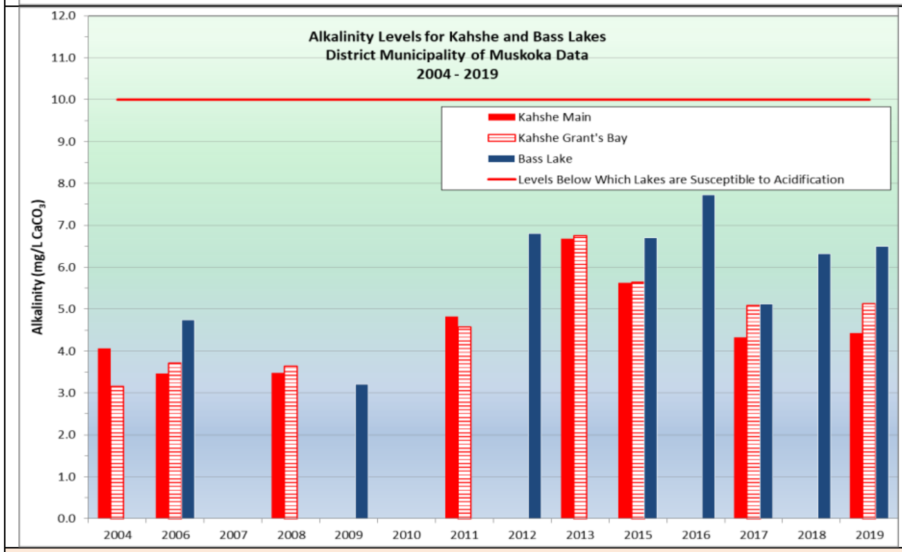




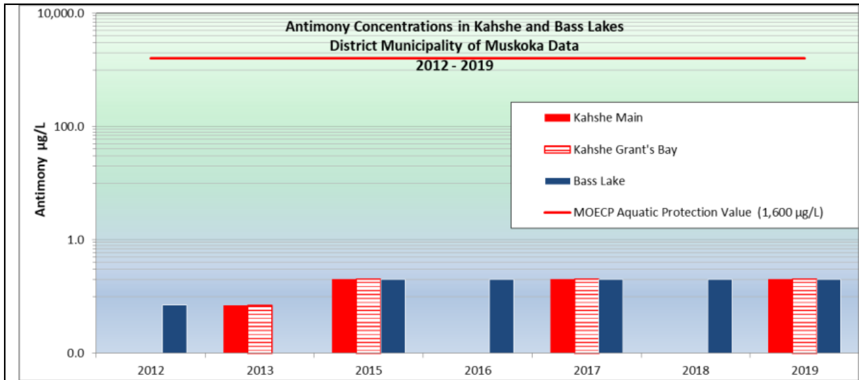
Other Chemicals

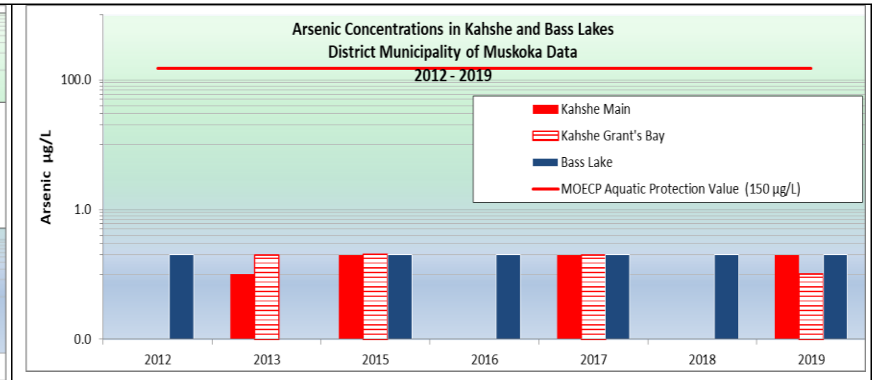


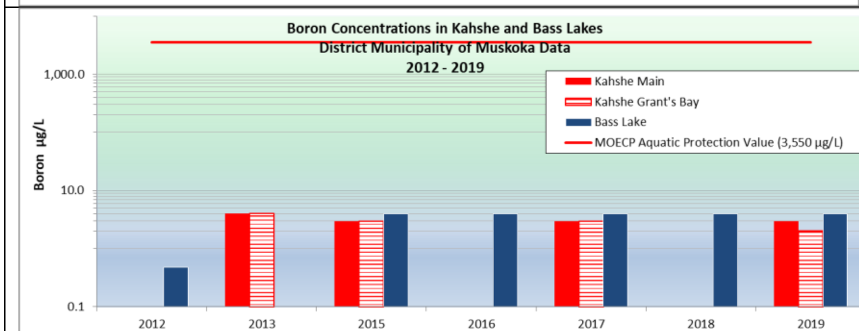


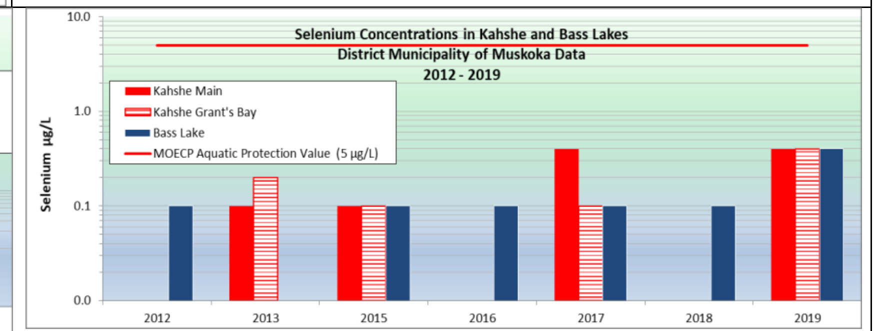


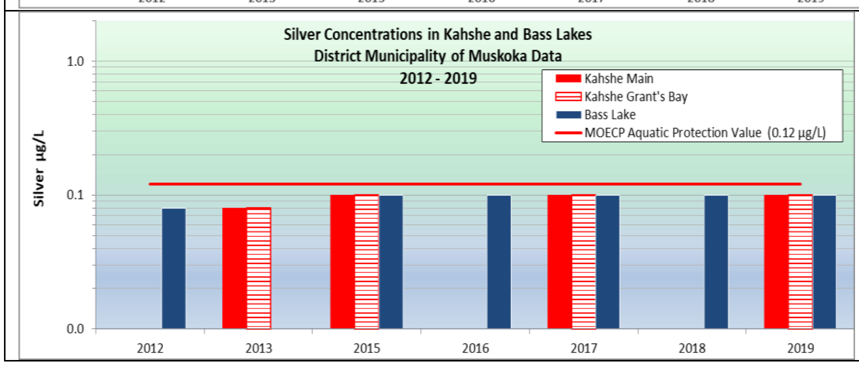
Recently Added Cations

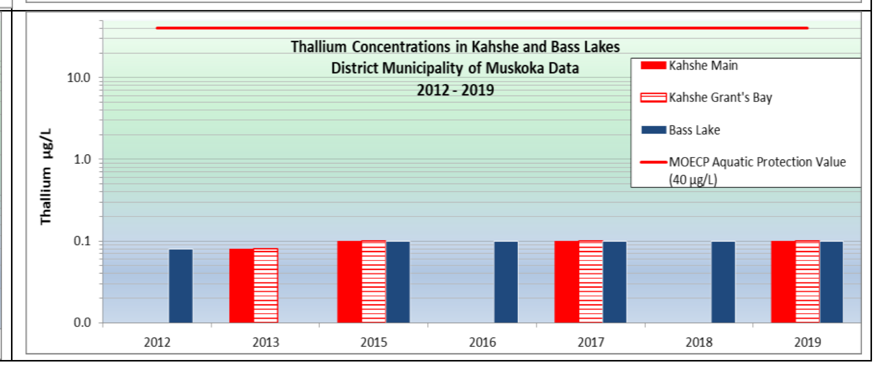

Antimony Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Antimony µg/L
10,000.0
100.0
1.0
0.0
2012
2013
2015
2016
2017
2018
2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (1,600 µg/L)

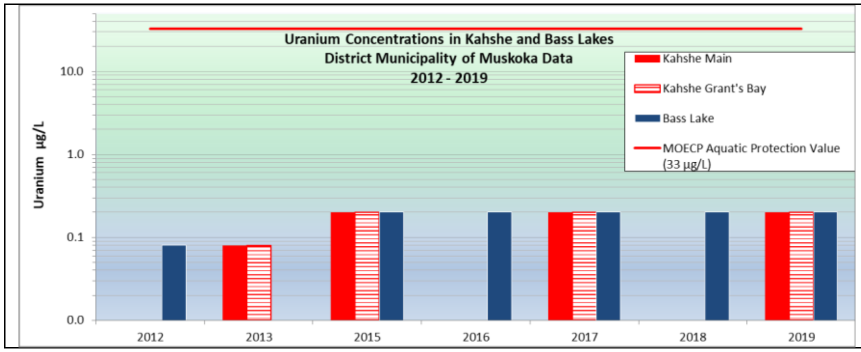

Arsenic Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Arsenic µg/L
100.0
1.0
0.0
2012
2013
2015
2016
2017
2018
2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (150 µg/L)


Boron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Boron µg/L
1,000.0
10.0
0.1
2012
2013
2015
2016
2017
2018
2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (3,550 µg/L)


Selenium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Selenium µg/L
10.0
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (5 µg/L)


Silver Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Silver µg/L
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (0.12 µg/L)


Thallium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Thallium µg/L
10.0
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (40 µg/L)


Uranium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECP Aquatic Protection Value (33 µg/L)
Uranium µg/L
10.0
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019