2018 KAHSHE AND BASS LAKE STEWARD REPORT

Kahshe Lake Steward

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

KAHSHE LAKE RATEPAYERS' ASSOCIATION - MAY 2019

2018 KAHSHE AND BASS LAKE STEWARD REPORT

TABLE OF CONTENTS

1.0 Kahshe Lake Stewardship Mandate 1
1.0 Overview of Climatic Factors and Water/Ice Conditions 2
2.0 Overview of Environmental Monitoring 5
3.0 Results of Monitoring on Kahshe and Bass Lakes 6
3.1 Nutrients, Water Clarity, Temperature and Algal Growth 7
3.2 Calcium Depletion 19
3.3 Lake Acidification 21
3.4 Anions, Cations and Other Chemicals 22
3.5 Dissolved Oxygen 25
3.6 Evaluation of Benthic Monitoring 28
4.0 Summary and Conclusions 32
5.0 References Cited 38

2018 Executive Summary

In accordance with the goals and objectives for the Kahshe Lake Steward, 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 2018. These documents as well as Executive Summaries are posted on the KLRA web-site. https://www.kahshelake.ca/ne/ls

This report summarizes the findings from sampling and analysis of both Kahshe and Bass Lakes in 2018. 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 sampling and measurement and the MOEC analyzes the samples and coordinates the data reporting.

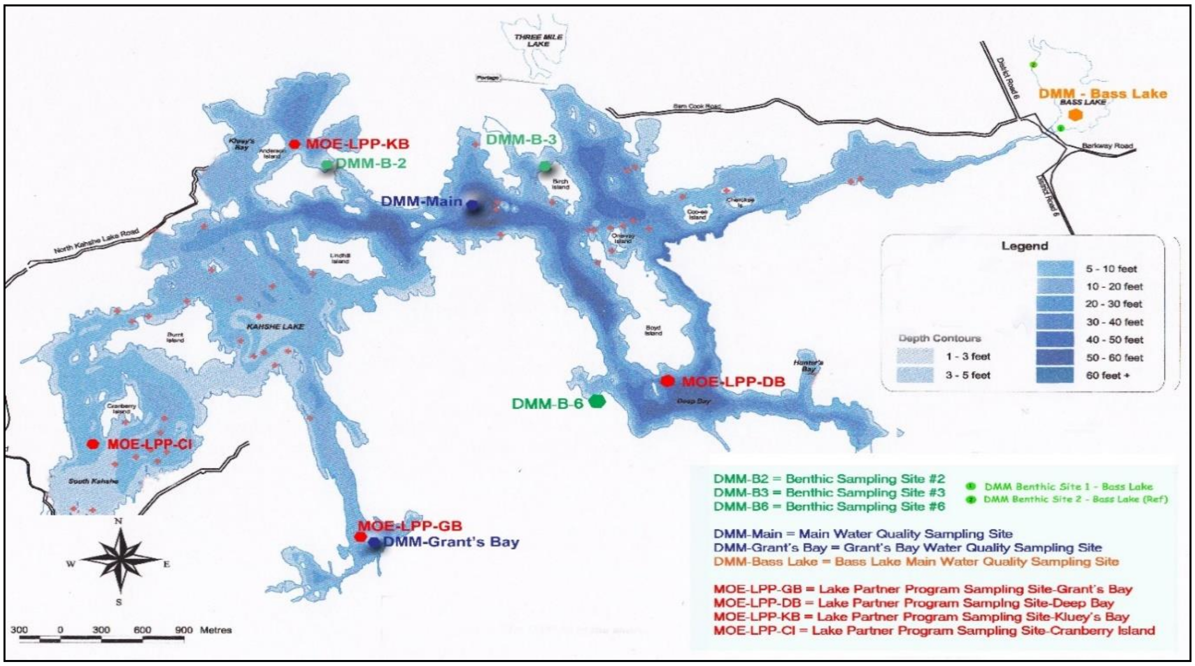
As in 2017, this report has been structured to address the following issues/areas of potential concern for both lakes. However, this year's report has been re-organized to focus more on factors associated with the development of harmful algal blooms.

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

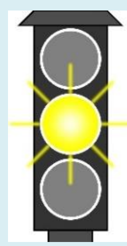
Before any discussion of the above six main areas of interest, it's also important to understand how climatic factors in 2018 compared with other years, as it is now well documented that we live in a time of changing climate conditions.

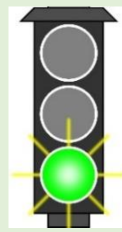
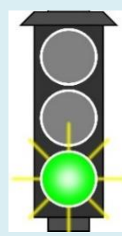
The information on weather and water/ice conditions confirmed that 2018 was significantly warmer and dryer during the summer months, with high water levels in the early spring and lower levels towards the end of summer. However, in contrast to the 125 year trend of earlier ice-out dates for the larger Muskoka Lakes, ice-out on these lakes in 2018 was much later than normal. In fact, the May 4th date was tied with 1956 as the second latest ice-out date since 1886. The ice-out date for Kahshe Lake (April 28) also was late compared to other years and in line with the reported ice-out date for the larger Muskoka lakes.

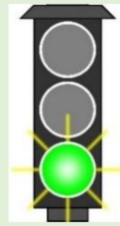
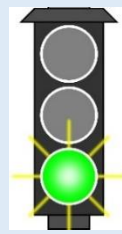
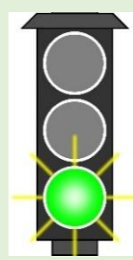
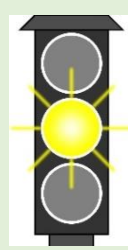
The map below shows the locations of all sampling sites for both DMM and MOECP (abbreviated to MOE) sampling programs, while the summary table that follows provides brief information on each of the six issues.



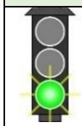
Summary of 2018 Findings for Kahshe and Bass Lakes

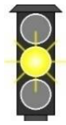
Issue	Why It's Important	Level of Concern*	Comments
Nutrients, Water Clarity, Temperature and Algal Growth	❑ Total P and Nitrogen are indicators of water quality degradation and increase the potential for algal blooms. ❑ The other factor associated with algal blooms is increasing water temperature ❑ 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	❑ 2018 results for Kahshe Lake show total P levels below Threshold and Background. ❑ In Bass Lake, the 2018 sampling results also were well below the existing Threshold level and marginally below the Background level. ❑ No upward or downward trend over almost 40 years has been detected. ❑ In the case of nitrogen, the levels are in a normal range and no trend has been detected. ❑ However, because of a late season algal bloom that was reported in Kahshe Lake in 2017, and the confirmed presence of a blue-green algal outbreak in nearby Leonard Lake and five other Muskoka water bodies in 2018 continued monitoring is essential. ❑ This is of even greater concern given the fact that the nutrient levels in Bass and to a lesser

Issue	Why It’s Important	Level of Concern*	Comments
			extent in Kahshe, are higher than in the algae impacted neighbouring lakes. ❑ Given the warmer than normal air and water temperature in 2018, climate change is now a factor that will require even greater effort to keep nutrient loading as low as possible.
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 (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.

Issue	Why It's Important	Level of Concern*	Comments
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 have been compared to chronic toxicity benchmarks from Ontario, Canada and the U.S. EPA. ❑ Sampling of Bass Lake in 2018 confirmed that most are well below aquatic benchmarks. ❑ 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, 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.	 Kahshe  Bass	❑ There are 3 locations on Kahshe Lake, but they have not been monitored since 2015. ❑ The DMM considers all 3 to be Reference Locations, and adds the findings to a database of Reference Levels across Muskoka. ❑ DMM has conducted benthic assessment at one Reference Site and one Potentially Impacted site on Bass L as part of the Transitional Lake study in 2016, 2017 and 2018. ❑ While there is some indication of potential impacts at one of the sampling locations compared to Muskoka Reference levels, there is insufficient data and significant variability to determine if any negative trend is taking place.

Issue	Why It's Important	Level of Concern*	Comments
			❑ DMM plans to continue the benthic program 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 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.

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 the 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 2018. These documents as well as Executive Summaries are posted on the KLRA web-site. https://www.kahshelake.ca/ne/ls. 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 – **<u>which is strongly not recommended</u>** - 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, 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.

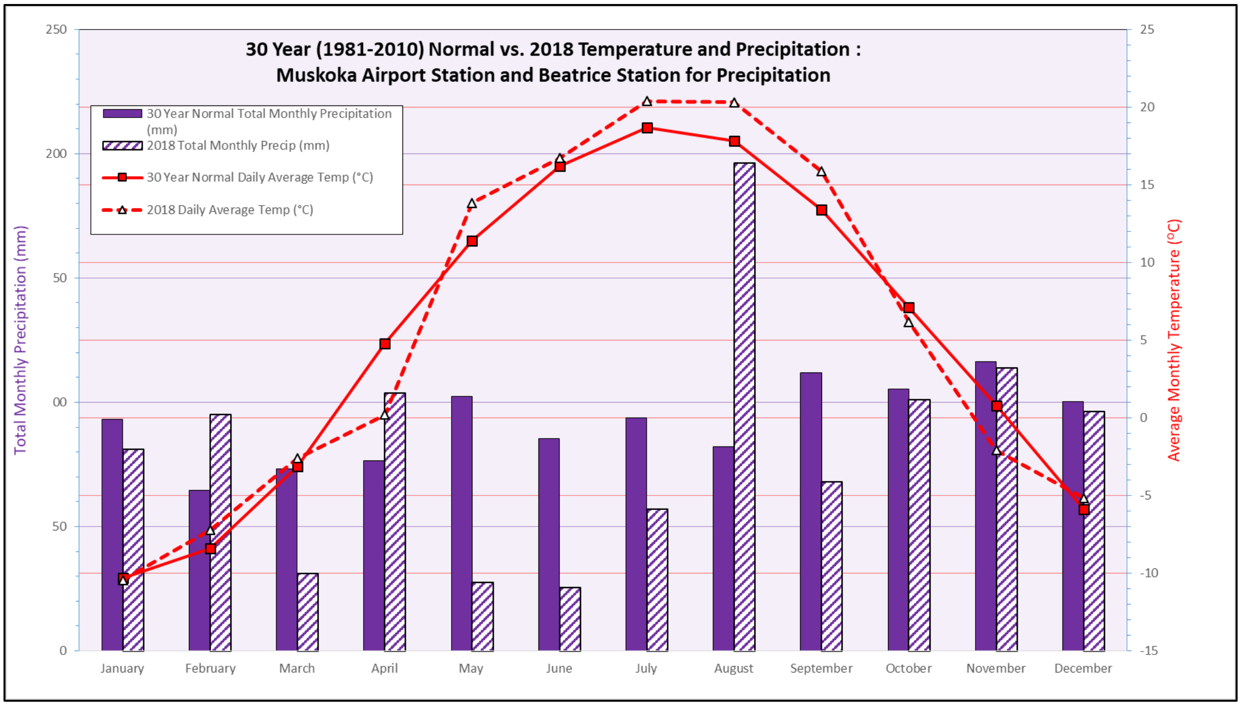
1.0 Overview of Climatic Factors and Water/Ice Conditions

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

Air Temperature and Precipitation

Air temperature and rainfall records from the Muskoka Airport and Beatrice weather monitoring stations in 2018 and earlier years were evaluated. The chart below shows the average monthly air temperature and total monthly precipitation (rain + snow) for the entire 2018 year. These results are then compared to the 30 year (1981-2010) normal monthly temperature and precipitation.

This comparison demonstrates that air temperatures in 2018 were well above the 30 year normal for the months of May through September. For the remainder of the year, the average temperature was below normal in April and November and normal for the remaining months. It comes as no surprise that precipitation was significantly lower than normal during the three warmer months of May, June and July and well above normal in August and February. Note also that for precipitation data, the results were from the Beatrice Station (north of Bracebridge), as the closer Muskoka Airport station which was used for the temperature assessment was missing a lot of precipitation data.



Water Levels

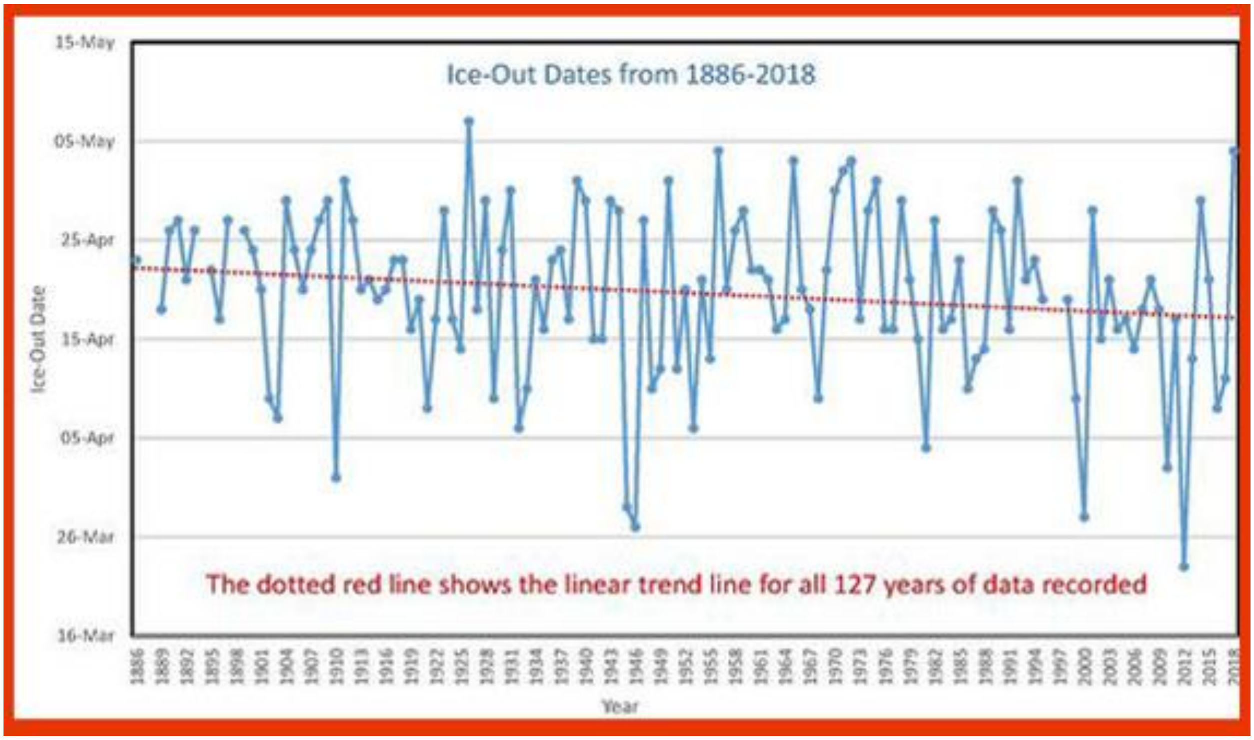
Data from the Ontario Ministry of Natural Resources (MNR) as collected at the dam near the south end of Kahshe Lake have been requested, but to date has not been provided. From memory, water levels were elevated the early spring after ice melt and were on the low side towards the end of the recreational season, likely due to the above average temperatures and below average rainfall.

Ice-Out Times

While there is no official record for ice-out times on Kahshe Lake, 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 has been updated to include 2018 and the chart of ice out dates is presented below. While the chart shows a slightly decreasing trend for ice-out dates (i.e. earlier over time), this cannot be taken as scientific evidence of earlier ice-out conditions for several reasons:

- The dates represent data collected on different lakes by different individuals;
- There is no information presented as to how the linear trend line has been produced.

That said, the 2018 ice-out date for the Muskoka lakes was May 4, which is the second latest recorded ice-out time since measurements began. On Kahshe, the approximate ice-out date was April 28, also several days later than normal.



Ice-Out Data Source and Qualifiers

* To the best of our knowledge, the following individuals were responsible for recording the Ice-Out dates referenced here:

1886-1899: The Henry Family of Minett
1900-1919: Captain John Rogers of Port Sandfield
1920-1930: Victor Croucher, Lake Joseph
1931-1945: Keith Croucher, Lake Rosseau
1946-2006: Cecil Frazer, Port Carling
2007-2016: Robert Goltz, Windermere Area Archive, Lake Rosseau

Not all Ice-Out dates were recorded in the same location or used the same methodology. Over the 130 year period referenced, there were 6 years for which we could find no recorded Ice-Out date. Those years were not included in the calculation of the average Ice-Out dates.

Climatic Factors and Water/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 the analytical findings. The information on weather and water/ice conditions confirmed that 2018 was significantly warmer and dryer during the summer months, with high water levels in the early spring and lower levels towards the end of summer. However, in contrast to the apparent 125 year trend of earlier ice-out dates for Muskoka Lakes, ice-out on Muskoka lakes was much later than normal in 2018. In fact, the May 4th date was tied with 1956 as the second latest ice-out date since 1886.

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 has consisted 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.

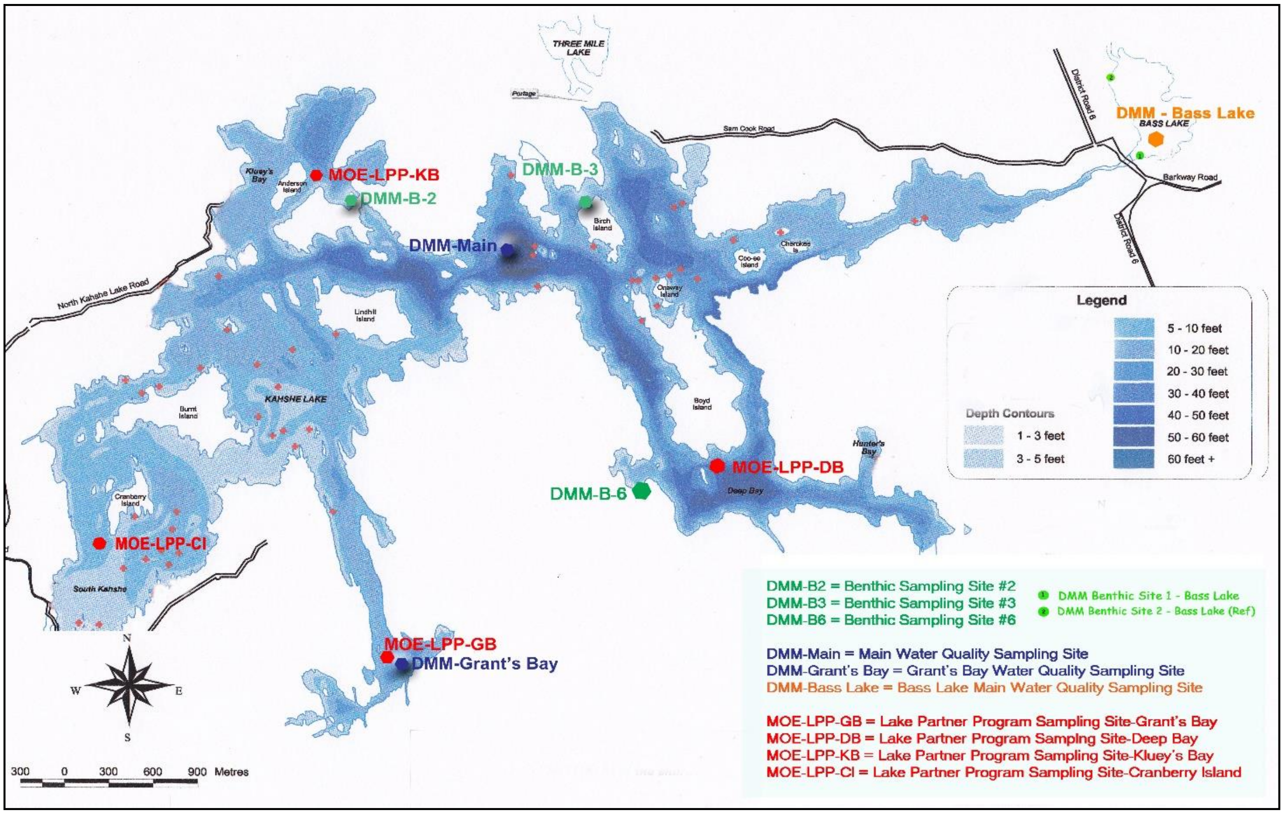
The monitoring program consists of 193 sampling sites on 164 lakes on a rotational basis. The program was designed to deliver a monitoring program which would establish a long-term record of key water quality parameters so that trends in water quality and lake system health could be identified and appropriate 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:

- Spring phosphorus sampling conducted in May or early June (2 sites in Kahshe Lake and 1 site in Bass L);
- 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 and August (2 sites in Kahshe Lake and one site in Bass Lake);
- Temperature and dissolved oxygen at increasing water depths taken in May 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 and since 2016, at one or two sites in Bass Lake.

Since the DMM program had been carried out on Kahshe Lake in 2017, sampling was not carried out in 2018. Although sampling in 2018 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 also was carried out on Bass Lake at one of two sampling locations in 2018 as part of the transitional lake sampling methodology.

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

Figure 1: Map Showing 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
- Benthic Health

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, 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, 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, here's 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:

- 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 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 <u>symptom</u> 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 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).

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 letter to property owners of lakes affected by this review, the DMM state:

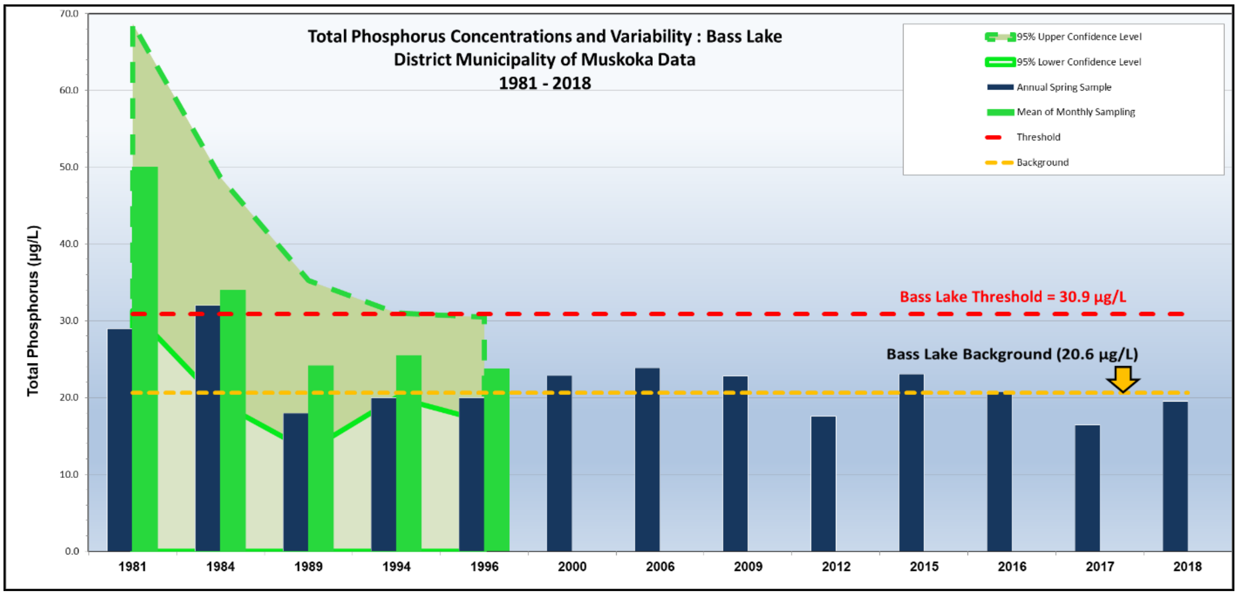
"The results of the review suggest the need for an updated approach governing development or redevelopment on lakes which reflects scientific advances in the last decade, in recognition that the existing model was too narrowly focused and had some limitations when used to evaluate an individual lake. 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 and 2018.

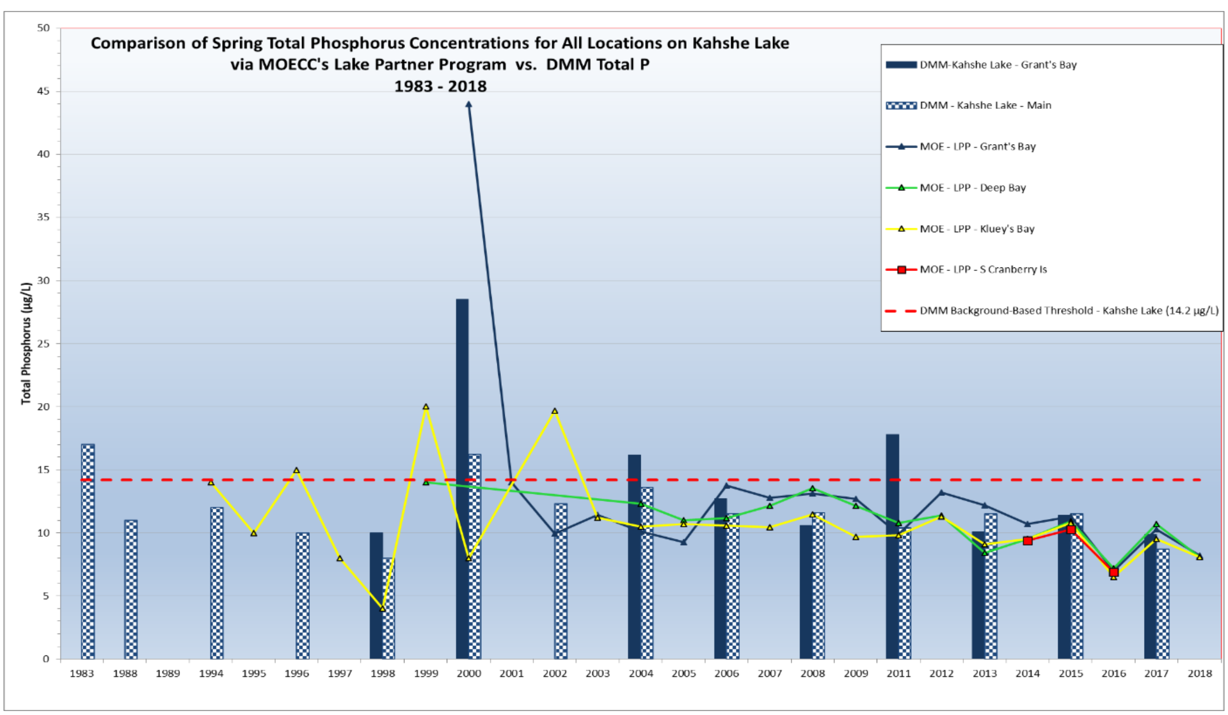
The Bass Lake total phosphorus results for 2018 as well as those of the past 30+ years are shown below:



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 2018 of 19.5 µg/L was well below the DMM's existing Threshold Level, marginally below both the Background Level and the concentration of 20 µg/L that triggered the special 'Transitional Lake' status by DMM in 2016.

As noted earlier, DMM did not sample Kahshe Lake in 2018. However, Kahshe Lake was sampled and analyzed for total phosphorus under the Lake Partner Program. The chart below shows the total phosphorus levels at the three LPP sampling sites in Kahshe Lake for 2018. 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 2018 results demonstrate a continued low level of total phosphorus (8.1, 8.1 and 8.2 µg/L) which is below both the Threshold value of 14.2 µg/L and 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 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).

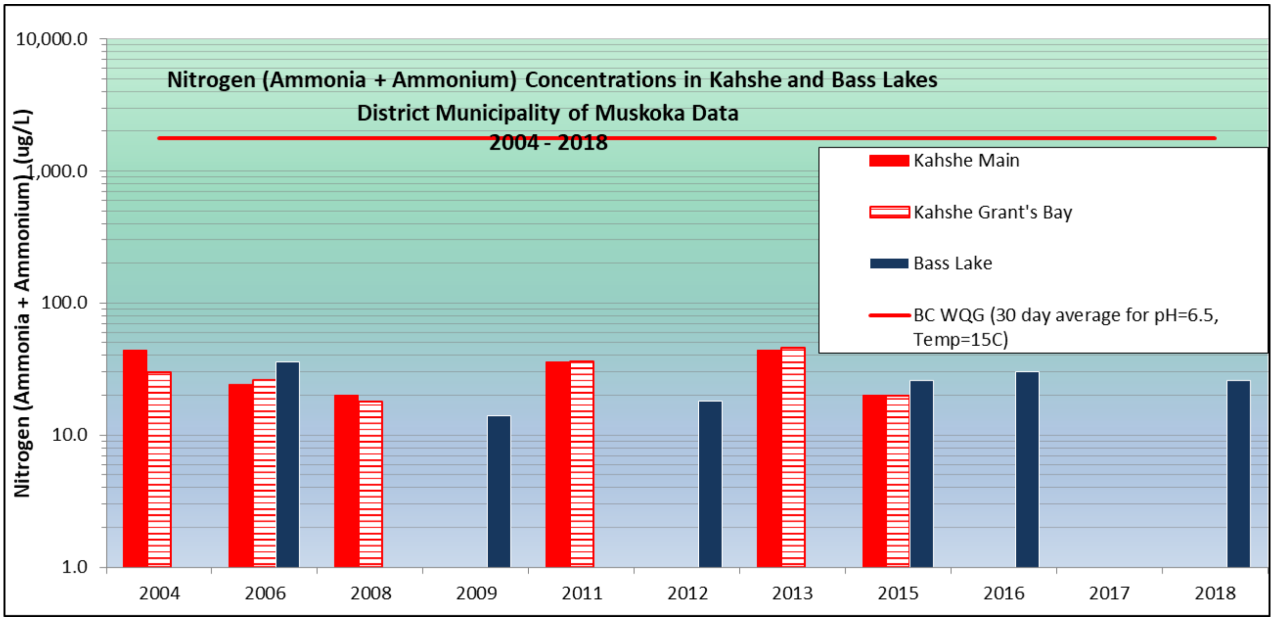
In water, nitrogen occurs in several different dissolved forms. These forms influence communities of algae and cyanobacteria in different ways, based largely on their abilities to convert the different nitrogen forms into biomass and compete with other organisms. Regardless of the form, cyanobacteria 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:

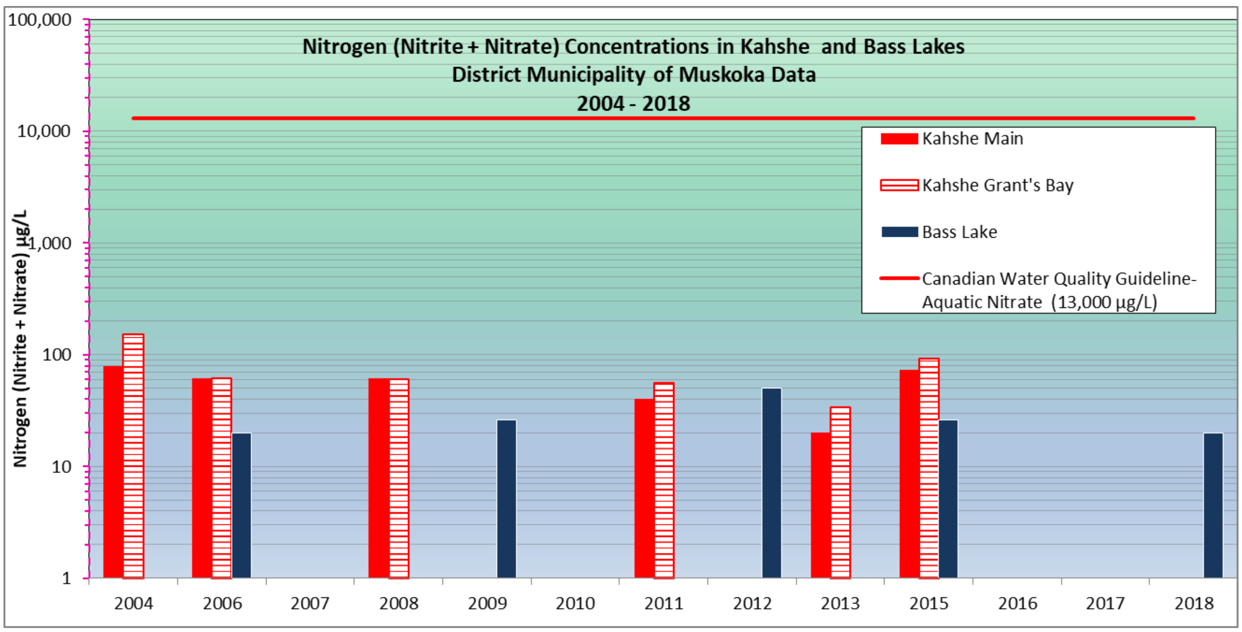
Ammonium	Urea	Nitrite	Nitrate	Atmospheric Nitrogen
Most Bioavailable				Least Bioavailable

(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.





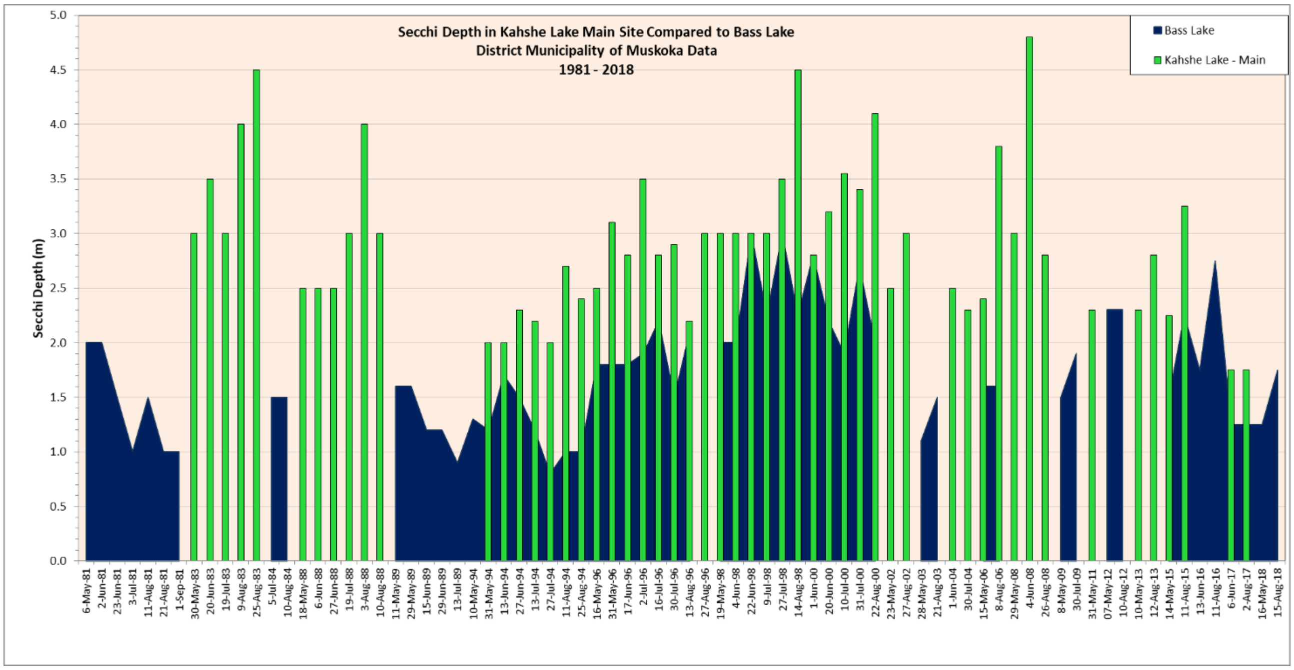
The results of this analysis have been summarized below.

- No evidence of a concentration trend in either 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 located, as the linkage between phosphorus, nitrogen and water temperature is too complex to set individual 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.

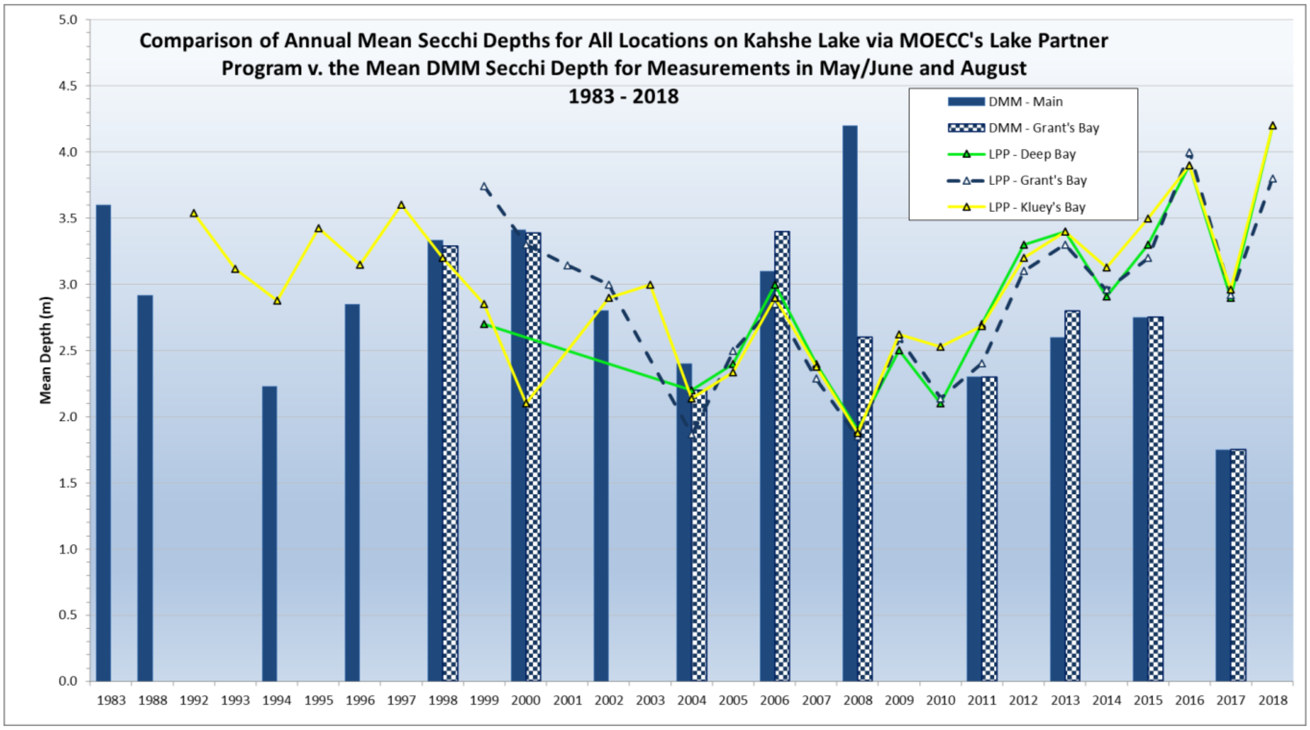
The DMM's water clarity levels for Bass Lake in 2018 and for Kahshe Lake in 2017 and earlier have been compared with the historical results dating back to 1980s in the chart that follows.



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

- Water clarity in Bass Lake in 2018 was slightly better than in 2017, but generally similar to historical measurements dating back to 1981.
- Water clarity is generally 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 depth measurements taken by the DMM in 2017 and earlier. The findings are shown below.



As noted in the previous 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 the findings for 2018 confirm an upward trend in clarity.

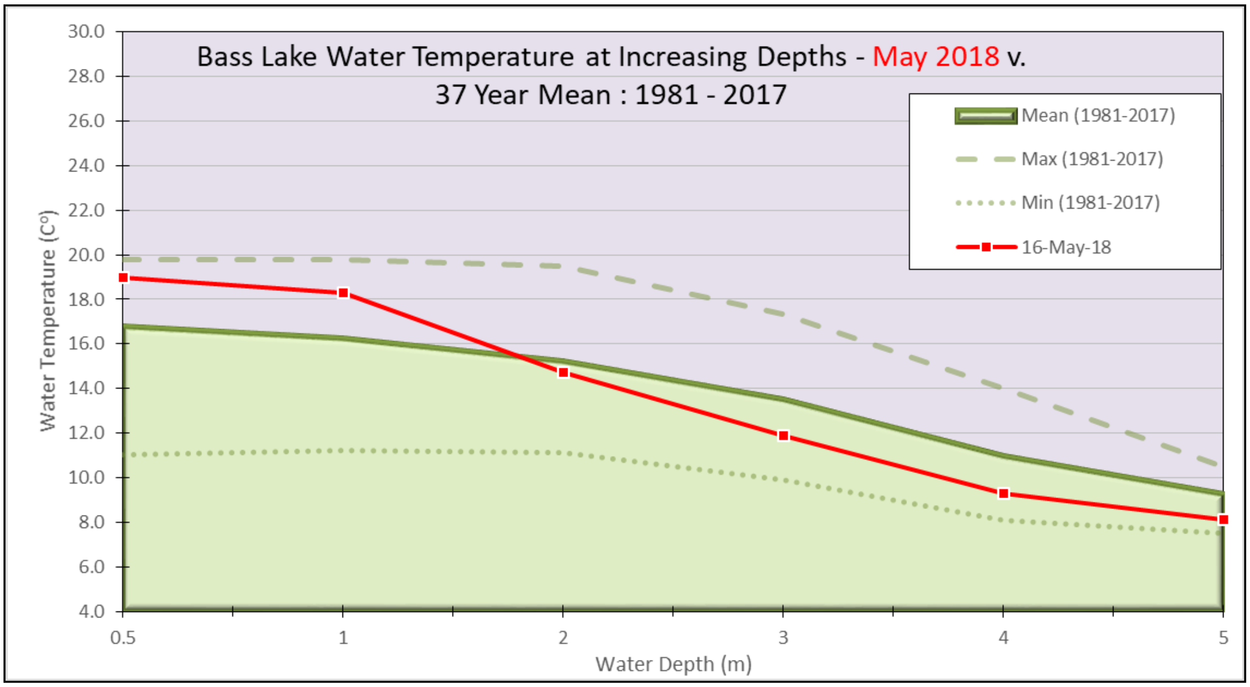
The most likely reason for the discrepancy in actual recorded depths between the DMM and LPP programs is that the DMM sampling is carried out on pre-planned dates irrespective of weather conditions, while the LPP clarity measurements are taken during days when it is sunny or at least not raining. This could account for the difference, as available sunlight can influence the depth to which the disc can be seen.

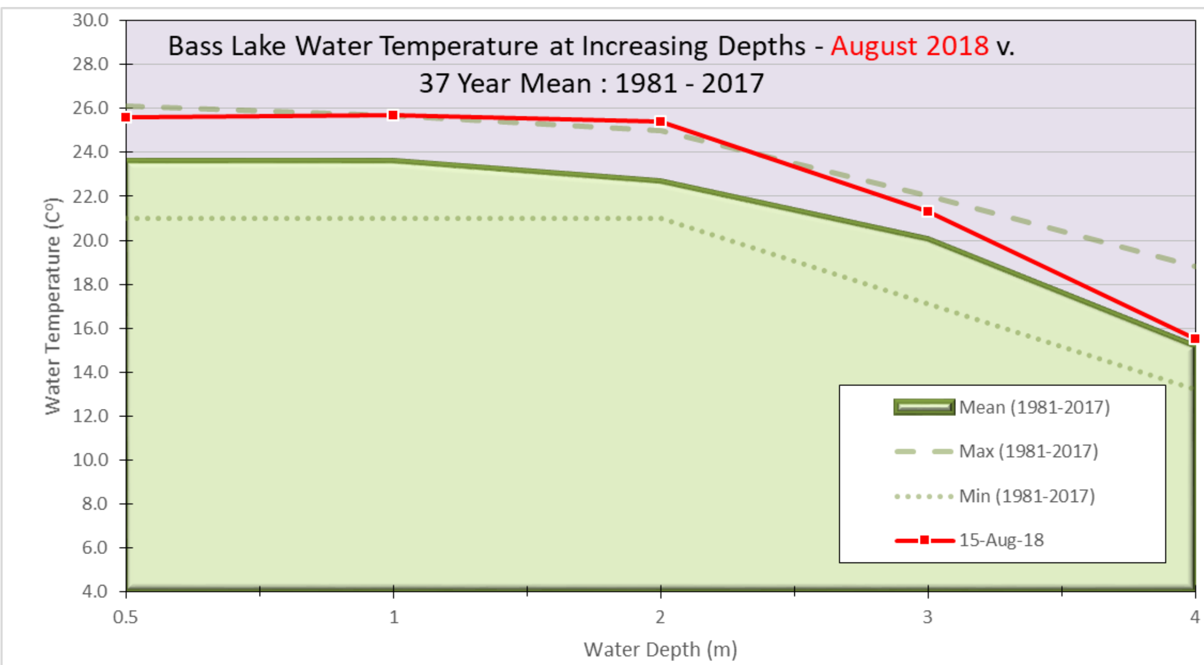
Water Temperature

The other 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 at increasing depths in Bass Lake data dating back to 1988 have been presented as an average (mean) with maximum and minimum values up to 2017, followed by the sampling measurements in June and August, 2018. The results for Kahshe Lake are not included, as there was no DMM sampling of Kahshe Lake in 2018.





It is apparent from the above two charts that water temperature in the spring of 2018 was similar to the historical average (slightly higher down to 2 m and slightly lower below 2 m). However, by August 2018, the temperature in the top 2m was well above the historical mean temperature and essentially at the upper range in the temperature over the past 37 years. Below 2m, the temperature was higher than the historical mean, but below the historical maximums.

In summary, the late summer results for Bass Lake appear in line with the findings of an analysis of the long term trend in water temperature using all Muskoka lakes which has shown a statistically significant increase in water temperature over time for all but the lowest depths (Palmer, 2005). These findings also are consistent with the warmer than normal air temperature data for 2018 which were presented and discussed earlier.

While the results from a single lake would not have the power to detect water temperature increases over time as small (approximately 1-2°C) as those reported using the larger database of all Muskoka lakes, it certainly is a finding that raises concern with respect to its role in algal bloom development.

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 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.

The findings for the three major input variables and for water clarity that have been evaluated are presented below:

Phosphorus

- In both lakes, there has been no detectable upward or downward trend in total phosphorus concentrations over the past 35 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 two times higher in Bass Lake than in Kahshe Lake, but well below the DMM's existing Threshold Level and below the expected Background concentration.
- As for Bass Lake, the total phosphorus levels in Kahshe Lake are well below the DMM's existing Threshold and Background Levels and are essentially unchanged over the past 35 years.

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. While the total phosphorus levels are about twice as high in Bass Lake compared to Kahshe, the fact that they have remained stable suggests that the loading is background based.

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 greater 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 2018 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 located, as the linkage between phosphorus, nitrogen and water temperature is 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 Bass Lake, water temperature in the spring of 2018 was similar to the historical (1981-2017) average, but by August, the temperature was well above the historical mean at all depths and above the historical maximum down to 2m depth. This finding appears in line with the findings of an analysis by the MOECP of the long term trend in water temperature using all Muskoka lakes which has shown a statistically significant increase in water temperature over time for all but the lowest depths (Palmer, 2005). These findings also are consistent with the warmer than normal air temperature data for 2018 which were presented and discussed earlier.

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 2018 results are summarized below:

- Water clarity in both Kahshe and Bass Lake in 2018 was noticeably better compared to 2017 and historical levels.
- The water clarity findings confirm that water clarity is generally better in Kahshe than in Bass Lake, possibly due to the higher DOC concentrations in Bass Lake.

Algal Growth

As noted in last year's report, an algal bloom was recorded at the east end of Kahshe Lake in November 2017 and the MOECP's Environmental Monitoring and Reporting Branch 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; 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 2018. The lakes/creeks with blue-green algal blooms in 2018 included:

- Three Mile Lake
- Lake Rosseau – Clark Falls
- Lake Rosseau - Boyd Bay, Indianhead Harbour
- Lake St. John
- Leonard Lake - South West Bay
- Lamont Creek (Wasaga Beach area)

To further explore the relationship between blue-green algal blooms and total phosphorus levels, the spring turnover total phosphorus levels in the three closest of the above water bodies to Kahshe and Bass Lakes were examined and in all cases total phosphorus concentrations in Bass Lake were well above those in any of the other algal impacted lakes. One of the impacted lakes had a lower total phosphorus concentration than the levels in Kahshe Lake while the levels in the other two impacted lakes were only marginally higher than those in Kahshe Lake.

Obviously, these findings are of concern, as it is apparent that a focus on total phosphorous concentrations as an indicator of potential algal bloom development is not going to ensure protection from harmful algal blooms. However, until this is explored more scientifically by examining the water chemistry/temperature profile of each impacted lake in 2018, it would appear reasonable to conclude that given the unusually warm summer in 2018, the most likely candidate driver for these blooms was elevated water temperature. Not conclusive, but certainly suggestive.

Accordingly, we must remain vigilant about maintaining the low total phosphorus and stable 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. This would seriously impact property values.

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. Arguably it is a dominant zooplankton species on the Shield. 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.

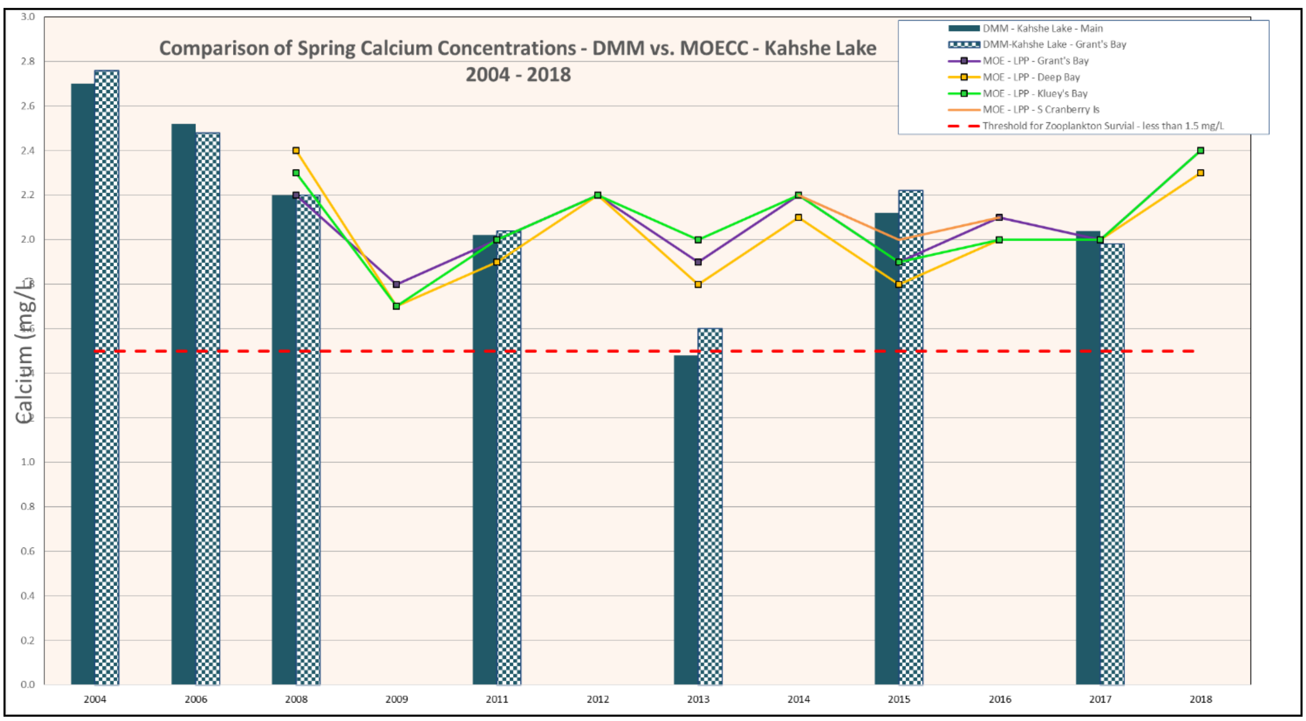
In our Muskoka lakes, the absolute abundance of *Holopedium* has increased by an average of about two fold over the last 20 years, and the relative abundance has increased more, said Yan, while the abundance of five species of *Daphnia* has declined. There are two other, smaller species of *Daphnia* 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 (2.36 mg/L in 2018) also were above the lower limit of 1.5 mg/L, they have not been separately charted.



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, but not all.
- While 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.

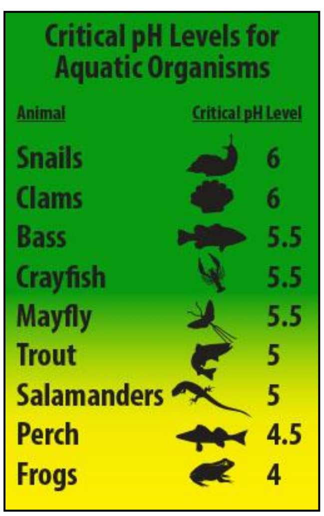
Levels of calcium below the growth limiting threshold range of 1.5 mg/L have not been identified in the sampling of Kahshe or Bass Lakes. However, as the calcium concentrations in both lakes are only marginally above the limiting value and as this threshold would not be protective of all aquatic organisms, 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 pH of about 5.6.

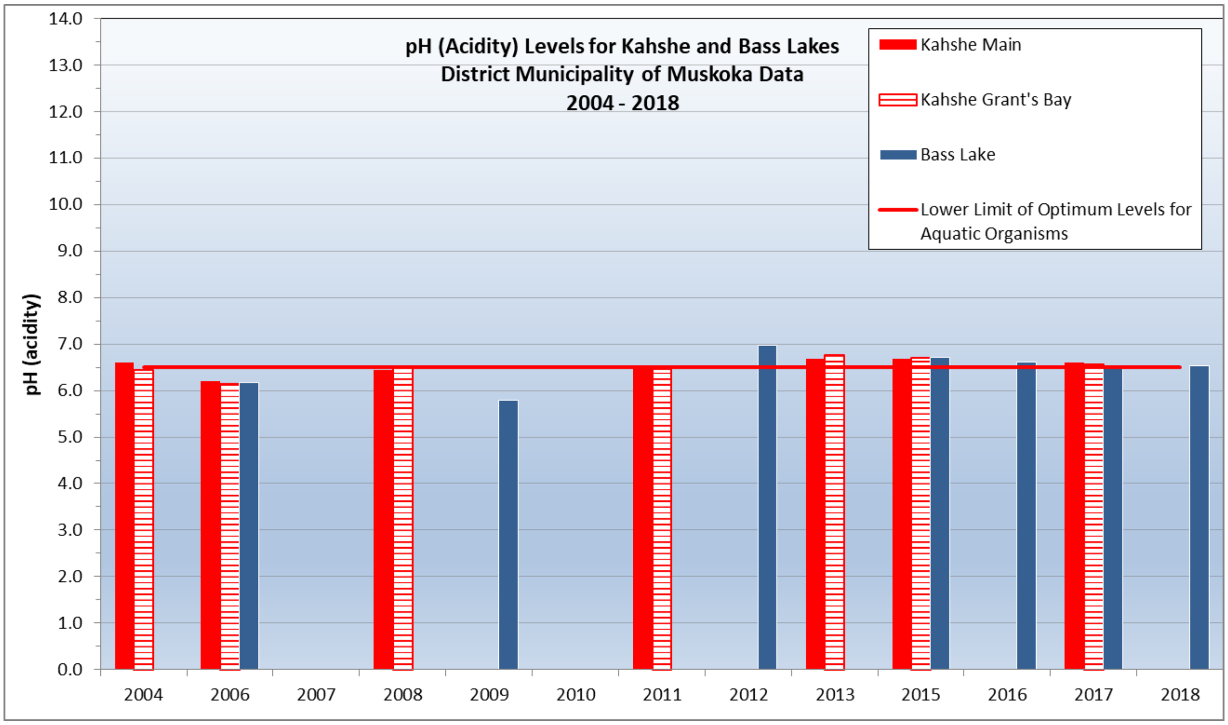
Although source-oriented acid gasses and particulates have contributed significantly to the acidification of lakes in Ontario, particularly around major sulphur sources in the Sudbury basin, there has been noticeable recovery over the last two decades as emission controls were implemented. The ingress 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 2018.



It is apparent from this chart that the acidity of both Kahshe and Bass Lakes is generally within the lower end of the optimum pH range of 6.5-8.5 and generally above the level of 6.0 where impacts to some sensitive aquatic species might be encountered (see EPA chart above). There is also no 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 recommended.

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 for each monitored lake.

The full suite of chemicals analyzed via the DMM sampling program in 2018 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 new chemicals 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 chemicals 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 and a summary of the findings has been presented in Table 1 below.

Table 1: Summary of Chemical Analysis Results – Bass Lake – 2018

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
Anions	Chloride	MOECP APV	All reported values well below aquatic benchmark. Note that the chart uses a logarithmic scale.
	Nitrogen (Nitrite + Nitrate)		All reported values well below aquatic benchmark. Note that the chart uses a logarithmic scale.
	Nitrogen (Ammonia + Ammonium)		All reported values well below aquatic benchmark. Note that the chart uses a logarithmic scale.
	Nitrogen (total Kjeldahl)	None Found	No benchmark
	Sulphate	BC AWQC	All reported values well below benchmark
Cations	Aluminum	U.S. EPA CCC	All reported values at or marginally above the Findings in most years for Bass Lake are marginally above the interim Canadian Water Quality Guideline. Note that the CWQG for Al is both pH and DOC dependent. As such, I've used the low end of the range of CWQGs based on the pH and DOC levels.

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
	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 also in two earlier years prior to 2018. The early exceedances are likely a sampling or laboratory quality control issue. Similarly, the apparent increase in the 2018 level for Bass Lake is due to a change in the Laboratory MDL values which now exceed the APV. Worth watching this one, but no impacts expected.
	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 appear to be generally higher than those of Kahshe Lake. This is confirmed with the 2018 level for Bass Lake.
	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 benchmark
	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	No benchmark
	Sodium	MOECP APV	All reported values well below benchmark. 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	No benchmark
	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 at or slightly higher than 7 mg//L, which is the Ontario aesthetic objective for recreational use.
	Electrical Conductivity	None Found	No benchmark
	Alkalinity	DMM Notes	Although there is no benchmark, the alkalinity of both Kahshe and Bass Lakes is below 10 mg/L, indicating that

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
			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 and Climate Change – 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

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 appear to exceed their respective aquatic benchmarks. Accordingly, until the laboratory detection limits for these substances are improved, they will continue to show as false positives. 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.

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.

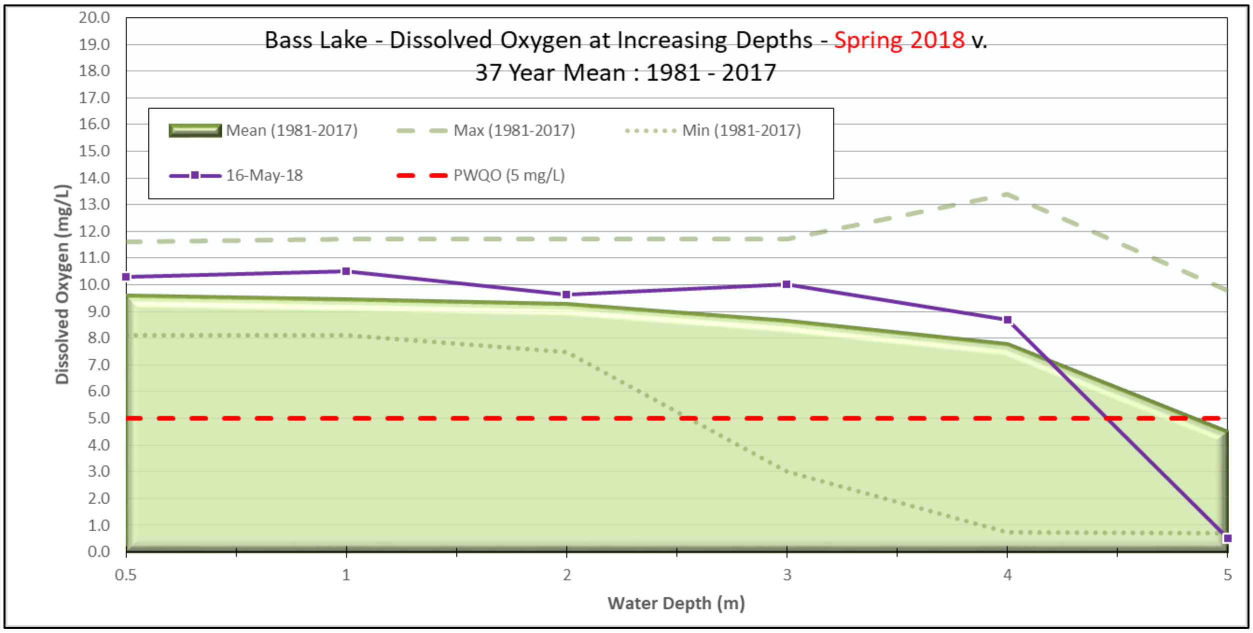
In addition to the consumption of oxygen by fish and other aquatic organisms, the decomposition of organic matter in all layers of the lake consumes oxygen. However, because of the minimal mixing of upper and lower layers of lake water during the ice-free period (referred to as thermal stratification), 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 (after the ice has melted) and these lower waters do not get re-oxygenated until the late fall turnover again takes place.

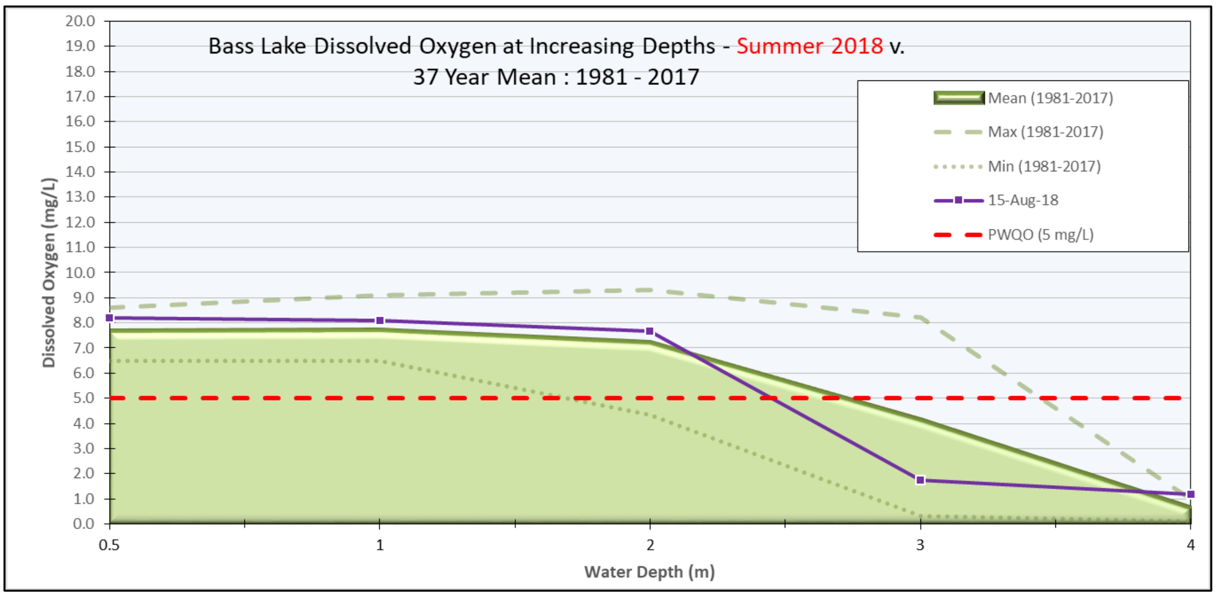
Water temperature also plays a role in the dissolved oxygen cycling process, as warm water becomes saturated at lower concentrations than required for cold water. However, the bottom line is that the colder waters near the bottom of the lake become gradually depleted of oxygen over the ice-free period 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 other agencies have set DO benchmarks in the 3-4 mg/L range.

To examine the DMM findings for DO, the mean, maximum and minimum for all sampling up to 2017 are plotted against the results for 2018 and the desirable aquatic objective of 5 mg/L. As only Bass Lake was sampled in both the spring and late summer of 2018, the chart for Bass Lake only is presented below.





In the case of Bass Lake, the spring sampling results in 2018 are similar to the historical average and well above the PWQO down to about 4.5 m, which is close to the bottom of the lake. By mid-August, the DO levels in late summer drop below the PWQO at about 2.5 m depth which is similar to the historical mean levels. While the result for 2018 shows more limiting DO than the historical average, it is still within the maximum-minimum range for the historical mean concentrations.

As DO levels are strongly linked to the lake stratification process (vertical circulation of water) there are many factors that could be responsible for this late summer decrease in DO to levels below average results recorded historically. This would be particularly true for a fairly shallow and small area lake like Bass L.

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 late summer at different water depths in Bass Lake for 2018 are summarized below. In the evaluation, the results for 2018 are compared to the mean results for the years from 1981 through 2017. In addition to the means, the maximum and minimum values over this span have been presented for comparison purposes.

- The Bass Lake DO results for 2018 are generally similar to the historical mean and within the maximum and minimum levels recorded during the 35+ year monitoring period.
- As expected, DO is higher in the spring and more evenly distributed with depth.
- By late summer, the 2018 DO levels start to decrease at about the same depth as for the historical mean but decrease to lower levels compared to the historical average; however, they remain within the historical maximum and minimum levels.

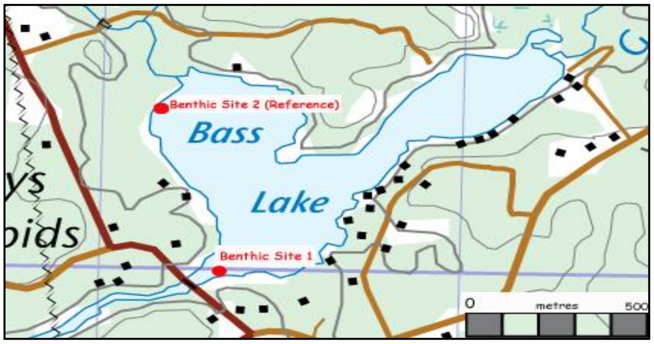
3.6 Evaluation of Benthic Monitoring

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.

Benthic monitoring provides an indirect measure of water quality and habitat disturbance, as the composition of the aquatic-invertebrate community and the relative abundances of different species can be used to evaluate the health of the ecosystem.

Aquatic invertebrates that are present in bottom sediments include worms, mollusks, insects, crustaceans, and mites. These animals are sensitive indicators of the health, or condition of lakes and streams, as different species have different sensitivities to environmental changes such as pollution or habitat alteration. Aquatic invertebrates live from one to three years and are in constant contact with lake sediments.

The DMM carried out benthic sampling at two locations on Bass Lake which were set up in 2016 as part of the Transitional Lake study. The two Bass Lake locations are shown on Figure 2 below. Note that one of the locations (Site 2) is considered a Reference Site and is located in an area that will help define the normal range of biological conditions for a given habitat type in Muskoka. Reference sites are not expected to represent ‘pristine’ conditions; rather, they reflect biological conditions in areas where impacts from several types of human disturbance are likely to be minimal.



It should be noted that all three benthic monitoring sites (Sites 2, 3 and 6) on Kahshe Lake as well as Site 2 on Bass Lake are considered Reference Sites, and as such, the data from these sites has been incorporated into the Muskoka Reference site database which is used for comparison with individual lake sampling results.

Figure 2: Map Showing Location of Benthic Monitoring Sites on Bass Lake

As in 2017, the results of the Bass Lake benthic sampling and analysis have been compared to the 10 year (2007-2016) Muskoka Reference average, which is based on 90 sampling sites on 41 lakes between 2007 and 2016. In order to better understand the variability that is associated with the average from the Muskoka Reference sites, the DMM was contacted and provided the results from each lake. From this data, the averages for each of the various indices (except HBI) were statistically evaluated to generate a 95% Upper and Lower Confidence Level for the mean index values as well as maximum and minimum values.

The Bass Lake findings for all locations that have been evaluated since monitoring began in 2016 have been presented in chart form below.

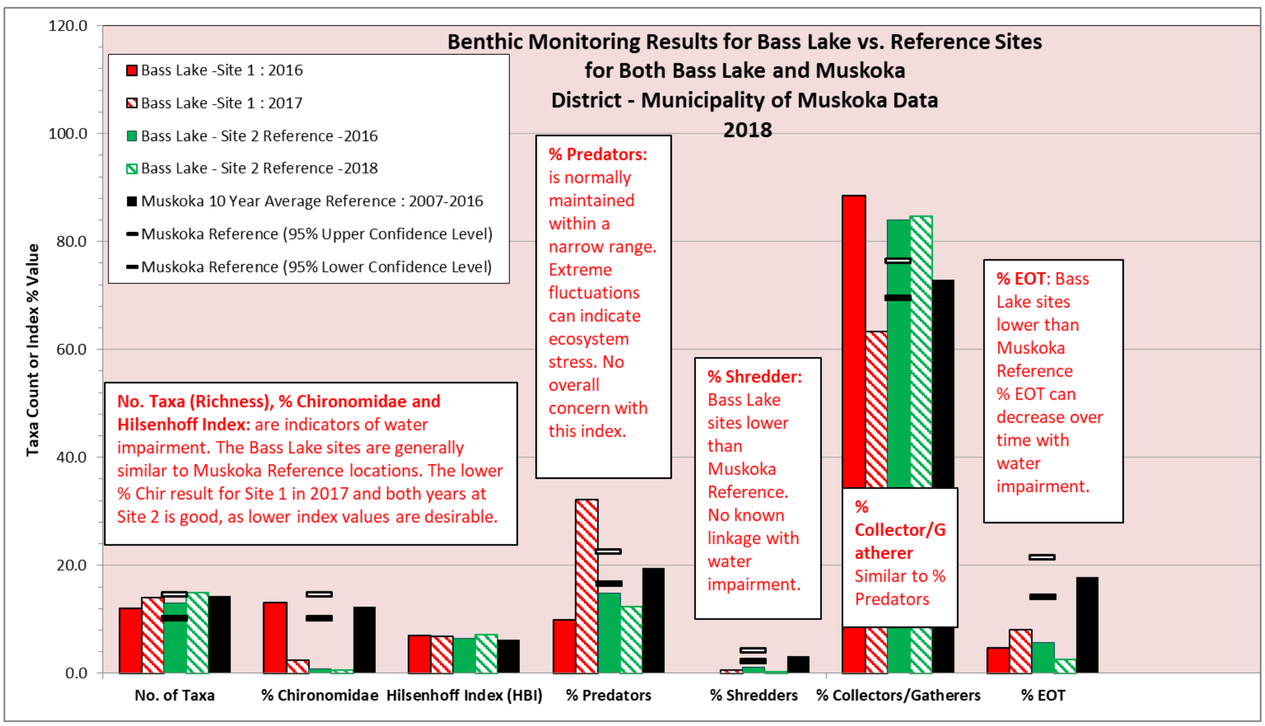
To understand how the sample findings are compared, it is necessary to understand the scoring system which uses indices of organism groupings as shown in Table 2 below.

Table 2: Benthic Indices used to summarize aquatic invertebrate composition in Muskoka.

Indicator	What it tells us
Number of taxa collected (Species Richness)	The number of taxa is a measure of biological diversity. Richness increases with increasing habitat diversity, suitability, and water quality; therefore, the healthier a site's community, the greater it's number of taxa.
Percent of collection made-up of mayflies, dragonflies, damselflies, and caddisflies (% EOT)	Ephemeroptera (mayflies), Odonata (dragonflies and damselflies), and Trichoptera (caddisflies) are very sensitive to pollution and habitat alteration. They should be prominent in healthy ecosystems, but their numbers will decline in response to stress imposed by human activities.
Percent of collection made-up of midges (% Chironomidae)	Midges (true flies in the family Chironomidae) are tolerant of pollution and habitat changes so their dominance indicates water quality problems.
Percent of collected animals that are predators (% predators)*	In a healthy ecosystem, the numbers of predators and prey are maintained within a narrow range. Extreme fluctuations in this balance signify that the ecosystem is under stress.
Percent of collected animals that are adapted to feeding on coarse plant matter (% shredders)*	Shredders are a group of plant eaters adapted to breaking down leaves, wood, and other plant matter that originates on land but gets transported into waterbodies. Such animals should be abundant if there is a good connection between a lake and its watershed. In addition to recycling nutrients, shredders are food for other animals.

Indicator	What it tells us
Percent of collected animals that are adapted to feeding by collecting small pieces of organic matter (% collector/gatherers)*	Collector-gatherers feed on small pieces of organic matter that arise from the processing activities of shredders (described above). Their presence indicates a good population of shredders, which provide them with food. Like shredders, these animals perform a vital role in energy cycling, and are prey for other animals.
Organic pollution score (Hilsenhoff Biotic Index : HBI)	The Hilsenhoff Biotic index combines information about the abundances of different types of animals collected at a site with information about those animals' sensitivities to sewage pollution, farm wastes, and other sources of nutrients like phosphorus, nitrogen, and carbon. High values of this index indicate pollution; low values indicate good water quality.
∗ In healthy ecosystems, the proportion of the aquatic-invertebrate community that is made-up of predators, shredders, collector/gatherers, and other animals is maintained within a narrow range. Marked divergences in abundances of any type of animal signifies a stressed ecosystem.	

The results for all benthic sampling on Bass Lake are shown below and discussed following the chart. Note that in the case of the Muskoka Reference sites, the chart shows the average (black column) as well as the Upper and Lower Confidence Interval (black and white tick marks) based on a 95% level of probability.



The results from the third year of benthic sampling on Bass Lake (2018) along with the earlier index values from sampling in 2016 and 2017 are summarized below and on the chart itself. Note that the DMM opted to conduct the 2018 sampling at Site 2, which has been identified as a Reference site. Keep in mind that the Muskoka reference results (Mean and Upper and Lower Confidence Intervals) are shown in black.

- The first three indicators of water impairment (No. Taxa, % Chironomidae and HBI) at Site 1 in 2016 and 2017 (red columns) are, with one exception, all within the Upper and Lower Confidence Limits for the Muskoka Reference data. The exception is the result for % Chironomidae at Site 1 in 2017, which is below the Lower Confidence Interval of the Muskoka reference data. This was also the case for the Site 2 results in both 2016 and 2018. However, the lower Bass Lake index values actually is a desirable finding, as lower percentages of Chironomidae good water quality as the index values for these organisms typically increase in locations with water impairment.

- The next three indicators (%Predators, %Shredders and %Collectors/Gatherers show significant variability, with some results higher and some lower than the Muskoka Reference values. As there is no known linkage for these indicators with impaired water quality, these findings appear normal.

- The one indicator (% EOT) where lower values can signal the potential of impaired water quality and possible impacts on aquatic vertebrate health shows some potential stress effects at Site 1 in both 2016 and 2017 and Site 2 in 2016 and 2018. In each case, the % EOT index values were lower than the Muskoka average and its lower confidence level (but within the Muskoka Reference site maximum and minimum range).

Based on the above findings there is some evidence of benthic population characteristics that are indicative of impaired benthic health at both Bass Lake sites. However, given the variability of the data and the limited time period over which data have been collected, any definitive conclusion regarding benthic health would require a much more extensive period of monitoring and more sites to enable the data to be scientifically evaluated and significant differences statistically isolated from the variability that is typical of this type of monitoring.

Benthic Health Summary

Benthic monitoring of aquatic invertebrates is carried out to provide an indirect biological measure of water quality and habitat disturbance, as the composition of the benthic community and the relative abundances of different species can be used to evaluate the health of the ecosystem. Aquatic invertebrates that are present in bottom sediments include worms, mollusks, insects, crustaceans, and mites.

The results from 2018 as well as previous years (2016 and 2017) of benthic sampling on Bass Lake showed both some positive outcomes (lower % Chironomidae index values) as well as negative outcomes (lower % EOT index values). The other indicators (% Predators, % Shredders and % Collectors/Gatherers) showed a typical amount of variability relative to the Muskoka Reference values and are not known to be indicative of impaired water quality or invertebrate health.

Based on the above findings there is some evidence of benthic population characteristics that are indicative of impaired benthic health at both sites in all three years. However, given the variability of the data and the limited time period over which data have been collected, any definitive conclusion regarding benthic health would require a much more extensive period of monitoring and more sites to enable the data to be scientifically evaluated and significant differences statistically isolated from the variability that is typical of this type of monitoring.

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 http://www.kahshelake.ca.

This report captures the findings from sampling and analysis of both Kahshe and Bass Lakes in 2018.

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
- Benthic Health

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 the analytical findings. The information on weather and water/ice conditions confirmed that 2018 was significantly warmer and dryer during the summer months, with high water levels in the early spring and lower levels towards the end of summer. However, in contrast to the 125 year trend of earlier ice-out dates for the larger Muskoka Lakes, ice-out on these lakes was much later than normal in 2018. In fact, the May 4th date for Muskoka lakes (April 28 for Kahshe Lake) was tied with 1956 as the second latest ice-out date since records were started in 1886.

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 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.

The findings for the three major input variables and for water clarity that have been evaluated are presented below:

Phosphorus

- In both lakes, there has been no detectable upward or downward trend in total phosphorus concentrations over the past 35 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 two times higher in Bass Lake than in Kahshe Lake, but well below the DMM's existing Threshold Level and below the expected Background concentration.
- As for Bass Lake, the total phosphorus levels in Kahshe Lake are well below the DMM's existing Threshold and Background Levels and are essentially unchanged over the past 35 years.

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. While the total phosphorus levels are about twice as high in Bass Lake compared to Kahshe, the fact that they have remained stable suggests that the loading is background based.

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 greater 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 2018 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 located, as the linkage between phosphorus, nitrogen and water temperature is 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 Bass Lake, water temperature in the spring of 2018 was similar to the historical (1981-2017) average, but by August, the temperature was well above the historical mean at all depths and above the historical maximum down to 2m depth. This finding appears in line with the findings of an analysis by the MOECP of the long term trend in water temperature using all Muskoka lakes which has shown a statistically significant increase in water temperature over time for all but the lowest depths (Palmer, 2005). These findings also are consistent with the warmer than normal air temperature data for 2018 which were presented and discussed earlier.

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 2018 results are summarized below:

- Water clarity in both Kahshe and Bass Lake in 2018 was noticeably better compared to 2017 and historical levels.
- The water clarity findings confirm that water clarity is generally better in Kahshe than in Bass Lake, possibly due to the higher DOC concentrations in Bass Lake.

Algal Growth

As noted in last year's report, an algal bloom was recorded at the east end of Kahshe Lake in November 2017 and the MOECP's Environmental Monitoring and Reporting Branch 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; 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 2018. The lakes/creeks with blue-green algal blooms in 2018 included:

- Three Mile Lake
- Lake Rosseau – Clark Falls
- Lake Rosseau - Boyd Bay, Indianhead Harbour
- Lake St. John
- Leonard Lake - South West Bay
- Lamont Creek (Wasaga Beach area)

To further explore the relationship between blue-green algal blooms and total phosphorus levels, the spring turnover total phosphorus levels in the three closest of the above water bodies to Kahshe and Bass Lakes were examined and in all cases total phosphorus concentrations in Bass Lake were well above those in any of the other algal impacted lakes. One of the impacted lakes had a lower total phosphorus concentration than the levels in Kahshe Lake while the levels in the other two impacted lakes were only marginally higher than those in Kahshe Lake.

Obviously, these findings are of concern, as it is apparent that a focus on total phosphorous concentrations as an indicator of potential algal bloom development is not going to ensure protection from harmful algal blooms. However, until this is explored more scientifically by examining the water chemistry/temperature profile of each impacted lake in 2018, it would appear reasonable to conclude that given the unusually warm summer in 2018, the most likely candidate driver for these blooms was elevated water temperature. Not conclusive, but certainly suggestive.

Accordingly, we must remain vigilant about maintaining the low total phosphorus and stable 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. This would seriously impact property values.

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 recommended.

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 appear to exceed their respective aquatic benchmarks. Accordingly, until the laboratory detection limits for these substances are improved, they will continue to show as false positives. 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.

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 late summer at different water depths in Bass Lake for 2018 are summarized below. In the evaluation, the results for 2018 are compared to the mean results for the years from 1981 through 2017. In addition to the means, the maximum and minimum values over this span have been presented for comparison purposes.

- The Bass Lake DO results for 2018 are generally similar to the historical mean and within the maximum and minimum levels recorded during the 35+ year monitoring period.
- As expected, DO is higher in the spring and more evenly distributed with depth.
- By late summer, the 2018 DO levels start to decrease at about the same depth as for the historical mean but decrease to lower levels compared to the historical average; however, they remain within the historical maximum and minimum levels.

Benthic Health Summary

Benthic monitoring of aquatic invertebrates is carried out to provide an indirect biological measure of water quality and habitat disturbance, as the composition of the benthic community and the relative abundances of different species can be used to evaluate the health of the ecosystem. Aquatic invertebrates that are present in bottom sediments include worms, mollusks, insects, crustaceans, and mites.

The results from 2018 as well as previous years (2016 and 2017) of benthic sampling on Bass Lake showed both some positive outcomes (lower % Chironomidae index values) as well as negative outcomes (lower % EOT index values). The other indicators (% Predators, % Shredders and % Collectors/Gatherers) showed a typical amount of variability relative to the Muskoka Reference values and are not known to be indicative of impaired water quality or invertebrate health.

Based on the above findings there is some evidence of benthic population characteristics that are indicative of impaired benthic health at both sites in all three years. However, given the variability of the data and the limited time period over which data have been collected, any definitive conclusion regarding benthic health would require a much more extensive period of monitoring and more sites to enable the data to be scientifically evaluated and significant differences statistically isolated from the variability that is typical of this type of monitoring.

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 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.

5.0 References Cited

B.C. 2000. Ambient Water Quality Guidelines for Sulphate. Ministry of Environment, Lands and Parks, Province of British Columbia. Technical Appendix, November 2000.

B.C. 2001a. Ambient Water Quality Guidelines for Manganese – Overview Report. Ministry of Environment, Lands and Parks, Province of British Columbia. ISBN 0-7726-4444-6. January 2001

B.C. 2001b. Water Quality Criteria for Nitrogen (Nitrate, Nitrite and Ammonia) – Overview Report. Ministry of Environment, Lands and Parks, Province of British Columbia. August 7, 2001.

Brookes, J.D. and Carey, C.C. 2011. *Resilience to blooms*. Science 333: 46-47.

Carey, C. C. Ibelings, B. W. Hoffmann, E. P. Hamilton, D. P. and Brookes, J. D. 2012. *Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate*. Water Research 46: 1394–1407.

Carey, C. C. Weathers, K. C. and Cottingham, K. L. 2008. *Gloeotrichia echinulata blooms in an oligotrophic lake: helpful insights from eutrophic lakes.* Journal of Plankton Research 30: 893– 904.

CCME, 2012. *Canadian water quality guidelines for the protection of aquatic life: Nitrate Ion*. Canadian Council of Ministers of Environment. Winnipeg, Manitoba.

CCME. 2012. *Draft Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life: Cadmium*. October 2012.

Conley, D. J. Paerl, H. W. Howarth, R. W Boesch, D. F Seitzinger, S. P. Havens, K. E Lancelot and CandLikens, G. E. 2009. *Controlling eutrophication: nitrogen and phosphorus*. Science 323: 1014– 1015.

Davis, T.W., Bullerjahn, G.S., Tuttle, T., McKay, R.M., and Watson, S.B. 2015. *Effects of increasing nitrogen and phosphorous concentrations on phytoplankton community growth and toxicity during Planktothrix blooms in Sandusky Bay, Lake Erie*. Environmental Science & Technology, 49(12), 7197-7207.

Downing, J. A. Watson, S. B. and McCauley, E. 2001. *Predicting cyanobacteria dominance in lakes*. Canadian Journal of Fisheries and Aquatic Sciences 58: 1905– 1908.

Elmgren, R. 2001. *Understanding human impact on the Baltic ecosystem: Changing views in recent decades*. Ambio 30: 222– 231.

Gartner Lee Limited. 2005. *Recreational Water Quality Management in Muskoka*. Prepared for the District Municipality of Muskoka. June 2005.

Great Lakes Commission. Great Lakes HABs Collaboratory. 2017. *How does nitrogen affect harmful algal blooms*? Contributions by: Silvia Newell, Laura Johnson, Mark McCarthy, Justin Chaffin, Kateri Salk, Mary Skopec, Austin Brian, Victoria Pebbles, and Ken Gibbons.http://www.glc.org/wp-content/uploads/HABS-Role-of-Nitrogen-20170912.pdf.

Harke, M.J., Steffen, M.M., Gobler, C.J., Pttem. T.G., Wilhelm, S.W., Wood, S.A., and Paerl, H.Q. 2016. *A review of the global ecology, genomics, and biogeography of the toxic cyanobacterium, Microcystis spp.* Harmful Algae 54: 4-20.

Jöhnk, K. D., Huisman, J., Sharples, J., Sommeijer, B., Visser, P.M. and Stroom, J. M. 2008. *Summer heatwaves promote blooms of harmful cyanobacteria*. Global Change Biology 14: 495– 512.

MOE. 2011. *Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario*. April 15, 2011, Standards Development Branch, Ontario Ministry of the Environment. PIBS 7386e01.

Municipal Affairs and Environment, Newfoundland and Labrador. 2019. *Blue-Green Algae: Frequently Asked Questions*. https://www.mae.gov.nl.ca/faq/algae/generel.html.

Ontario Ministry of the Environment. 2014. *Blue-Green Algae: Background, potential impacts to human health and safety of drinking water.* Fact Sheet. © Queen's Printer for Ontario, PIBS 9734e

Paerl, H. W., Hall, N. S. and Calandrino, E. S. 2011. *Controlling harmful cyanobacterial blooms in a world experiencing anthropogenic and climatic-induced change*. Science of the Total Environment409: 1739–1745.

Palmer, M. Ontario Ministry of the Environment. *Our Lakes: How Have they Changed Over the Last 25 Years?* Environmental Lecture Series, Muskoka Watershed Council. July 26, 2012. Port Carling, Ontario.

Posch, T., Koster, O., Salcher, M. M. and Pernthaler, J. 2012. *Harmful filamentous cyanobacteria favoured by reduced water turnover with lake warming.* Nature Climate Change 2: 809– 813.

Smith, V. Hand Schindler, D. W 2009. *Eutrophication science: where do we go from here*? Trends In Ecology & Evolution 24: 201– 207.

Suter II, G.W. and Tsao, C. L. 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*. U.S. Risk Assessment Program, Oak Ridge, Tennessee. ES/ER/TM-96/R2.

U.S. EPA. 1986. *Quality Criteria for Water 1986*. United States Environmental Protection Agency. Office of Water, Regulations and Standards, Washington, DC. EPA 440/5-86-001

U.S. EPA. 2012. National Recommended Water Quality Criteria. http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#altable

United States Environmental Protection Agency, *ed*. Hudnell, H.K. 2008. *Harmful Algal Blooms: State of the Science and Research Needs*. Triangle Park, USA. Springer. Online ISBN 978-0-387-75865-7 https://link.springer.com/book/10.1007/978-0-387-75865-7.

Wagner, C. and Adrian, R 2011. *Consequences of changes in thermal regime for plankton diversity and trait composition in a polymictic lake: a matter of temporal scale*. Freshwater Biology 56: 1949– 1961.

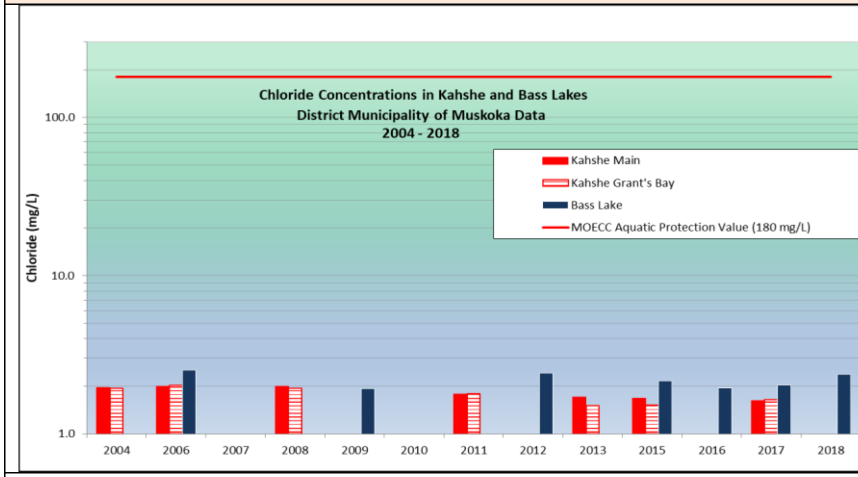
Ron Pearson

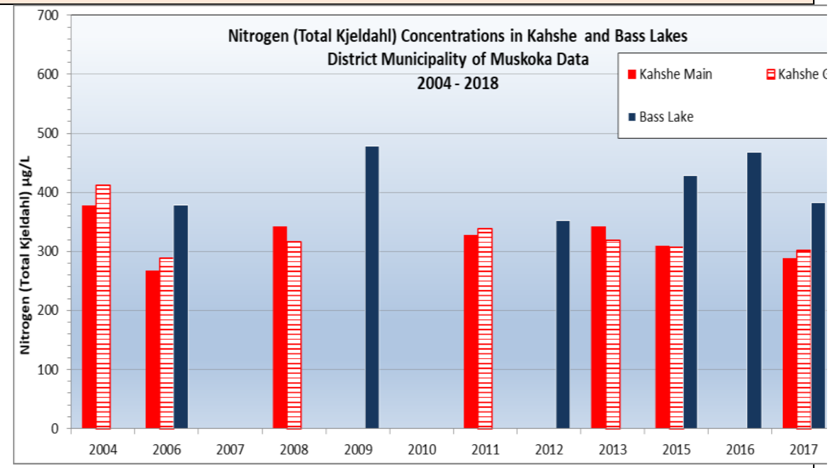
Kahshe Lake Steward

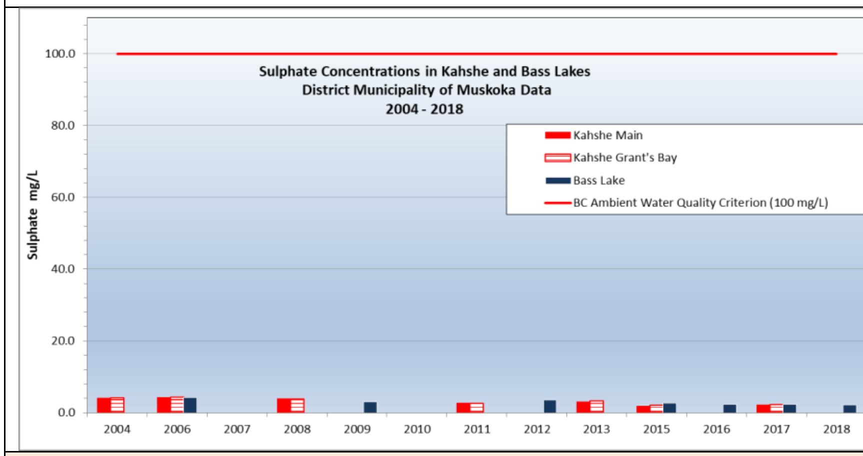
Attachments

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

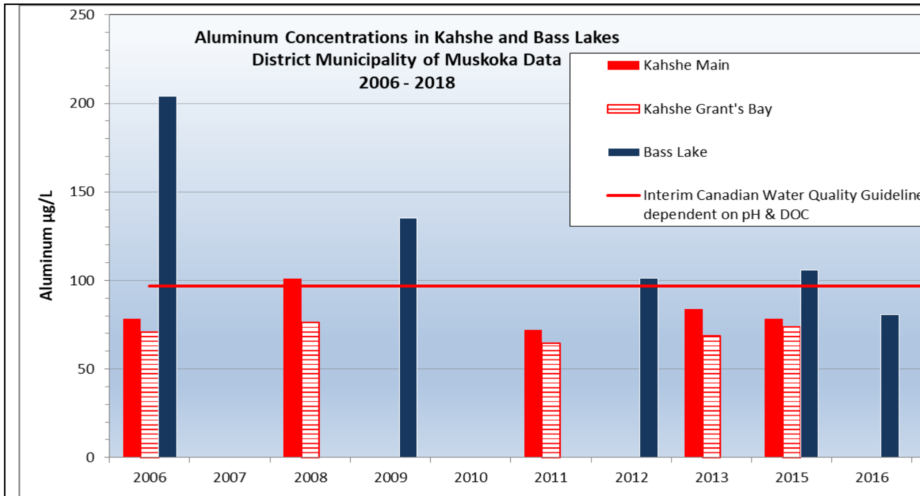
Anions

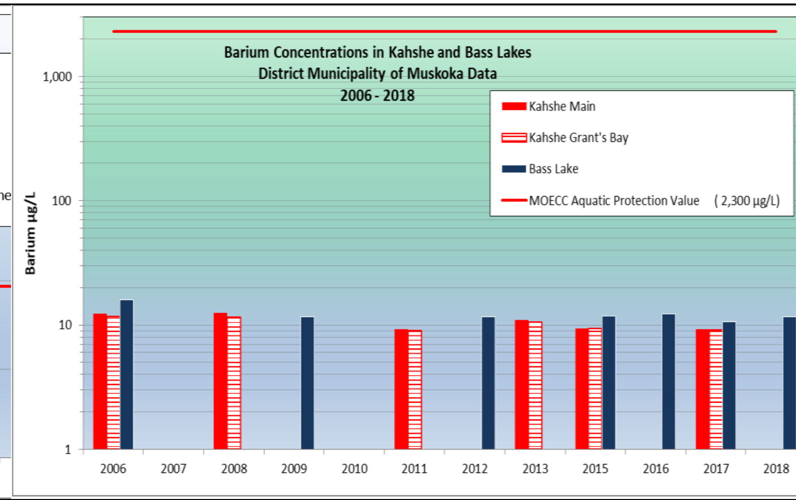


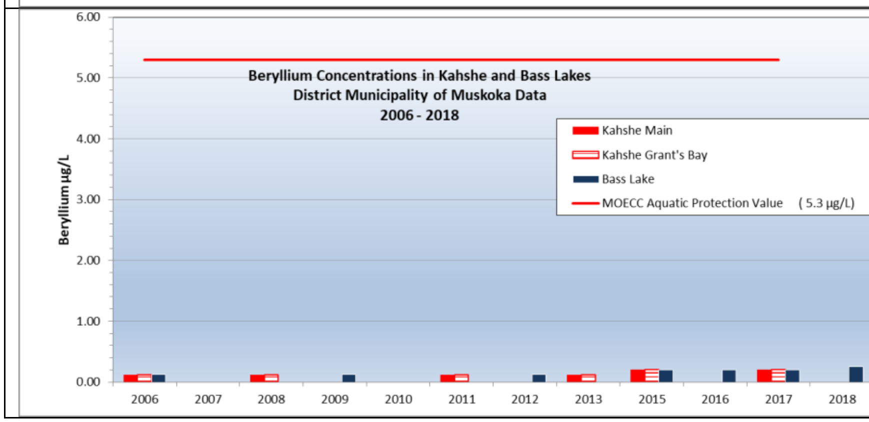


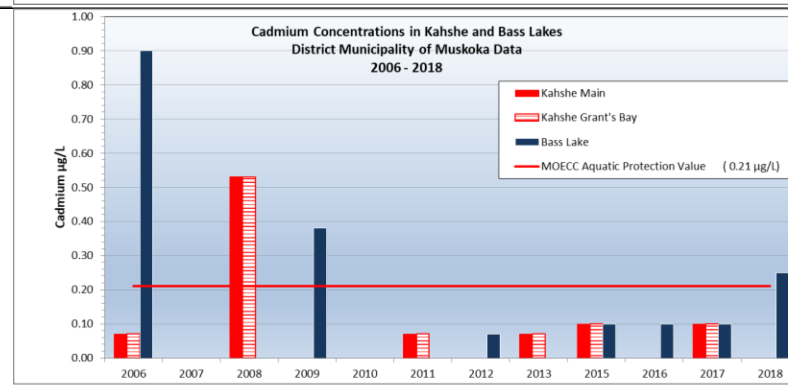


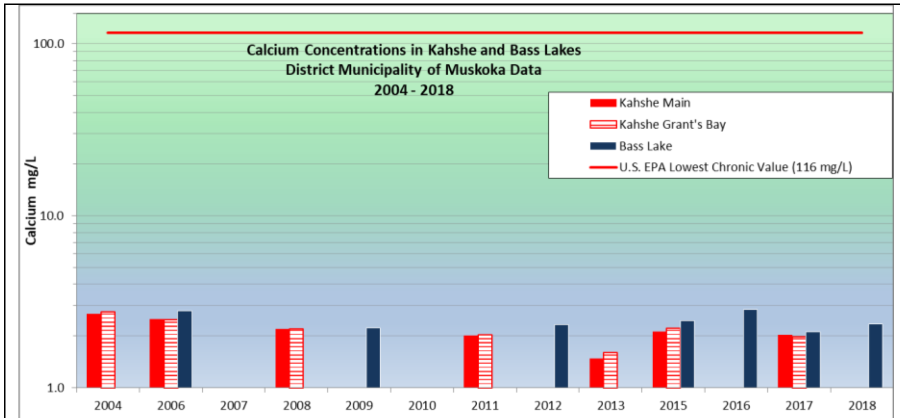
Cations

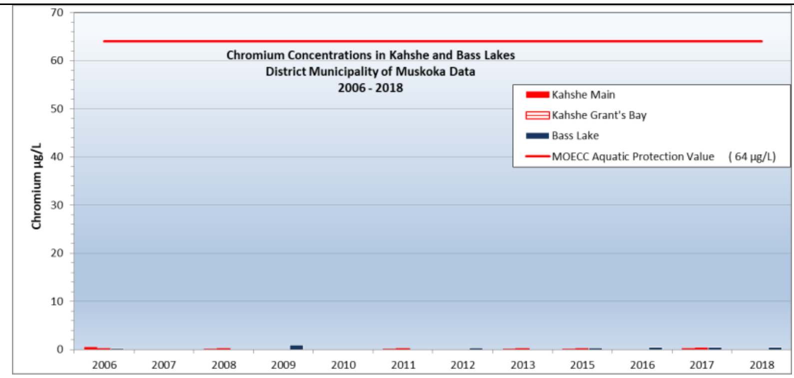

Aluminum Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Interim Canadian Water Quality Guideline dependent on pH & DOC
Aluminum µg/L
250
200
150
100
50
0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016

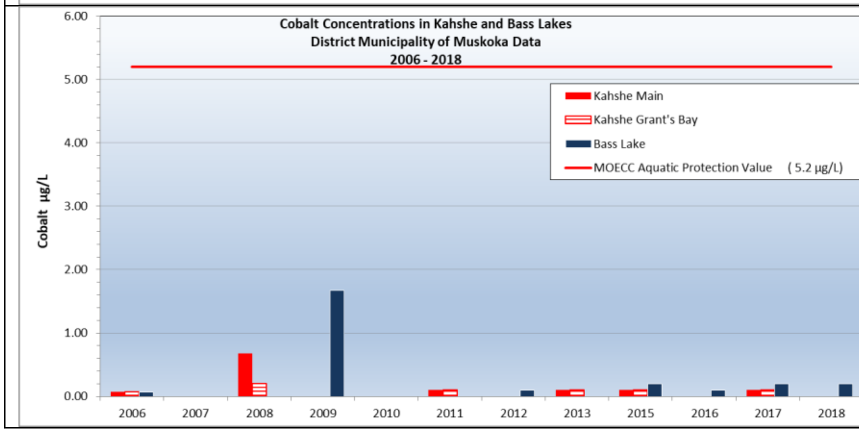

Barium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (2,300 µg/L)
Barium µg/L
1,000
100
10
1
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

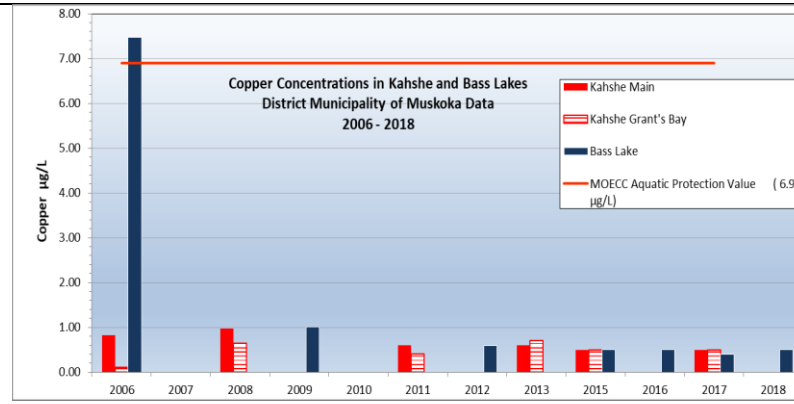

Beryllium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (5.3 µg/L)
Beryllium µg/L
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

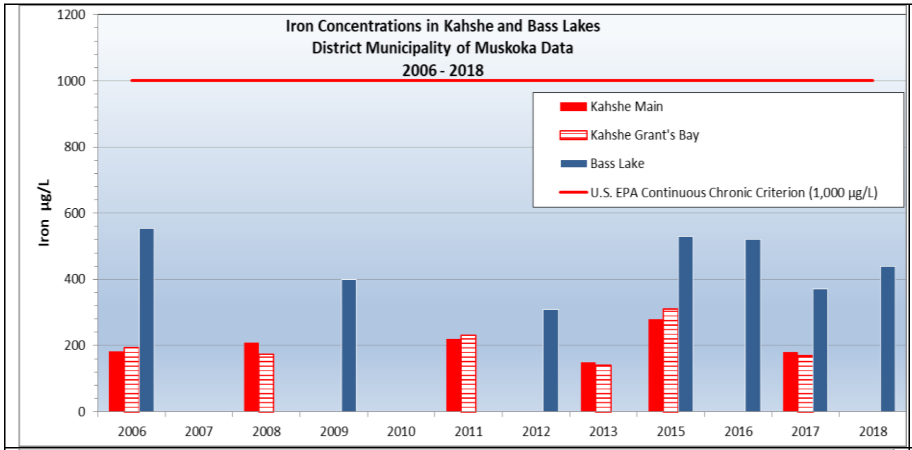

Cadmium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (0.21 µg/L)
Cadmium µg/L
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017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


Calcium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2018
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

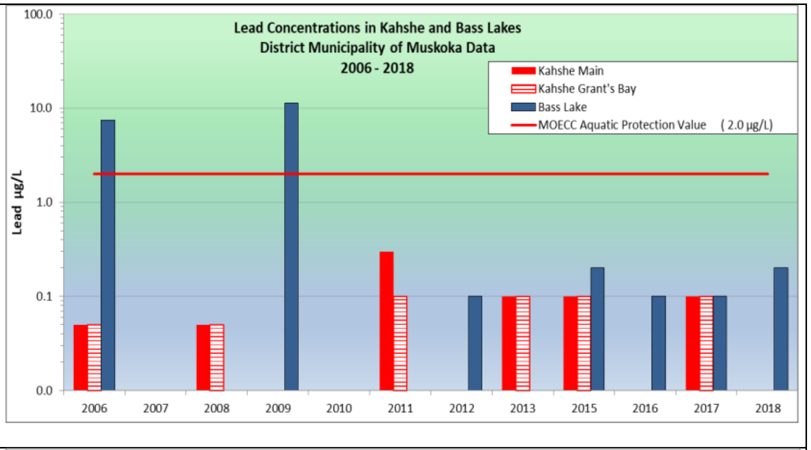

Chromium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (64 µg/L)
Chromium µg/L
70
60
50
40
30
20
10
0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018


Cobalt Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC 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
2011
2012
2013
2015
2016
2017
2018

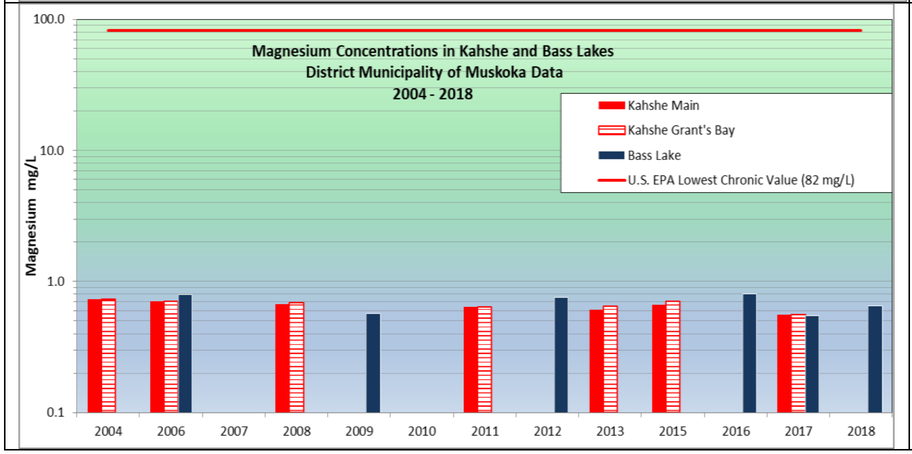

Copper Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (6.9 µg/L)
Copper µg/L
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018



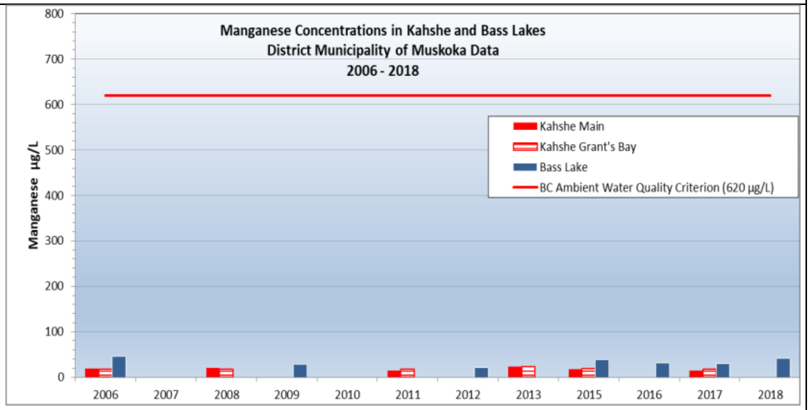
Iron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Continuous Chronic Criterion (1,000 µg/L)
Iron µg/L



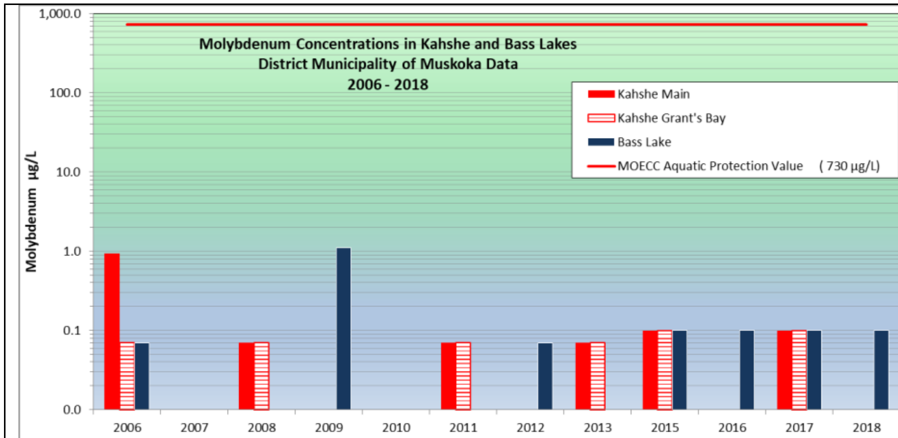
Lead Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (2.0 µg/L)
Lead µg/L

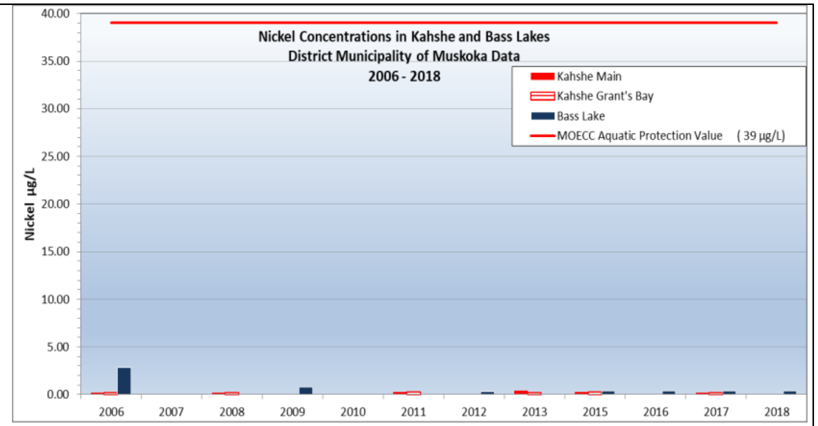


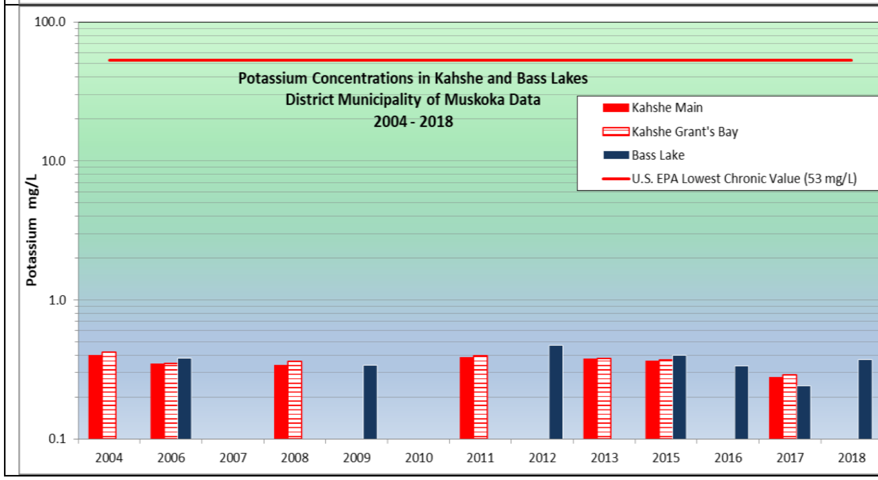
Magnesium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (82 mg/L)
Magnesium mg/L

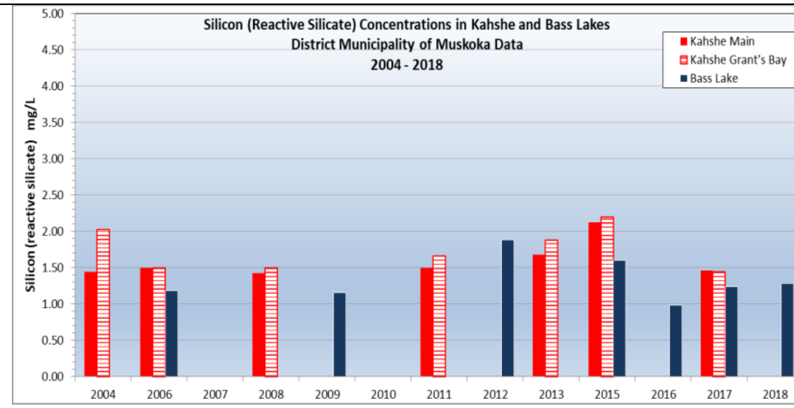


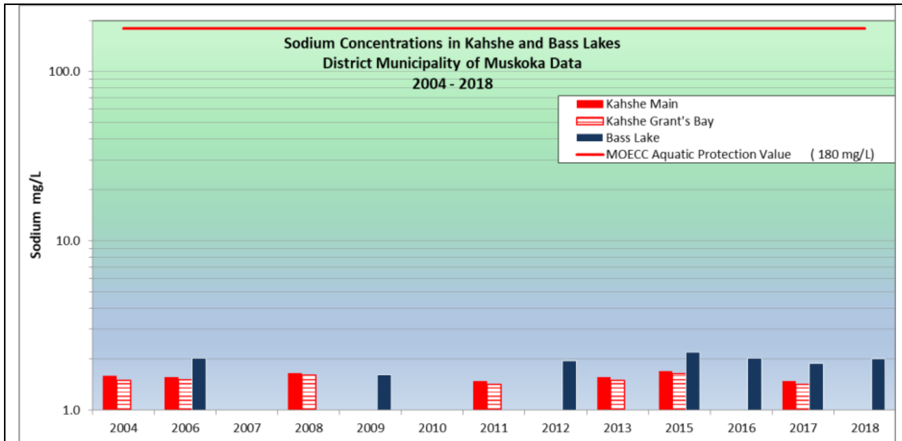
Manganese Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
BC Ambient Water Quality Criterion (620 µg/L)
Manganese µg/L

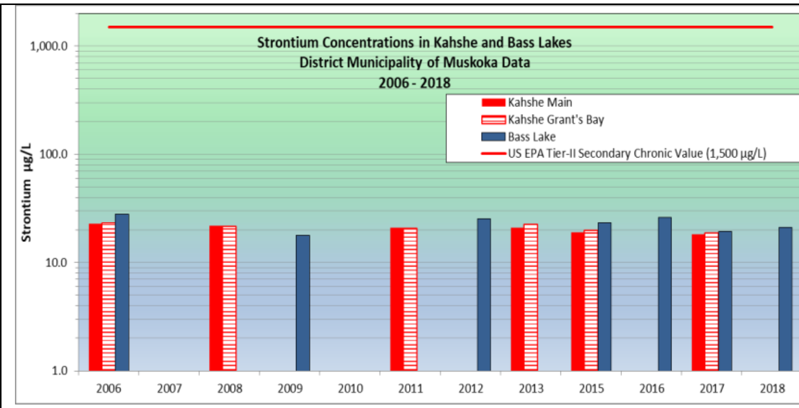

Molybdenum Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (730 µg/L)
Molybdenum µg/L
1,000.0
100.0
10.0
1.0
0.1
0.0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

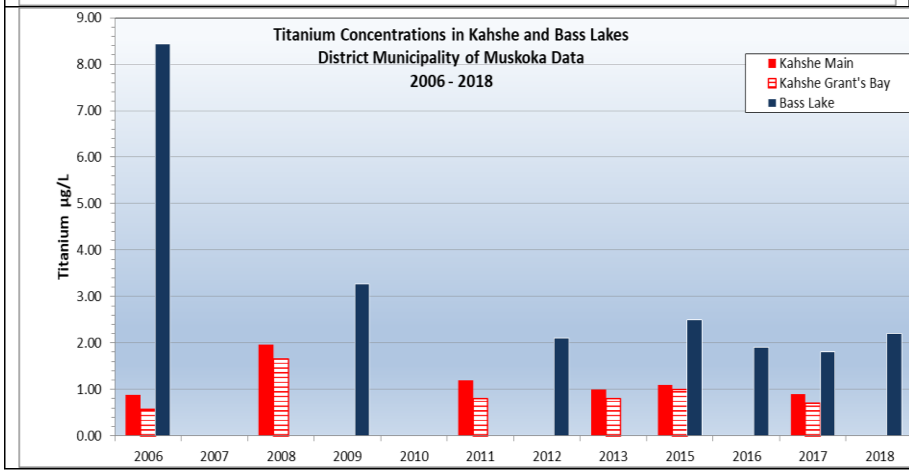

Nickel Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (39 µg/L)
Nickel µg/L
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

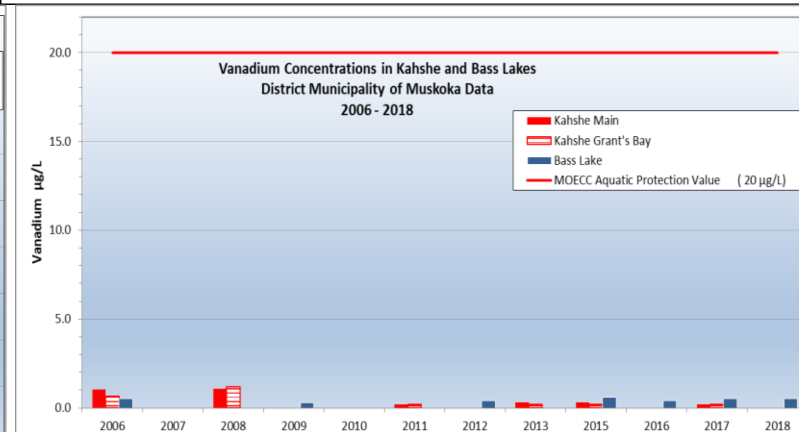

Potassium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (53 mg/L)
Potassium mg/L
100.0
10.0
1.0
0.1
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

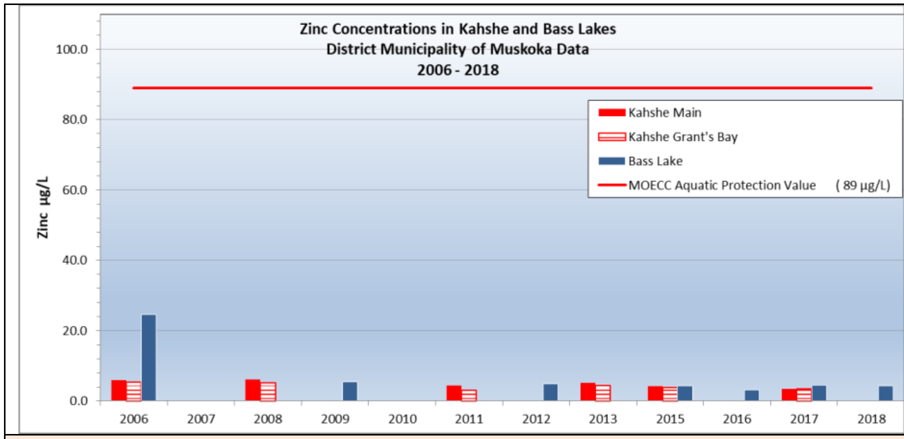

Silicon (Reactive Silicate) Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Silicon (reactive silicate) mg/L
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018


Sodium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (180 mg/L)
Sodium mg/L
100.0
10.0
1.0
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

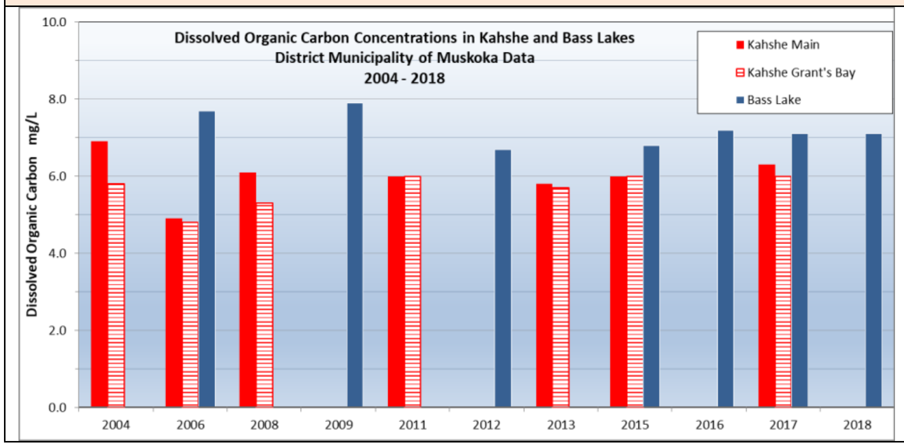

Strontium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
US EPA Tier-II Secondary Chronic Value (1,500 µg/L)
Strontium µg/L
1,000.0
100.0
10.0
1.0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

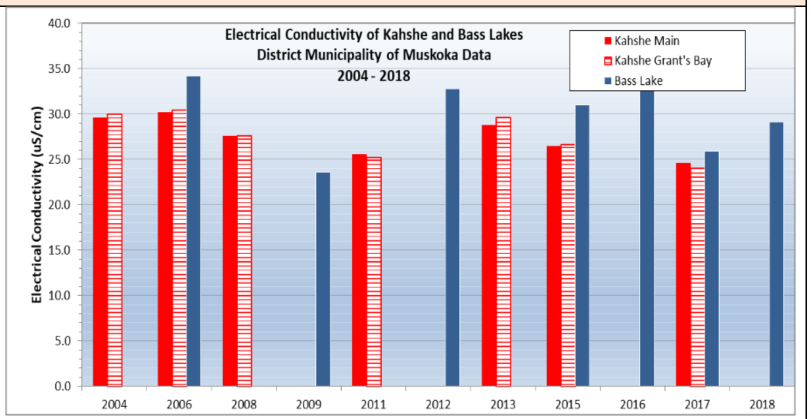

Titanium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Titanium µg/L
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018

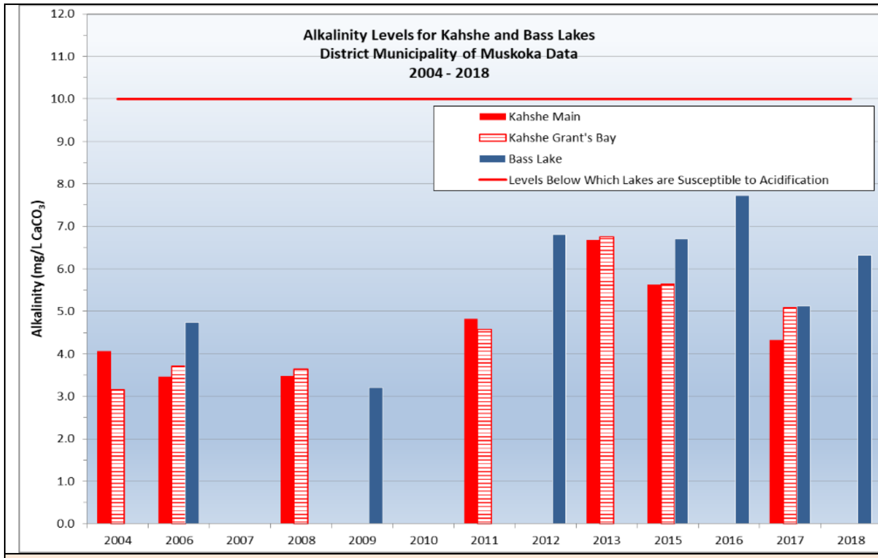

Vanadium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (20 µg/L)
Vanadium µg/L
20.0
15.0
10.0
5.0
0.0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018



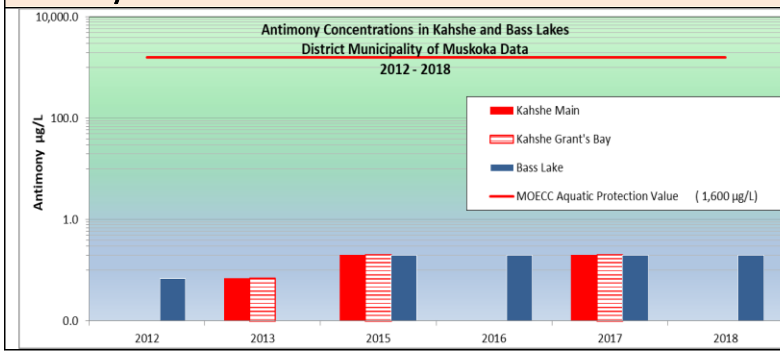
Other Chemicals

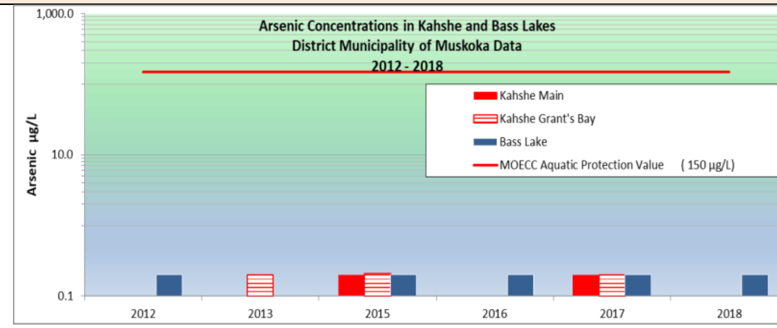


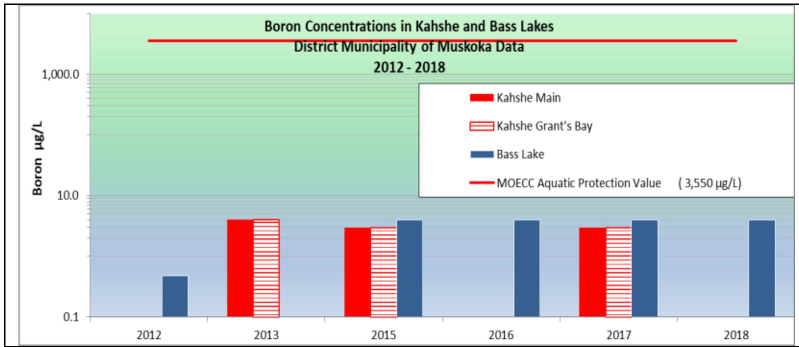


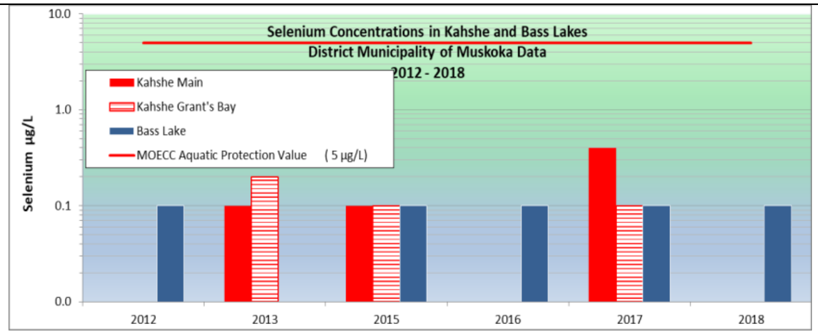


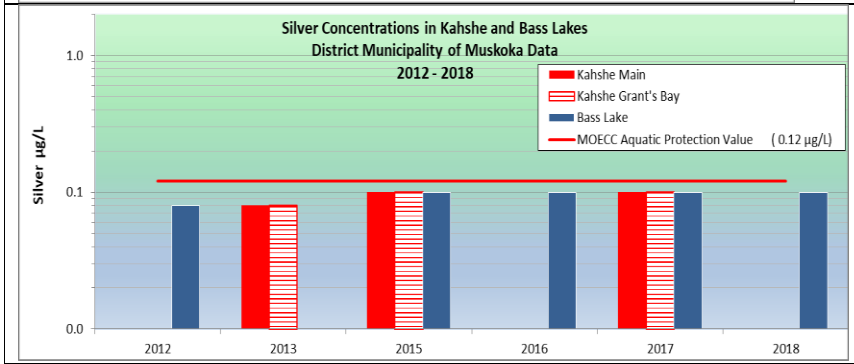
Recently Added Cations

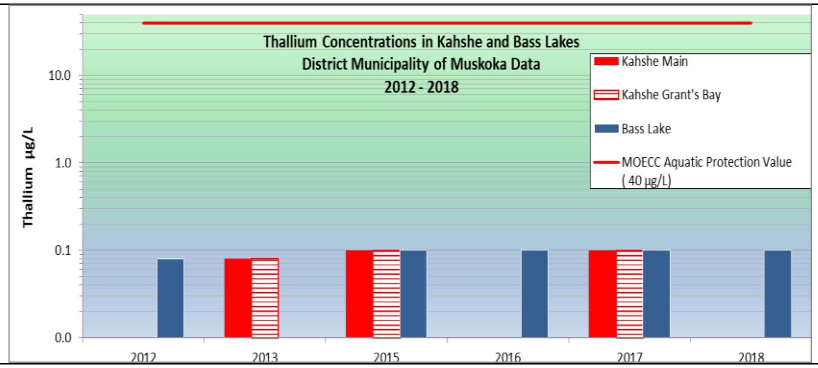


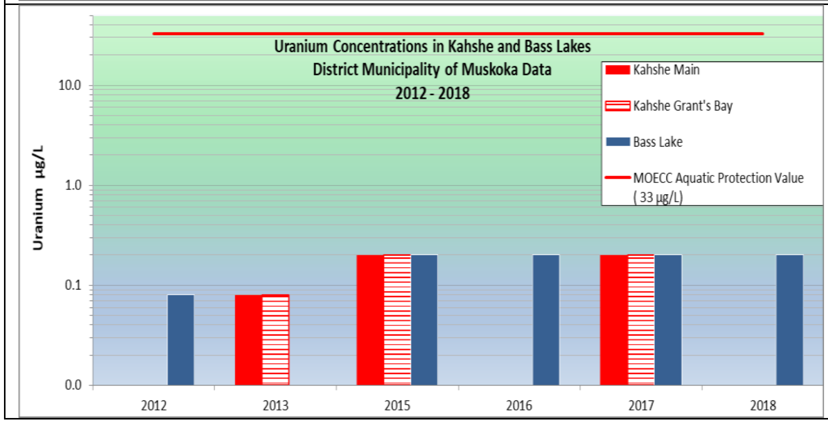



Boron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2018
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MOECC Aquatic Protection Value (3,550 µg/L)
Boron µg/L
1,000.0
10.0
0.1
2012
2013
2015
2016
2017
2018


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


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


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


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