2021 KAHSHE AND BASS LAKE STEWARD REPORT

Ron Pearson, M.Sc. - Kahshe and Bass Lake Steward

ABSTRACT
The findings of all environmental water quality monitoring for both Kahshe and Bass Lakes in 2021 have been summarized and compared to acceptable water quality and aquatic health benchmarks for algal friendly nutrients nitrogen and phosphorus as well as over 30 different chemical parameters. Historical trends in water quality over almost 40 years also have been presented and have identified no major contamination issues or trends in algal-friendly nutrient levels that would explain why Kahshe Lake has been impacted by harmful algal blooms (HABs) in both 2020 and 2021. Why is this happening? And, Is there anything we can do to help? We need look no further than our own shoreline water quality to understand why the historical tracking of algal-friendly nutrients based on mid-lake, deep water sampling locations is not identifying water quality degradation. To explore this issue, the KLRA funded a Near-Shore Water Sampling Program that was designed and completed in 2021. This investigation identified some very useful insights and linkages between our changing climate, its impact on water quality and the development of late season HABs in Kahshe Lake. This information provides shoreline property owners with a science-based approach to actions we can and must take to prevent further water quality degradation and reduce the likelihood of another HAB.

KAHSHE LAKE RATEPAYERS' ASSOCIATION – CONSERVATION COMMITTEE - NOVEMBER 2022

2021 KAHSHE AND BASS LAKE STEWARD REPORT

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Executive Summary

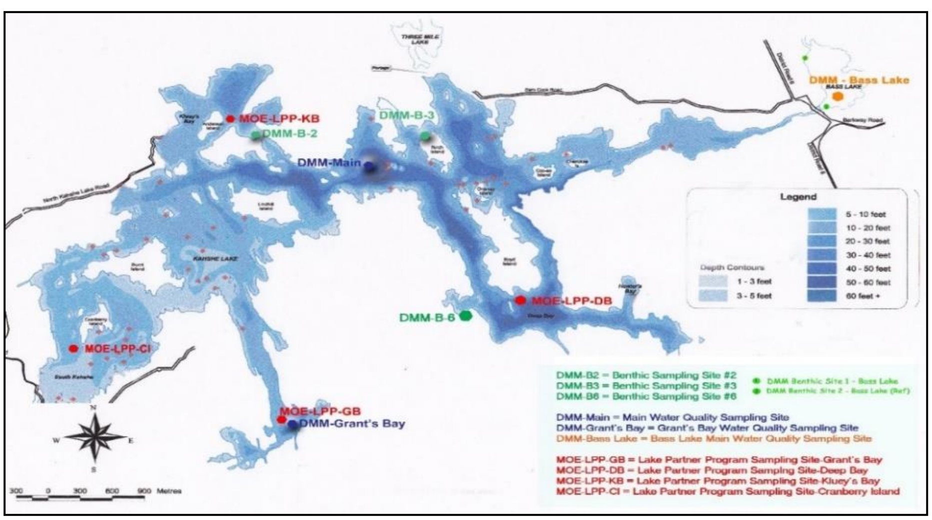
2021 Kahshe and Bass Lake Steward Report

A comprehensive review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes has now been completed and presented in annual Lake Steward Reports from 2012 through 2021. These documents as well as Executive Summaries are posted on the **Lake Health** tab of the KLRA web-site: https://kahshelake.ca/Water-Quality. This report summarizes the findings from sampling and analysis of both Kahshe and Bass Lakes in 2021. The sampling programs include those of two agencies: The District Municipality of Muskoka (DMM) and the Ontario Ministry of Environment, Conservation and Parks (MECP). In the latter, the Lake Stewards of Ontario carry out the water sampling and clarity measurements and the MECP analyzes the samples and coordinates the data reporting.

As in 2019 (there was no sampling or analysis in 2020 due to the COVID-19 pandemic), this report has been structured to address the following issues/areas of potential concern for both lakes with emphasis on the development of harmful algal blooms (HABs).

- 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 2021 report includes an overview of the climatological factors that have the potential to influence lake conditions. This evaluation demonstrated that air temperatures in 2021 were generally similar to the two previous years and to the 30 year normal for most months, with the exception of noticeably warmer conditions in August and October. In the case of precipitation, total monthly amounts were lower than normal from January through May but much higher than normal in June, July and September. Ice-out on Kahshe in 2020 and 2021 occurred around April 9 and 7th, respectively. Ice-out records for Deep Bay also have been recorded dating back to 1987 and have been compared to ice-out times for Muskoka lakes dating back to 1886, and these records show no clear trend towards an earlier or later ice-out condition.



A map showing sampling site locations in Kahshe and Bass Lakes for both the DMM and MECP programs has been inserted.

A full summary of the findings of DMM and MECP water quality and biological monitoring programs can be found in Section 4 of this report. Based on these investigations, the following conclusions have been reached regarding water quality in both Bass and Kahshe Lakes in 2021.

Based on the 2021 water quality and benthic monitoring of Kahshe and Bass Lakes by the DMM and the MECP, no major water quality issues or trends were identified. However, given the documented occurrence of HABs in Kahshe Lake in both 2020 and 2021 as well as the late season population explosion of a zooplankton organism (Holopedium) known to be associated with decreasing levels of available calcium in Muskoka region lakes, it is clear that the tracking of water quality via the mid-lake, deep water sites of the DMM and MECP is not providing a meaningful indication of water quality degradation associated with the onset of these negative impacts on the health of the lakes.

In the case of Bass Lake, the DMM has identified it as a 'Vulnerable' lake and has undertaken a more comprehensive Causation Study in 2021. Hopefully, the findings from those investigations will shed light on the cause of the elevated total phosphorus which has been recorded in Bass Lake since monitoring by the DMM began back in the early 1980s. The report of the DMM's investigation was to be released in early 2022, but was delayed and has not yet been released.

So, for Kahshe Lake, where do we go from here?

Kahshe Lake also has been identified by the DMM as a 'Vulnerable' lake and a DMM-funded Causation Study will be undertaken when funds and staffing are available following the completion of Causation Studies on the first group of vulnerable lakes (including Bass L). Given the uncertainty regarding the implementation of a DMM-funded Causation Study and the concern of property owners regarding the late season HABs in 2020 and 2021, the KLRA decided to fund a Conservation Committee project in 2021. The purpose of this study was to explore the chemistry of near-shore waters over the spring and summer season in an effort to better understand why Kahshe Lake has been impacted by HABs in spite of reasonably low and unchanged phosphorous levels reported by the DMM and MECP over the past 40 years.

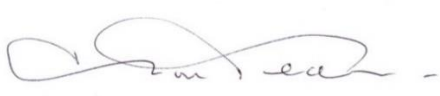
The findings from this Near-Shore Water Sampling Project (NSWSP) have been published in a final report available on the KLRA Water Quality web portal. The NSWSP identified some very useful insights and linkages between our changing climate, its impact on water quality and the development of late season HABs in Kahshe Lake. These findings are briefly shown below and should help in the development and implementation of the DMM's Causation Study when it does get funded. Briefly, the NSWSP demonstrated that:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a true assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture much higher total phosphorus levels in the east end of the lake, as there are no DMM or MECP sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) tend to increase as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry findings for some algal-friendly nutrients appear to be associated with effluents from human & animal waste sources and are known to be linked with HABs.

- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

Although we have virtually no control over the change that is affecting our climate, there are actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future algal blooms. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain water into rock-filled drainage pits.**
2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil & goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town will be inspecting in 2023, but we don't need to wait until then and be subject to system shutdown until failing systems are repaired.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**



Ron Pearson, M.Sc.

Kahshe and Bass Lake Steward - Conservation Committee

1.0 Kahshe Lake Stewardship Mandate

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

- Educating the residents and other users of Kahshe and Bass Lakes on how to **preserve** and **improve** the quality of both lakes and their shorelines.

- Monitoring the water quality of both lakes and keeping the association members up to date on the results of all analytical and biological monitoring programs.

In accordance with this mandate, a comprehensive review and analysis of all historical environmental monitoring on Kahshe and Bass Lakes has now been completed and presented in annual Lake Steward Reports from 2012 through 2021. These documents as well as Executive Summaries are posted on the **Lake Health** tab of the KLRA web-site https://kahshelake.ca/Water-Quality. Prior to 2012, a few Lake Steward reports were located; 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 bacterial contamination. If you are drinking water from the lake – **which is strongly not recommended** - and want to ensure that your filtering system is functioning properly, you can submit a sample of water to the Simcoe Muskoka Health Unit for coliform analysis. The contact info is:

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

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

Given the importance of and responsibility for maintaining fully functional septic systems and keeping septic-sourced fecal 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 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 when the septic system was installed or on previous re-inspection findings. As it currently stands, the last Town inspections for road access properties was conducted in 2013 and in 2009 for water access properties. The COVID-19 pandemic further delayed planned re-inspection in 2021 and the program was aborted in 2022 due to staffing issues. Given this performance history, 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 for MECP by the Lake Steward. Although coliform analysis was included as part of the Near-Shore Water Sampling Project undertaken by the KLRA in 2021, this was a once only sampling and will not be carried out on a routine basis for several reasons:

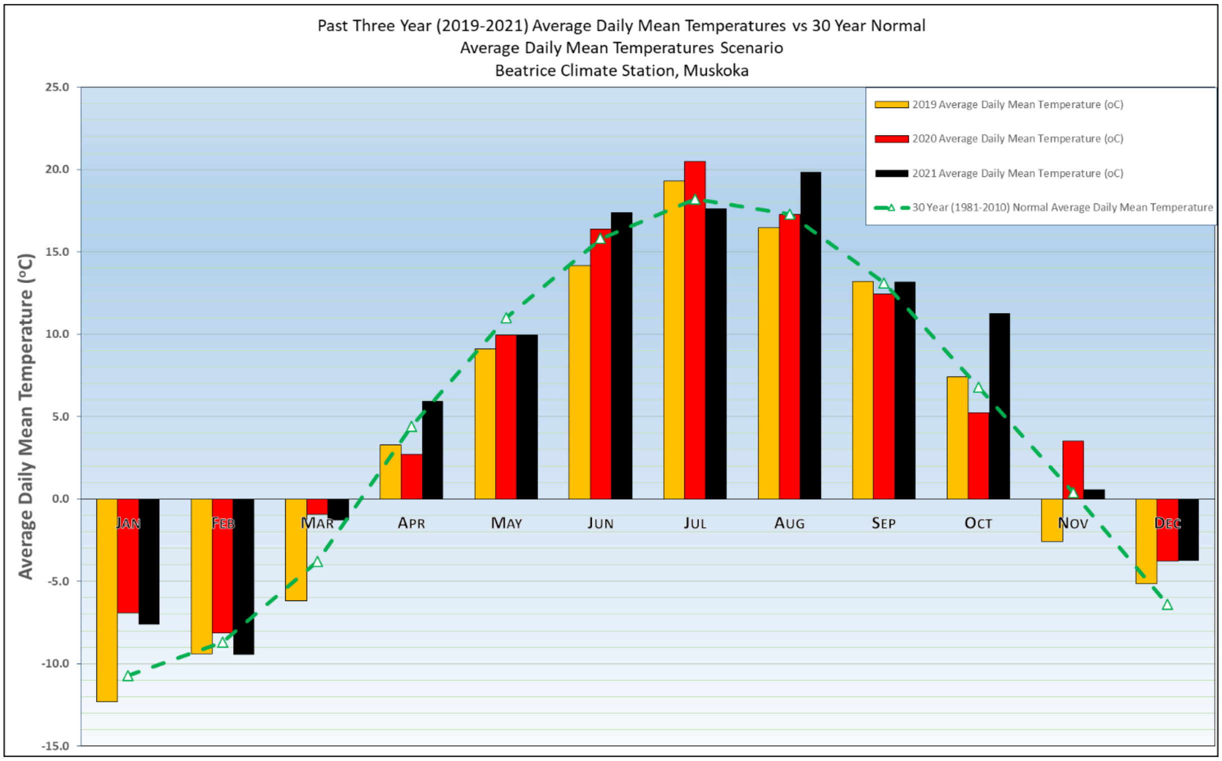
- as a KLRA citizen volunteer, I am not qualified as a medical or public health authority to interpret or advise on the findings from this type of sampling program.
- Coliform concentrations are highly variable, which would make any predictive type of notification regarding use of the water for consumption 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 benefit would be limited, as detrimental health effects would already have taken place by the time the results were received.

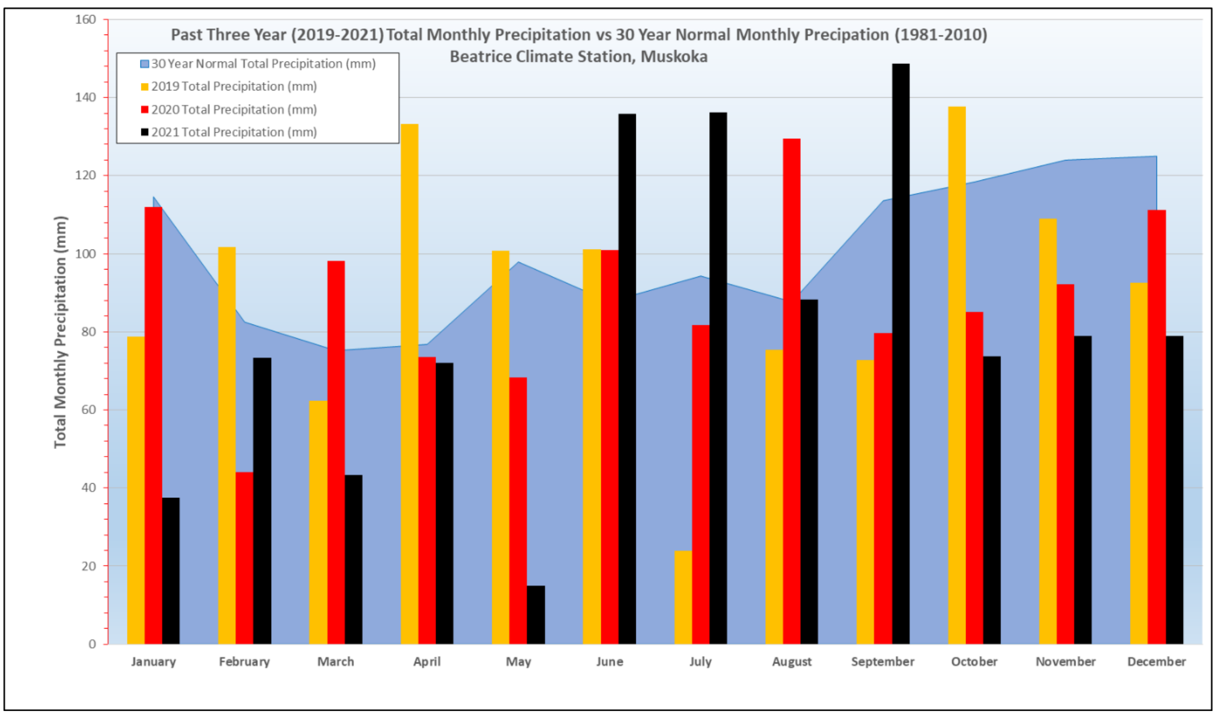
2.0 Overview of Climatic Factors and Water/Ice Conditions

In order to better understand the chemical and physical data that have been collected and their relationship (if any) to weather conditions, this year's report again includes an overview of average monthly air temperature and monthly total precipitation that have the potential to influence the lake monitoring findings. These findings have been compared to the data from 2019 and 2020 as well as to the 30 year normal results.

Air Temperature and Precipitation

Air temperature and rainfall records from the Beatrice climate station were evaluated. The charts below show the average daily mean monthly air temperature and total monthly precipitation (rain + snow) for 2021 and for the two previous years for comparison. These results are also compared to the 30 year (1981-2010) normal monthly temperature and precipitation.



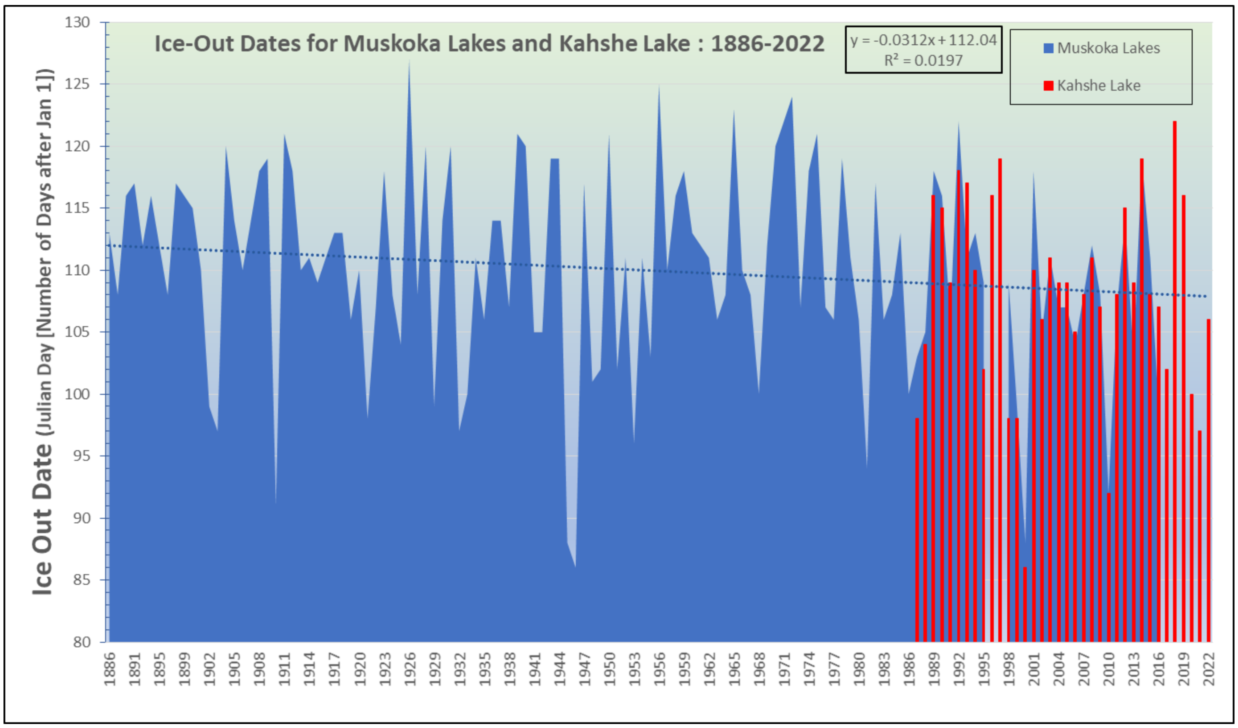


This comparison demonstrates that air temperatures in 2021 were generally similar to the two previous years and the 30 year normal for most months, with the exception of much warmer conditions in August and October. In the case of precipitation, total monthly amounts were noticeably lower from January through May but very significantly higher in June, July and September. These findings have been discussed more thoroughly in terms of their role in the development of late season blue-green algal blooms in both 2020 and 2021 in the 2021 Near Shore Water Sampling Project carried out by the Conservation Committee with the financial support of the KLRA.

Ice-Out Times

Although there are no DMM or MECP records for ice-out times on Kahshe or Bass Lakes, a publicly available record for ice-out times of Muskoka Lakes (Rosseau and Joseph) dating back 125 years was located. These data from 1886 through 2016 have been charted below using Julian Day, which is the number of days after January 1 each year. Although a trendline based on the assumption of a linear relationship does slope toward an earlier ice out times over this 125 year period, this trend was not statistically significant, with an R squared value of only 0.0197.

To give some perspective on how ice-out conditions on Kahshe Lake compare with corresponding dates from Muskoka Lakes, data generated by R. Cronin from the Deep Bay area of Kahshe Lake have been located for the period from 1987 through 2019. This database has been updated with ice-out dates for Kahshe Lake based on personal records (R. Pearson) from 2020 through 2022, and these dates have been plotted in the chart below (red bars). The data for Kahshe Lake appear to generally follow the ice-out dates for the larger Muskoka Lakes and as for the trend, there appears to be no evidence of a trend towards earlier or later ice-out times on Kahshe Lake over this 35 year period. Attachment 2 provides the ice-out dates for Muskoka and Kahshe Lakes which were used to generate this chart.



3.0 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) – MECP – Kahshe Lake Only

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

- **Water clarity measurements**

  Clarity of the water is measured every two weeks during the ice-free period at three locations using a Secchi disc, and these findings are forwarded to the MECP 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 MECP 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 MECP and several other participating agencies.

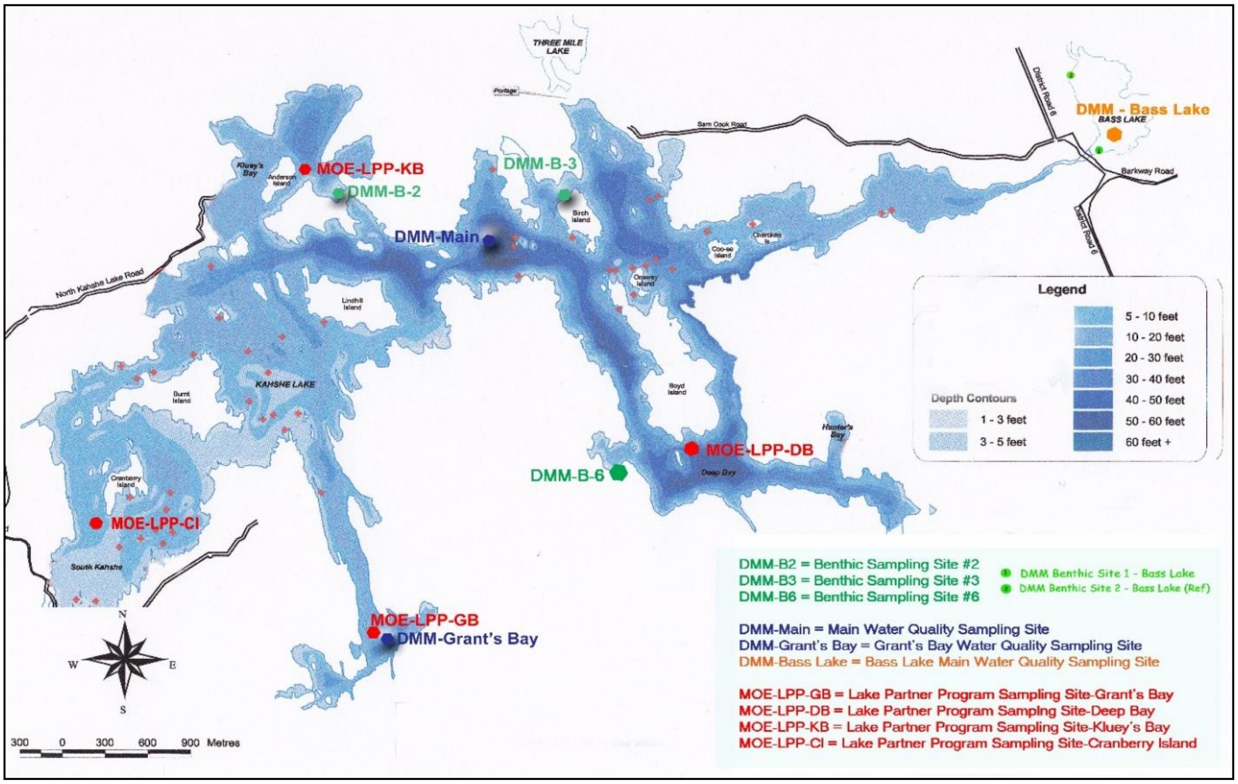
The monitoring program consists of 193 sampling sites on 164 lakes on a rotational basis. The program was designed to deliver a monitoring program which would establish a long-term record of key water quality parameters so that trends in water quality and lake system health could be identified and appropriate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

- Water sample collection for total phosphorus and a suite of other physical and chemical parameters in May/June (2 sites in Kahshe Lake and 1 site in Bass Lake);
- Secchi disc depth measurements collected in May/June and August (2 sites in Kahshe Lake and one site in Bass Lake);
- Temperature and dissolved oxygen at increasing water depths taken in May/June and August (2 sites in Kahshe Lake and 1 site in Bass Lake);
- Benthic invertebrate sampling at one of three sites in Kahshe Lake in August each year from 2004 through 2007, 2011 through 2015 and 2019-2021 and in Bass Lake in 2016 through 2021.

Although water quality and benthic sampling of Kahshe and Bass Lakes in 2021 would not normally have been carried out, it was conducted to further assess water quality, as both lakes have been determined to be "Vulnerable" due to either elevated total phosphorus (Bass L) or to the documented presence of a blue-green algal bloom (Kahshe) in both 2020 and 2021.

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

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



4.0 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 MECP 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/concern in terms of water quality:

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

4.1 Nutrients, Water Clarity, Temperature and Algal Growth

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

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

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

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

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

To give a better idea of the potential impact of a blue-green algal bloom, a copy of the Health Unit's 2020 advisory to the property owners on Kahshe Lake following a late-season bloom in the vicinity of Oak Road has been shown below:

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

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

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

Those sources that to some degree 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 MECP has been to track the quality of the water in terms of its total phosphorus levels. This in turn has served as a driver of shoreline management and property development strategies. However, emerging research shows that nitrogen is more involved in harmful algal growth than originally thought (Great Lakes Commission, 2017).

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

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

PHOSPHORUS

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

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

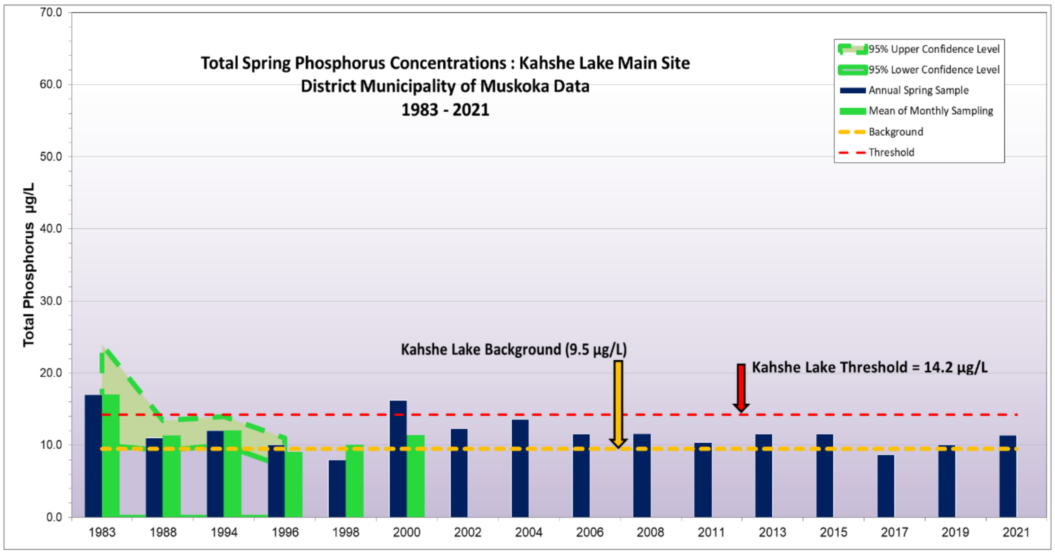
In the late 1960s and early 70s, David Schindler, a Canadian limnologist oversaw a number of whole-lake experiments designed to determine which nutrient (out of nitrogen and phosphorus) was primarily responsible for eutrophication. His studies clearly demonstrated that phosphorus was the main contributor.

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

If the lake's measured and modelled phosphorus concentrations over a 10-year period are greater than its threshold value, then the lake is considered "over threshold" and actions may be initiated to reduce the amount of phosphorus entering the lake from its watershed. As noted in previous reports, 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. They have also declared both Kahshe and Bass Lakes as 'Vulnerable', based on elevated total phosphorus levels (Bass L) and the documented presence of a blue-green harmful algal bloom (Kahshe in 2020 and 2021). As a result of this Vulnerable status, the DMM now conducts water quality and benthic sampling and analysis every year.

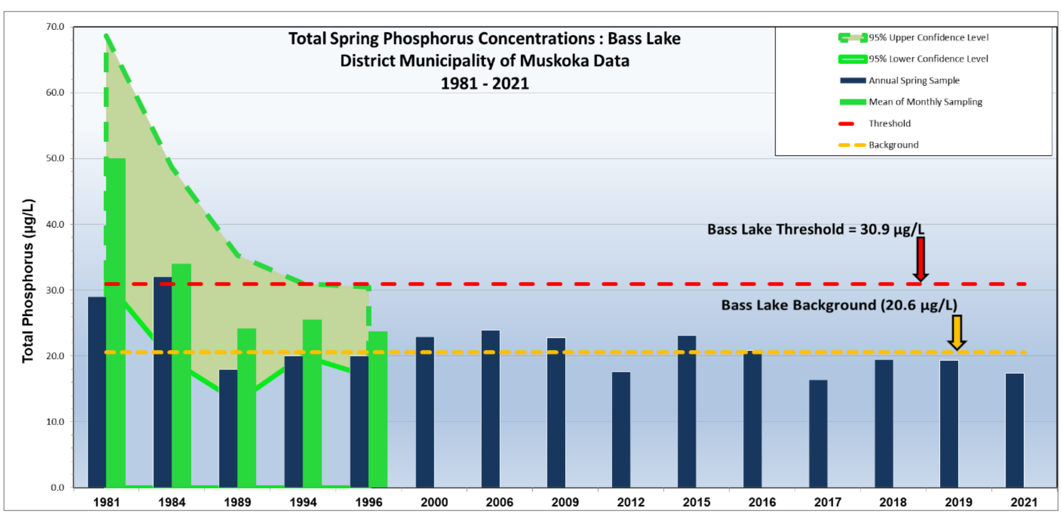
The DMM's total spring phosphorus results for 2021 in Kahshe Lake as well as those of the past 38 years are shown in Figure 2 below:

Figure 2:



The DMM's Bass Lake total spring phosphorus results for 2021 as well as those of the past 40 years are shown in Figure 3 below:

Figure 3:

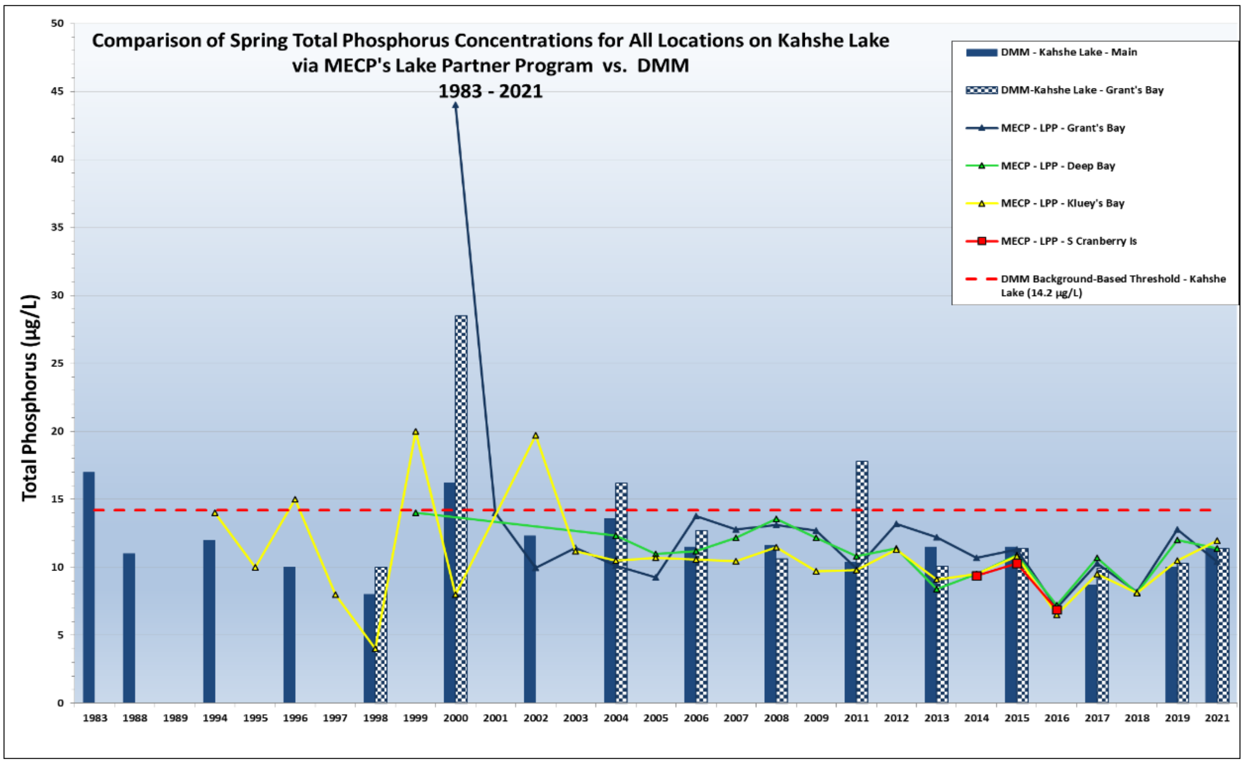


These findings can summarized as follows:

- In both lakes, there has been no detectable trend in total phosphorus concentrations over the past 38-40 years and in both lakes, the levels are consistent with what is regarded as background concentrations and well below levels determined by the DMM to be Total Phosphorus Threshold levels.
- Historically, the total phosphorus levels in Bass Lake are about twice as high as in Kahshe Lake; however; this appears to be a natural condition, as the levels in Bass L have not changed since monitoring began back in 1981.

As noted above, Kahshe Lake also was sampled and analyzed for total spring phosphorus under the Lake Partner Program (LPP). Figure 4 below shows the total phosphorus levels at the three LPP sampling sites in Kahshe Lake for 2021. The historical findings dating back to 1994 for the LPP program and to 1983 for the DMM results also are presented for comparison purposes.

Figure 4:



This comparison confirms that:

- After the year 2003, the total phosphorus concentrations determined via the DMM and MECP sampling programs (both of which are analyzed by the MECP's Dorset laboratory) have yielded very similar findings, with most of the differences in phosphorus likely due to different spring sampling dates which would be influenced by the degree of lake stratification (turnover).
- Prior to 2003, the variability is likely attributed to sample collection procedures, in particular the filtering of water samples to remove zooplankton and other biological material in the water column.
- The 2021 results also confirm that the total phosphorus concentrations in the various deep water areas of the lake are more or less similar.
- While not shown in this chart, the finding of similar total spring phosphorus levels at the five different sampling locations on Kahshe Lake contrasts with the findings from the 2021 KLRA-

funded Near Shore Water Sampling Project which found noticeably higher total phosphorus concentrations in the water from the East end of the lake which has not been sampled via either the DMM or MECP's LPP program.

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 graphically summarized in Figure 5 below:

Figure 5:

(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 Kahshe and Bass 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, especially in areas where food sources like lawn grass are available.

The nitrogen monitoring results for the two forms of nitrogen that are analyzed by DMM have been charted below in **Figures 6 and 7**.

Figure 6:

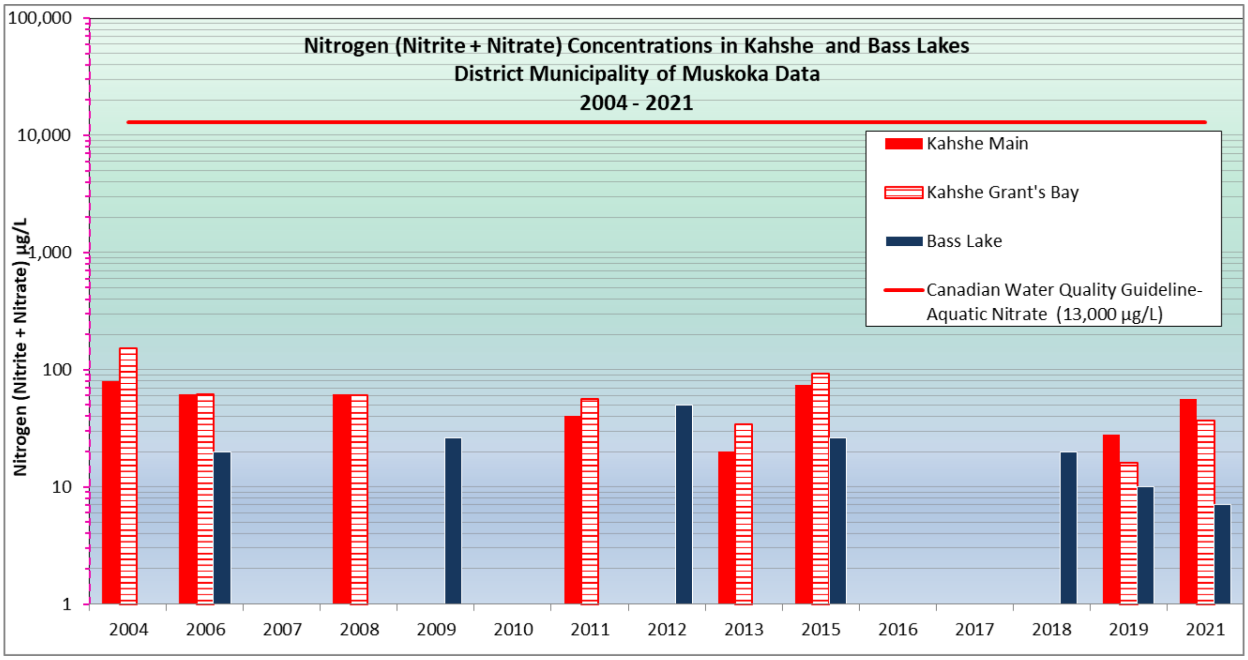
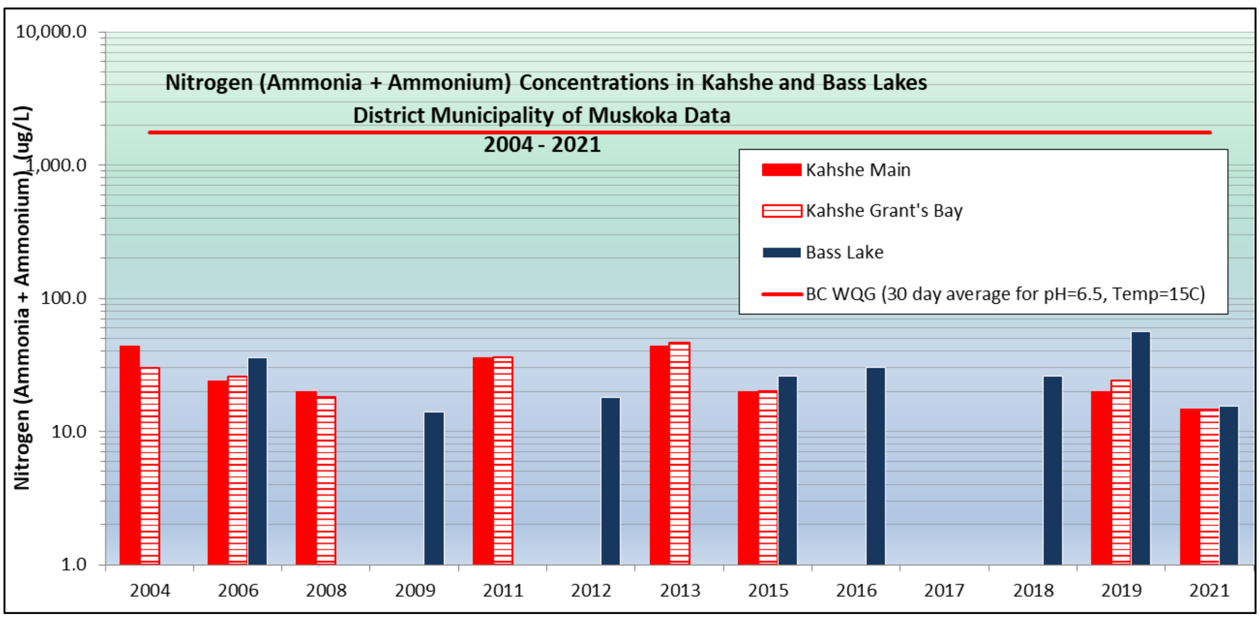


Figure 7:



The results of this analysis have been summarized below.

- No evidence of a concentration trend in either of the two analyzed forms of nitrogen has been detected in Bass or Kahshe Lakes over the years dating back to 2004.
- In contrast to total phosphorus, the concentrations of nitrate + nitrite in Bass Lake are generally lower than the corresponding analysis results for Kahshe Lake.
- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive aquatic species.

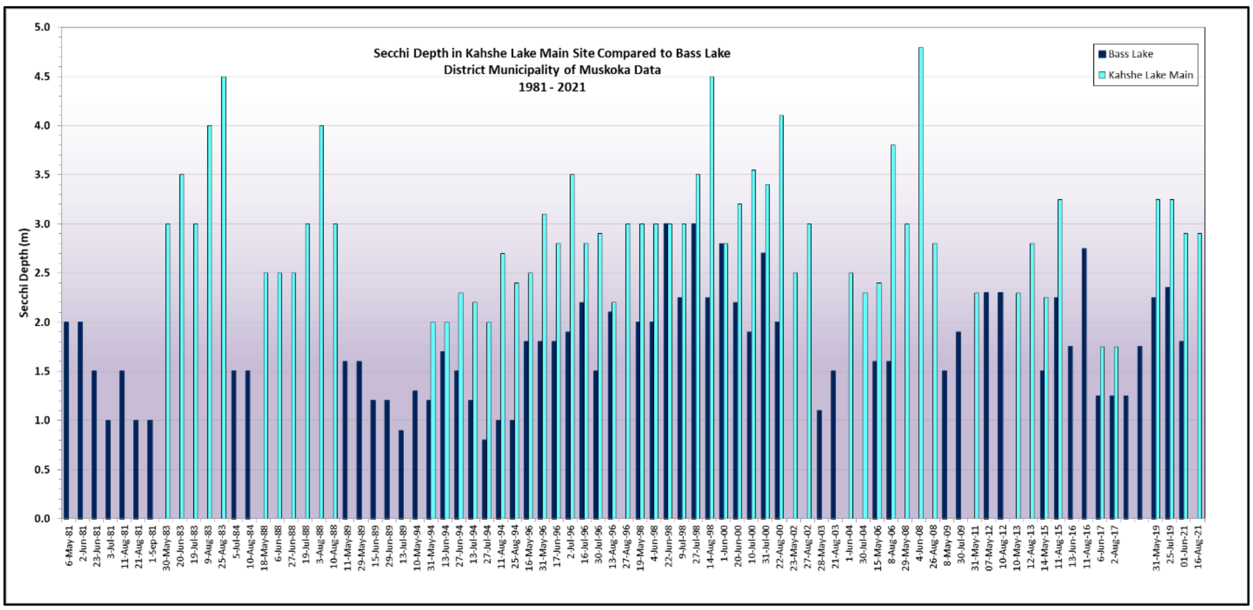
- No algal growth benchmarks for either form of nitrogen have been located, as the linkage between phosphorus, nitrogen and water temperature is too complex to set individual nutrient benchmarks.
- While not shown above, the findings from the KLRA-funded Near-Shore Water Sampling Project conducted in 2021 demonstrate that nitrogen concentrations in the near-shore environment are often considerably higher than these spring sampled mid-lake levels, generally increase as the season progresses and have likely contributed to the harmful blue-green algal bloom that was documented in 2021. This is discussed in greater detail in the 'Algal Growth' section.

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.

The DMM's 2021 water clarity levels for both lakes have been compared with the historical results dating back to 1980s in Figure 8 below.

Figure 8:

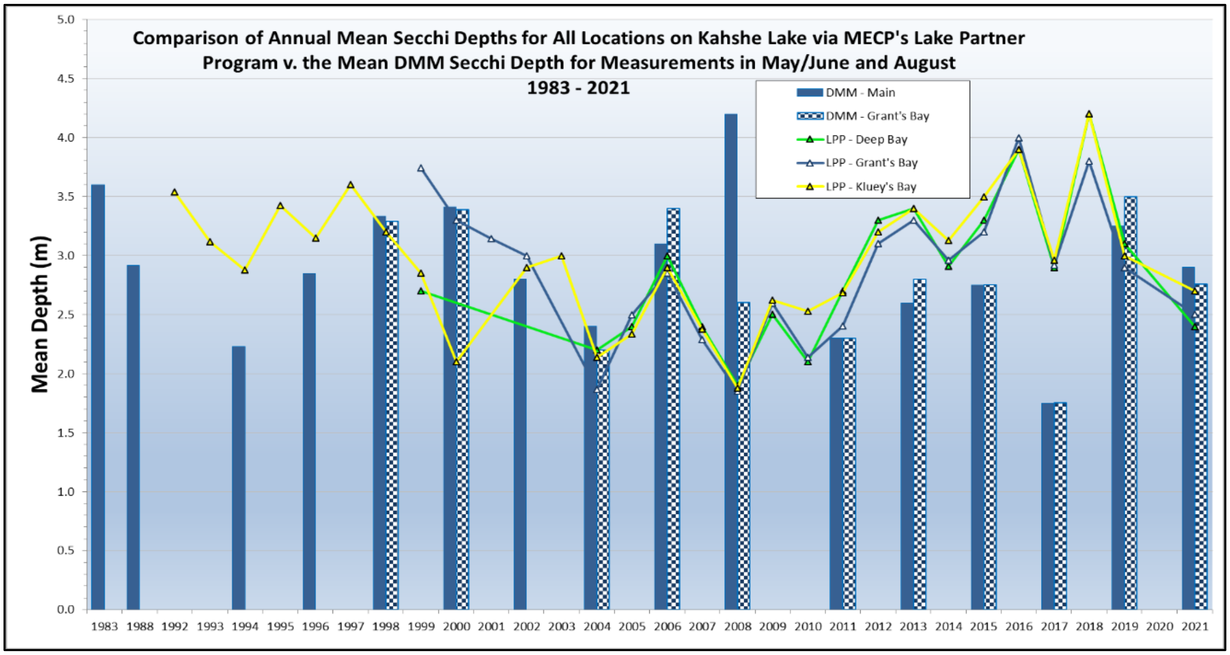


In this comparison, Bass Lake is represented by the dark blue columns while the Secchi data from the Main Site on Kahshe Lake are shown via the light blue columns. The findings from this comparison are summarized below:

- Water clarity in Bass Lake in 2021 was slightly less than in 2019, but generally similar to historical measurements dating back to 1981.
- Water clarity in Kahshe Lake in 2021 also was slightly less than in 2019 but generally similar to historical measurements dating back to 1983.
- Water clarity is noticeably better in Kahshe Lake than in Bass Lake, most likely due to the more tea coloured nature of Bass Lake - as confirmed by slightly higher Dissolved Organic Carbon [DOC] levels in Bass Lake.

To further explore the water clarity in Kahshe Lake as determined by the DMM, the MECP's Lake Partner data for water clarity at the three sampling sites in Kahshe Lake also were charted for comparison. The findings are shown below in Figure 9.

Figure 9:



In contrast to the findings in previous years, water clarity in Kahshe Lake as measured by the DMM was slightly greater in both 2019 and 2021 compared to the water clarity measurements recorded at three locations on Kahshe Lake via the MECP's Lake Partner Program. This may be related to the methodology for recording water clarity, as the DMM measurements are the average of two sampling events while the LPP measurements by the Lake Steward represent an average of 9-10 measurements at each site over the period from May through October.

WATER TEMPERATURE

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

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

The DMM water temperature readings at increasing depths in both Kahshe and Bass Lake data dating back to 1988 have been plotted in the four charts below (Figures 10-13). In an attempt to explore any trends in water temperature, the 2021 results have been compared with historical means grouped over two time periods:

- Pre 2000 (1980s and 1990s)

- The decade of 2000-2009
- The decade of 2010-2019

Figure 10:

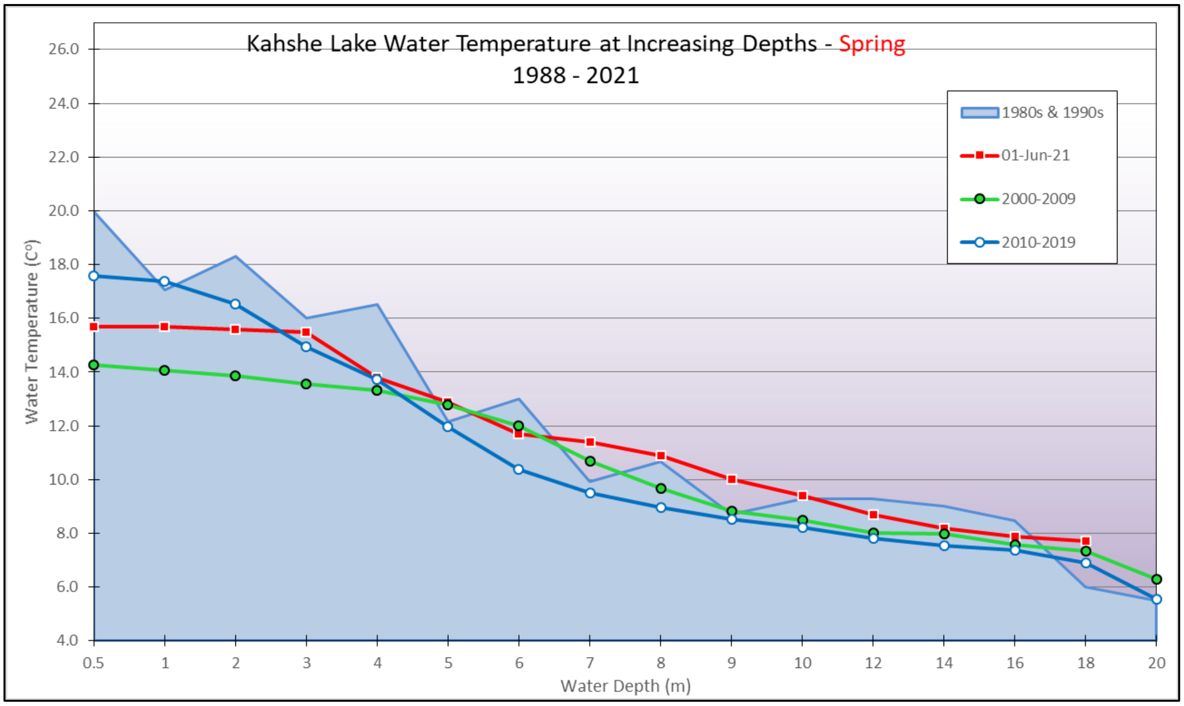
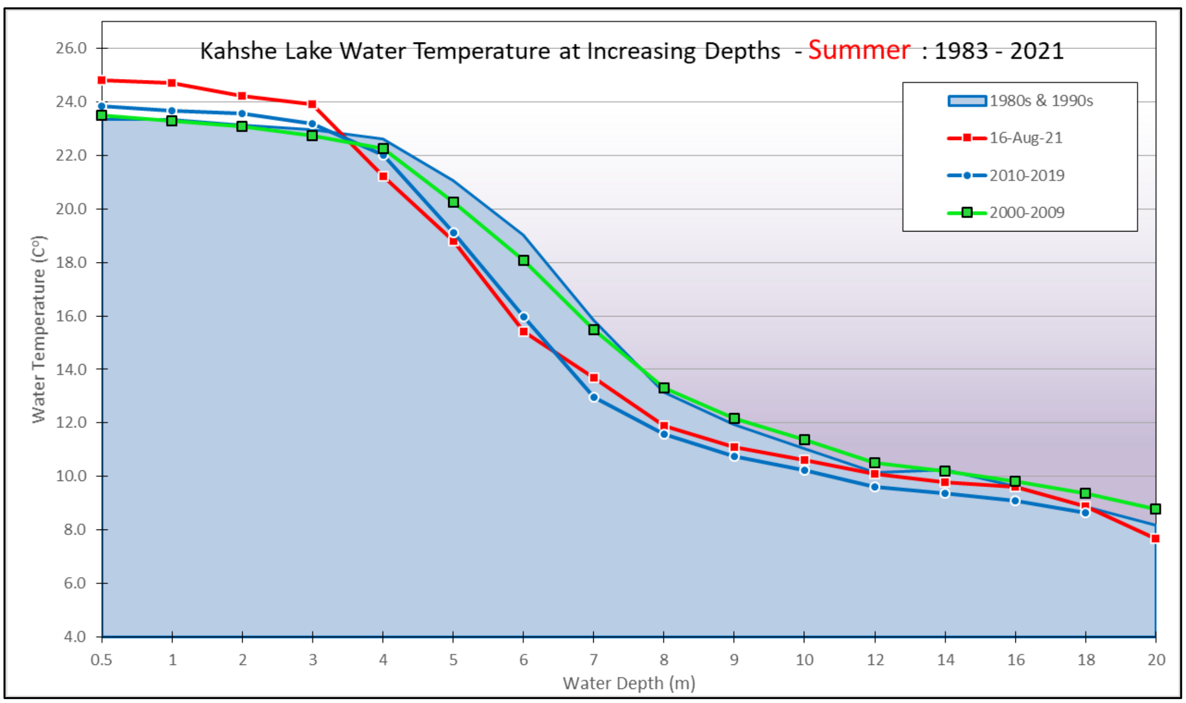


Figure 11:



It is apparent from Figures 10 and 11 that:

- Water temperature in the spring of 2021 in Kahshe Lake was a little cooler than 1980s and 1990s within the top 5m but similar to the previous years beyond that depth.
- However, by August 2021, the temperature in the top 3m was well above the early years mean but lower than in earlier years at depths from 3 to around 10m.
- Based on these records, the good news is that there appears to be no noticeable increase in late season water temperature in the layer directly below the top 3m surface layer where air temperatures would be expected to more directly influence water temperature.

The water temperature findings for Bass Lake in both Spring and Summer are presented in Figures 12 and 13 below:

Figure 12:

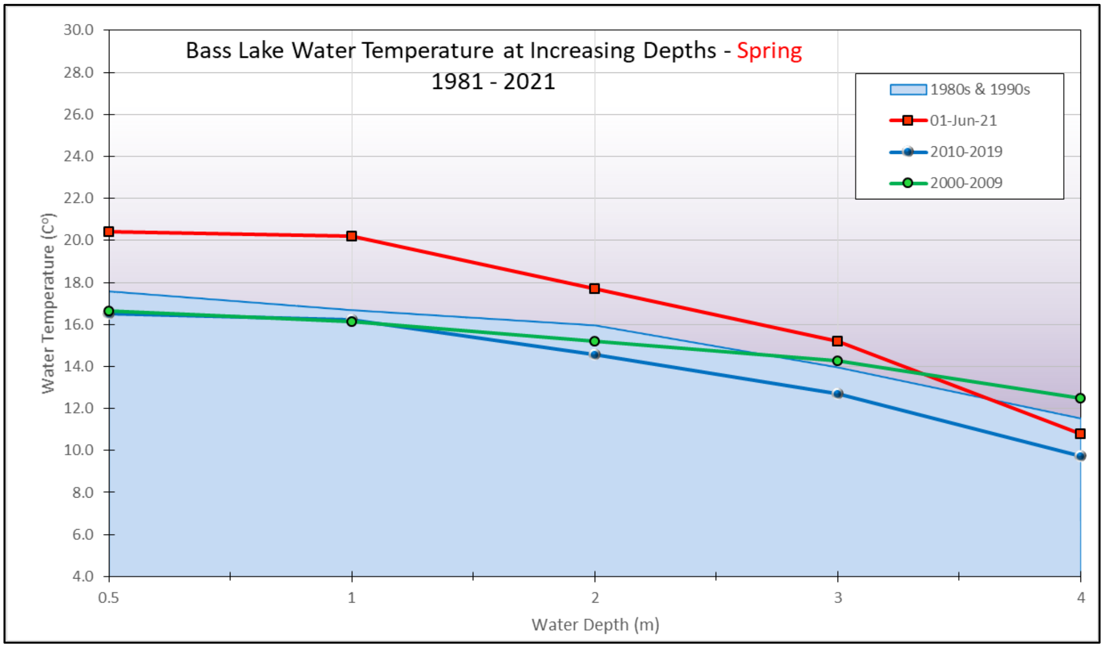
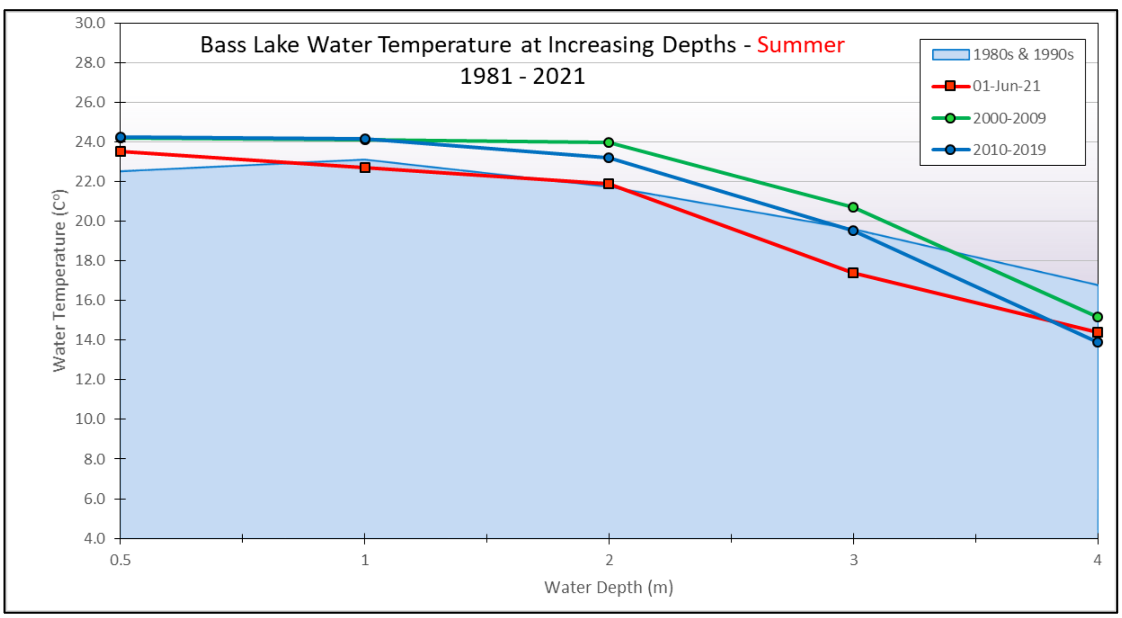


Figure 13:



It is apparent from Figures 12 and 13 above for Bass Lake that:

- In the spring of 2021 Bass Lake was noticeably warmer in the top 2m compared to water temperatures in this surface layer in all previous years.
- However, by August 2021, the temperature in the top 2m was similar to values recorded in all previous years.
- Below 2m, water temperatures in 2021 were moderately lower than in previous years.
- Based on these records, the good news is that there appears to be no noticeable increase in late season water temperature in the layer directly below the top 2m surface layer where air temperatures would be expected to more directly influence water temperature.

In summary, it appears that in both lakes, the spring temperatures, which are taken during the period of active lake stratification (turnover) more than likely reflect differences in the timing of the sampling, as in Kahshe L, the temperature of the surface layer was lower than in previous years, while in Bass L it was higher. By late August, the measurements are showing a possible warming trend for the surface layers in Kahshe L but not Bass L and a trend towards a slight cooling of the deeper layers in both lakes. The apparent trend toward a slight cooling of the deeper layers is good news, as water temperature in these deeper zones would not be directly influenced by daily fluctuations in air temperature.

ALGAL GROWTH

Algae are simple, typically small aquatic organisms and range in structure from unicellular (a microscopic single cell) to multicellular and as they produce and grow, form colonies that appear on the surface or attached to various substrates. Algae are always present in lakes and rivers and are at the base (primary) of most lake food webs, and as such, are critical components of a healthy aquatic environment. Without algae, zooplankton (small animals that feed on algae) would not survive, and this would impact the survival of fish and other animals further up the food chain.

When conditions are favourable, both benthic and planktonic cyanobacteria as well as other types of algae can increase to levels that result in poor water quality and an algal bloom or scum may form. Conditions that promote bloom development include:

- sufficiently high levels of nutrients in either sediments or water (primarily phosphorus and to a lesser extent nitrogen), as some species can manufacture their own nitrogen from the atmosphere);
- calm weather conditions and shallow water with low water flow;
- strong sunlight; and,
- high air and surface water temperatures

Nutrient enrichment and phosphorus in particular has been associated with increases in algal biomass in freshwater systems worldwide, and recent studies indicate that climate change is a potent catalyst for the further expansion of algal blooms because of the warming of surface waters, longer periods of open water (fewer ice covered days) and more intense rainfall which flushes soil-borne nutrients into near-shore waters. Rising air and water temperatures favour most bloom-forming planktonic blue-green cyanobacteria because they have higher temperature requirements and because they are able to regulate their buoyancy under conditions of reduced vertical water column mixing (lake turnover) which occurs under rising surface water temperatures as the season progresses.

Although algal blooms are the primary focus of concern, the sediment dwelling algae and those that grow on rocks along the shoreline are also of concern. They are aesthetically unpleasant and also make shoreline navigation difficult, due to their slimy and slippery nature. As the season progresses, and they complete their life cycle, they can be dislodged from bottom and shore growing locations and can drift into slow moving water of bays along the shore where they start to decompose. Many on Kahshe Lake have noticed the unpleasant odours that begin to arise in the late summer and fall as this process takes place. These floating mats also can be mistaken for late-season blooms, as they are dislodged and float into shoreline locations. However, on closer examination, they typically appear less vibrant than the colours of algae in an active bloom.

In a 2011 publication (Winter et al., 2011), the Environment Ministry's investigations of algal blooms in Ontario were summarized and their findings confirmed the following trends:

- The total number of algal blooms reported in Ontario increased significantly from 1994 to 2009, and there also were significant increases in the number of blooms dominated by cyanobacteria and chlorophytes.
- Most lakes (50) had a single bloom report, 11 lakes had blooms reported in two years, four lakes had reports in three years, and one lake had reports in eight of the years between 1994 and 2009.
- In 2009, 16 of the 24 blooms reported tested positive for the presence of microcystin, one of several toxic substances which can be released by blue-green algal blooms.
- A significant increase in day of year the last bloom was reported in a given year was observed, indicating that blooms are being detected and reported later in the year compared to 15 years ago. In contrast, no change was seen in day of year the first bloom was reported.

While this Environment Ministry report only covered algal bloom development through 2009, the detection of increasing numbers of harmful blue-green algal blooms has continued to increase, as confirmed by the Simcoe- Muskoka Health Unit in Table 1 below.

Table 1: Blue-Green Algae Impacted Lakes in the Muskoka Area- 2018 through 2020

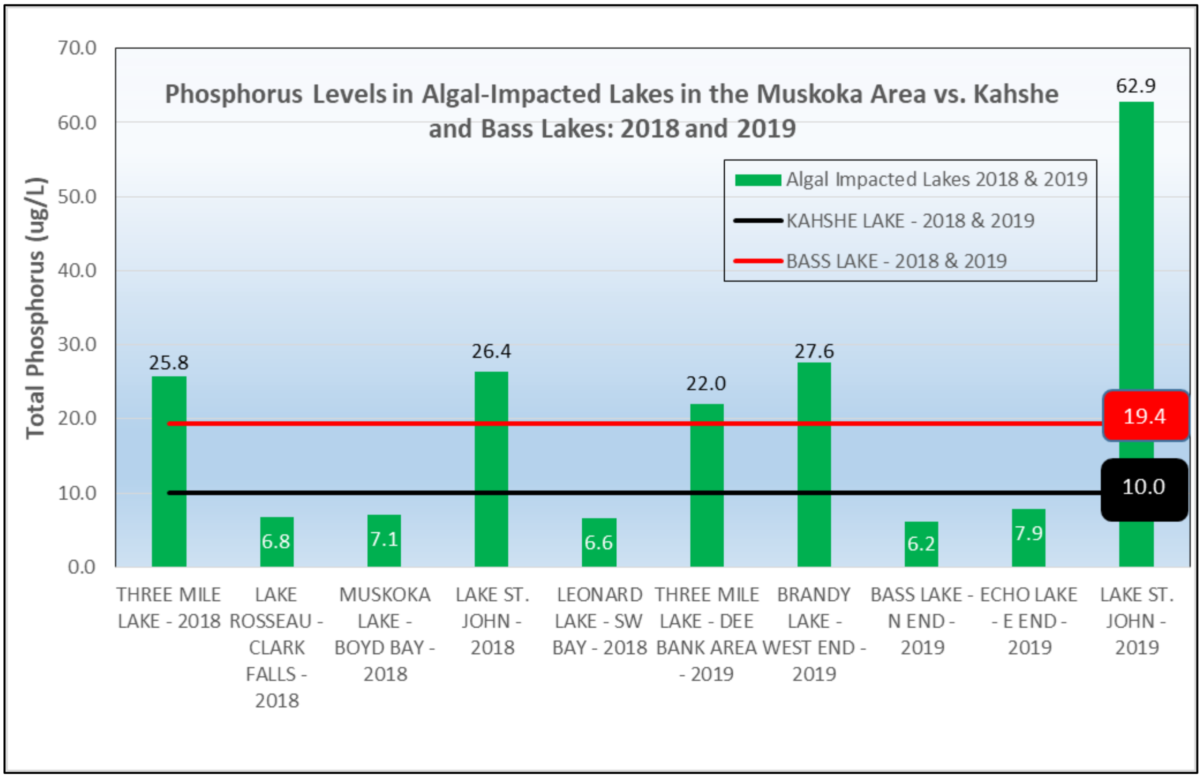
Year	Blue-Green Algal Bloom Impacted Lakes	Number of Bloom Alerts
2018	Three Mile, St. John, Leonard, Rosseau, Lamont Creek	6
2019	Three Mile, Brandy, Bass (not ours), Echo, St. John, St. George, MacLean	8
2020	Three Mile, Brandy, St. John, Black, Leonard, Simcoe, Bruce, Muskoka, Silver, Stewart, Little, Ten Mile, Otter and **Kahshe Lakes**	18
2021	Georgian Bay, Three Mile, Little, Stewart, **Kahshe**, Mary, Menaminee, Fawn, Paint, St. John, Leonard, Bass Lakes	13

Unfortunately, as noted above, harmful blue-green algal blooms have now been confirmed in Kahshe Lake in both 2020 and 2021. In 2020, the bloom was located along the northern shoreline in the Oak Road vicinity and was investigated by staff from the MECP. In 2021, the first report of a bloom was in the east end of the lake (actually in the Kahshe River), but this was followed by reports of similar blooms in several areas of the lake, and as such, the alert was issued to cover the entire lake. Further details on these specific blooms and any others going forward have been described in greater detail in the KLRA Web's Water Quality portal and can be accessed via this link:
https://kahshelake.ca/resources/Documents/Lake%20Steward/2022/Current%20Algal%20Bloom%20Status%20for%20Kahshe%20and%20Bass%20Lake-R3%20Feb2022-TCAccepted.pdf

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

The total phosphorus levels in the 10 lakes with data are shown in Figure 14 below.

Figure 14:



As is apparent from Figure 14 above, three of the impacted lakes (Three Mile, St. John and Brandy Lakes) had very high total phosphorus levels, so the presence of an algal bloom in these lakes could not be considered a surprising result. However, five of the impacted lakes (Rosseau, Muskoka, Leonard, Bass and Echo) had total phosphorus levels well below those of both Kahshe and Bass Lakes.

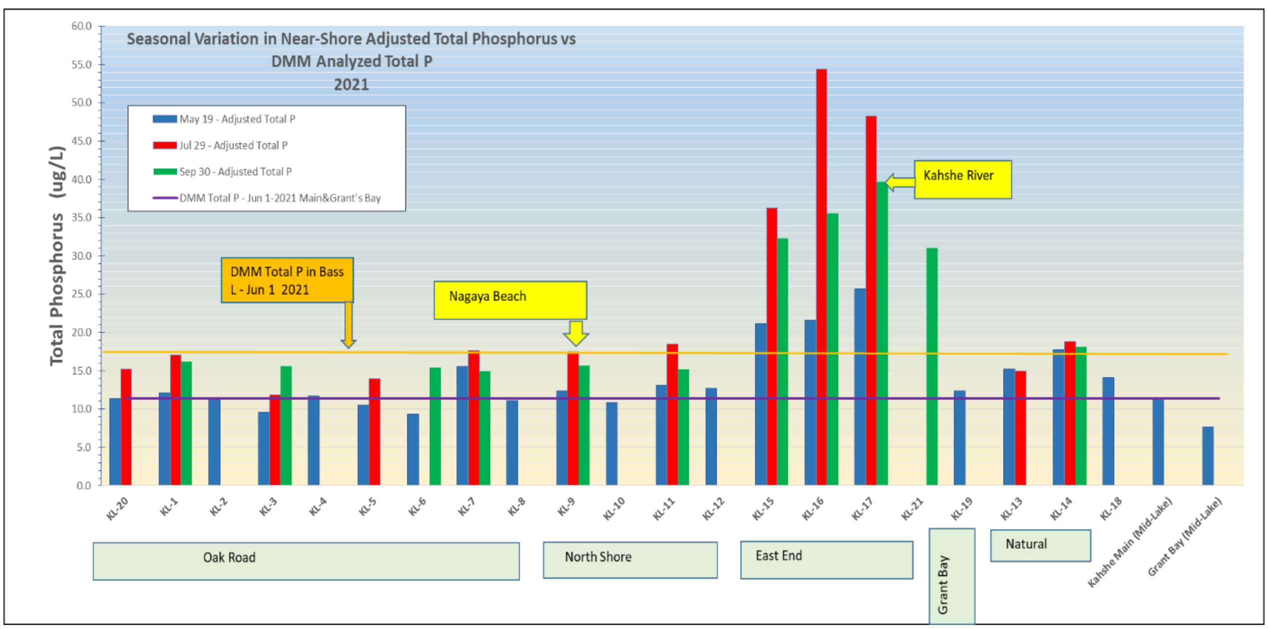
These findings give cause for concern, as this trend towards increasing numbers of late-season harmful algal blooms throughout Muskoka does not appear to be directly associated with increasing levels of total phosphorus or nitrogen compounds determined via these early spring water quality sampling programs from the deep water of mid-lake sampling sites.

This apparent anomaly prompted the development of the KLRA-funded Near Shore Water Sampling Project (NSWSP) in 2021 and the findings from those water sampling activities identified a causal linkage between algal bloom development and water quality parameters indicating the leaching of soil-borne and mobile nitrogen compounds from septic systems or lawns located near the shore which attract large numbers of Canada geese were involved. This appears to be associated with higher intensity rainfall events characteristic of a changing climate which are accelerating the leaching process. The findings from the NSWSP have been reported and posted on the KLRA's Water Quality web portal which is accessible via this link: https://kahshelake.ca/resources/Documents/Lake%20Steward/2022/Full%20NSWSP%20-%20Jan16-22.pdf

The NSWSP findings are briefly summarized below:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a true assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture much higher total phosphorus levels in the east end of the lake, as there are no DMM or MECP sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) tend to increase as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry for some algal-friendly nutrients appear to be associated with effluents from human & animal waste sources and are known to be linked with HABs.
- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

To demonstrate some of the above NSWSP findings, Figure 4A from the near-shore project has been reproduce here and shows how total phosphorus levels in the near-shore environment compared to those from the historical DMM and MECP mid-lake, deep water monitoring locations.



Although we have virtually no control over the change that is affecting our climate, there are very definitely actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future algal blooms. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain water into rock-filled drainage pits.**
2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil & goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town will be inspecting in 2023, but we don't need to wait until then and be subject to system shutdown until failing systems are repaired.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

4.2 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 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 some 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 zooplankton, as we move from a higher calcium, phosphorus world in our lakes to a lower calcium, lower phosphorus world.

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

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

1) We are losing biodiversity here, as several species of *Daphnia* are losing out to only one *Holopedium* species;
2) The nutritional value of the large animal plankton is reduced, as *Holopedium* has a much lower mineral content than *Daphnia*. The implications of this should be explored, but are not yet known; and,

3) There may well be less food passed up the food chain to fish in our small lakes where invertebrate predators are actually key steps between plankton and fish, because *Holopedium* is pretty well protected from most invertebrate predators by its jelly coat. When it is eaten, it has lower mineral content.

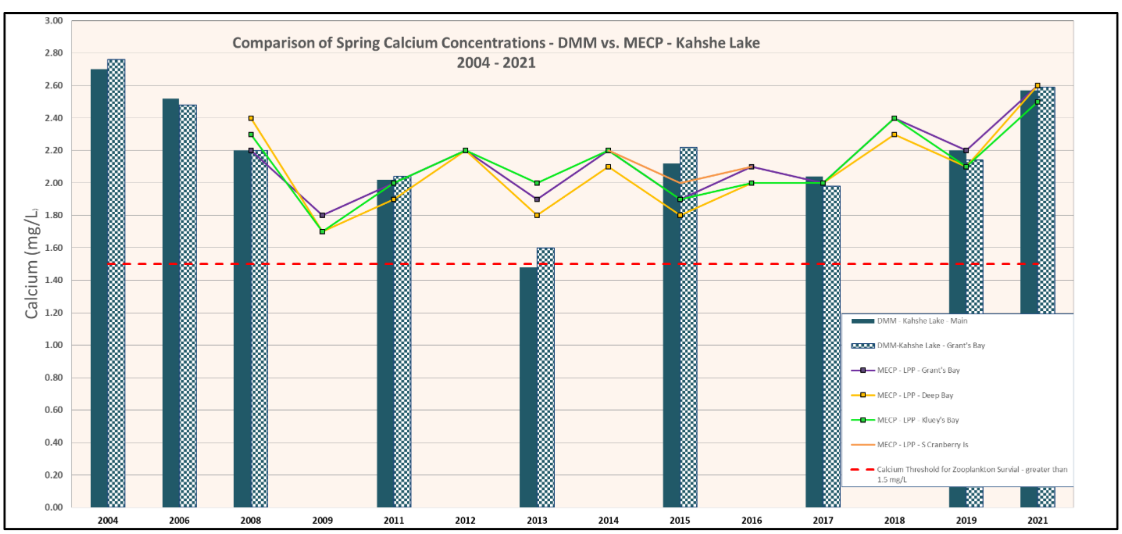
In our Muskoka lakes, the absolute abundance of *Holopedium* has increased by an average of about two fold over the last 20 years, and the relative abundance has increased more, said Yan, while the abundance of five species of *Daphnia* has declined. There are two other, smaller species of *Daphnia*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

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

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

Fortunately, the DMM water sampling program has included calcium since 2004, while the MECP have been analyzing Kahshe Lake water for calcium since 2008. Figure 15 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*.

Figure 15:



Based on this information, it can be concluded that:

- Calcium concentrations in Kahshe Lake are well above the lower limit that has been set to protect some sensitive zooplankton species.
- Although we don't have an extensive history of calcium monitoring results, the data we do have show no obvious signs of increasing or decreasing concentrations.
- While the calcium results look favourable, there was a population explosion of *Holopedium sp*. In Kahshe Lake late in 2021; although these jelly-like orbs were a nuisance in the water for swimmers, it is not known if this represents a concern ecologically via the food chain.
- In contrast to Kahshe Lake, the calcium concentration in Bass Lake decreased fairly significantly in 2021 (1.8 mg/L) from levels in earlier years ranging in the mid-2 mg/L range; however, there were no reports of a Holopedium population explosion in Bass Lake.

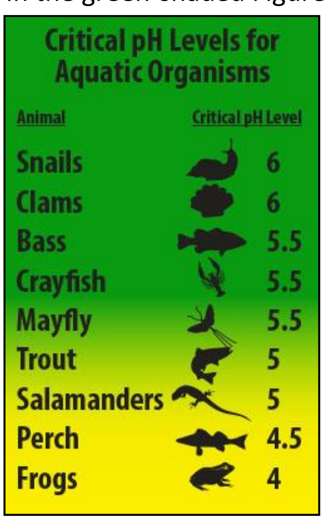
4.3 Lake Acidification

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

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

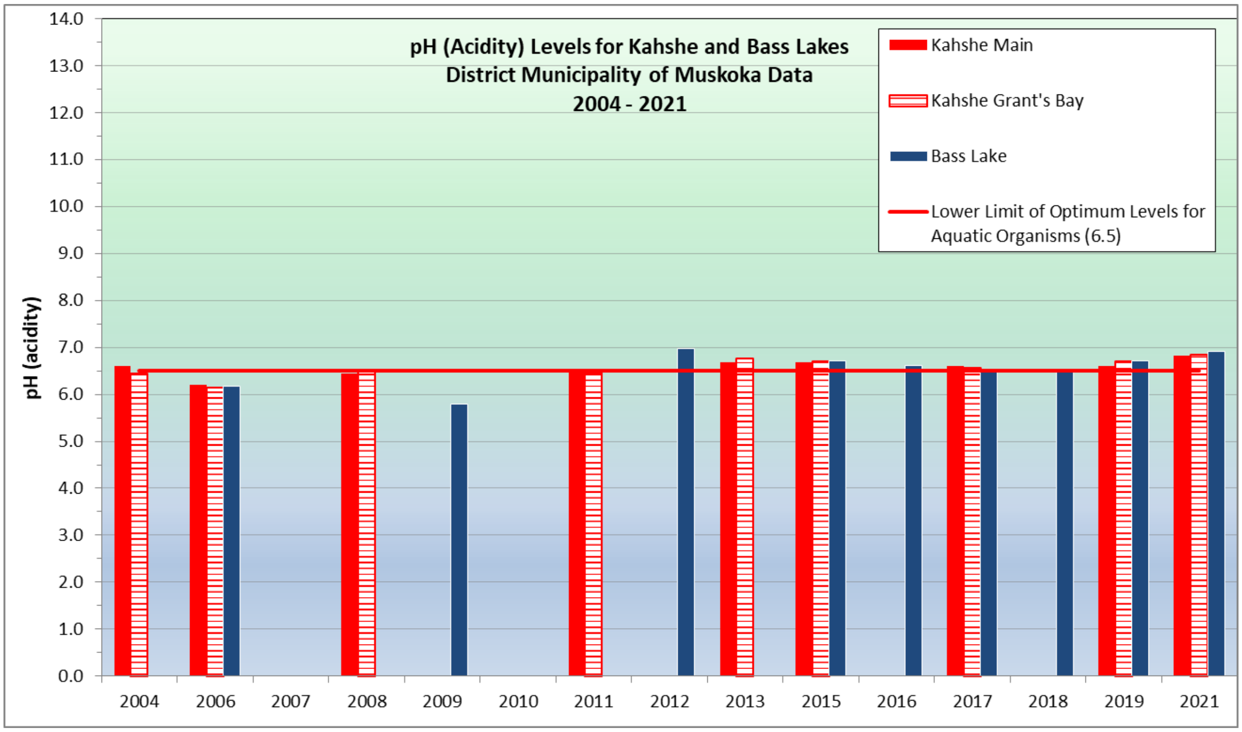
The Provincial water quality objective is to keep pH between 6.5 and 8.5, as values above or below those levels can be harmful to some aquatic organisms.

In the green-shaded Figure 16 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 in Figure 17 shows the pH values for Kahshe and Bass Lakes from 2004 through 2019.

Figure 17:



It is apparent from Figure 17 that the pH of Kahshe and Bass Lakes is:

- At or slightly above the lower end of the optimum pH range of 6.5-8.5, which is good.
- Above the level of 6.0 where impacts to some sensitive aquatic species might be encountered (see EPA species sensitivity picture above), which also is good news.
- Not showing any evidence of either an increase or decrease in acidity over the 15 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.

4.4 Anions, Cations and Other Chemicals

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

The full suite of chemicals analyzed via the DMM sampling program in 2031 included: chloride, nitrogen (ammonia + ammonium), nitrogen (nitrite+nitrate), total nitrogen, sulphate, aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silicon, sodium, strontium, titanium, vanadium, zinc. In addition, the following additional parameters were added to the suite of chemicals in 2012 and repeated annually since then: antimony, arsenic, boron, selenium, silver, thallium and uranium.

As most of these parameters have not been included in the DMM summary table of additional chemical parameters, this report attempts to do this by comparing the results for all years for which data exist to surface water benchmarks that are available from the MECP 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 MECP (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 MECP APV was not available, a similar format to the one used by the MECP in protecting surface water from ground water discharges associated with contaminated sites (*O. Reg. 153/04* as amended) has been followed. This involved first checking for a U.S. EPA chronic ambient water quality criterion (based on a continuous chronic criterion, (U.S. EPA, 2012; U.S. EPA, 1986));

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

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

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

Table 2: Summary of Chemical Analysis Results – Kahshe and Bass Lake – 2019

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
Anions	Chloride	MECP APV	All reported values well below aquatic benchmark and chloride concentrations in Bass Lake are slightly higher than those in Kahshe. Note that the chart uses a logarithmic scale.
	Nitrogen (Ammonia + Ammonium)	BC Water Quality Guideline	All reported values well below aquatic benchmark and concentrations in Bass Lake are slightly higher than those in Kahshe. Note that the chart uses a logarithmic scale. The impact of ammonium nitrogen also is important as an algal friendly nutrient, and this is discussed in Section 3.1 of the report.
	Nitrogen (Nitrite + Nitrate)	Canadian Water Quality Guideline	All reported values well below aquatic benchmark and concentrations in Kahshe are slightly higher than those in Bass. Note that the chart uses a logarithmic scale. The impact of nitrate nitrogen also is important as an algal friendly nutrient, and this is discussed in Section 3.1 of the report.
	Nitrogen (total Kjeldahl)	None Found	Total Kjeldahl nitrogen analysis was discontinued in 2021, as the laboratory now reports its findings for total nitrogen. The impact of nitrogen also is important as an algal friendly nutrient, and this is discussed in Section 3.1 of the report. Also interesting to note that total nitrogen is higher in Bass L while its two main components do not reflect this finding.
	Sulphate	BC WQC	All reported values well below benchmark and no trend is apparent.
Cations	Aluminum	Interim Canadian WQG	All reported values for Kahshe Lake well below the WQG. Bass Lake values are higher than those from Kahshe Lake and most are close to or marginally above the upper range in the WQG. Note that the CWQG for Al is both pH and DOC dependent. As such, the low end of the range of CWQGs based on the pH and DOC levels has been plotted.
	Barium	MECP APV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Beryllium	MECP APV	All reported values well below benchmark.
	Cadmium	MECP APV	The Aquatic Protection Value is exceeded in 2018, 2019 and 2021 as well as in two earlier years. The early exceedances are likely a sampling (water filtering) or laboratory quality control issue, as the APV is very close to the detection levels of most laboratories. Similarly, the apparent increase in the 2018 and 2019 levels is due to a change in the Laboratory DL values which now exceed the APV. This issue is further apparent in 2021, as the laboratory increased its DL by 2-fold. As such, the reported exceedances are not measured concentrations, simply the level of detection by the laboratory. As such, cadmium concentrations warrant continued monitoring, but no aquatic impacts are anticipated.
	Chromium	MECP APV	All reported values well below benchmark and in 2021, the laboratory DL increased by 2-fold. As such the apparent increase in Cr concentration is simply a laboratory artifact.

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
	Cobalt	MECP APV	All reported values well below benchmark. However, as for Cr, the Co DL increased 10-fold in 2021, and as such the apparent increase in Co concentration is simply a laboratory artifact.
	Copper	MECP APV	As for Co, the DL for Cu increased 10-fold in 2021, and as such, the apparent increase in Cu concentration is simply a laboratory artifact.
	Iron	U.S. EPA CCC	All reported values for both lakes are well below benchmark, although the 2021 results for Bass Lake continue the trend of being about 2-times higher than in Kahshe Lake.
	Lead	MECP APV	Two exceedances of the benchmark in Bass Lake in early years, but none since 2009; likely a sampling or laboratory quality control issue. The DL in 2021 has increased more than 2-fold, so the apparent increase is simply a laboratory artifact. Note that the chart uses a logarithmic scale.
	Magnesium	U.S. EPA LCV	All reported values prior to 2021 were well below benchmark. For some reason, not analyzed in 2021. Note that the chart uses a logarithmic scale.
	Manganese	BC AWQC	All reported values well below aquatic benchmark and manganese concentrations in Bass Lake are noticeably higher than those in Kahshe.
	Molybdenum	MECP APV	All reported values well below benchmark. In 2021, the laboratory DL increased by 2-fold. As such the apparent increase in Mo concentration is simply a laboratory artifact. Note that the chart uses a logarithmic scale.
	Nickel	MECP APV	All reported values well below benchmark and as for others, DL increased by 10-fold, so the apparent increase in 2021 is a laboratory artifact.
	Potassium	U.S. EPA LCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Silicon	None Found	In most years, including 2021, silicon concentrations in Kahshe Lake are noticeably higher than those in Bass Lake. No aquatic protection benchmark was found for comparison.
	Sodium	MECP APV	All reported values well below aquatic benchmark and concentrations in Bass Lake are noticeably higher than those in Kahshe. Note that the chart uses a logarithmic scale.
	Strontium	U.S. EPA T-II SCV	All reported values well below benchmark. Note that the chart uses a logarithmic scale.
	Titanium	None Found	In most years up to 2019, titanium concentrations in Bass Lake noticeably higher than those in Kahshe Lake. An increase in the DL in 2021 masks this difference as all values were reported as DLs. No aquatic protection benchmark was found for comparison.
	Vanadium	MECP APV	All reported values well below benchmark and a 2-fold increase in the DL masks any interpretation of the 2021 values.
	Zinc	MECP APV	All reported values well below benchmark.
Other Chemicals	Dissolved Organic Carbon	DMM Notes	Although there is no aquatic benchmark, the findings for Bass Lake are noticeably higher than those in Kahshe and also are at or slightly higher than 7 mg/L, which is the Ontario aesthetic objective for recreational use.

Category	Analyzed Parameter	Evaluation Benchmark[1]	Comments
	Electrical Conductivity	None Found	In most years including 2021, EC levels in Bass Lake are slightly higher than those in Kahshe Lake. No aquatic protection benchmark was found for comparison.
	Alkalinity	DMM Notes	Although there is no aquatic protection benchmark, the alkalinity of both Kahshe and Bass Lakes (generally higher in Bass L) is below 10 mg/L, indicating that both lakes have low buffering capacity and therefore are potentially susceptible to acidification.
Recently Added Cations	Antimony	MECP APV	All reported values well below benchmark and as for several other parameters, the DL increased in 2021 masking any comparison of the levels in both lakes. Note that the chart uses a logarithmic scale.
	Arsenic	MECP APV	All reported values well below benchmark and as for several other parameters, the DL increased in 2021 masking any comparison of the levels in both lakes. Note that the chart uses a logarithmic scale.
	Boron	MECP APV	All reported values well below benchmark and as for several other parameters, the DL increased in 2021 masking any comparison of the levels in both lakes. Note that the chart uses a logarithmic scale.
	Selenium	MECP APV	All reported values well below benchmark and as for several other parameters, the DL increased in 2021 masking any comparison of the levels in both lakes. Note that the chart uses a logarithmic scale.
	Silver	MECP APV	Historically, silver has never been detected as all values dating back to 2004 have been less than the DL. In 2021, the DL increased 5-fold, masking any comparison of the data between the two lakes. As the 2021 DL now exceeds the APV, the potential impact of this parameter cannot be determined. Note that the chart uses a logarithmic scale.
	Thallium	MECP APV	Historically, thallium has never been detected as all values dating back to 2004 have been less than the DL. In 2021, the DL increased 5-fold, masking any comparison of the data between the two lakes. Note that the chart uses a logarithmic scale.
	Uranium	MECP APV	Historically, uranium has never been detected as all values dating back to 2004 have been less than the DL. In 2021, the DL increased 2-fold, masking any comparison of the data between the two lakes. All DL values are well below benchmark. Note that the chart uses a logarithmic scale.

Legend:

[1] Evaluation Benchmarks

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

Although the main goal of the above discussion was to examine the potential of these parameters to impact water quality in terms of aquatic health, the comparison also identified a number of cases where concentrations in Kahshe or Bass Lake were higher in one than in the other. While the cause of this finding is not immediately apparent, it is interesting given the finding of noticeably higher concentrations of total phosphorus in Bass Lake compared to Kahshe Lake. To explore this further, Table 3 below identifies the parameters which are either slightly or noticeably elevated in one lake compared to the other. The increase in the laboratory DL for several parameters in 2021 has masked this type of comparison for titanium, but the DL increase did not affect the intra lake comparison for any others.

Table 3: Comparison of Chemical Parameters in Kahshe vs Bass Lakes - 2021

Bass Lake Concentrations Higher than in Kahshe		Kahshe Lake Concentrations Higher than in Bass	
Noticeably	**Slightly**	**Noticeably**	**Slightly**
▪ N-Kjeldahl (now reported as N-Total) ▪ Al ▪ Fe ▪ Mn ▪ Na ▪ Ti (masked in 2021 by DL increase) ▪ DOC ▪ Alkalinity	▪ Cl ▪ $N\text{-}NH_4$ ▪ Ca ▪ EC	▪ Si ▪ $N\text{-}NO_3$	▪ None

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

4.5 Dissolved Oxygen

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

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

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

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

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

To examine the DMM findings for DO, the data have been averaged in a manner similar to what was done with water temperatures. This generated an a mean for the 1980s&1990s, 2000-2009 and 2010-2019. for all Spring and Summer sampling up to 2021, and these findings for Kahshe Lake are plotted below in Figures 18 and 19.

Figure 18:

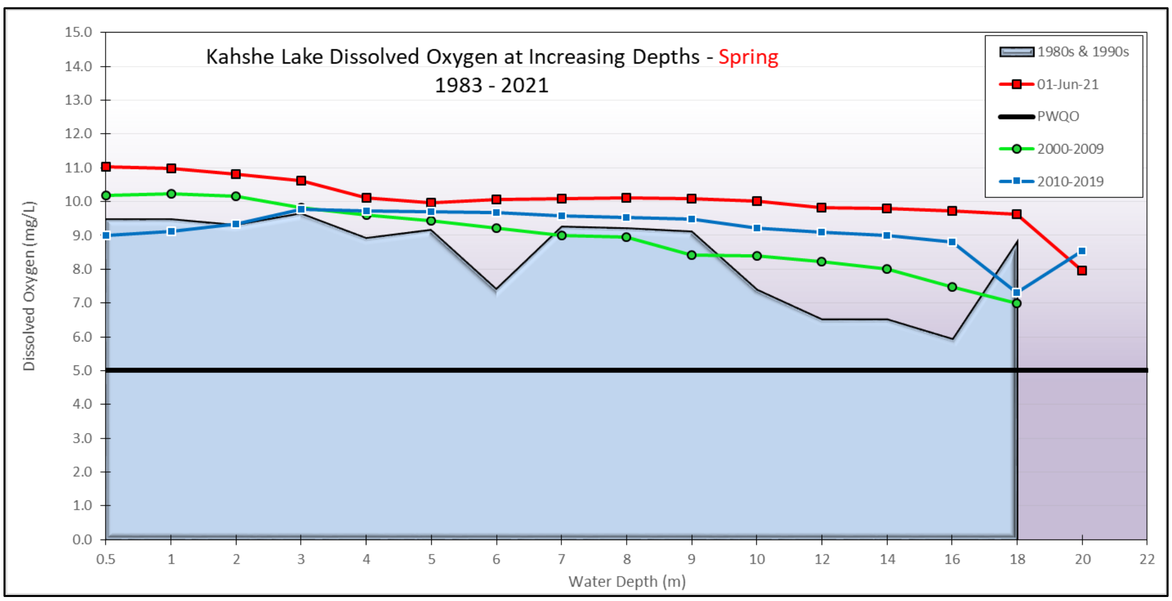
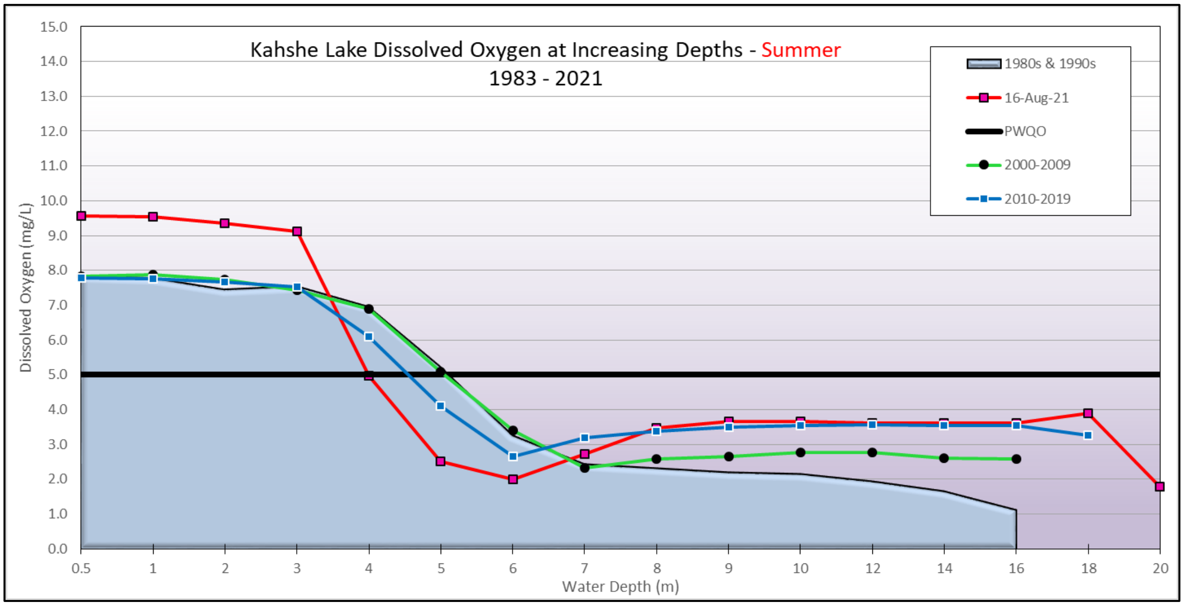


Figure 19:



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

- As expected, the DO levels in the Spring sampling event reveal only a slight trend to decreasing DO levels with increasing water depth, and in all cases the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixes the water across the depth of the lake.
- However, by late July, the 2021 DO levels are considerably higher than in previous years/decades down to around 3m depth and then decrease sharply from 3-6m before rising slightly between 6-8m and remaining fairly constant down to the full depth of 20m.
- More importantly, the DO levels from 2021 appear to follow the trend of falling below the PWQO at a more shallow depth of around 4m than was the case in the 1980s and 1990s where levels below the PWQO were not encountered until depths below around 5m.

The Bass Lake DO levels for both Spring and Summer sampling times are charted below in Figures 20 and 21.

Figure 20:

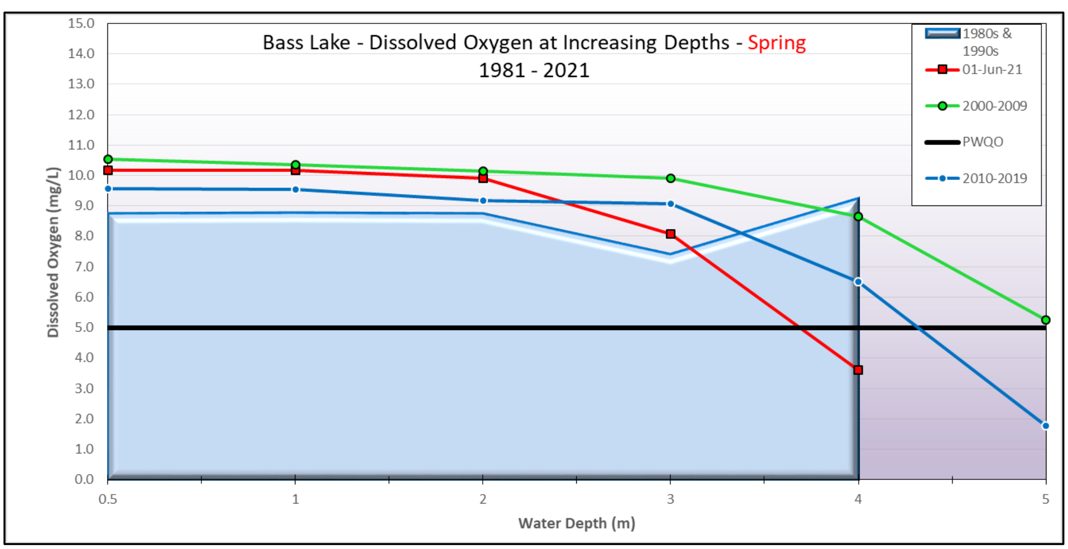
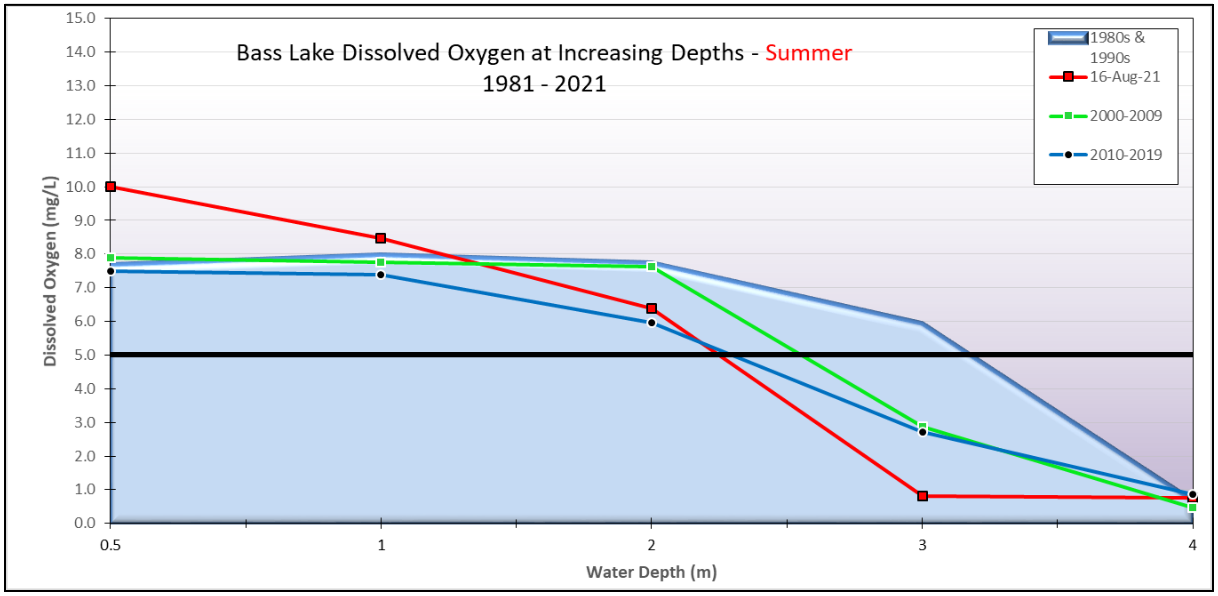


Figure 21:



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

- As for Kahshe Lake, the DO levels in the spring sampling event reveal only a slight trend to decreasing DO levels with increasing water depth, and in all but the lowest depths, the DO levels are well above the aquatic health-based PWQO. These findings are consistent with lake water turnover that vertically mixes the water across the depth of the lake, although to a lesser extent in Bass Lake due to its more shallow depth.
- However, by late July, the 2021 DO levels are essentially similar to the two historical records of DO levels down to about 2m depth and then decrease gradually through the 4m depth, falling below the PWQO just below the 2m depth.
- More importantly, as for Kahshe Lake, there appears to be a trend towards DO levels falling below the PWQO at more shallow depths (just below 2m) than back in the 1980s and 1990s when DO crossed below the PWQO at depths just below 3m.

4.6 Evaluation of Benthic Monitoring

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

As both lakes were declared 'Vulnerable' in 2020 due to either total phosphorus above 20 µg/L or the documented presence of a harmful algal bloom, benthic monitoring was again undertaken in 2021 and will be conducted annually until the completion of planned Causation Studies by the DMM.

The findings from the 2021 benthic sampling and counting survey which was undertaken at Site B3 (Birch Island) on August 25, 2021 are presented below. This activity could not have been undertaken without the support of the following Kahshe Lake volunteers who carried out the count under sweltering conditions under the supervision of Ms Jess Lario, the Biotechnician from the DMM:

- Clare and Judy Henderson

- Toby Fletcher and Laurie Turner
- Barb and Brian Riley
- Nancy McLean and Lily Sahli
- Dave Barker
- Gail Pearson

A few pictures of the sampling at B3 and of the volunteers have been inserted below:

Following the counting, Jess identified the benthos that were detected and prepared a report on the

findings as noted below. To give some perspective to the reader, a picture of the most common benthos encountered in Muskoka lakes has been inserted aside.

The report from the DMM follows:

Monday August 30th, 2021

Ron Pearson and Kahshe Lake Association,

I wanted to say thank you for your help with the benthic monitoring on

Kahshe Lake this summer. It was a great group of friendly and genuinely interested people, and I am glad to see that so many people were able to attend. I am glad that Kahshe Lake Association is back in the program and eager to help with the monitoring on Kahshe Lake.

Each year we sample our established sites to determine which benthic macroinvertebrates are found. These benthos indicate the health of the riparian zone (section between shallow water and dry land) and the littoral zone (shallow water nearest to dry land). These two zones are especially important to lake health as they are impacted by snowmelt, runoff, sedimentation, etc.

*Collected benthos are grouped into seven (7) different categories, in which three (3) are mainly focused on: EOT, Chironimids, and Richness. The % EOT includes mayflies, dragonflies, and caddisflies, which are benthic macroinvertebrates who are **intolerant** to pollution. % Chironimids is focused on the invertebrate named a Midge (or blood worm) which are **tolerant** to pollution and can survive in harsh environments. Richness is the biodiversity of species found within the sample, and with biodiversity, the more the better. The other four (4) categories are more used as reference, in that if one year a number drastically jumps or falls, further investigation might be required.*

With these numbers alongside the Muskoka Average, we are able to understand the direction the lake is heading in regards to shoreline and lake health. If the % EOT (intolerant) is low, and % Chironimids (tolerant) is high, this indicates that the environment may not suitable for the intolerant benthic invertebrates. This indicates to us that this section of the lake may be impacted by sources such as development, runoff, or other anthropogenic sources.*

Below I have explained results from our testing on August 25th, 2021.

- *Richness is at 10. As stated above, richness is important as it represents biodiversity within the lake. Biodiversity shows that there is a healthy relationship between benthos. Even though this is less than the average in Muskoka, this is still a good number.*
- *%EOT is at 38. This is the main indicator of good water quality. These species are pollutant intolerant, so having it this far above the average is very good.*
- *%Chironimids is at 1. This area is the main indicator of poor water quality, so having it this far below average is very good.*

The following categories are the reference categories. The importance for these values is that there are no large increases or decreases. This number should be monitored closely for any changes. Its value relative to the average within Muskoka is not as important.

- *%Predators is at 20, which is slightly above the average.*
- *%Shredders is 20, above the average in Muskoka.*
- *%Collectors/Gatherers is at 56. This is below the average for Muskoka.*
- *Hilsenhoff Index looks very good at 5.75. The lower the number, the better for the Hilsenhoff Index. This number is less than the average found in Muskoka and is a good value.*

Most of the values observed are consistent with past sampling events at this site. Since Kahshe Lake has been added to the vulnerable list it will be sampled each year, and alternating sites will be sampled. It is great to see associations that care about the lakes they live on and actively taking part in monitoring *programs. I hope I have answered any possible questions or concerns about the results, but if you have any others please feel free to e-mail me at biotech@muskoka.on.ca or call my cell number at 705-644-9047. I hope you all enjoy the rest of your summer!*

Sincerely,

Jess Lario

5.0 Summary and Conclusions

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

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

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

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

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

Climatic Factors and Ice Condition Summary
To better understand the chemical and physical data that have been collected, this year's report includes an overview of the climatological factors that have the potential to influence lake conditions. This comparison demonstrates that air temperatures in 2021 were generally similar to the two previous years and to the 30 year normal for most months, with the exception of noticeably warmer conditions in August and October. In the case of precipitation, total monthly amounts were lower than normal from January through May but much higher than normal in June, July and September. Ice-out on Kahshe in 2020 and 2021 occurred around April 9 and 7th, respectively. Ice-out records for Deep Bay also have been recorded dating back to 1987 and have been compared to ice-out times for Muskoka lakes dating

back to 1886, and these records shows no clear trend towards an earlier or later ice-out condition for in either data set.

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 MECP is to provide an early warning for both undesirable nutrient enrichment and the potential for harmful algal blooms.

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

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

PHOSPHORUS

- In both lakes, there has been no detectable trend in total phosphorus concentrations over the past 38-40 years and in both lakes, the levels are consistent with what is regarded as background concentrations and well below levels determined by the DMM to be Total Phosphorus Threshold levels.
- Historically, the total phosphorus levels in Bass Lake are about twice as high as in Kahshe Lake; however; this appears to be a natural condition, as the levels in Bass L have not changed since monitoring began back in 1981.
- After the year 2003, the total phosphorus concentrations determined via the DMM and MECP sampling programs (both of which are analyzed by the MECP's Dorset laboratory) have yielded very similar findings, with most of the differences in phosphorus likely due to different spring sampling dates which would be influenced by the degree of lake stratification (turnover).
- The 2021 results also confirm that the total phosphorus concentrations in the various deep water areas of the lake are more or less similar.
- The finding of similar total spring phosphorus levels at the five different sampling locations on Kahshe Lake contrasts with the findings from the 2021 KLRA-funded Near Shore Water Sampling Project which found noticeably higher total phosphorus concentrations in the water from the East end of the lake which has not been sampled via either the DMM or MECP's LPP program.

NITROGEN

While recognition of the role of nitrogen in nutrient enrichment and algal growth has not been a focus for as long as phosphorus, there is a growing attention 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 2021 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 contrast to total phosphorus, the concentrations of nitrate + nitrite in Bass Lake are generally lower than the corresponding analysis results for Kahshe Lake.
- In all cases, the reported nitrogen concentrations are well below any aquatic benchmarks that have been set to protect sensitive species.
- No algal growth benchmarks for either form of nitrogen have been developed, as the linkage between phosphorus, nitrogen and water temperature is simply too complex to set individual benchmarks.

Based on these findings, as for phosphorus, our efforts to minimize septic leaching bed discharges and to manage our shorelines to reduce disturbance and erosion as well as minimizing fertilizer use on lawns and gardens close to the lake appear to be holding nitrogen levels stable over the period dating back to 2004.

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)

The 2021 findings for Kahshe and Bass Lakes are summarized below:

- Water temperature in the spring of 2021 in Kahshe Lake was a little cooler than 1980s and 1990s within the top 5m but similar to the previous years beyond that depth.
- However, by August 2021, the temperature in the top 3m was well above the early years mean but lower than in earlier years at depths from 3 to around 10m.
- The good news is that there appears to be a noticeable decrease in late season water temperature in the layer directly below the top 3m surface layer where air temperatures would not be expected to more directly influence water temperature.
- Water temperature in the spring of 2021 in Bass Lake was noticeably warmer in the top 2m compared to water temperatures in this surface layer in all previous years.
- However, by August 2021, the temperature in the top 2m was similar to values recorded in all previous years.
- As for Kahshe Lake, the good news is that below 2m, water temperatures in 2021 were moderately lower than in previous years.

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 2021 results are summarized below:

- Water clarity in Bass Lake in 2021 was slightly less than in 2019, but generally similar to historical measurements dating back to 1981.
- Water clarity in Kahshe Lake in 2021 also was slightly less than in 2019 but generally similar to historical measurements dating back to 1983.
- In contrast to the findings in previous years, water clarity in Kahshe Lake as measured by the DMM was slightly greater in both 2019 and 2021 compared to the water clarity measurements recorded at three locations on Kahshe Lake via the MECP's Lake Partner Program. This may be related to the methodology for recording water clarity, as the DMM measurements are the average of two sampling events while the LPP measurements by the Lake Steward represent an average of 9-10 measurements at each site over the period from May through October

ALGAL GROWTH

Unfortunately, harmful blue-green algal blooms have now been confirmed in Kahshe Lake in both 2020 and 2021. In 2020, the bloom was located along the northern shoreline in the Oak Road vicinity and was investigated by staff from the MECP. In 2021, the first report of a bloom was in the east end of the lake (actually in the Kahshe River), but this was followed by reports of similar blooms in several areas of the lake, and as such, the alert was issued to cover the entire lake. Further details on these specific blooms and any others going forward have been described in greater detail in the KLRA Web's Water Quality portal and can be accessed via this link:
https://kahshelake.ca/resources/Documents/Lake%20Steward/2022/Current%20Algal%20Bloom%20Status%20for%20Kahshe%20and%20Bass%20Lake-R3%20Feb2022-TCAccepted.pdf

To assess how phosphorous levels in our lakes compare to those in other algal-impacted lakes in the Muskoka region, data from 2018 and 2019 were utilized. The main finding from this comparison was that out of 10 impacted lakes with available total phosphorus levels, five had levels well below those found in Kahshe and Bass Lakes.

These findings give cause for concern, as this trend towards increasing numbers of late-season harmful algal blooms throughout Muskoka does not appear to be directly associated with increasing levels of total phosphorus or nitrogen compounds determined via these early spring water quality sampling programs from the deep water of mid-lake sampling sites.

This apparent anomaly prompted the development of the KLRA-funded Near Shore Water Sampling Project (NSWSP) in 2021 and the findings from those water sampling activities identified a causal linkage between algal bloom development and water quality parameters, indicating the leaching of soil-borne and mobile nitrogen compounds from septic systems or lawns located near the shore which attract large numbers of Canada geese were involved. This appears to be associated with higher intensity rainfall events characteristic of a changing climate which appear to be accelerating the leaching process. The findings from the NSWSP have been reported and posted on the KLRA's Water Quality web portal which is accessible via this link: https://kahshelake.ca/resources/Documents/Lake%20Steward/2022/Full%20NSWSP%20-%20Jan16-22.pdf

The NSWSP findings are briefly summarized below:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a true assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture much higher total phosphorus levels in the east end of the lake, as there are no DMM or MECP sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) tend to increase as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry for some algal-friendly nutrients appear to be associated with effluents from human & animal waste sources and are known to be linked with HABs.
- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

Although we have virtually no control over the change that is affecting our climate, there are actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future algal blooms. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain water into rock-filled drainage pits.**
2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil & goose poop runoff into the lake.**
3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town will be inspecting in 2023, but we don't need to wait until then and be subject to system shutdown until failing systems are repaired.**
4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

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. The concern regarding a gradual decline in calcium concentrations and a shift in the population of essential zooplankton species across lakes in Muskoka was noted, and a late season population explosion of *Holopedium* was documented in Kahshe Lake in 2021. Although the overall ecological impacts of this *Holopedium* dominance are not known, they certainly represented an uncomfortable experience by many swimmers in Kahshe Lake in 2021.

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 15 year monitoring period.

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

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

Anions, Cations and Other Chemical Summary

The analysis of several additional anions, cations and other chemicals by the DMM has identified no pressing issues from an aquatic health aspect. While there were some minor exceedances of chronic (long term) benchmarks established by the MECP 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 several cases (cadmium, silver and selenium), the laboratory detection limits are similar to or slightly below the aquatic protection value, and as a result, the non-detected levels of these substances are either just above or below their respective aquatic benchmarks. This situation was exacerbated by the increase in DLs in 2021. Aluminum in Bass Lake also exceeds the aquatic benchmark in several years; however, as noted, the benchmark consists of a range in values and must be evaluated based on the pH and DOC concentrations in lake water. Based on these findings, these substances will be followed carefully in future monitoring to ensure that the waters of Kahshe and Bass Lakes are safe from an aquatic perspective.

The other finding from this data set is that there are numerous parameters that, like total phosphorus, are slightly or noticeably higher in Bass Lake compared to Kahshe Lake. There are also a couple of parameters (silicon and $N\text{-}NO_3$) where the opposite (Kahshe higher than Bass) is documented. The reason for these differences in the two lakes is unknown but may be helpful when the DMM Causation Study of both lakes is undertaken.

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 (mixed) in the fall and again following the winter ice melt and then begins to stratify through the spring, summer and fall as water temperature increases at the surface and DO levels decrease with increasing depth.

The DO findings for spring and summer at different water depths in both Kahshe and Bass Lakes for 2019 are summarized below. In the evaluation, the results are compared to the mean results historically, broken into the 1980s & 1990s, 2000-2009 and 2010-2019.

- In both lakes, the Spring DO levels are relatively stable across all sampling depths, reflecting the action of vertical mixing from the turnover of cold and warm water from the fall through the spring.
- In the much deeper Kahshe Lake, by late July, the 2021 DO levels are considerably higher than in previous years/decades down to around 3m depth and then decrease sharply from 3-6m before rising slightly between 6-8m and remaining fairly constant down to the full depth of 20m.
- More importantly, the DO levels from 2021 appear to follow the trend of falling below the PWQO at a more shallow depth of around 4m than was the case in the 1980s and 1990s when levels below the PWQO were not encountered until depths below around 5m.
- In Bass Lake, by late July the 2021 DO levels are essentially similar to the two historical records of DO levels down to about 2m depth and then decrease gradually through the 4m depth, falling below the PWQO just below the 2m depth.
- More importantly, as for Kahshe Lake, there appears to be a trend towards DO levels falling below the PWQO at more shallow depths (just below 2m) than back in the 1980s and 1990s when DO crossed below the PWQO at depths just below 3m.

Benthic Health Summary

Benthic health assessment is now undertaken annually, as Kahshe Lake is now considered a 'Vulnerable' lake due to the appearance of a harmful algal bloom in 2020. This involves sampling by the DMM's Biotechnician at established sites to determine which benthic macroinvertebrates are found. These benthos indicate the health of the riparian zone (section between shallow water and dry land) and the littoral zone (shallow water nearest to dry land). These two zones are especially important to lake health as they are impacted by snowmelt, runoff, sedimentation and other development activities.

Collected benthos are grouped into seven (7) different categories based on their typical response to environmental contamination and are then compared to the Muskoka average for relevance purposes and to detect changes over time in species richness and biodiversity. The findings are briefly summarized below:

- Richness was good and represents biodiversity within the lake and demonstrates that there is a healthy relationship between benthos.
- %EOT was very good and indicates a population of pollutant intolerant species, so having it this far above the Muskoka average is very good.
- %Chironimids which is an indicator of poor water quality was well below the Muskoka average, so this was a favourable finding.
- The remaining four indicators (%Predators, %Shredders, %Collectors and the Hilsenhoff Index all were normal and serve to detect any major population deviations from the Muskoka average.

Conclusion

Based on the 2021 water quality and benthic monitoring of Kahshe and Bass Lakes by the DMM and the MECP, no major water quality issues or trends were identified. However, given the documented occurrence of harmful blue-green algae blooms (HABs) in Kahshe Lake in both 2020 and 2021 as well as the late season population explosion of a zooplankton organism (Holopedium) known to be associated with calcium depleted lakes in the Muskoka region, it is clear that the tracking of water quality via the mid-lake, deep water sites of the DMM and MECP is not providing a meaningful indication of water quality degradation associated with the onset of these negative impacts on the health of the lakes.

In the case of Bass Lake, the DMM has undertaken a more comprehensive Causation Study in 2021 and hopefully, the findings from those investigations will shed light on the cause of the elevated total phosphorus which has been recorded in Bass Lake since monitoring by the DMM began back in the early 1980s. The report of the DMM's investigation was to be released in early 2022, but was delayed and has not yet been released.

So, for Kahshe Lake, where do we go from here?

Kahshe Lake also has been identified by the DMM as a 'Vulnerable' lake and a DMM-funded Causation Study will be undertaken when funds and staffing are available following the completion of Causation Studies on the first group of vulnerable lakes (including Bass L). Given the uncertainty regarding the implementation of a DMM-funded Causation Study and the concern of property owners regarding the late season HABs in 2020 and 2021, the KLRA decided to fund a Conservation Committee project in 2021. The purpose of this study was to explore the chemistry of near-shore waters over the spring and summer season in an effort to better understand why Kahshe Lake has been impacted by HABs in spite of reasonably low and unchanged phosphorous levels reported by the DMM and MECP over the past 40 years.

The findings from this Near-Shore Water Sampling Project (NSWSP) have been published in a final report available on the KLRA Water Quality web portal. The NSWSP identified some very useful insights and linkages between our changing climate, its impact on water quality and the development of late season HABs in Kahshe Lake. These findings are briefly shown below and should help in the development and implementation of the DMM's Causation Study when it does get funded. Briefly, the NSWSP demonstrated that:

- Mid-lake, deep water sampling in the spring of the year is a reasonable way to track long-term, historical changes in water quality but is not providing a true assessment of water quality in the near-shore environment where HABs have been documented.
- The mid-lake, deep water sampling also has failed to capture much higher total phosphorus levels in the east end of the lake, as there are no DMM or MECP sampling sites in that area.
- Levels of algal-friendly nutrients (phosphorus and nitrogen) tend to increase as the season progresses, further limiting the relevance of the spring sampling of mid-lake sites in terms of assessing the potential for HAB development.
- The near-shore water chemistry findings for some algal-friendly nutrients appear to be associated with effluents from human & animal waste sources and are known to be linked with HABs.
- Although more study is warranted, the near-shore findings point to accelerated leaching and/or runoff of soil-borne nutrients due to a changing climate which is resulting in more intense rainfall events.

Although we have virtually no control over the change that is affecting our climate, there are actions we can and must take to minimize the accelerated leaching of algal friendly nutrients to our shoreline water and thereby reduce the potential for future algal blooms. These actions have been thoroughly explored by the Conservation Committee and are summarized below:

1. **Divert roof drainage and runoff from paths and other hard surfaces away from your septic system and the shoreline. If necessary, direct rain water into rock-filled drainage pits.**

2. **Keep most of your shoreline as natural as possible with a zone of trees, shrubs or tall grass between the shore and any lawn area to discourage grazing by Canada geese and to reduce soil & goose poop runoff into the lake.**

3. **Have a licensed professional pump out and inspect your septic system for failures and deficiencies every 3-5 years and more often for aging systems installed pre-2000. The Town will be inspecting in 2023, but we don't need to wait until then and be subject to system shutdown until failing systems are repaired.**

4. **Don't use phosphorus or nitrogen fertilizers or cleaning agents anywhere near the shore.**

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Ron Pearson, M.Sc. - Kahshe Lake Steward

Attachments

Attachment 1

Total Phosphorus Results - Bloom-Impacted Lakes with Lake Partner Program Data - 2019						
Lake	Township	Location in Lake	Sampling Date	Total Phosphorus (ug/L)		
				TP1	TP2	Average
THREE MILE LAKE	WATT	Deep Spot, South West Bay	8-Jun-19	16.8	18.8	17.8
THREE MILE LAKE	WATT	Deep Spot, South West Bay	2-Jul-19	23.0	24.2	23.6
THREE MILE LAKE	WATT	Deep Spot, South West Bay	9-Aug-19	26.8	26.6	26.7
THREE MILE LAKE	WATT	Deep Spot, South West Bay	16-Sep-19	20.4	19.0	19.7
THREE MILE LAKE	WATT	Deep Spot, South West Bay	11-Oct-19	23.0	21.2	22.1
Average						**22.0**
BRANDY LAKE	WATT	West	6-Jun-19	9.0	5.2	7.1
BRANDY LAKE	WATT	West	23-Jun-19	25.2	21.2	23.2
BRANDY LAKE	WATT	West	26-Jul-19	22.4	23.6	23.0
BRANDY LAKE	WATT	West	23-Aug-19	27.4	27.2	27.3
BRANDY LAKE	WATT	West	20-Sep-19	51.8	38.8	45.3
BRANDY LAKE	WATT	West	3-Nov-19	37.6	41.4	39.5
Average						**27.6**
BASS LAKE	MUSKOKA LAKES	District Municipality of Muskoka*	10 Year Average to 2017			**6.2**
ECHO LAKE	MCLEAN	Mid Lake, deep spot	16-May-19	7.2	8.6	**7.9**
ST. JOHN LAKE	RAMARA	Main Basin-deep spot	11-Aug-19	76.0		76.0
ST. JOHN LAKE	RAMARA	Main Basin-deep spot	14-Sep-19	48.4	49.0	48.7
ST. JOHN LAKE	RAMARA	N end, deep spot	11-Aug-19	80.0		80.0
ST. JOHN LAKE	RAMARA	N end, deep spot	14-Sep-19	55.2	55.2	55.2
ST. JOHN LAKE	RAMARA	S end, deep spot	14-Sep-19	55.4	53.4	54.4
Average						**62.9**
MACLEAN LAKE (BLACK)	MATCHEDASH	Mid Lake, deep spot	29-May-04	32.8	32.7	32.8
MACLEAN LAKE (BLACK)	MATCHEDASH	Mid Lake, deep spot	29-May-05	21.9	21.6	21.8
Average						**27.3**
* No LPP data for this lake. Data from District Municipality of Muskoka						

Attachment 2

Ice-Out Records for Muskoka Lakes and Kahshe Lake – 1886-2022

Year	Muskoka Lakes		Kahshe Lake	
	Ice Out Date	Julian Day1	Ice Out Date	Julian Day1
1886	04/23/1886	113		
1889	04/18/1889	108		
1890	04/26/1890	116		
1891	04/27/1891	117		
1892	04/21/1892	112		
1893	04/26/1893	116		
1895	04/22/1895	112		
1896	04/17/1896	108		
1897	04/27/1907	117		
1899	04/26/1899	116		
1900	04/24/1900	115		
1901	04/20/1901	110		
1902	04/09/1902	99		
1903	04/07/1903	97		
1904	04/29/1904	120		
1905	04/24/1905	114		
1906	04/20/1906	110		
1907	04/24/1907	114		
1908	04/27/1908	118		
1909	04/29/1909	119		

1910	04/01/1910	91		
1911	05/01/1911	121		
1912	04/27/1912	118		
1913	04/20/1913	110		
1914	04/21/1914	111		
1915	04/19/1915	109		
1916	04/20/1916	111		
1917	04/23/1917	113		
1918	04/23/1918	113		
1919	04/16/1919	106		
1920	04/19/1920	110		
1921	04/08/1921	98		
1922	04/17/1922	107		
1923	04/28/1923	118		
1924	04/17/1924	108		
1925	04/14/1925	104		
1926	05/07/1926	127		
1927	04/18/1927	108		
1928	04/29/1928	120		
1929	04/09/1929	99		
1930	04/24/1930	114		
1931	04/30/1931	120		
1932	04/06/1932	97		
1933	04/10/1933	100		

1934	04/21/1934	111		
1935	04/16/1935	106		
1936	04/23/1936	114		
1937	04/24/1937	114		
1938	04/17/1938	107		
1939	05/01/19339	121		
1940	04/29/1940	120		
1941	04/15/1931	105		
1942	04/15/1942	105		
1943	04/29/1943	119		
1944	04/28/1944	119		
1945	03/29/1945	88		
1946	03/27/1946	86		
1947	04/27/1947	117		
1948	04/10/1948	101		
1949	04/12/1949	102		
1950	05/01/1950	121		
1951	04/12/1951	102		
1952	04/20/1952	111		
1953	04/06/1953	96		
1954	04/21/1954	111		
1955	04/13/1955	103		
1956	05/04/1956	125		
1957	04/20/1957	110		

1958	04/26/1958	116		
1959	04/28/1959	118		
1960	04/22/1960	113		
1961	04/22/1961	112		
1962	04/21/1962	111		
1963	04/16/1963	106		
1964	04/17/1964	108		
1965	05/03/1965	123		
1966	04/20/1966	110		
1967	04/18/1967	108		
1968	04/09/1968	100		
1969	04/22/1969	112		
1970	04/30/1970	120		
1971	05/02/1971	122		
1972	05/03/1972	124		
1973	04/17/1973	107		
1974	04/28/1974	118		
1975	05/01/1975	121		
1976	04/16/1976	107		
1977	04/16/1977	106		
1978	04/29/1978	119		
1979	04/21/1979	111		
1980	04/15/1980	106		
1981	04/04/1981	94		

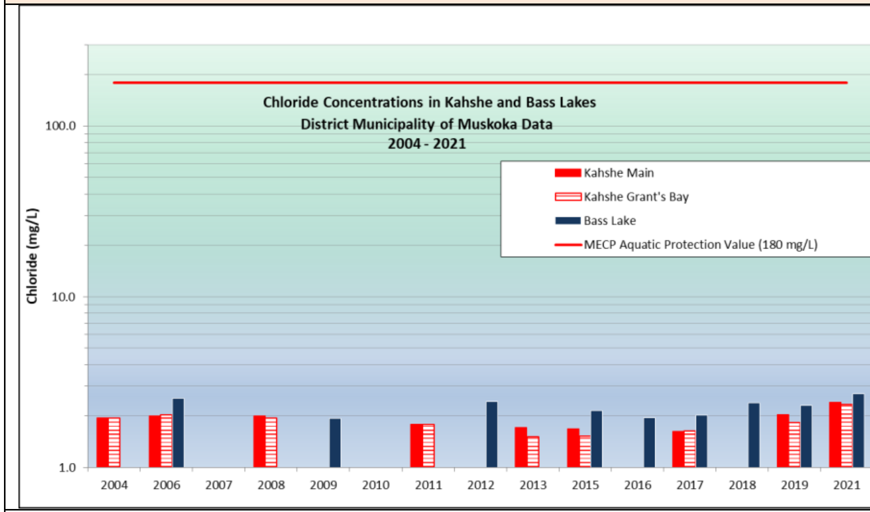
1982	04/27/1982	117		
1983	04/16/1983	106		
1984	04/17/1984	108		
1985	04/23/1985	113		
1986	04/10/1986	100		
1987	04/13/1987	103	04/08/1987	98
1988	04/14/1988	105	04/13/1988	104
1989	04/28/1989	118	04/26/1989	116
1990	04/26/1990	116	04/25/1990	115
1991	04/16/1991	106	04/19/1991	109
1992	05/01/1992	122	04/28/1992	118
1993	04/21/1993	111	04/27/1993	117
1994	04/23/1994	113	04/20/1994	110
1995	04/19/1995	109	04/12/1995	102
1996			04/25/1996	116
1997			04/29/1997	119
1998	04/19/1998	109	04/08/1998	98
1999	04/09/1999	99	04/08/1999	98
2000	03/28/2000	88	03/26/2000	86
2001	04/28/2001	118	04/20/2001	110
2002	04/15/2002	105	04/16/2002	106
2003	04/21/2003	111	04/21/2003	111
2004	04/16/2004	107	04/18/2004	109
2005	04/17/2005	107	04/19/2005	109

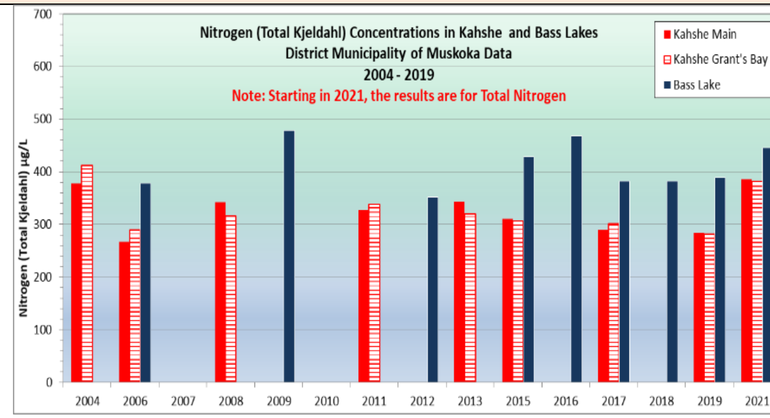
2006	04/14/2006	104	04/15/2006	105
2007	04/18/2007	108	04/18/2007	108
2008	04/21/2008	112	04/20/2008	111
2009	04/18/2009	108	04/17/2009	107
2010	04/02/2010	92	04/02/2010	92
2011	04/17/2011	107	04/18/2011	108
2012	04/23/2012	114	03/24/2012	115
2013	04/13/2013	103	04/19/2013	109
2014	04/29/2014	119	04/29/2014	119
2015	04/21//2015	111	04/18/2015	108
2016	04/08/2016	99	04/16/2016	107
2017			04/12/2017	102
2018			05/02/2018	122
2019			04/26/2019	116
2020			04/09/2020	100
2021			04/07/2021	97
2022			04/16/2022	106
Yellow shaded years designate a leap year, which adds one day to the Julian dates				
Julian Day1 represents the number of days after Jan 1 that ice went out				

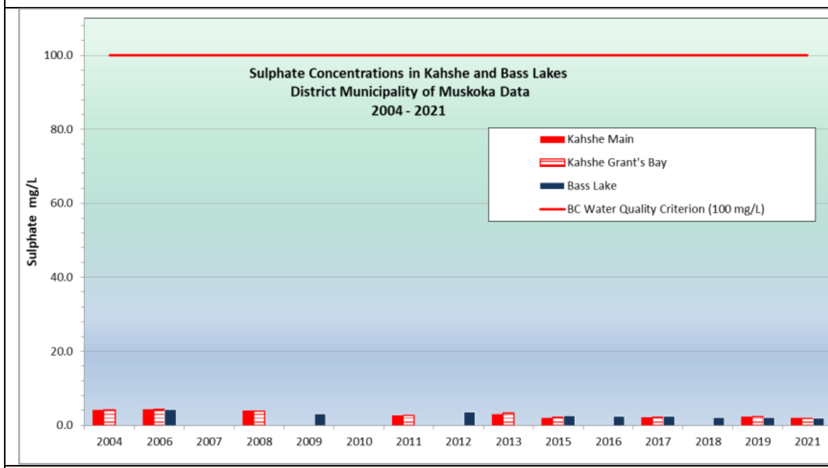
Attachment 2

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

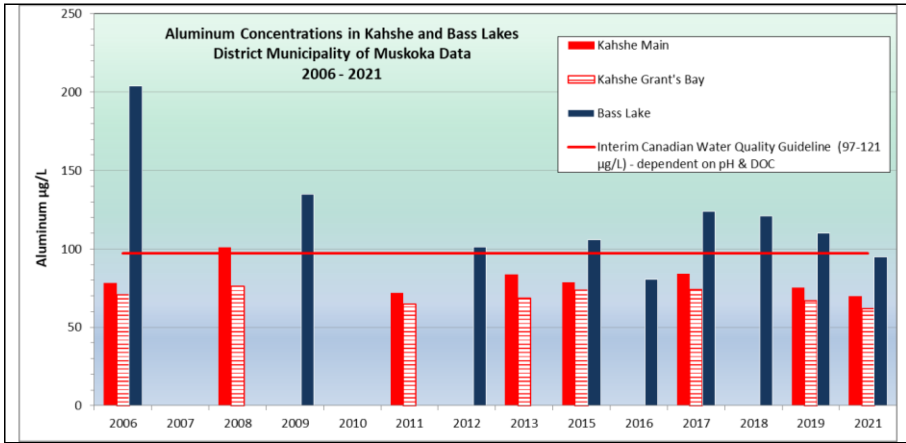
Anions

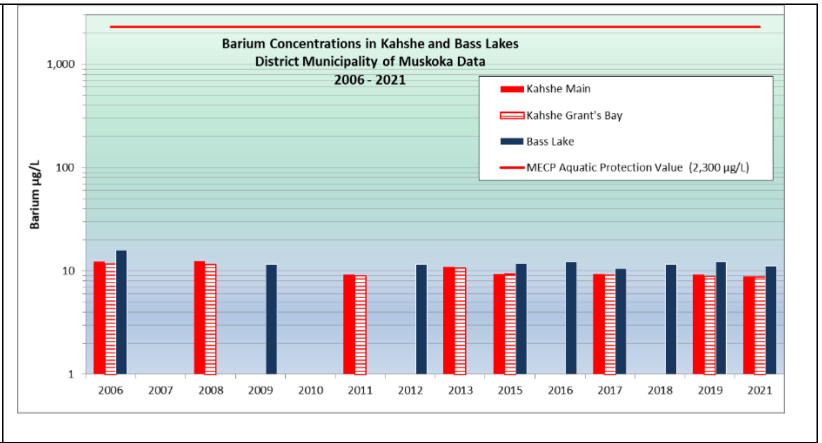


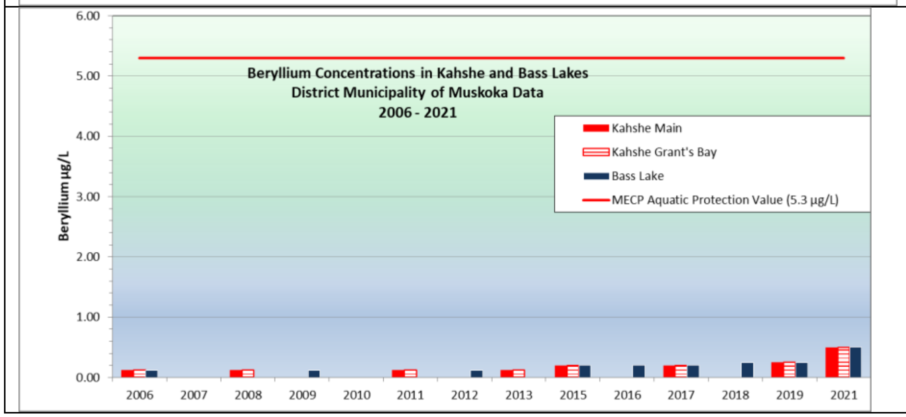


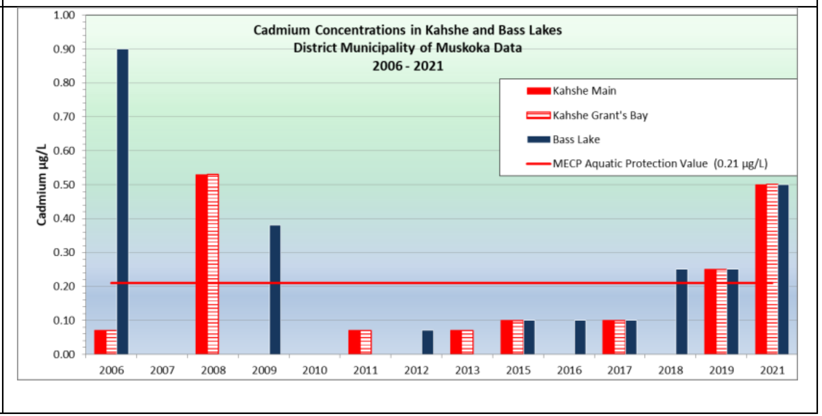


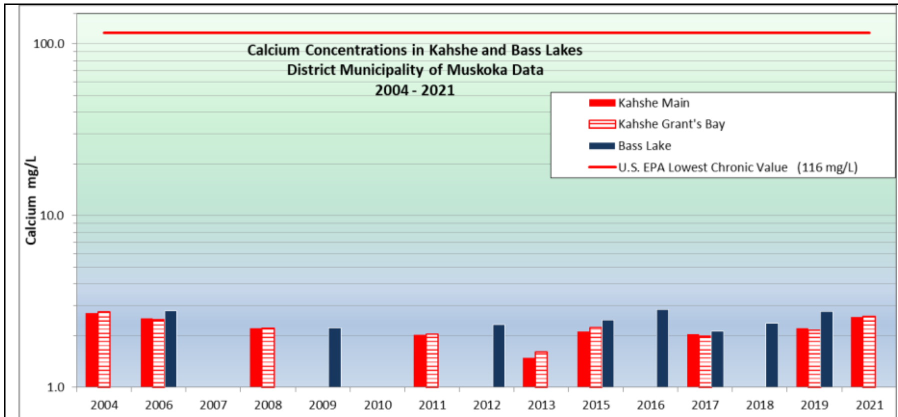
Cations

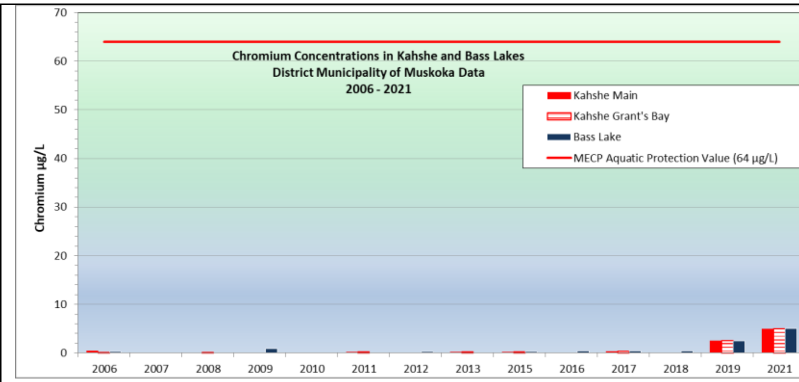

Aluminum Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Interim Canadian Water Quality Guideline (97-121 µg/L) - dependent on pH & DOC
Aluminum µg/L
2006 2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2021

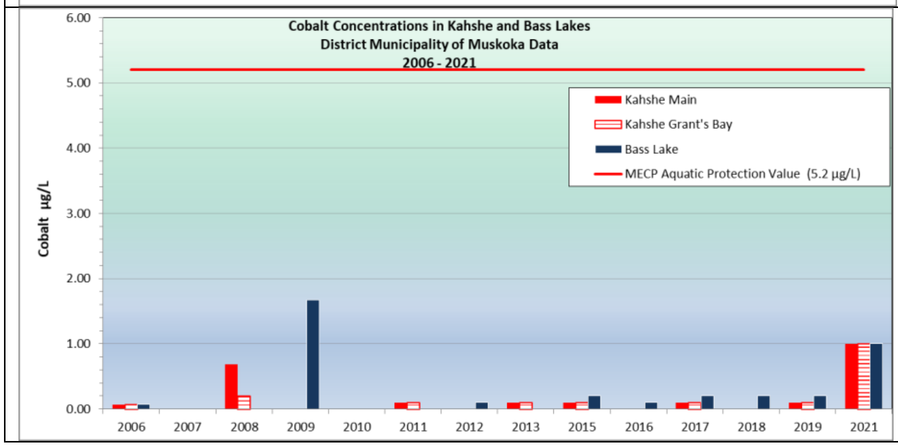

Barium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (2,300 µg/L)
Barium µg/L
2006 2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2021

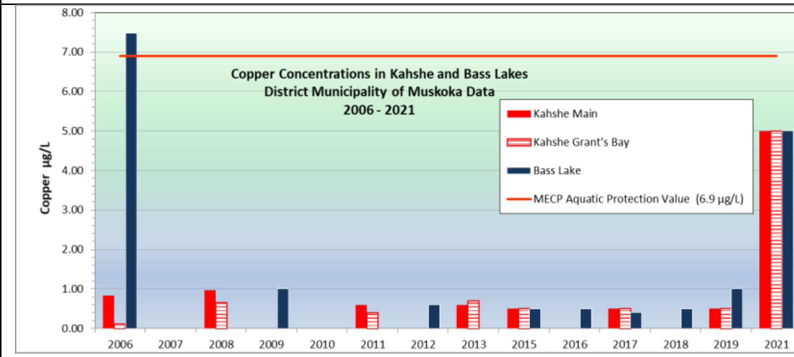

Beryllium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (5.3 µg/L)
Beryllium µg/L
2006 2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2021

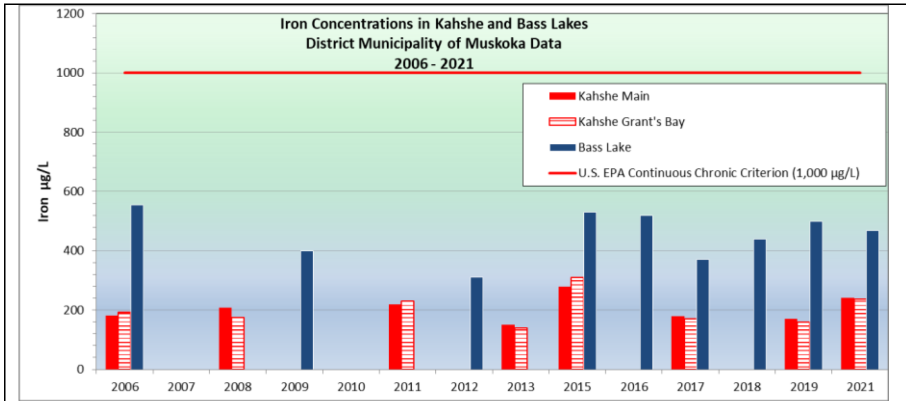

Cadmium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (0.21 µg/L)
Cadmium µg/L
2006 2007 2008 2009 2010 2011 2012 2013 2015 2016 2017 2018 2019 2021

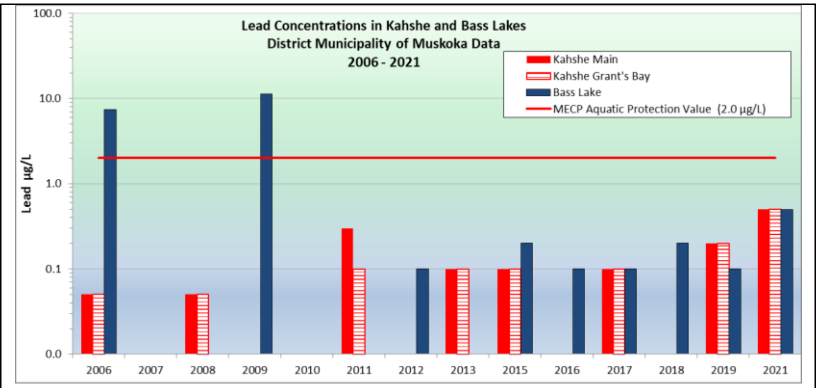

Calcium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (116 mg/L)
Calcium mg/L
100.0
10.0
1.0
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

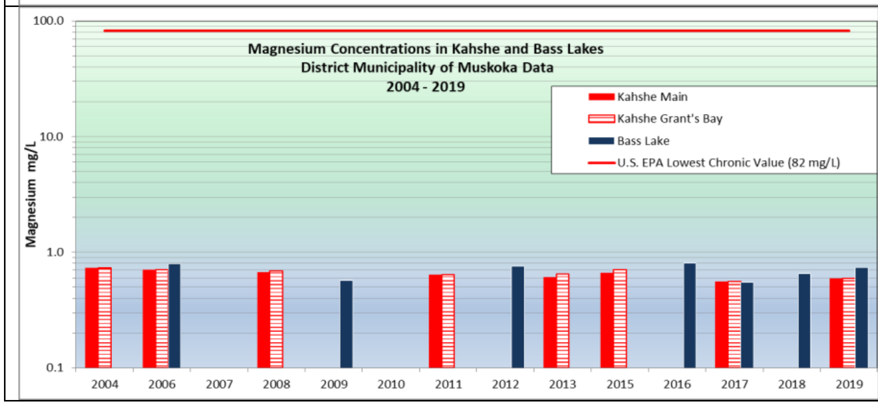

Chromium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (64 µg/L)
Chromium µg/L
70
60
50
40
30
20
10
0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

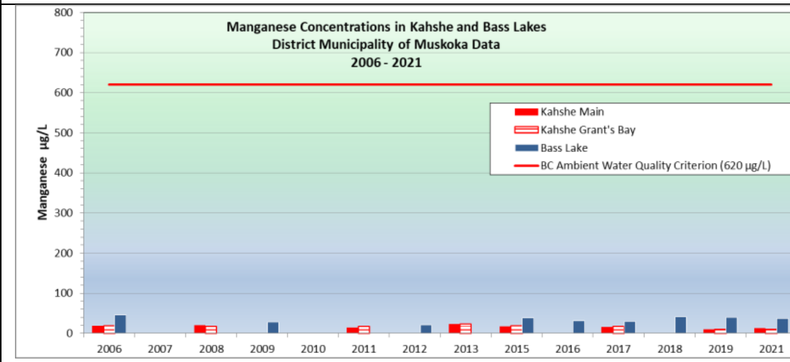

Cobalt Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (5.2 µg/L)
Cobalt µg/L
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

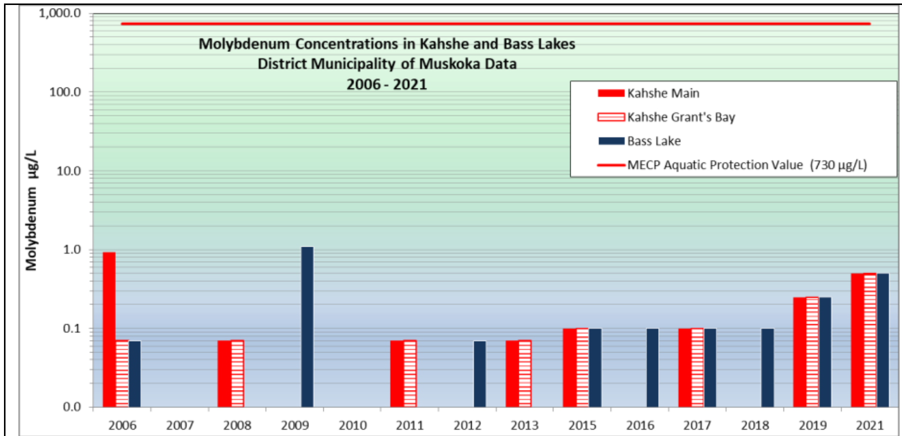

Copper Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (6.9 µg/L)
Copper µg/L
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

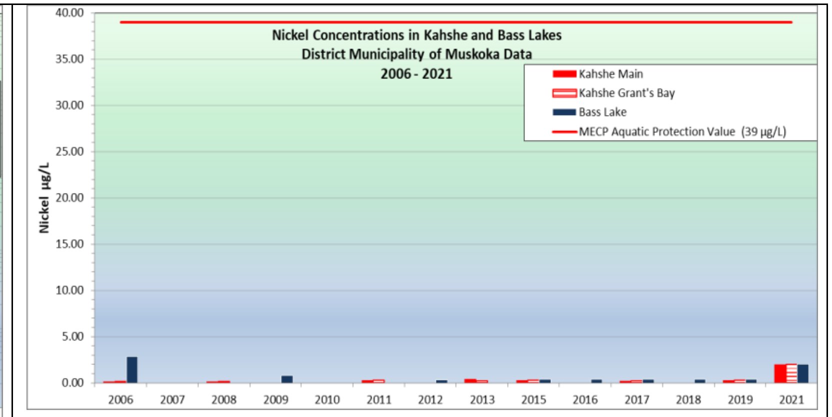

Iron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Iron µg/L
1200
1000
800
600
400
200
0
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Continuous Chronic Criterion (1,000 µg/L)
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

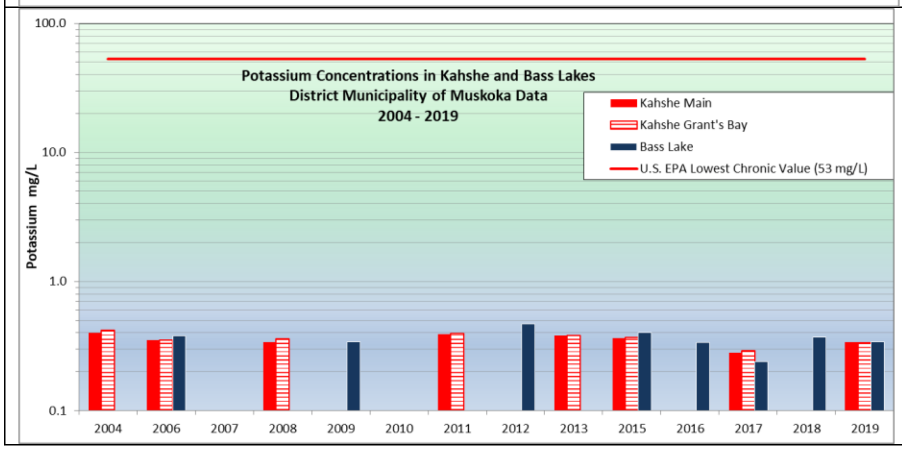

Lead Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Lead µg/L
100.0
10.0
1.0
0.1
0.0
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (2.0 µg/L)
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

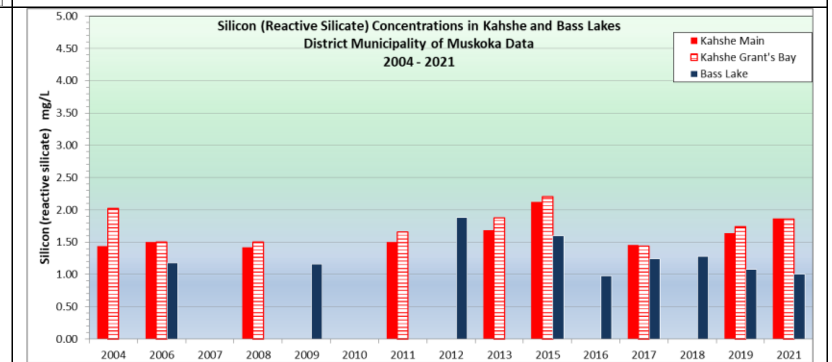

Magnesium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Magnesium mg/L
100.0
10.0
1.0
0.1
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (82 mg/L)
2004
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019

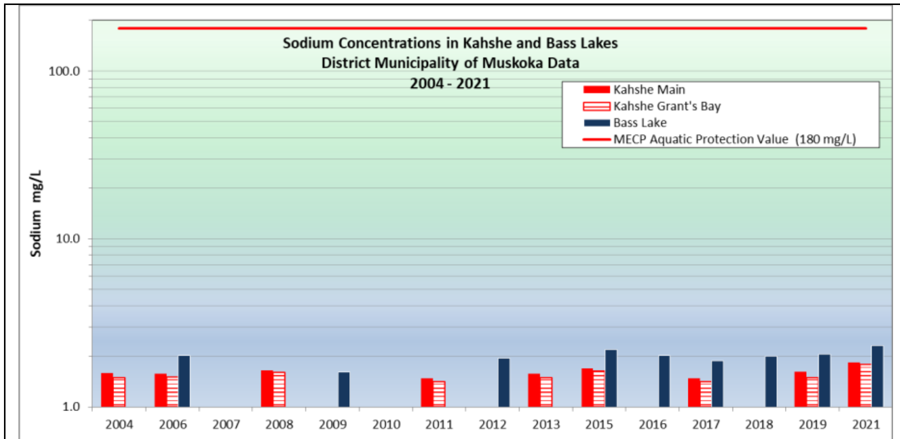

Manganese Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Manganese µg/L
800
700
600
500
400
300
200
100
0
Kahshe Main
Kahshe Grant's Bay
Bass Lake
BC Ambient Water Quality Criterion (620 µg/L)
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

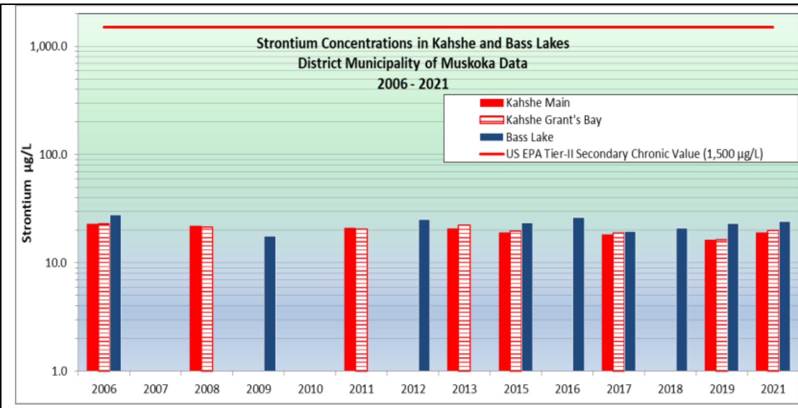

Molybdenum Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (730 µg/L)
Molybdenum µg/L

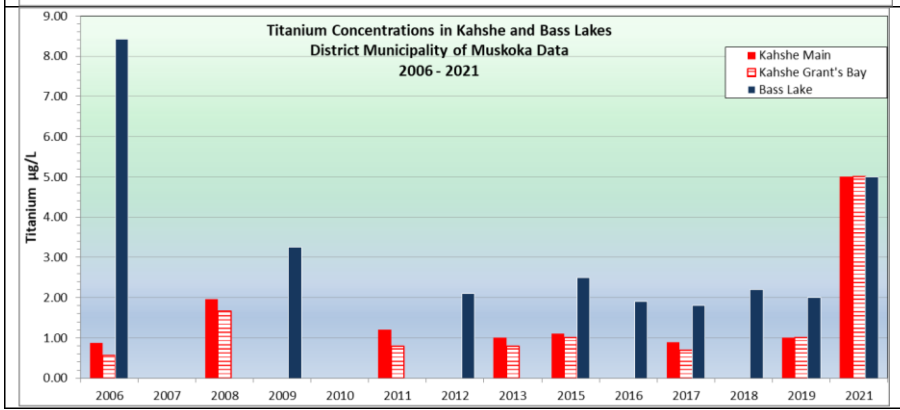

Nickel Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (39 µg/L)
Nickel µg/L

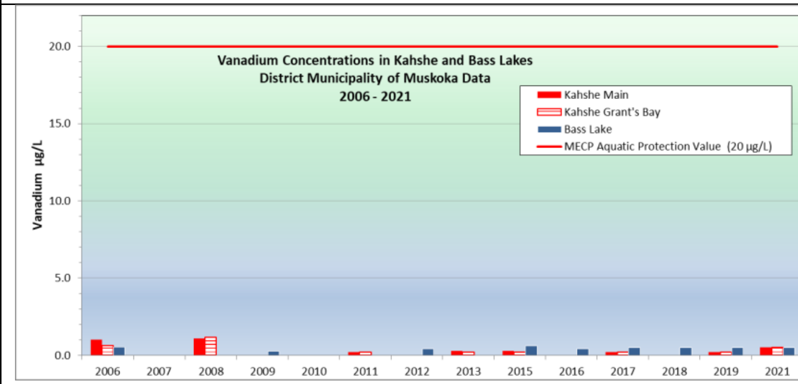

Potassium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2019
Kahshe Main
Kahshe Grant's Bay
Bass Lake
U.S. EPA Lowest Chronic Value (53 mg/L)
Potassium mg/L

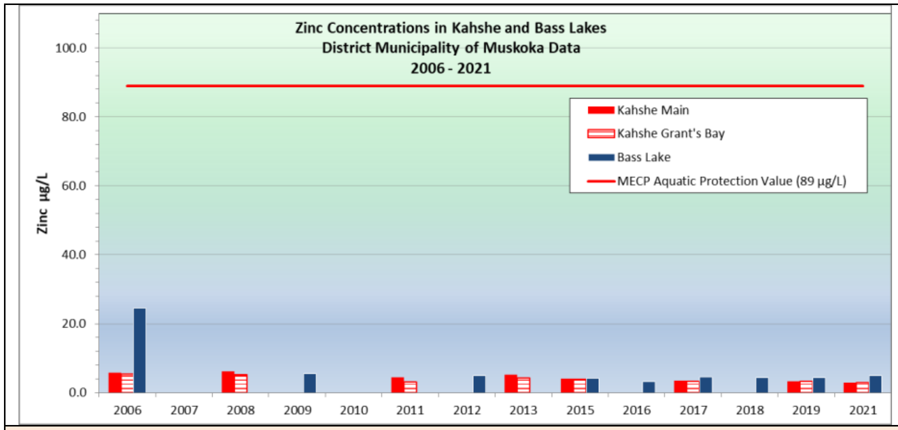

Silicon (Reactive Silicate) Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Silicon (reactive silicate) mg/L


Sodium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2004 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP 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
2019
2021

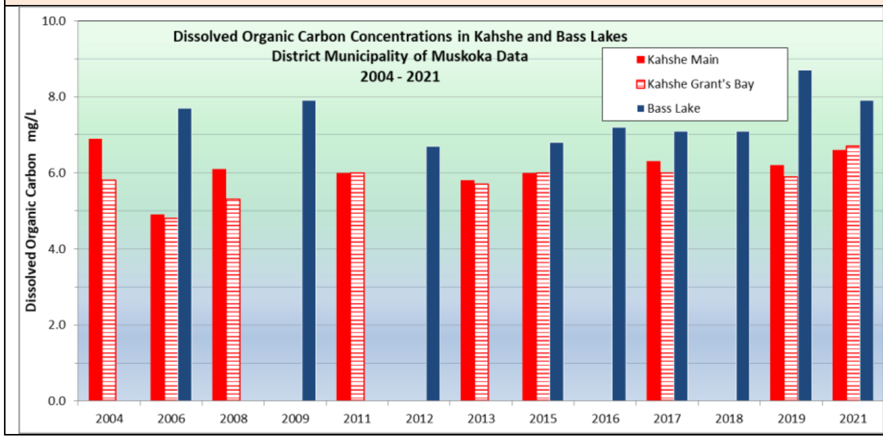

Strontium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
US EPA Tier-II Secondary Chronic Value (1,500 µg/L)
Strontium µg/L
1,000.0
100.0
10.0
1.0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

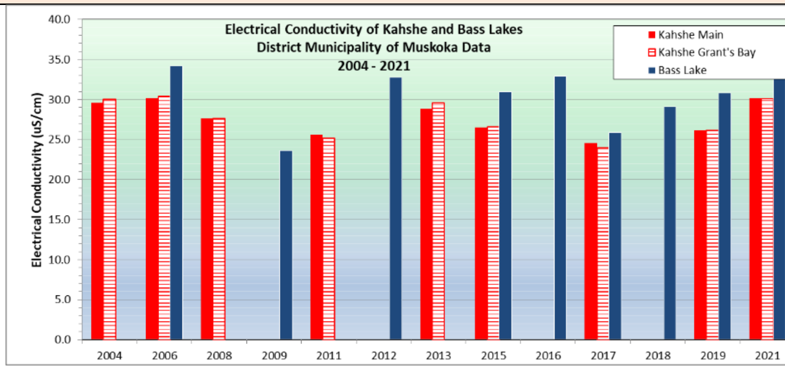

Titanium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
Titanium µg/L
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021

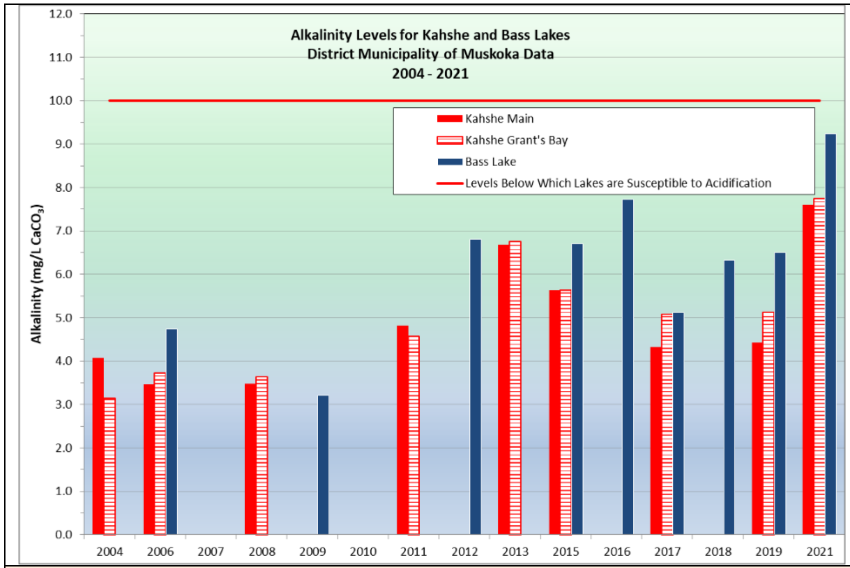

Vanadium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2006 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (20 µg/L)
Vanadium µg/L
20.0
15.0
10.0
5.0
0.0
2006
2007
2008
2009
2010
2011
2012
2013
2015
2016
2017
2018
2019
2021



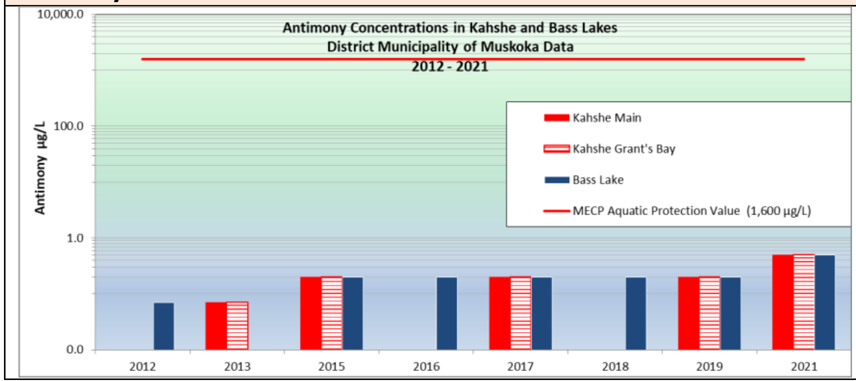
Other Chemicals

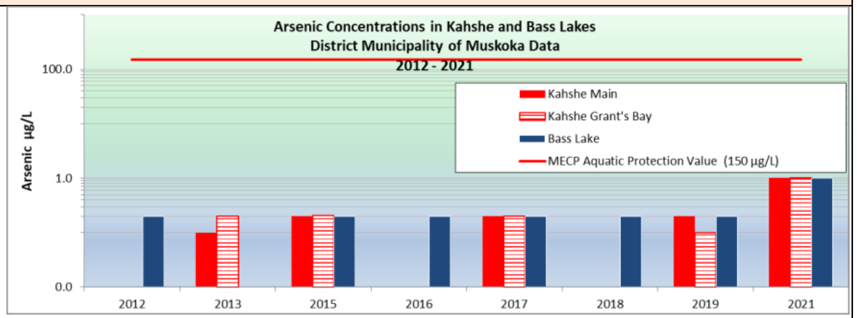


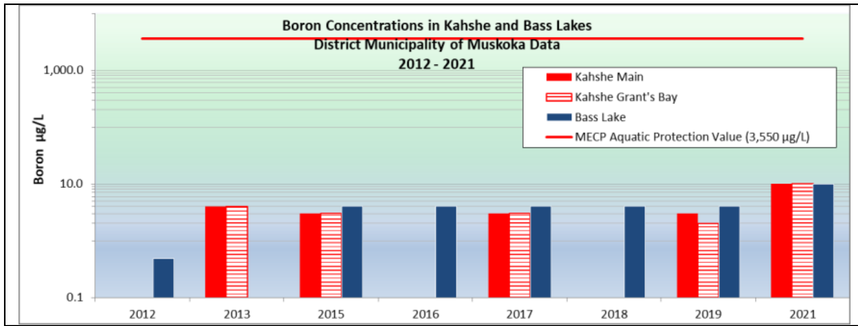


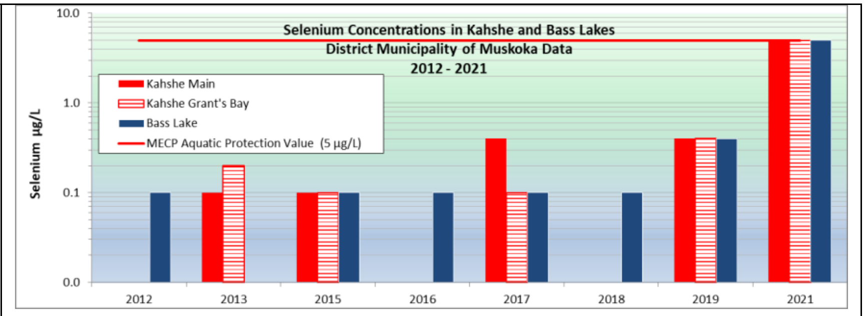


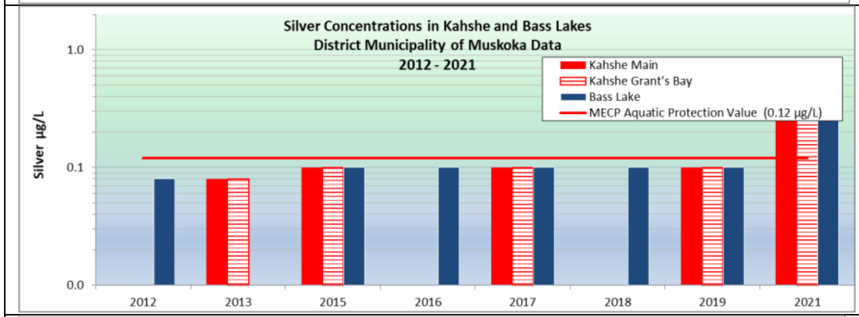
Recently Added Cations

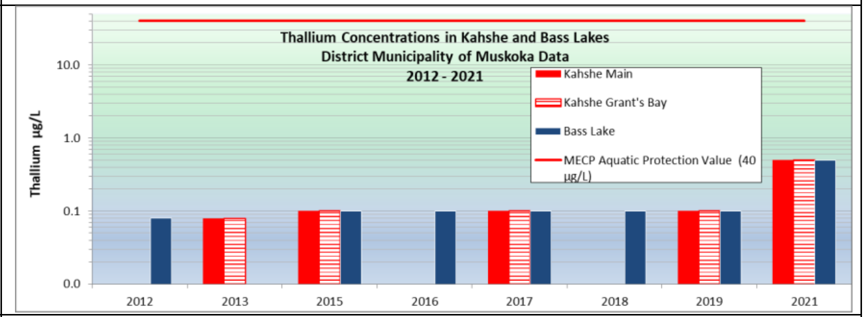


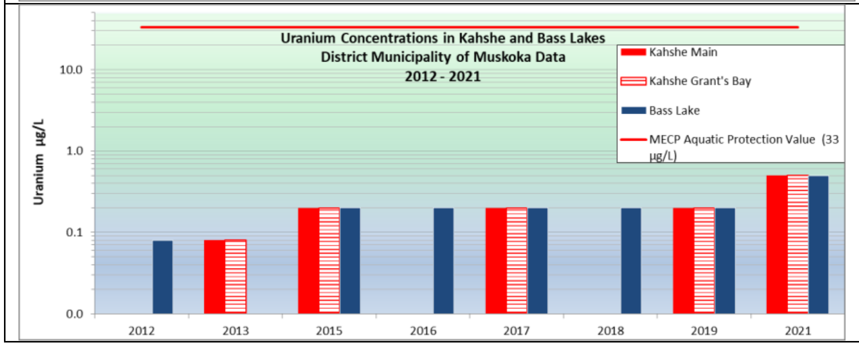



Boron Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (3,550 µg/L)
Boron µg/L
1,000.0
10.0
0.1
2012
2013
2015
2016
2017
2018
2019
2021


Selenium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (5 µg/L)
Selenium µg/L
10.0
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
2021


Silver Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (0.12 µg/L)
Silver µg/L
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
2021


Thallium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (40 µg/L)
Thallium µg/L
10.0
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
2021


Uranium Concentrations in Kahshe and Bass Lakes
District Municipality of Muskoka Data
2012 - 2021
Kahshe Main
Kahshe Grant's Bay
Bass Lake
MECP Aquatic Protection Value (33 µg/L)
Uranium µg/L
10.0
1.0
0.1
0.0
2012
2013
2015
2016
2017
2018
2019
2021