



Hutchinson

Environmental Sciences Ltd.

Bass Lake Causation Study

Prepared for: The District of Muskoka
Job #: J200098

May 4, 2023

Final Report



May 4, 2023

HESL Job #: J200098

The District Municipality of Muskoka
70 Pine Street, Bracebridge, ON
P1L 1N3

Re: Bass Lake Causation Study - Final Report

We are pleased to offer this draft report of our investigations into the potential cause(s) of the high phosphorus concentrations in Bass Lake to The District Municipality of Muskoka (the District). This final report builds on comments on earlier drafts from District staff and from our meeting on June 16, 2020. Our research included a detailed examination of existing data on the lake as well as a limited field campaign in Fall of 2021.

Bass Lake is a mesotrophic lake with no evidence of long-term changes in nutrients or dissolved oxygen and no formally documented phytoplankton blooms; however, anecdotal evidence obtained from our survey of local residents suggests that increased algae growth may have occurred in recent years. Sampling of Bass Lake tributaries (i.e., Kahshe River and Gartersnake Creek) in the spring of 2021 did not indicate nutrient enriched waters, however these data represent a single sampling event. A targeted sampling program would be required to determine if upstream agriculture or sewage lagoons near Barkway Lake have had any impact on water quality in Bass Lake.

Bass Lake has been monitored since the mid-1980s; however, the majority of the development on the lake took place prior to the initiation of monitoring, and we are therefore limited to "post-impact" data. We have developed recommendations for further data collection that could better characterize nutrient concentrations in the lake and how they have changed since development began but generally modelling data suggest that local watershed development represents a minor contribution to the overall phosphorus budget and long-term records suggest that the minor development that has occurred since monitoring began has not had a measurable impact on lake water quality. Lastly, naturally occurring features of the lake and watershed, such as the large watershed to lake ratio and shallow depth, commonly cause elevated phosphorus concentrations in lakes.

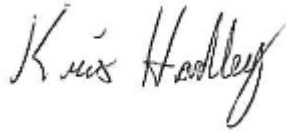
We thank the District for the opportunity to work on this project. Please do not hesitate to contact me (519-576-1711 ext. 304) if you have any questions or concerns.

Sincerely,
per. Hutchinson Environmental Sciences Ltd.

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Signatures

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Executive Summary

Hutchinson Environmental Sciences Ltd. (HESL) was retained by The District Municipality of Muskoka (the District) to prepare a causation study report for Bass Lake in response to long-term elevated total phosphorus concentrations and the related Muskoka Official Plan policies adopted in June 2019. The “Bass Lake Causation Study” was designed to assess long-term data collected on water quality, climate and algal history in the lake to determine the cause of elevated total phosphorus concentrations. The study incorporated data collected by the District, stakeholders and the Ministry of the Environment, Conservation and Parks (MECP), to determine if clear causation of elevated phosphorus concentrations could be confirmed to assist in developing potential approaches for managing the recreational water quality of the lake.

Causation studies are part of a new approach to the protection of water quality recommended in the Revised Water Quality Model and Lake System Health Program report dated April 2016 undertaken by HESL (HESL, 2016) and implemented through recent updates to the Muskoka Official Plan (MOP, 2019) which was approved by the Province in June of 2019. Under the revised policies, all lakes are afforded a high level of protection by ensuring development occurs in a manner that minimizes impacts to water quality. A subset of lakes is identified as potentially more vulnerable based on a set of indicators derived from the District’s long-standing annual water sampling program. Lakes are considered vulnerable and listed on Schedule E2 of the MOP (2019) if indicators are met for three consecutive years or if an algal bloom is confirmed in any year. The trigger for the Bass Lake Causation Study was elevated phosphorus concentrations, specifically an average concentration over the last five years $>20 \mu\text{g/L}$. A waterbody-wide causation study is then undertaken to determine the cause(s) of and/or relative contributing factors to the water quality indicator for waterbodies listed in Schedule E2.

The general causation study process consisted of:

- Assessing the existing water quality conditions in the lake;
- Quantifying annual and seasonal trends in water quality;
- Where possible, providing a historical perspective on water quality;
- Modelling and quantifying the relative contributions of sources of nutrients to the lake, including phosphorus from natural and human sources;
- Determining if water quality is deteriorating and/or algal composition/communities are changing relative to previous years; and
- Attributing a specific cause or contributing factors to the water quality indicator, where possible.

To understand the relative contribution of different phosphorus sources and determine the importance of development in Bass Lake in driving elevated total phosphorus concentrations, we assessed lines of evidence under two broad categories:

1.1 Climate

- We observed elevated air temperature at the Beatrice Meteorological Station in post-2015 data.



- Long-term regional monitoring shows reduced wind speed in the Muskoka area (Yao et al., 2013).
- Periods of sustained low wind speed and high air temperature lead to increased water column stability and reduced mixing; these factors can promote internal loading of phosphorus. Internal loading of phosphorus could also occur through a variety of other process that are common in shallow lakes such as the resuspension of phosphorus-laden sediment through wave mixing or macrophyte senescence (Welch and Cooke, 2005).
- The potential for overland runoff is increased in more severe rainfall events, such as is predicted for a changing climate. However, overland runoff from developed areas does not represent a significant contribution to the phosphorus budget of Bass Lake, and therefore changes to precipitation as a result of climate change are not expected to significantly impact the load of phosphorus to the lake from overland runoff relative to other sources. Effects of increased precipitation more likely impact Bass Lake through natural processes such as flushing of total phosphorus and dissolved organic carbon (DOC) from wetlands, and increased flow to the lake from the Kashes River and Gartersnake Creek.

1.2 Water Chemistry

- We did not document any significant long-term changes in total phosphorus concentrations in the lake over time, nor any abnormalities in recent monitoring that could explain the elevated nutrients that triggered the Causation Study. Total phosphorus concentrations have been relatively elevated over the entirety of the historical dataset.
- Long-term data on potential anoxia showed low deep-water oxygen (<2.0 mg/L) in 12 of 15 years, indicating that there is an internal load of phosphorus from sediments, but data did not suggest anoxia has increased over time.
- DOC concentrations in the lake suggest the importance of catchment wetlands to the lake. Fall sampling demonstrated that these wetlands inputs result in marked seasonal changes in DOC concentrations in the lake.

1.3 Summary of Findings

Our investigation concludes that the cause for the elevated phosphorus concentrations at Bass Lake cannot be reliably determined with the current information. There was no evidence of changes in waterborne phosphorus concentrations in the lake over time, suggesting that recent development and land use change (ca. 2008 – 2018) have not significantly altered phosphorus in the lake based on the available data. Long-term elevated nutrient concentrations in Bass Lake may be the result of:

- 1) the natural influence of
 - a. A large watershed to lake ratio

Nutrient loading to a drainage lake (i.e., a lake with inflowing streams and rivers) generally increases as the ratio of the watershed area to the lake area increases (Schindler 1971). Typically, when the watershed to lake area increases there are additional sources (e.g., agricultural or urbanized areas) and high volume of



runoff to a lake. In larger watersheds, there is also a greater opportunity for interaction between water from precipitation and the soil which may result in increased leaching of nutrients and minerals prior to discharging into the lake.

b. Prolonged periods of hypolimnetic anoxia and internal phosphorus loading

Internal phosphorus (P) loading (i.e., the release of phosphate from anoxic sediment surfaces to overlying water) represents a substantial summer P input to many lakes (Nurnberg and LaZerte 2016). Climate change may exacerbate deep water anoxia and internal loading of phosphorus, however data in Bass Lake do not indicate an increase in the frequency of the occurrence of anoxia during the monitoring record.

c. Influence of catchment wetlands and lake hydrology (i.e., a significant contribution of phosphorus from upstream sources);

Wetland area in a catchment is a key contributor to nutrient concentrations (Dillon and Molot, 1997; Creed et al. 2008). Based on modelling data from Bass Lake, the majority of the nutrient load to the lake comes from upstream sources via the Kahshe River and Gartersnake Creek. DOC concentrations measured by HESL in 2021 suggest that wetlands are a key source of DOC (and likely phosphorus) to the lake and this influence is seasonal and occurs outside of the typical monitoring period.

a. Shallow depth of Bass Lake (mean depth = 2 m)

Shallow lakes are susceptible to a variety of mechanisms that support internal loading of phosphorus where phosphorus is recycled from sediments such as wave and wind induced suspension of phosphorus-laden sediment and decomposition of organic matter (Welch and Cooke, 2010). The limited volume of Bass Lake ($67 \times 10^4 \text{ m}^3$ [MNR, 2010]) also limits dilution of nutrients.

2) shoreline development that occurred prior to the monitoring period of record (and thus no trends are detectable in the available dataset).



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1 Project Background

Hutchinson Environmental Sciences Ltd. (HESL) was retained by The District Municipality of Muskoka (DMM) to prepare a causation study report for Bass Lake in response to long-term elevated total phosphorus concentrations and the related Muskoka Official Plan policies adopted in June 2019. The “Bass Lake Causation Study” was designed to assess long-term data collected on water quality, climate and algal history in the lake to determine the causation of elevated total phosphorus concentrations. The study incorporated data collected by the District, stakeholders and the Ministry of the Environment, Conservation and Parks (MECP), to determine if clear causation of elevated phosphorus concentrations could be confirmed to assist in developing potential approaches for managing the recreational water quality of the lake.

Bass Lake is a small (0.4 km²), shallow (mean depth = 2 m, maximum depth = 4 m [Ontario Ministry of Natural Resources 2010]), mesotrophic lake which receives inflow from a large watershed (165 km²) via the Kahshe River and Gartersnake Creek (Figure 1). The resulting watershed to lake ratio of 412x is very large. The Bass Lake watershed contains 7% wetlands, including a significant wetland to the east, which drains to the lake via Gartersnake Creek (Ontario Ministry of Natural Resources and Forestry, 2022).

The Muskoka Official Plan (MOP) identifies a lake as vulnerable based on the following water quality indicators:

1. A long-term, statistically significant ($p < 0.1$) increasing trend in total phosphorus concentration demonstrated by at least five (5) spring overturn phosphorus measurements obtained through the District of Muskoka water quality sampling program since 2001;
2. A long-term total phosphorus concentration of greater than 20 µg/L demonstrated by the average of five (5) most recent spring overturn phosphorus measurements obtained through the District of Muskoka water quality sampling program within the last ten (10) years; and/or
3. A blue-green algal (cyanobacterial) bloom confirmed and documented by the Province and/or Health Unit.

Average total phosphorus concentrations in excess of 20 µg/L resulted in the listing of the lake as Schedule E2 under the MOP in accordance with water quality indicator #2 listed above (DMM, 2019). Lakes are considered vulnerable and listed on Schedule E2 if indicators 1 or 2 are met for three consecutive years or if indicator 3 is confirmed in any year. A waterbody-wide causation study is undertaken to determine the cause(s) of and/or relative contributing factors to the water quality indicator for waterbodies listed in Schedule E2. The general causation study process consists of:

- Assessing the existing water quality conditions in the lake;
- Quantifying annual and seasonal trends in water quality and/or algal communities;
- Where possible, providing a historical perspective on water quality and/or algal abundances;
- Estimating the relative contributions of sources of nutrients to the lake, including phosphorus from sediments;
- Determining if water quality is deteriorating and/or algal composition/communities are changing relative to previous years; and
- Attributing a specific cause or contributing factors to the water quality indicator where possible.



Long-term monitoring has already taken place to quantify lake health and inform ongoing management on Bass Lake through the DMM's Lake Health Program which maintains a single sampling site on the lake. Based on data collected at the DMM sampling stations, Bass Lake was listed as vulnerable under Schedule E2 when total phosphorus concentrations met Condition 2. In addition, samples were collected annually between 2002 and 2007 by volunteers as a part of the Lake Partner Program coordinated by the MECP.

2 Methods

2.1 Overview

HESL gathered historical water quality data from a number of sources, including the DMM and the Lake Partner Program, to characterize the water quality of Bass Lake and to evaluate the presence of any trends. HESL sampled the lake on October 13, 2021 to characterize the late-summer algae community, hypolimnetic oxygen status, and deep-lake water quality at the long-term monitoring location (Figure 1). HESL also collected spring samples (May 12, 2021) from the Kahshe River and Gartersnake Creek during high flow as an exploratory assessment of water quality in the inflowing tributaries to Bass Lake.

The DMM monitoring program is operated in collaboration with the Dorset Environmental Science Centre (DESC). Trained summer staff collect Secchi depth, temperature and dissolved oxygen profiles along with a suite of chemistry parameters including metals, major ions, calcium, chloride, nutrients, and pH. The Lake Partner Program (LPP) is a volunteer-based water-quality monitoring program which collects total phosphorus, calcium and chloride samples, and water clarity (Secchi disk depth) observations on lakes across Ontario. Long-term phosphorus concentrations from both programs were reviewed to determine if trends or step changes in nutrients have occurred which suggest development has had an impact on productivity in Bass Lake.

The following summary statistics were calculated: minimum (Min), arithmetic mean, percentiles (25th, 50th, and 75th), and maximum (Max). The focus of our data analysis was total phosphorus (TP), dissolved organic carbon (DOC) and dissolved oxygen concentrations, as these parameters are most informative to the potential inputs and sources of phosphorus to the lake.

2.2 Specific Tasks Undertaken

Our work plan comprised seven tasks:

Task 1: Start-up Meeting – HESL scientists organized a project start-up meeting with the project team from the DMM to review and confirm our approach to the project, acquire reports for review which were not publicly available, strategize stakeholder engagement, identify resources to consult for background information, and confirm the schedule and format of deliverables.

Task 2: Compile and Review Existing Data – This task included identification and documentation of data on water quality, climate and nutrient sources to the lake from existing sources and involved stakeholder engagement that could inform the causation study. These sources and resultant information are presented in Sections 3, 4, 5 and 6 of this report.



Task 3: Gap Analysis – Our approach was focused on determining if development was expected to be a significant factor in causing the elevated phosphorus concentrations in Bass Lake or if other factors were suspected. We used the available historical water quality data, land use data, modelling tools and our own water quality and algae sampling results from May and October of 2021 to inform our analysis. A gap analysis was included to highlight areas where additional data or research would be beneficial but was outside the scope of the causation study. Formal documentation of data gaps and recommendations to fill them are provided in Section 7.

Task 4: 2021 Field Program – Our work plan included a limited field sampling program to gain information on the algal community composition and the potential for internal loading of phosphorus in Bass Lake, while limiting the cost of the data collection. Field sampling to measure current water quality in Bass Lake was completed in October of 2021 to assess water quality as late in the stratified season as possible (i.e., when the potential for hypolimnetic anoxia and internal phosphorus loading was greatest; see Section 5.2). Additional sampling was proposed during the start-up meeting to assess the phosphorus contributions from the Kahshe River and Gartersnake Creek. A single exploratory sampling event was completed to collect preliminary data from each watercourse and to determine if additional sampling in the future would be valuable in the ongoing management of the lake. Water quality samples were collected from mid-river. Samples were put on ice in a laboratory-provided cooler and delivered to ALS ENvironmental, which is a Canadian Association for Laboratory Certification – CALA – accredited laboratory) within 24 hours of collection.

Task 5: Phosphorus Modelling – The relative contributions of different sources of phosphorus to Bass Lake is addressed in Section 4 of this report using the DMM Water Quality Model (HESL, 2016; derived using MECP methods¹) and discussions on the potential for internal phosphorus loading are addressed.

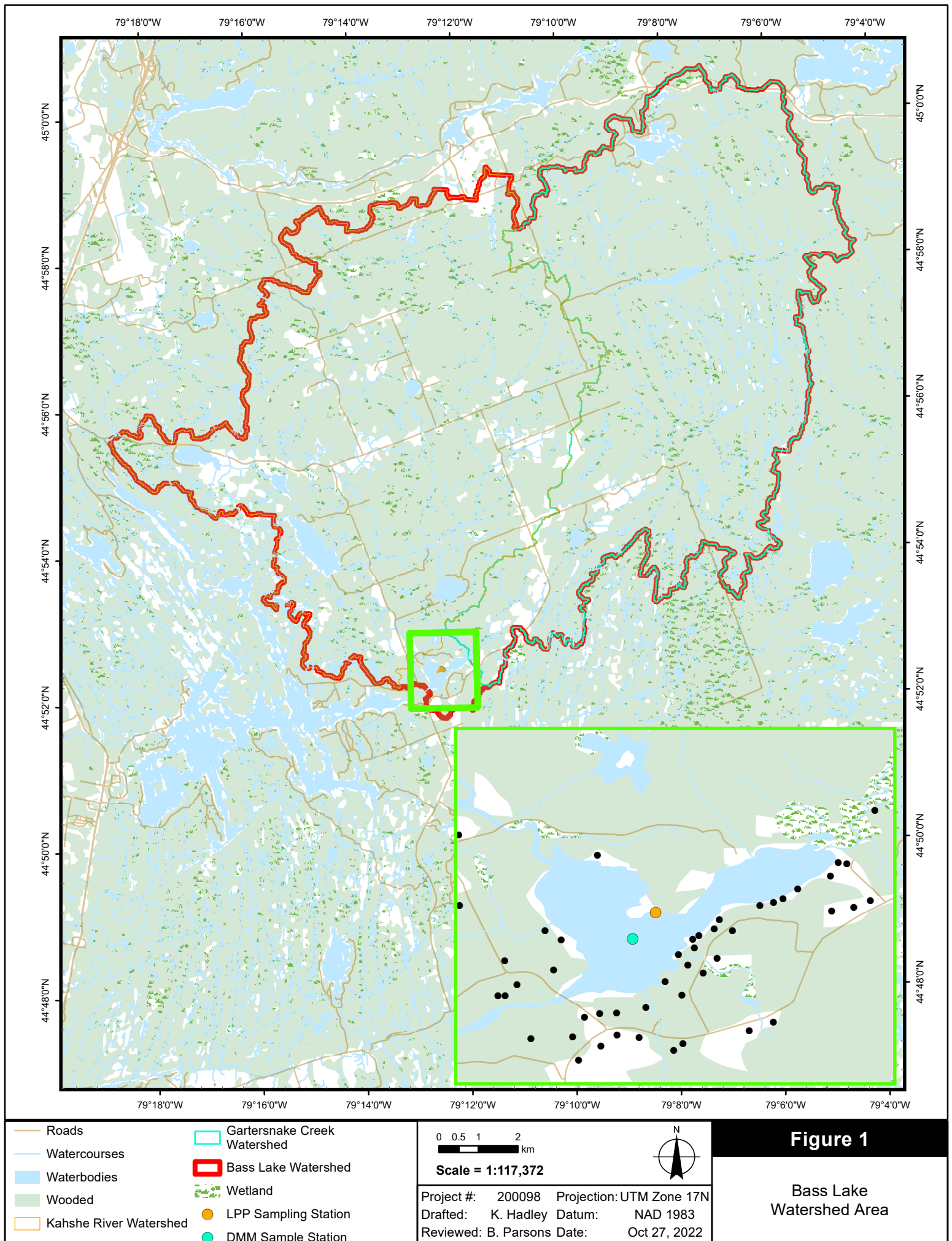
Task 6: Stakeholder Engagement and Meetings – The details on stakeholder engagement were developed by Ecovue Consulting Services Inc. with DMM staff at the start-up meeting (see Task 1 above) and are fully described in Appendix B.

Task 7: Reporting and Deliverables – Our work plan included submission of the draft and final reports which addressed the required elements:

- A summary of background (e.g., MECP) and current water quality information, including assessment of long-term trends in nutrients and algae where possible
- Identification of significant data gaps
- Results of the spring and fall field sampling programs
- Identification of the point- and non-point-source discharges to Bass Lake (from the water quality model), including those from septic systems
- Updates to the Current Causation Study Framework to inform future studies which included:
 - Lessons Learned
 - Detailed Statistical and Sampling Methodology
 - Recommendations for Additional Monitoring and/or special studies
 - Recommendations on waterbody-specific policies that should be implemented, if applicable

¹ Ontario Ministry of the Environment. 2010. Lakeshore Capacity Assessment Handbook. Protecting Water Quality in Inland Lakes on Ontario's Precambrian Shield. PIBS 7642e. Queens Printer for Ontario. 106pp.





3 Causation Study Lines of Evidence

3.1 Algal Bloom History

Published reports, including MECP and DMM records, do not show a history of algal blooms in Bass Lake, however algal blooms were noted in 2020 and 2021 downstream in Kahshe Lake and the Kahshe River. In our survey of local residents, it was noted by 7 of the 14 respondents that changes on the lake included increased algae. In several cases residents defined these as blooms, while in others it was noted that no blooms had been witnessed. Both green and brown water were described by survey participants. Brown water in the fall may suggest a proliferation of chrysophytes, which typically comprise an increasing percentage of the algal community in the fall. Some species of chrysophytes can result in taste and odour issues in freshwater lakes (Paterson et al. 2004). Algal samples were collected in 2021 and results were analyzed and reported because of survey results but the focus of the report is on elevated phosphorus concentrations, because without a formally documented bloom history a comparison of blooms against climate and nutrients (to determine causation) is not possible.

3.2 Water Quality Analysis

3.2.1 Historical Reporting

3.2.1.1 *Shoreline Assessment Report – 2019*

Muskoka Watershed Council completed a Shoreline Assessment Report in 2019 as part of the Love Your Lake Program. The Shoreline Assessment Report summarizes the results of field work and GIS analysis to describe existing conditions on the shoreline, suggests stewardship and reclamation actions and provides guidance to inform good stewardship practices and shoreline management.

On Bass Lake, trained surveyors assessed 34 properties encompassing the entire shoreline of the lake. Based on the 2019 survey data, 14 properties were identified that would benefit from shoreline naturalization, specifically, by expanding the existing buffer between the property and the lake (13 properties) or by creating a buffer (1 property). Erosion of the shoreline was not identified by the shoreline survey, however increased large-boat traffic and its impact on shallow waters was discussed as a potential cause of deteriorating water quality in the Causation Study survey.

3.2.2 Current Water Quality Records

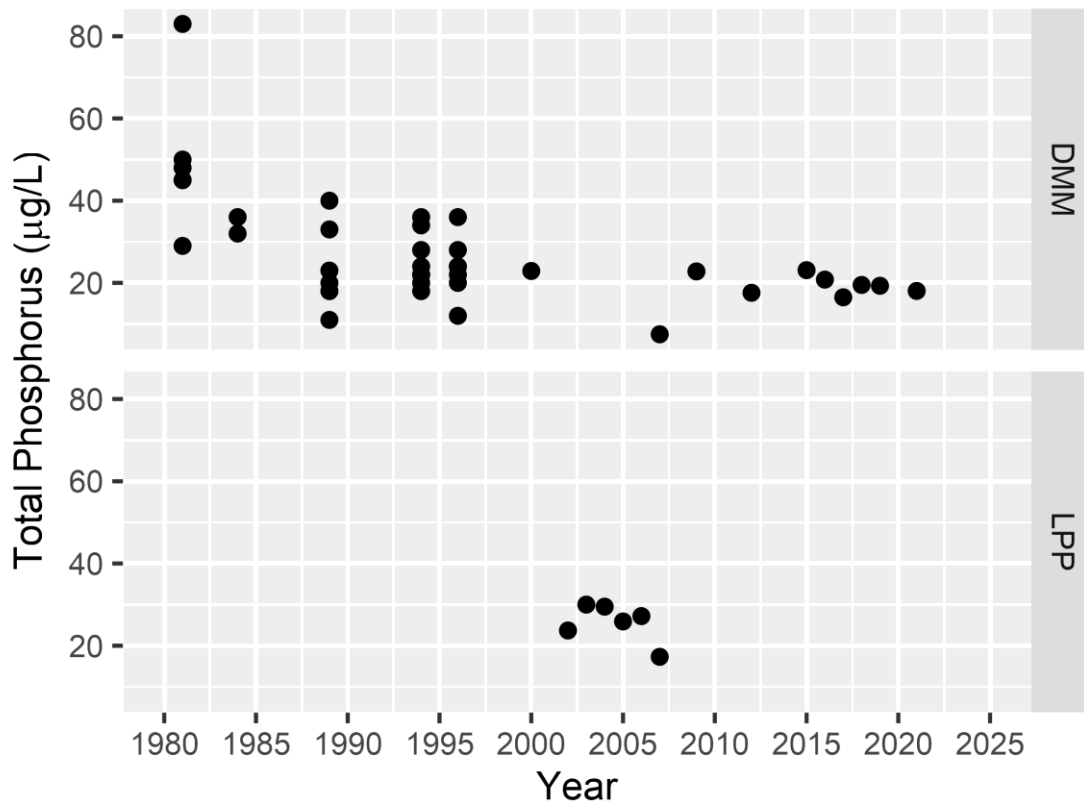
3.2.2.1 *Total Phosphorus Concentrations*

Bass Lake was listed as vulnerable under Schedule E2 when total phosphorus concentrations met Condition 2 (i.e., TP > 0.020 mg/L). We reviewed long-term total phosphorus concentrations to determine if any step changes or long-term increases could be measured. Data sources included long-term monitoring by the DMM (Lake System Health Program), and the MECP Lake Partner Program (Figure 2). Data collected by the DMM began in the early 1980s, however this is prior to the methodological change of 2002 (sample filtration through a Nitex mesh and sampling directly into phosphorus tubes used during laboratory analysis). As a result, while pre-2002 data are included for completeness, they are not directly comparable to data collected after 2002.



Data collected since 2002 show no significant long-term monotonic trend in phosphorus concentration ($p>0.05$), nor is there an indication of a stepwise change that may be expected to occur in response to local development or a significant shift in phosphorus delivery from the immediate watershed or upstream sources. Lake Partner Program data have not been collected since 2007, these data would serve as a valuable addition to the DMM Lake System Health Program data if sampling is reduced by the DMM to every few years following the completion of the Causation Study.

Figure 2. Lake Partner Program and District of Muskoka data for Total Phosphorus Concentrations in Bass Lake.



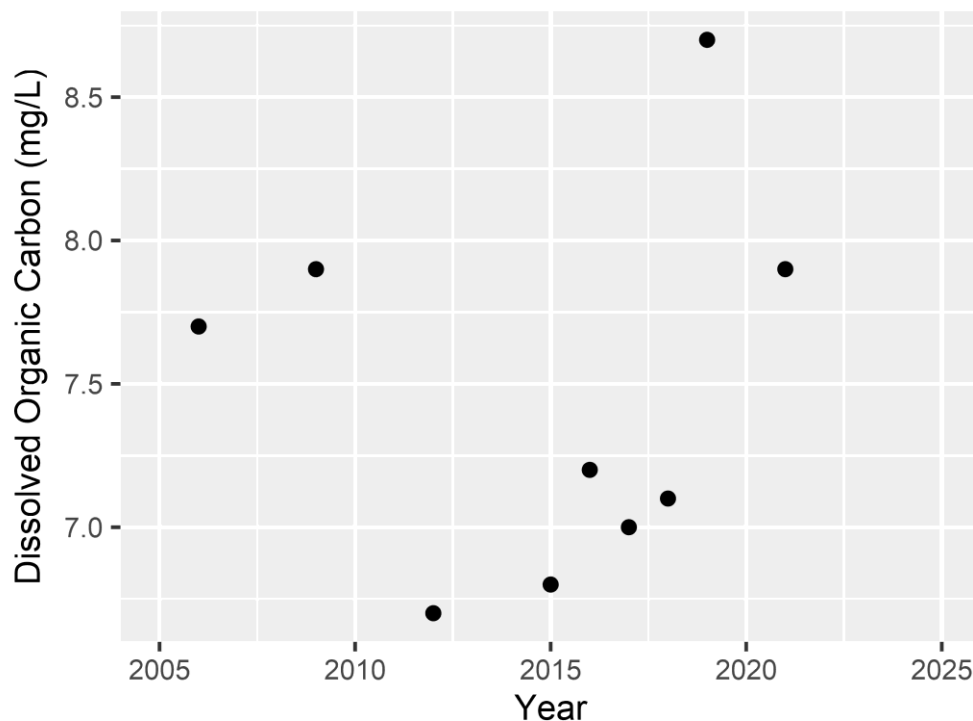
3.2.2.2 Dissolved Organic Carbon

The primary source of Dissolved Organic Carbon (DOC) to streams, rivers and lakes is the catchment (O'Connor et al. 2009). Previous research has demonstrated the importance of wetlands to DOC concentrations in streams, rivers and lakes and correlated DOC concentrations to the proportion of wetland area in a catchment (Dillon and Molot 1997; Creed et al. 2008). DOC concentration in lakes is also partially climate dependant, with supply being influenced by both temperature (affecting the production and decomposition of organic matter) and precipitation (exporting DOC to lakes via precipitation) (Dillon and Molot 2005; Eimers et al. 2008). DOC is a major determinant of the transparency of lakes and therefore is vital in shaping lake thermal structure (i.e., the depth of the surface mixed layer). DOC is also closely related to total phosphorus concentrations in Muskoka lakes (Gartner Lee Ltd. 2005) and has been increasing in Precambrian Shield lakes (Eimers 2008) and Muskoka lakes (Palmer et al. 2011) likely as a result of changes in hydrology, the effects of warming temperatures on soils dynamics and the cycle of drought and flooding in wetlands in a changing climate (HESL 2016).



Mean DOC concentrations in Bass Lake were 5.26 mg/L which is close to average for Muskoka lakes (i.e., 5 mg/L; HESL 2016). We observed a decrease in spring DOC concentrations in 2012, followed by a steady increase to 8.75 mg/L in 2019 before a decline in 2021 in the DMM dataset. In the Experimental Lakes Area and the Adirondacks, the Chrysophyte (*Synura sphagnicola*) was associated with smaller and warmer lakes which were high in DOC and nutrients (Mushet et al. 2017; Arseneau et al. 2016). It is possible that the inter-annual and seasonal variability in DOC concentrations have contributed to Chrysophyte dominance in Bass Lake (Section 3.1.2.5) and to the water quality observations noted by the local residents (i.e., brown water in the fall [which could be just increased DOC], cloudy/slimy water). Sampling in the fall of 2021 as part of the causation study found elevated DOC concentrations in Bass Lake (14.5 mg/L) compared to typical spring concentrations (6.7-8.7 mg/L), suggesting the importance of natural wetlands in the catchment to water quality in the lake, more specifically the flushing of tea-stained and DOC-rich water from wetlands to the lake as the result of fall rains following macrophyte senescence. Regional climate records show >20 mm of precipitation fell in the area 72 hours prior to fall sampling supporting the wetland as a likely source of increased DOC in October (Beatrice Station).

Figure 3. District of Muskoka data for Dissolved Organic Carbon in Bass Lake.



A linear regression was completed with total phosphorus (dependent variable) and DOC (independent variable) to determine if a cause-and-effect relationship was evident. Data from seven DMM sampling events where total phosphorus and DOC were both analyzed were used in the analysis. The regression was not statistically significant ($R^2 = 0.025$, $f = 0.128$, $p = 0.735$) and it was determined that DOC did not predict total phosphorus concentrations although the dataset and subsequent power of the regression was limited.



3.2.2.3 Other Water Quality Parameters

The DMM data set includes long-term monitoring of additional water quality parameters including total metals, general chemistry (e.g., cation and anions) and nutrients. No significant differences over time were apparent. Summary statistics for all water quality data are provided in Appendix D.

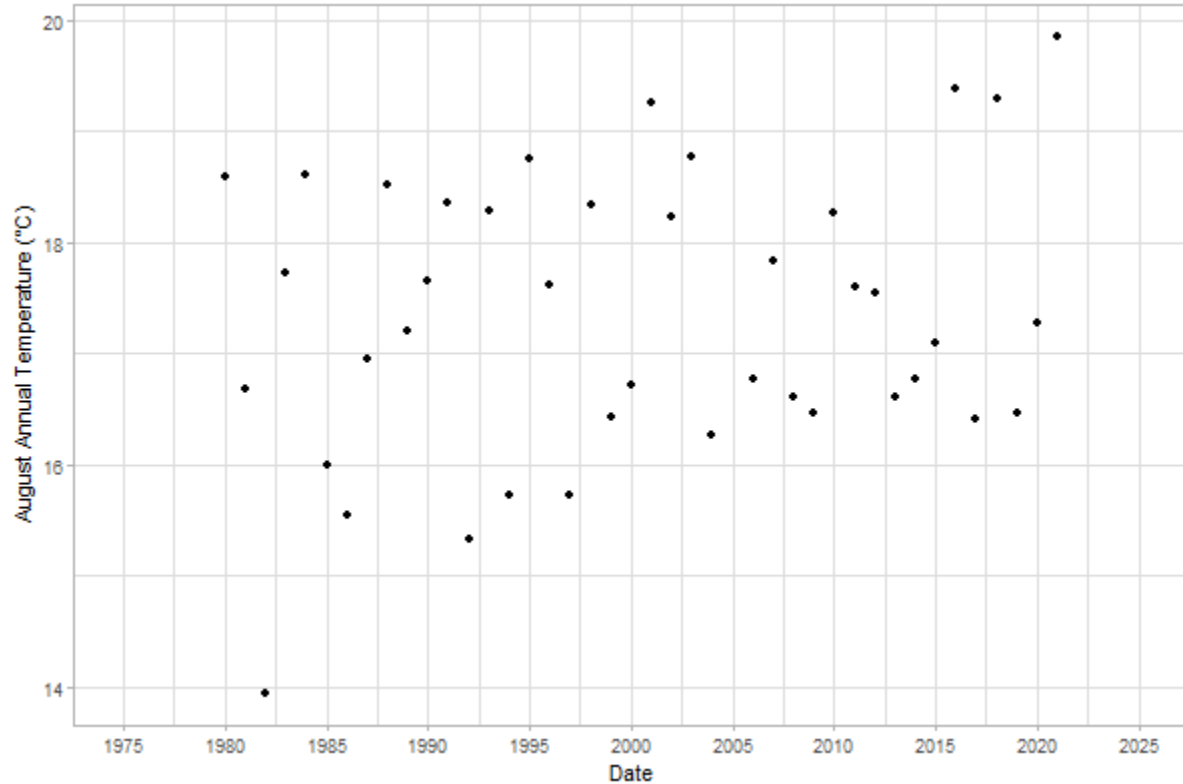
3.2.2.4 Temperature, Dissolved Oxygen Profiles and Deep-Water Sampling

Surface water temperature in August varied between 21.0 and 26.1 °C with an average surface water temperature of 23.5 °C (1994 – 2021; Figure 4). August data are shown as this was the most consistent monthly data set, however no August samples were collected in 2020 as part of the District Program due to restrictions on travel related to the Covid-19 pandemic. Furthermore, sampling was not performed on the same date each year and therefore formal trend assessment is not appropriate for this data set. Long-term climate records at the Beatrice Climate Station show a gradual but insignificant increase in air temperature over the period of record, with substantial annual variation (Figure 5). Air temperature records also show that the three hottest years on record have occurred since 2015. Increased air temperature may result in high water column stability, which increases resistance to mixing and may result in deep water anoxia and increased rates of internal phosphorus loading.

Figure 4. Long-term Records of Surface Water Temperature (0.5m) in Bass Lake.



Figure 5. Average August Annual Air Temperature at Beatrice Climate Station.

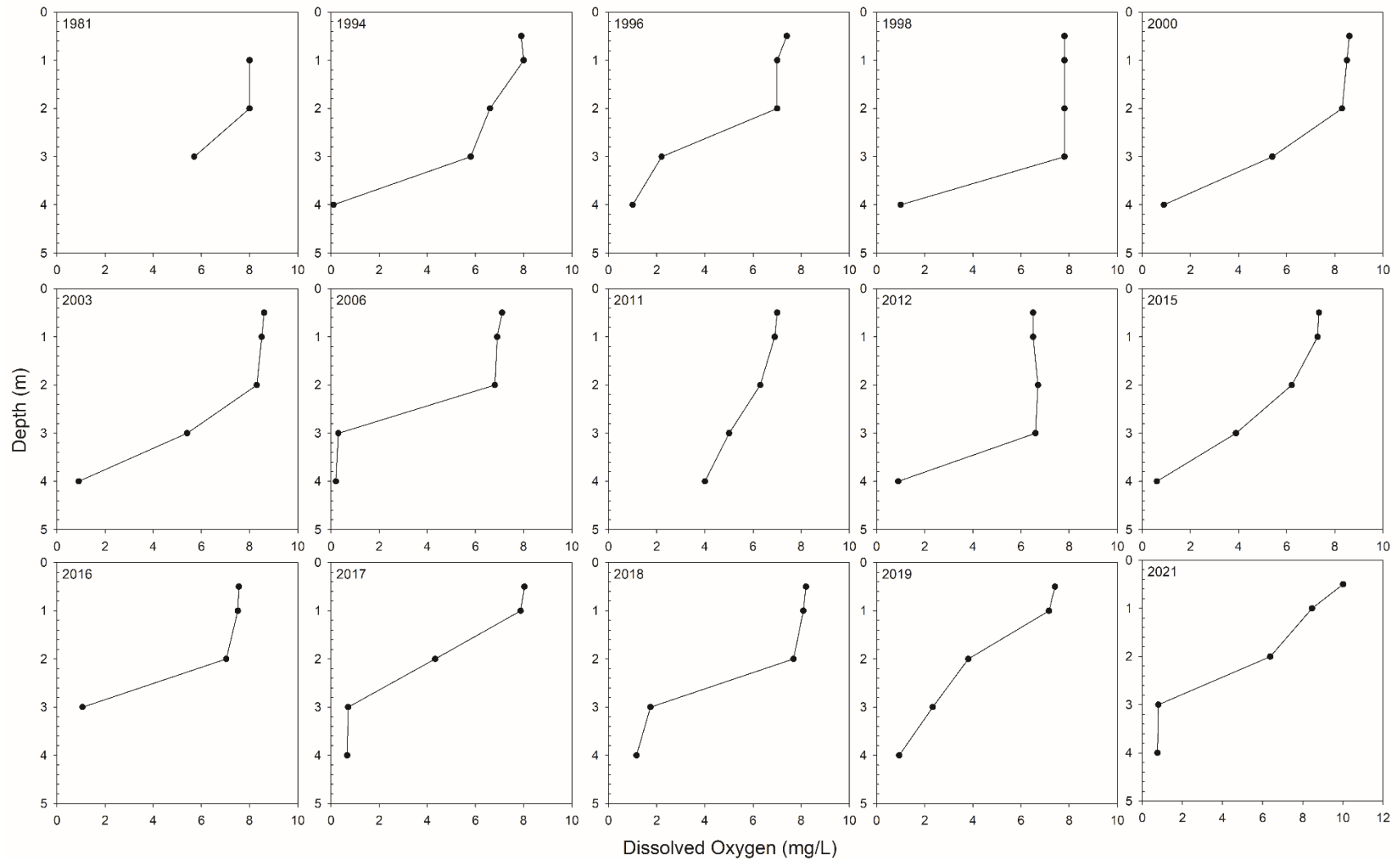


Historical records of deep-water oxygen in Bass Lake show that concentrations consistently fell below 2.0 mg/L during late summer sampling a criterion used for indicating anoxia (Nurnberg 1995). These results suggest the potential for the development of hypolimnetic anoxia and the internal loading of phosphorus to the lake. The current DMM sampling program does not collect profile data beyond August and dissolved oxygen concentration may continue to decline into September or October, depending on weather conditions, particularly wind speed, due to its influence on vertical mixing.

In Bass Lake, historical records collected by the DMM showed that hypolimnetic dissolved oxygen concentrations fell below 2.0 mg/L during late summer sampling in 12 of 15 sampling years; data collected by DMM in 2021 was completed earlier in July, potentially before the period of hypolimnetic anoxia developed (Figure 6). Field data collected on October 13, 2021 by HESL showed some mixing of the thermal layers of Bass Lake had already occurred as a deep-water oxygen concentration of 4.29 mg/L was measured. Dissolved oxygen data suggest that Bass Lake has a prolonged period of bottom-water anoxia which would cause internal loading of phosphorus.



Figure 6. Bass Lake Dissolved Oxygen August Profiles.



Note: 2019 sampling took place in July.



3.2.2.5 Algae Communities

Algae communities were sampled on October 13, 2021 as part of the scheduled field program in response to concerns expressed in the stakeholder survey. Communities were dominated by chrysophytes which accounted for 55% of the algae enumerated (Figure 7). Chlorophytes (green algae) and cryptophytes were the next most abundant algal groups, accounting for 21% and 23% of the algal community, respectively. Cyanobacteria (“blue-green algae”) comprised only 0.1% of the relative abundance of the algal community, including only species from the *Aphanocapsa* genus.

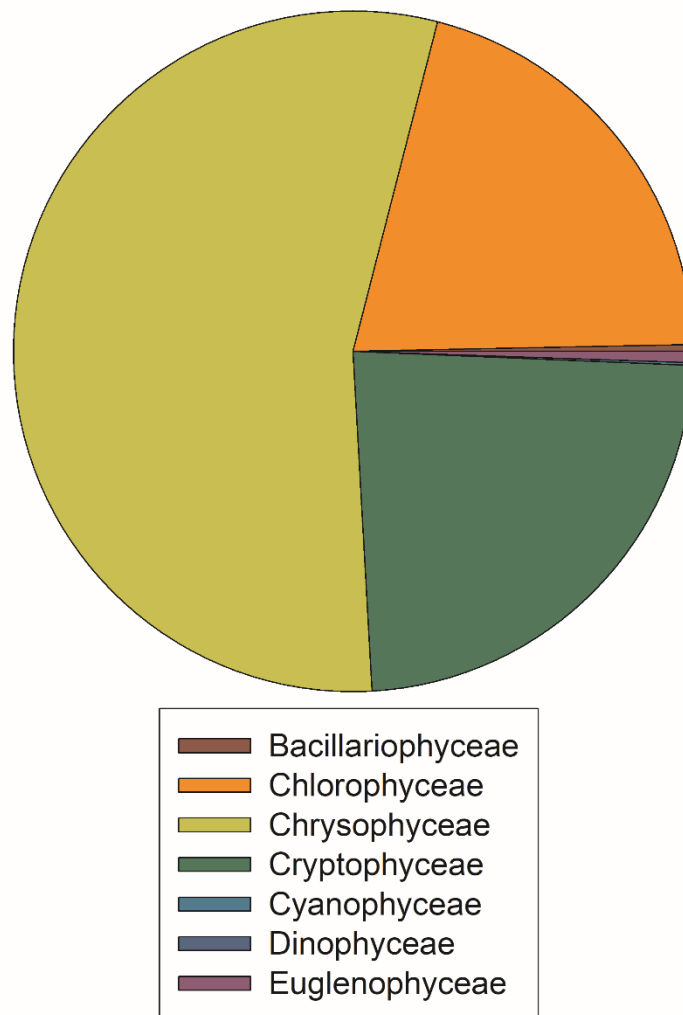
Chrysophytes are common in late-summer phytoplankton assemblages under normal conditions where seasonal algal succession results in a shift of dominant algal species. During initial summer stratification, increased water temperature stabilizes the water column and light availability increases, while nutrient concentrations decline. During this period, total phytoplankton biomass generally decreases as grazing pressure from zooplankton rapidly increases. By late summer, high water temperatures and water column stability often favour chrysophytes and colonial green algae. The mixing of the water column in the fall is typically characterized by decreased water temperatures and light availability along with increased concentrations of key nutrients (phosphorus and nitrogen). Large unicellular and filamentous diatoms often dominate fall phytoplankton assemblages; however, in Bass Lake chrysophytes remained dominant during our sampling in October.

During the past several decades, the Dorset Environmental Science Centre (DESC) has tracked the effects of anthropogenic stressors on the aquatic and terrestrial ecosystems in the Muskoka area. Complex interactions amongst multiple stressors, including forest clearance and regrowth, increases in shoreline residential development, the deposition of strong acids via the atmosphere, invasion by non-indigenous species, and climate change, have resulted in significant changes to physical, chemical and biological conditions of lakes during the past several decades. One consequence of these changes has been a regional increase in the relative abundance of colonial, scaled chrysophytes in boreal shield lakes, often characterized by near systemic increases in relative abundance of the nuisance taxon *Synura petersenii* which is a scaled, colonial chrysophyte (e.g., Hyatt et al. 2010). Blooms of *Synura petersenii* have been linked to taste and odour problems in freshwater lakes and reservoirs (e.g., Watson et al. 2001).

Based on the data collect in Bass Lake, it is unclear what may be driving chrysophyte dominance of the algae community or if these algae are reaching nuisance concentrations in the lake as taste and odor issues were not reported during the stakeholder survey. Mechanisms believed to contribute to taxonomic shifts in chrysophyte species include: 1) variation in species-or group-level tolerances to pH (Paterson et al. 2001), 2) increased transparency associated with declining DOC concentration (Leavitt et al. 1999), 3) changes in deposition of metals (Davis et al. 2006), 4) climate-driven changes in lake thermal stability (Paterson et al. 2004; Ginn et al. 2010), and 5) resource limitation driven by changes in nutrients and light regime (Findlay et al. 2001). DMM data does not indicate changes in pH, DOC or metals as likely mechanisms for chrysophyte dominance in Bass Lake, suggesting climate may be an important factor, however a targeted study on chrysophytes would be required if blooms become an issue in Bass Lake.



Figure 7. Relative Abundance of Phytoplankton Taxa in Bass Lake – October 13, 2021.



4 Phosphorus Sources

The DMM uses their Water Quality Model (MWQM), a variant of the Ministry of Environment's (MOE) "Lakecap" Model (2010), as one component of the Lake System Health program to guide planning policies for recreational lake development in a large and complex watershed of over 500 lakes and lake segments. The MOE released their "Lakecap" Model and guidance document in 2010 as their recommended means of Lakeshore Capacity Planning. Prior to 2010, the MOE encouraged use of this approach, although it had not yet been finalized as formal Provincial guidance. In 2010, the DMM began a project to review and update the model to address changes in the Provincial approach and scientific background to the model since the last update was completed in 2005.

The "Lakecap" approach is based on modelling the current phosphorus concentrations in a lake resulting from natural (or "background") sources and human inputs and then calculating the amount of phosphorus from human inputs (generally shoreline development) that the lake can sustain while remaining below a modelled phosphorus concentration of "Background + 50%" (the "lake capacity"). The MOE approach requires that the model produce accurate estimates of phosphorus concentration that can be verified through a reliable lake monitoring program, such as that of the DMM.

Although the MOE model was developed and calibrated on a set of small headwater lakes in Muskoka and Haliburton, the MOE advised that the model should be used in a watershed context – that is, any lake that is being modelled should incorporate hydrologic and phosphorus loading from all upstream lakes in its watershed (p. 29, MOE 2010). The Muskoka application of the model is thus complex, as it includes over 500 lakes and lake segments in the Muskoka, Black, and Severn River watersheds. The Muskoka application also includes lakes and watersheds that exceed the calibration range used to develop the MOE model, as it did in the previous versions. The MOE recognized this in their guidance document and cautioned that modelling lakes that fall outside of the calibration range may be one reason that the model does not perform well.

Monitoring data show no recent changes in TP or oxygen concentrations in Bass Lake over the available period of record, suggesting that phosphorus concentrations are either naturally elevated in the lake due to the large watershed or that concentrations increased due to anthropogenic influence prior to monitoring (Section 5.2). A phosphorus budget for Bass Lake was reviewed to determine if recent changes in development pressure resulted in substantial changes to phosphorus loads to the lake.

Gartner Lee Ltd. (2005) produced an updated phosphorus model for Muskoka's lakes which was reviewed by HESL (2016) and included an accounting of phosphorus sources to Bass Lake. Natural sources from the watershed and precipitation account for the majority (97%) of the phosphorus loading to Bass Lake (Table 2). Approximately 75% of this load is from upstream sources (i.e., lakes and rivers) which flow into Bass Lake because Bass Lake receives drainage from a large watershed area via the Kahshe River and Gartersnake Creek (Figure 1). Overland runoff represents a potential source of particulate and dissolved phosphorus from fertilizers, dust deposition and erosion. Runoff from developed areas (including cottages) contributed an estimated 1% of the total phosphorus load to Bass Lake (Table 2) based on 1997 development numbers. In 2018, the DMM updated the development data for vulnerable lakes. Using these revised numbers in the most recent version of the DMM Water Quality Model we estimated that the phosphorus contributions associated with overland runoff from cottages increased from 0.71 to 1.02 kg/yr.



The phosphorus contributions associated with septic systems from cottages increased from 11.37 to 16.24 kg/yr. These modelled increases in phosphorus load is minor relative to other phosphorus sources to the lake, particularly the upstream phosphorus load which accounts for an estimated 72% of the phosphorus entering the lake. Phosphorus concentrations have not changed during that time suggesting that direct impacts to the lakes from the small increase in development have not been significant enough to have been noticed through monitoring.

Table 1. Phosphorus Budget for Bass Lake.

Source	Revised Lot Count	Percent	Lot Count (2018) Developed/ Vacant	Old Lot Count	Percent	Lot Count (1997) Developed/ Vacant
	kg/yr			kg/yr		
Natural (Watershed and Precipitation)	1197.57	96.68		1197.57	97.09	
<i>Upstream Sources</i>	<i>884.47</i>			<i>884.47</i>		
Overland Runoff – Cottage	1.02	0.08	30/11	0.71	0.06	21/13
Overland Runoff – Other	0.44	0.04		0.44	0.04	
Septic Systems (after attenuation by soil; Attenuation Factor = 1)	16.24	1.31		11.37	0.92	
Upstream Developed	23.38	1.89		23.38	1.90	
Total	1238.65	100.0		1233.47	100.0	

4.1 Upstream Watershed Sources

We collected spring samples (May 12, 2021) from the Kahshe River and Gartersnake Creek during high flow as an exploratory assessment of water quality in the inflowing tributaries to Bass Lake. We sampled the Kahshe River at Cooks Road, downstream of developed areas including a large open agricultural field adjacent to the river (Figure 8). Numerous waterfowl (geese) were also noted during spring field sampling on the Kahshe River. Gartersnake Creek was sampled just upstream of the inflow to the east end of Bass Lake (Figure 9).

No evidence of elevated phosphorus concentrations (i.e., elevated above concentrations in the lake, or above provincial water quality objectives of 30 µg/L) in the incoming watercourses was noted during spring sampling, with total phosphorus concentrations in the Kahshe River and Gartersnake Creek of 14.5 and 13.4 µg/L, respectively (Table 3). However, our field sampling represents only a single point in time and information on incoming phosphorus from these watercourses could be improved with expanded sampling, including targeted storm sampling, to better understand the impact of runoff events and flushing of nutrients and DOC from wetlands following significant precipitation events.



Table 2. Water Quality of Bass Lake Tributaries (May 12, 2021).

	Units	Kahshe River at Cooks Road	Gartersnake Creek
Physical Parameters			
Total Suspended Solids	mg/L	<3.0	<3.0
Anions and Nutrients			
Alkalinity	mg/L	<10	6.1
Total Ammonia as N	mg/L	<0.010	0.010
Total Kjeldahl Nitrogen	mg/L	0.410	0.380
Total Phosphorus	µg/L	14.5	13.4
Chlorophyll a	µg/L	3.61	2.32

Figure 8. Kahshe River at Cooks Road



Figure 9. Gartersnake Creek at Bass Lake.



5 Weight of Evidence Analysis

Lake systems are complex physical, chemical and biological systems whose individual components are interconnected through numerous mechanisms. To understand the relative contribution of different phosphorus sources and determine the importance of development in Bass Lake in driving elevated total phosphorus concentrations, we assessed lines of evidence under two broad categories:

5.1 Climate

- We observed elevated air temperature at the Beatrice Meteorological Station in post-2015 data and a general increase since the 1980s
- Long-term regional monitoring shows reduced wind speed in the Muskoka area (Yao et al. 2013).
- Periods of sustained low wind speed and high air temperature lead to increased water column stability and reduced mixing; these factors can promote internal loading of phosphorus. Internal loading of phosphorus could also occur through a variety of other process that are common in shallow lakes such as the resuspension of phosphorus-laden sediment through wave mixing or macrophyte senescence (Welch and Cooke 2005).
- The potential for overland runoff is increased in more severe rainfall events, such as is predicted for a changing climate. However, overland runoff from waterfront properties does not represent a significant contribution to the phosphorus budget of Bass Lake, and therefore changes to



precipitation as a result of climate change are not expected to significantly impact the load of phosphorus to the lake from overland runoff relative to other sources. Effects of increased precipitation are more likely to impact Bass Lake through natural processes such as flushing of TP and DOC from wetlands, and increased flow to the lake from the Kahshe River and Gartersnake Creek.

5.2 Water Chemistry

- We did not document any significant long-term changes in total phosphorus concentrations in the lake over time, nor any abnormalities in recent monitoring that could explain the elevated nutrients that triggered the causation study. Total phosphorus concentrations have been relatively elevated over the entirety of the historical dataset.
- Long-term data on potential anoxia showed low deep-water oxygen (<2.0 mg/L) in 12 of 15 years, indicating that there is an internal load of phosphorus from sediments, but data did not suggest anoxia has increased over time.
- Dissolved organic carbon concentrations in the lake suggest the importance of catchment wetlands to the lake. Fall sampling demonstrated that these wetlands inputs result in marked seasonal changes in DOC concentrations in the lake.

5.3 Summary of Findings

Our investigation concludes that the cause for the elevated phosphorus concentrations at Bass Lake cannot be reliably determined with the current information. There was no evidence of changes in waterborne phosphorus concentrations in the lake over time, suggesting that recent development and land use change (ca. 2008 – 2018) have not significantly altered phosphorus in the lake based on the available data. Long-term elevated nutrient concentrations in Bass Lake may be the result of:

2) the natural influence of

a. A large watershed to lake ratio

In general, nutrient loading to a drainage lake (i.e., a lake with inflowing streams and rivers) increases as the ratio of the watershed area to the lake area increases (Schindler 1971). Typically, when the watershed to lake area increases there are additional sources (e.g., agricultural or urbanized areas) and high volume of runoff to a lake. In larger watersheds, there is also a greater opportunity for interaction between water from precipitation and the soil which may result in increased leaching of nutrients and minerals prior to discharging into the lake.

b. Prolonged periods of hypolimnetic anoxia and internal phosphorus loading

Internal phosphorus (P) loading (i.e., the release of phosphate from anoxic sediment surfaces to overlying water) represents a substantial summer P input to many lakes (Nurnberg and LaZerte 2016). Climate change may exacerbate deep water anoxia and internal loading of phosphorus, however data in Bass Lake do not indicate an increase in the frequency of the occurrence of anoxia during the monitoring record.



- c. Influence of catchment wetlands and lake hydrology (i.e., a significant contribution of phosphorus from upstream sources);

Wetland area in a catchment is a key contributor to nutrient concentrations (Dillon and Molot 1997; Creed et al. 2008). Based on modelling data from Bass Lake, the majority of the nutrient load to the lake comes from upstream sources via the Kahshe River and Gartersnake Creek. DOC concentrations measured by HESL in 2021 suggest that the wetland is a key source of DOC (and likely phosphorus) to the lake and this influence is seasonal and occurs outside the typical monitoring period.

- d. Shallow depth of Bass Lake (mean depth = 2 m)

Shallow lakes are susceptible to a variety of mechanisms that support internal loading of phosphorus where phosphorus is recycled from sediments such as wave and wind induced suspension of phosphorus-laden sediment and decomposition of organic matter (Welch and Cooke 2010),

- 3) shoreline development that occurred prior to the monitoring period of record (and thus no trends are detectable in the available dataset).

6 Gap Analysis and Recommendations for Bass Lake

Substantial long-term data collection has taken place to quantify the health of Bass Lake, which for the purpose of this causation study has been supplemented by a literature review and stakeholder observations. Our 2021 field data collection focused on characterizing the late-summer algae community and hypolimnetic oxygen status. Our intent was to determine the potential cause of the elevated (i.e., >20 µg/L) total phosphorus in Bass Lake and to establish if additional investigations were warranted, including:

- The assessment of point source or non-point source loads to inform the phosphorus budget for the lake;
- A septic system survey;
- Seasonal sampling of water quality;
- Hydrology and inflow assessment;
- Sampling of additional parameters which may inform the causation study but are not currently a part of the DMM sampling program.

Stream and river sampling is generally underrepresented in the watershed. The current monitoring program is focused on a sampling site in deep water, as is common as a metric for overall water quality in a lake. However, based on modeling of phosphorus concentrations in Bass Lake, the majority of the phosphorus entering the lake is from upstream sources and information on the water quality of the incoming streams is limited to the fall sampling carried out under this study. Targeted monitoring of the Kahshe River and Gartersnake Creek would be required for more precise quantification of the upstream sources of phosphorus to the lake and may also provide valuable data on the contributions of the eastern wetland. Stakeholder concerns about upstream agriculture on the Kahshe River and sewage lagoons (@Snowcrest Trail) which drain via Barkaway Lake cannot be addressed without more a targeted monitoring program.

Loading of phosphorus to the lake from developed areas adjacent to Bass Lake occurs by two primary pathways, overland runoff and septic systems, which account for an estimated 0.71 and 11.37 kg/yr of



phosphorus to the lake, respectively. Runoff estimates and assessment of the shoreline by the DMM suggest that land-use alterations in Bass Lake are not likely a substantial issue. Septic system phosphorus represents only 1% of the total phosphorus budget for the lake, however these data are derived using modelling assumptions. Currently, no septic system data is available from Bass Lake, while survey results from local residents have suggested that septic leakage and grey water leakage are a concern on the lake (though no specific information on sources was indicated). A septic survey of lakeshore properties would be required to identify the condition and need for improvement of wastewater treatment systems on the lake. Alternatively targeted nearshore sampling in areas of concern could identify potential septic issues without the need for a lake-wide survey and may identify manageable sources of phosphorus.

The Lake System Health Monitoring Program does not pre-date the majority of the cottage development on the lake and thus a significant gap in the Bass Lake dataset is an understanding of historical conditions (i.e., phosphorus concentrations prior to significant lakeshore development). Paleolimnological analysis (using algae preserved in sediments to reconstruct phosphorus concentrations over time) may be a valuable tool in determining if the nutrient concentrations in Bass Lake have change over the past 100–150 years and therefore determine whether development has resulted in changes in nutrient concentrations in the lake or if the lake has historically been high in phosphorus. Paleolimnological studies can be costly and therefore collaboration with an academic partner is recommended. We note that modelling data suggest that development in the local watershed of Bass Lake contributes little to the overall phosphorus budget of the lake and therefore we believe it is unlikely that historical development impacted the lake to an obviously measurable degree.

Algae blooms are not currently an identified problem on Bass Lake as no recent documented blooms (i.e., sampled and confirmed by the MECP) have occurred. However, anecdotal observations (uncovered via our resident survey) suggest that blooms may have been an issue on Bass Lake in the past, though it is unclear if these refer to the documented bloom on downstream Kahshe Lake. Citizen-science observation of potential blooms on Bass Lake would be a valuable asset to managing recreational uses and development in the future. During the pilot program of these causation studies on Peninsula Lake one of the key data gaps identified was the lack of information on blooms (HESL 2018). We recommend development of a citizen scientist program for bloom monitoring. Recording the date of onset, extent and severity of algal blooms for comparison against these data to characterize the conditions contributing to blooms is invaluable in the effort to manage recreational water quality.

Our survey of the stakeholders of Bass Lake also identified increased use of recreational watercraft such as Jet Skis and wakeboard boats as a concern for the protection of waterfront areas due to a perceived increase in wave action. Bass Lake is relatively shallow and therefore susceptible to erosion and resuspension of sediments that may occur during periods of substantial wave action. Erosion of the shoreline was not identified by the shoreline survey, however the shoreline survey noted that 18% of the properties on Bass Lake contain retaining walls which may reflect wave energy causing excess turbulence in the water, which scours the sediments from the lakebed. Since no data is currently available to quantify the impact of boat use on the lake, a boating survey may be useful in quantifying the severity of the problem and allow for further recommendations including restricting boat operation on the lake. However, it will not be possible to determine how boating intensity has changed over time.

Causation studies were originally proposed by HESL (2016) and were adopted by the District of Muskoka to support planning policy on individual lakes identified as vulnerable. The goal is to determine whether



Bass Lake Causation Study

shoreline development practices were increasing the phosphorus concentrations in some lakes or resulting in algal blooms, so that appropriate planning responses could be implemented where warranted. We note that this rationale would be strongest where nutrient concentrations have increased over time. This would increase the likelihood that the cause was a long-term change in lake characteristics (such as increased nutrient loading from development) and not the result of naturally high nutrients. Phosphorus concentrations in Bass Lake are stable, appear to be elevated due to a variety of natural lake and watershed-specific factors and did not increase following additional recent development.



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Appendix A. Public Survey Reports - DMM





Survey Summary - Bass Lake

Prepared for: District of Muskoka
Hutchinson Environmental

EcoVue Reference No.: 21-2116

Date: June 28, 2021

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1.0 INTRODUCTION

The District Municipality of Muskoka (“the District”), along with Hutchinson Environmental Sciences Limited and EcoVue Consulting (the Project Team), are undertaking a Causation Study for Bass Lake in the District of Muskoka. Bass Lake is 0.40 km² in size and is located in the Town of Gravenhurst. Bass Lake contains over 4.5 kilometres of shoreline, with the majority of development on the lake being residential. Bass Lake is relatively small with approximately thirty-four cottages on the lake.

This Causation Study provides for a number of opportunities for the public to share local knowledge with the project team. A Public Meeting to introduce the project to the public and stakeholders took place on April 30th, 2021. In order to gather local knowledge of the lake participants were asked to complete a survey and to forward the survey link to people who were not able to attend the meeting.

The following report summarises the results of the survey. This report is a summary only of the information gathered in the survey and does not include any conclusions or results. The information gathered as part of the survey will be included in the technical analysis and recommendations/conclusions of the overall Causation Study. The information presented in this report has been forwarded to the technical project team to be included in the technical analysis for the project. Raw data, including pictures, has also been forwarded to the technical team. A copy of the survey questions is provided at the end of this report.

2.0 SURVEY RESULTS

Eighteen (18) respondents completed the survey with the eleven (11) of survey respondents identifying themselves as recreational users on the lake and nine (9) as residential property owners on or near the lake (Figure 1). The location of the lake where people spend most of their time is included in Figure 2. Eleven (11) of survey respondents have been on the lake for over 20 years (Figure 3) with five (5) people being year around visitors/owners (Figure 4). Twelve (12) respondents when asked if the water quality on the lake was deteriorating said it was not (Figure 5).

Figure 1 - Interaction with Bass Lake

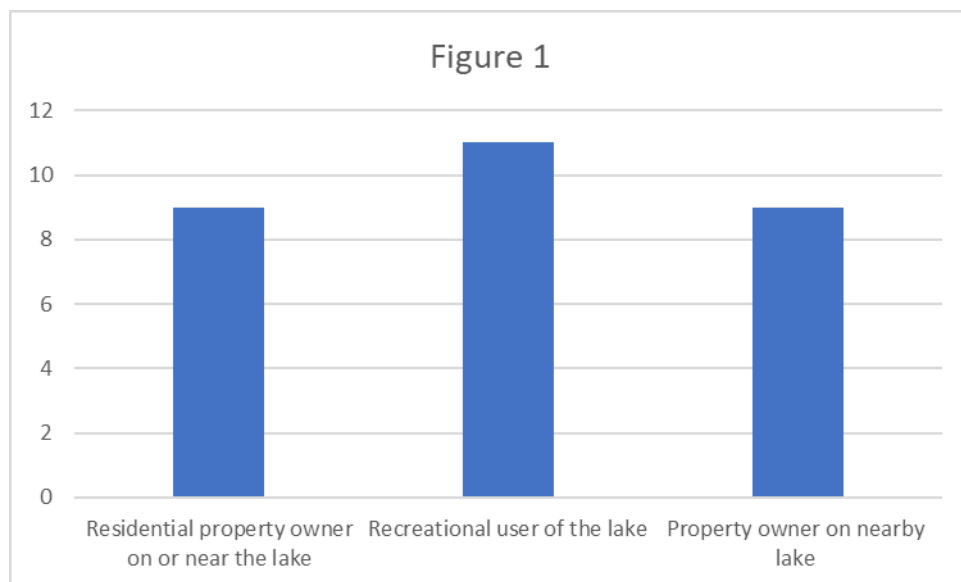


Figure 2 – Location on the Lake Where you Spend Time on Bass Lake

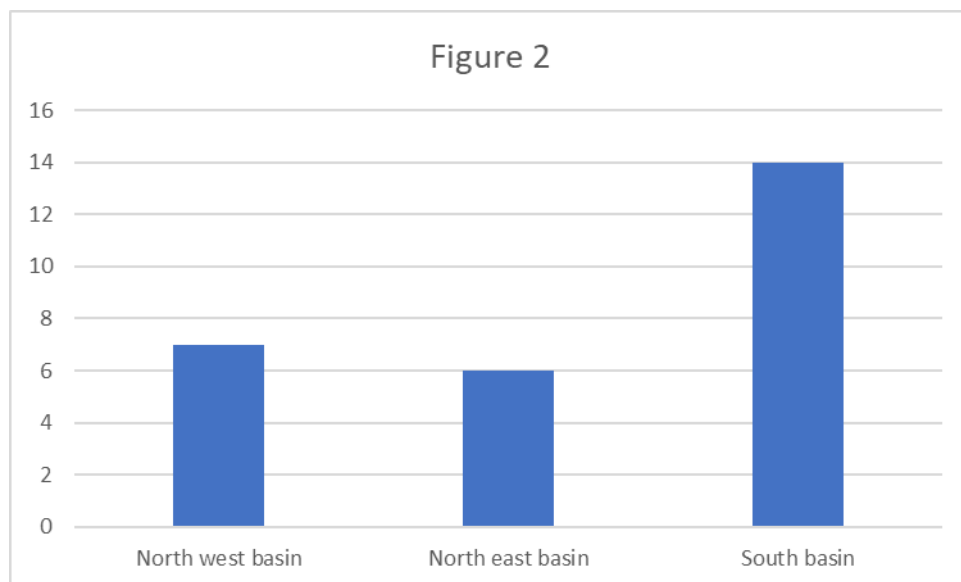


Figure 3 - How long have you been coming to or living in the area?

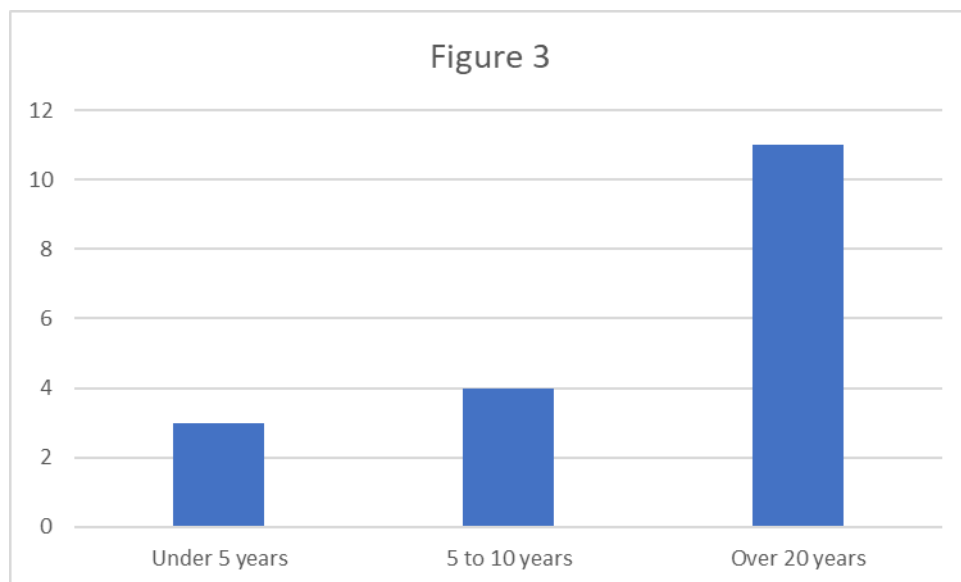


Figure 4 - Do you live in/come to the area year-round or seasonally?

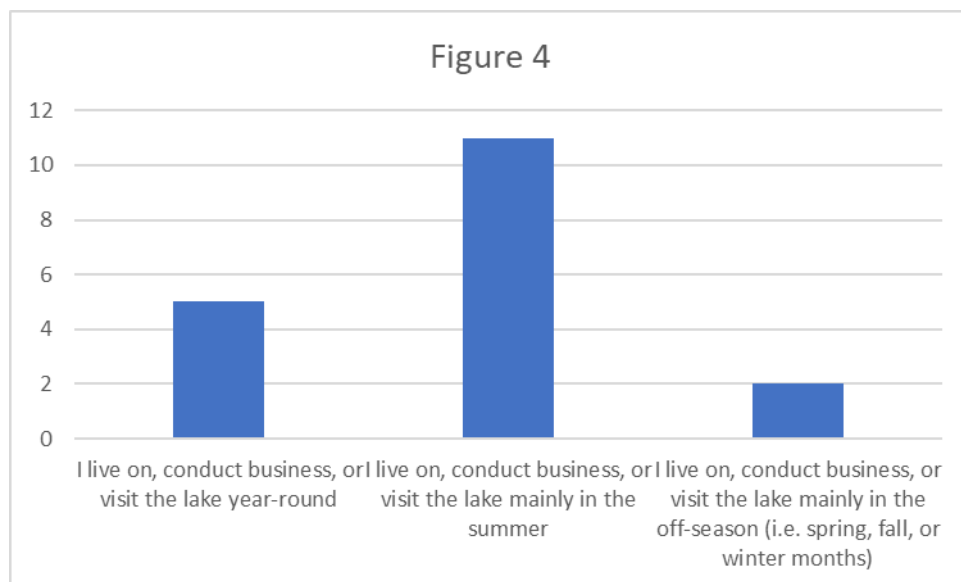
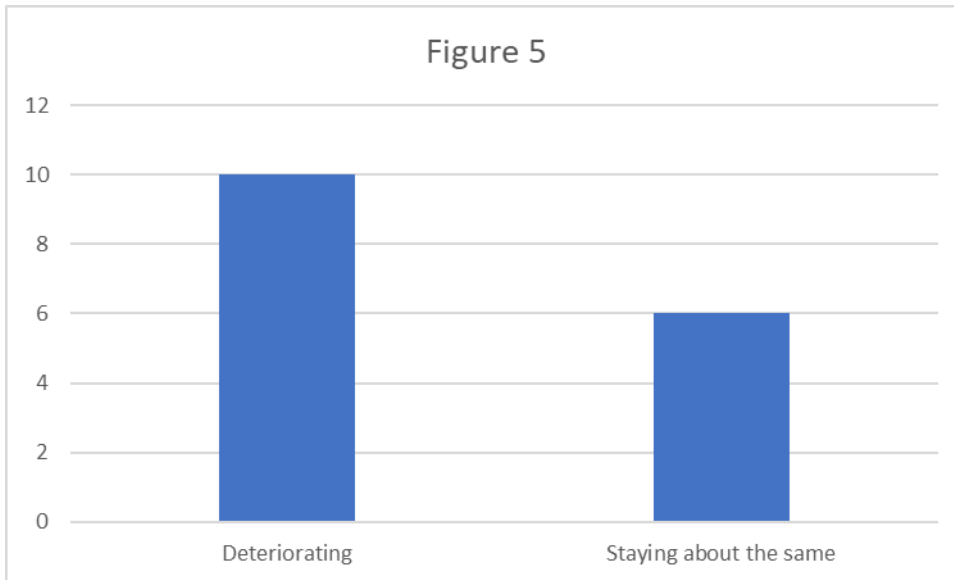


Figure 5 - In your opinion, how is water quality changing on the lake?



When asked to explain the reason for their answer the following responses were provided:

- Algae bloom, less fish
- No noticeable changes (2 responses)
- Many people at the park means limited enjoyment of the lake
- Possible blue-green algae in river between Bass and Kahshe
- The water is brown and slimy
- Excessive vegetation in the shallow lake with warmer water temps.
- I haven't noticed any significant difference in the last 20 years
- Last year water was very brown in the fall. Always cloudy and low visibility.
- More of the floating type of algae on our waterfront in July/ August and the brief appearance of possible blue green algae
- Need to rake beach water area more often than the past to remove algae

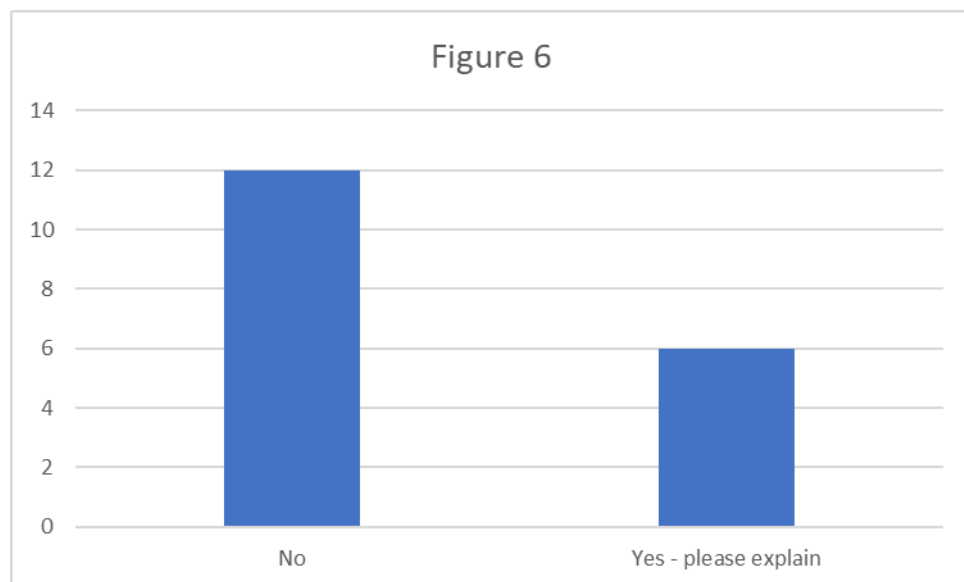
- Water clarity, algae, foaming on shores.
- More larger boat traffic churning up shallow waters, more cottages being built and older cottages have no or poor septic systems.

When asked if respondents had noticed any changes to the lake since they had been coming to following observations were made:

- Increase in Algae blooms (6 responses)
- Water clarity (less clarity) (3 responses)
- Decrease in water quality (2 responses)
- High water level in spring (2 responses)
- Increase in water vegetations (1 response)
- Low water level (1 response)
- Frosty algae clumps that do not develop into blooms (1 response)
- Garbage in the town parking lot (1 response)

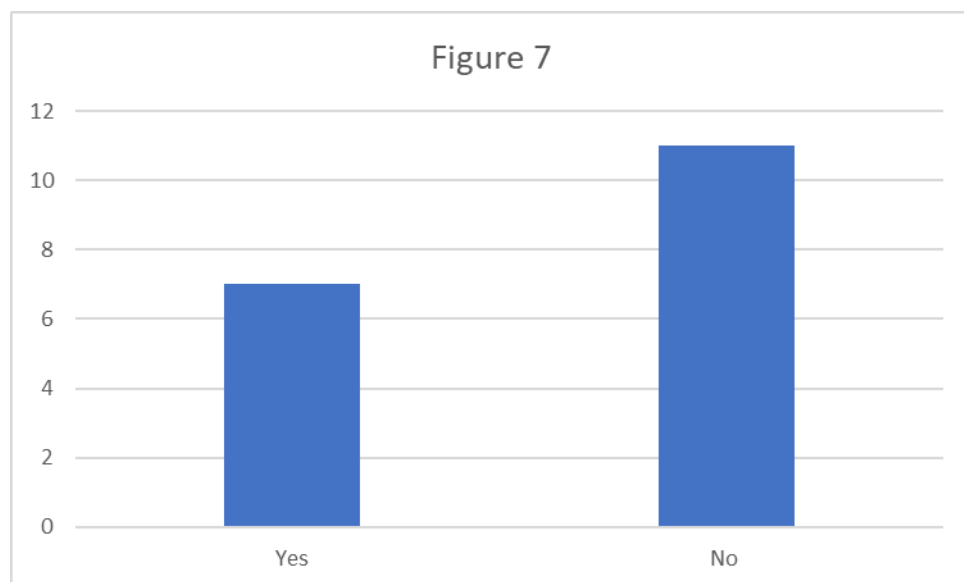
When asked if the water quality in Bass Lake had ever impacted the respondents drinking water eighteen participants indicated it had not (Figure 6).

Figure 6 - Has water quality in Bass Lake ever impacted your drinking water?



Although Bass Lake has not had any blooms confirmed by the Ministry of Environment, Conservation and Parks respondents were asked if they believed they had witnessed an unconfirmed bloom (Figure 7).

Figure 7 – Have you witnesses an unconfirmed bloom on Bass Lake?



Participants were asked to identify which bloom looked most like the bloom they had observed based on the following photos provided:

Photo 1



Photo 2

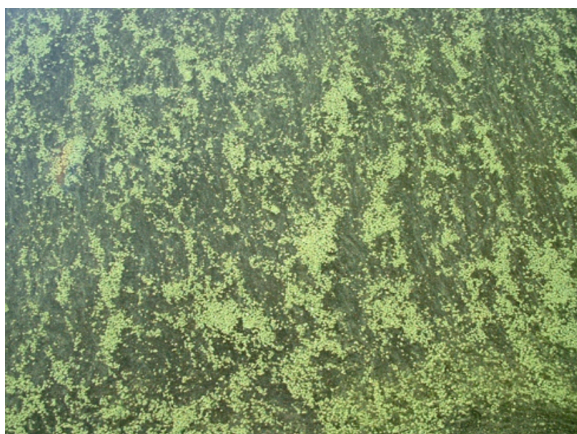


Photo 3



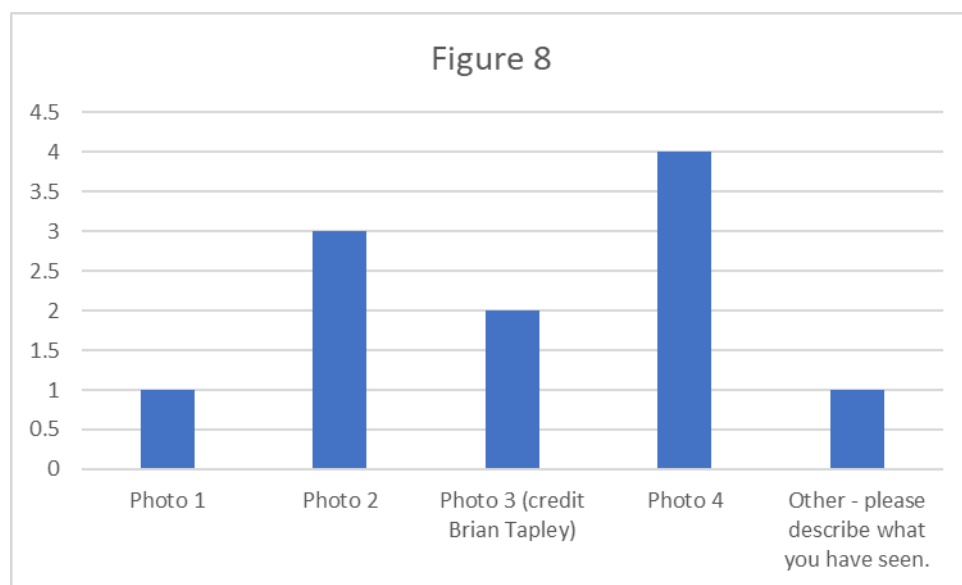
*Brian Tapley

Photo 4



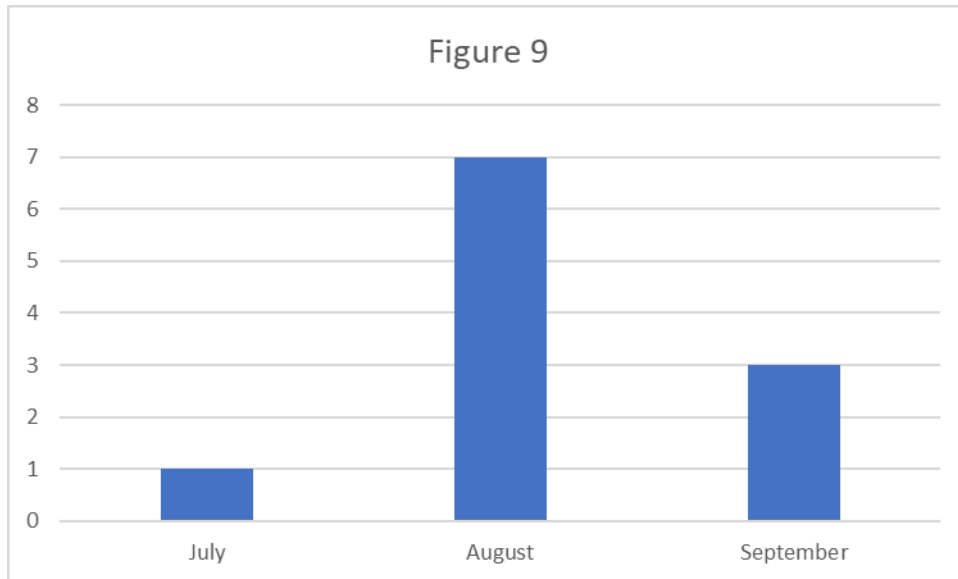
Figure 8 outlines which picture people felt best represented the bloom that they had observed.

Figure 8 - Do any of these images look like the blooms you have seen?



Most of the observations were recorded in August as outlined in Figure 9.

Figure 9 - What time of year did you observe the algal blooms?



When asked how long the blooms lasted the following observations were made:

- Less than one Week (1 response)
- One to 2 weeks (4 responses)
- Three to four weeks (1 response)

More respondents did not observe a storm event around the time of the bloom (Figure 10), while they did observe extended warm or clam periods around the time of the algae blooms (Figure 11).

Figure 10 - Did you note any storms around the time the algae bloom(s) took place?

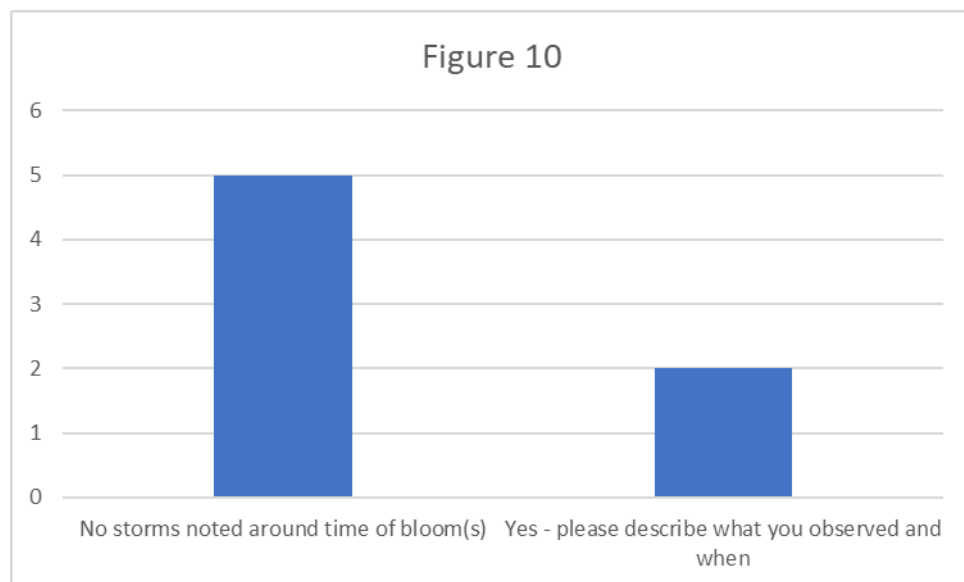
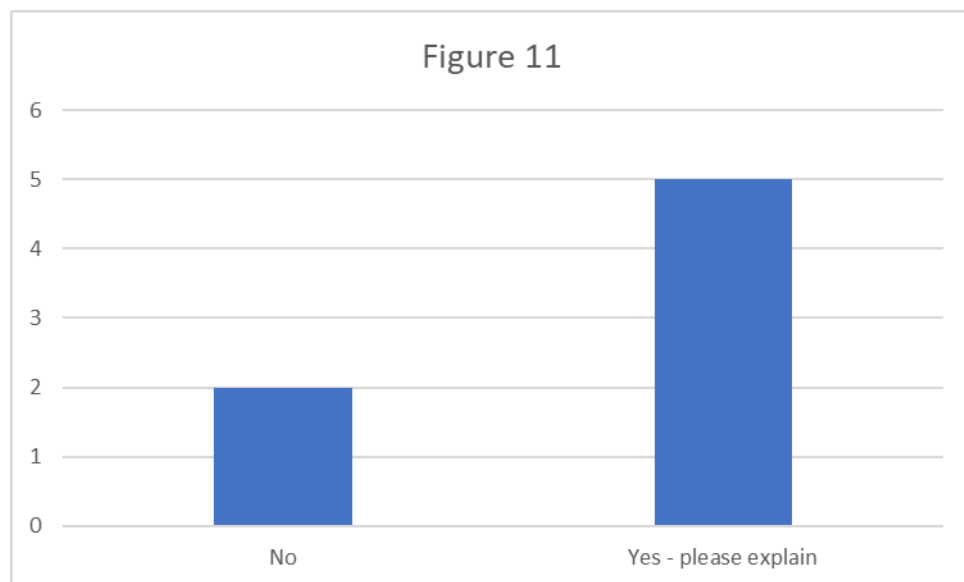
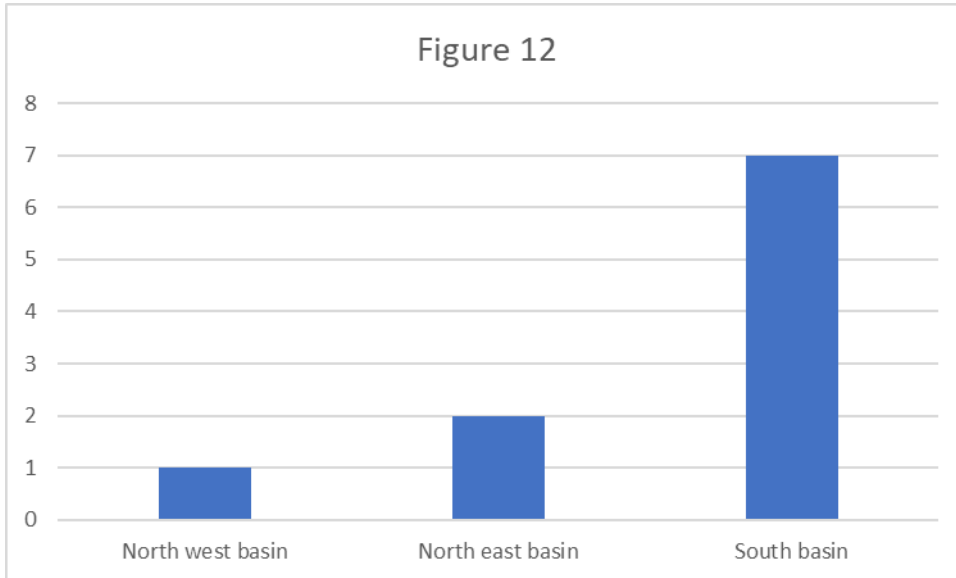


Figure 11 - Did you note any extended warm or calm (low wind) periods around the time of the algae bloom?



Blooms were observed on the following locations on the lake (Figure 13).

Figure 12 - On what part(s) of the lake have you observed the algal blooms?



A number of photos were provided to the project team from Bass Lake and will be forwarded to the technical project team.

When asked if respondents had any data of for Bass Lake relating to water quality, climate, aquatic vegetation, algae, and/or pollution they wanted to share the following was provided:

- Have always had Mussels along shoreline in shallow water. Unsure if invasive species and or contributing to issues?
- Pictures can be provided of various levels of misuse of the Bass Lake Park.
- Contact details for a respondent were provided to the consultant team.

When asked what factors respondents thought might be affecting the potential for algal blooms in Bass Lake, the following responses were received and summarised below:

- Fertilizer from farms (4 responses)
- Septic leakage (4 responses)
- Run off from properties (4 responses)

- Increase in cottage use (2 responses)
- Warning lake (2 responses)
- Climate change (2 responses)
- Low water levels (1 response)

When asked about any point sources, activities or other factors do you think might be impacting water quality on Bass Lake the following responses were received:

- Grassy properties (3 responses)
- Farms (2 responses)
- Large camp (2 responses)
- Septic (2 responses)
- Geese (1 response)
- Water temperature increase (1 response)
- Bass Lake Park (1 response)
- Power boats (1 response)
- Sandy beaches (1 response)
- New construction the lake (1 response)

Survey participants were asked what do they hope for the final recommendation of the causation study. The following provides a summary of the respondents hopes for the recommendations:

- Increase in water quality (6 responses)
- Plan to fix septic leakage (3 responses)

- Fixable solutions (2 responses)
- restrict development (1 response)
- Agricultural runoff (1 response)
- Allow water to fluctuate naturally (1 response)
- Protection of Wetlands (1 response)
- Control runoff (1 response)
- Testing at Kahshe River and Gartersnake River (1 response)

The following additional comments were received and summarized below:

- This is a small lake and vulnerable to warming temperature and environmental pollution from farms and septic tanks.
- Kahshe River used to be a logging river. There is a lot of wood in the river. Would dredging the river connecting the two lakes help?
- Not sure if related but greatly increased use of recreational watercraft such as Jet skis and wakeboard boats are taking a great toll on the waterfront areas due to very excessive wave action which is often in play for hours on end, day after day. It is common for Kahshe lake boaters to come to Bass Lake to find "calm waters", ironically to create massive wakes.

3.0 SUMMARY AND NEXT STEPS

The next step in the project will be for the technical project team to review the information presented as part of this report and the raw data gathered during the survey. The project team may follow up with information provided as part of this survey should additional information be required. The technical team continues to work on their analysis of the data and planned sampling in the lake. The final documentation for the Causation Study will include an explanation of how the results of the survey have been incorporated into the overall study.

Respectfully Submitted,



ECOVUE CONSULTING SERVICES INC.

A handwritten signature in blue ink, appearing to read "FW", is written above a horizontal line.

Frances Wilbur, MES, RPP, MCIP

Appendix B. Stakeholder Contributions.






Consultation Report

Bass Lake Causation Study

Prepared for: The District Municipality of Muskoka

EcoVue Reference No.: 21-2116

Date: February 13, 2023

A large, light-colored, stylized tree graphic is positioned on the left side of the page, extending from the bottom to the middle. It has a thick trunk and a dense, rounded canopy with many small, light-colored leaves.

311 George St. N. Suite 200
Peterborough, ON K9J 3H3

T 705.876.8340 | F 705.742.8343

www.ecovueconsulting.com



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1.0 INTRODUCTION

The District Municipality of Muskoka (“the District”), along with Hutchinson Environmental Solutions Ltd. (“HESL”) and EcoVue Consulting (“EcoVue”), referenced in this report as the “project team”, have undertaken a Causation Study (“the Study”) for Bass Lake in the District of Muskoka. The Muskoka Official Plan (MOP), as amended by Official Plan Amendment 47 (OPA 47), outlines several water quality indicators and associated required actions to be implemented when a lake is listed as vulnerable in Schedule E2. A waterbody-wide Causation Study is generally completed to determine the cause(s) and relative contributing factors to the water quality indicator(s) that led to the lake’s vulnerable status. The Study was completed in view of the status of the lake and recent history of algal blooms, EcoVue was included in the project team to provide advice on, and lead portions of the consultation process for the Study. This was particularly important for this Study given the public interest in the work, including the Kabshe Lake Association and other stakeholders, the active citizen participation in monitoring the lake, and the need to compile local knowledge regarding the lake’s condition.

The consultation process for the Causation Study is intended to improve the project in two ways:

1. Ensuring local knowledge of Bass Lake informed the scientific method and analysis that was used to develop conclusions and propose recommendations. This was to be accomplished ensuring locally collected data and observations could feed into the scientific process, where relevant, to allow for more accurate results and conclusions.
2. Ensuring all stakeholders understand the scientific process being applied, how conclusions were be drawn, and understand the implications of these results both at the onset of the project and at its conclusion.

A Consultation Plan prepared by EcoVue, dated July 2nd, 2021, was developed for the Study for Bass Lake which set out the consultation program to be undertaken in conjunction with the study¹. This report, in combination with the Study prepared by HESL, summarizes the results of the Consultation Plan, and describes the ways that stakeholder’s input was addressed and contributed to the study process.

¹ The Consultation Plan was posted on the Engage Muskoka website at the following link:
<https://www.engagemuskoka.ca/bass-lake>

It should be noted that further communications by the District will occur to describe next steps as it relates to policy implications at the District level, after the completion of the final report.

2.0 ENGAGEMENT TOUCHPOINT SUMMARY

During initial project meetings for the Study, there was a high-volume public engagement and participation of stakeholders asking questions, and sharing input, data, and theories. Therefore, it was evident that a large focus on public engagement should be prioritized throughout the Study's lifecycle to ensure everyone understood what was being completed as part of the Study. The Consultation Plan was intentionally designed with several specific engagement efforts (i.e., "touchpoints") to ensure stakeholder contributions were encouraged and welcomed throughout the study process as all comments, observations, questions, and input were reviewed and considered within the scope of the project. In addition to the Consultation Plan, the Study's Terms of Reference (ToR)² prepared by HESL, dated August 20th, 2021, provided additional details regarding public consultation that further informed and guided the Study's engagement touchpoints. The ToR was posted on the Study's Engage Muskoka page for public access. This section provides further details on the touchpoints of the project described in the Consultation Plan and ToR, and their associated results.

2.1 Engage Muskoka Website Maintenance

The Engage Muskoka website for the Bass Lake Causation Study³ has been the primary touchpoint since the project launch. This website includes a general project description, District staff contact information for providing ongoing inquiries and comments, a "project lifecycle" chart showing what stage the project is in, a newsfeed providing updates, and relevant links to applicable documents. To date, the newsfeed has included nine posts, including:

1. Announcement of request for proposal, February 18th, 2021
2. First public meeting announcement, April 1st, 2021
3. Public survey release, April 29th, 2021
4. Posting of first public meeting recording, May 5th, 2021,

² The Terms of Reference is available at the following link: www.engagemuskoka.ca/bass-lake

³ The website for the Bass Lake Causation Study is found at the following link: www.engagemuskoka.ca/bass-lake

5. Public survey results report posting, July 26th, 2021
6. Causation Study update, with frequently asked question responses, August 24th, 2022;
7. Second public meeting announcement, November 11th, 2022; and
8. Posting of the second public meeting recording, December 6th, 2022; and
9. Draft report posted on Engage Muskoka for public review, December 9th, 2022.

Stakeholders and the general public could subscribe to the Bass Lake Causation Study and be sent notifications on the Study's progression. Notifications were sent periodically throughout the study to keep subscribers informed of important dates and new information or documents. Maintenance of the Engage Muskoka page by District staff will continue over the course of the project lifecycle.

2.2 Indigenous Consultation

Indigenous consultation was undertaken by District Staff and took place through the District's Muskoka Area Indigenous Leadership Table (MAILT) on April 9th, 2021. The purpose and scope of the ongoing Causation Studies, including the one conducted for Bass Lake, was communicated to MAILT and opportunity for engagement was encouraged. It is EcoVue's understanding no additional engagement was requested or undertaken.

2.3 Stakeholder Meeting #1

The first stakeholder meeting was held on April 30th, 2021. The meeting, consisting of a PowerPoint presentation and question/answer period, was held via Zoom and was attended primarily by residents and members of the Kahshe Lake Association., although some non-residents attended stating general interest in the study. Key objectives of the meeting were to: (1) ensure stakeholders understood the scope of the study and the scientific process that would be undertaken to develop conclusions; and (2) the project obtain local information or comments from stakeholders. A recording of the meeting was made available on the Engage Muskoka website⁴ on May 5th, 2021 for those who were unable to attend. All comments, questions, and associated responses were recorded and are included in the

⁴ The first public stakeholder meeting recording is available at the following link: [Bass Lake Causation Study - April 30, 2021 Public Meeting Recording - YouTube](https://youtu.be/AdsGbfgL0Kw) or <https://youtu.be/AdsGbfgL0Kw>

general comment and response table in an Appendix of the final Bass Lake Causation Study report ("final report").

2.4 Survey

Subsequent to the first stakeholders meeting, a survey was made available to those who attended and the greater public through the Engage Muskoka website. Eighteen (18) respondents completed the survey with the majority identifying themselves as recreational users on the lake. A summary of the results was posted to the Engage Muskoka Website on July 26th, 2021⁵ and is available there for reference. The survey data was provided to HESL to use in their analysis and corroborate conclusions found in the overall analysis, where applicable.

2.5 Ongoing Stakeholder Feedback

The District contact for the project was provided on the Engage Muskoka throughout the study term. All correspondences, studies, and data available on the project was forwarded to HESL throughout the study. This information was reviewed by HESL and was used to scope the research questions and analysis undertaken on the lake. It is provided in an Appendix of the final Study Report and indicates how this information was used.

2.6 Stakeholder Meeting #2

The second stakeholder meeting was held on November 29, 2022. The meeting, which included a PowerPoint presentation and question/answer period, was held via Zoom and attended by stakeholders and the project team. Key objectives of the meeting were to ensure the stakeholders understood the research conducted, the draft results, and the associated conclusions. A recording of the video was posted on the Engage Muskoka website on December 06, 2022⁶. All comments, questions, and associated responses were recorded and are included in the general comment and response table in an Appendix of the final Bass Lake Causation Study report.

⁵ The survey results summary is available at the following link: <https://www.engagemuskoka.ca/bass-lake>

⁶ The video recording of the Second stakeholder meeting is available at the following link: [Bass Lake Causation Study - November 29, 2022 Public Meeting Recording - Youtube](#)

3.0 ADDITIONAL CONSULTATION – COMMENTING PERIOD

Though not originally anticipated in the Consultation Plan, District staff requested an additional touchpoint with stakeholders to ensure comments and questions were appropriately considered and responded to in the final report. Specifically, a commenting period on the draft Causation Study report was added to the project scope for this purpose.

To this end, the draft report was released on the Engage Muskoka website on December 9th, 2022 for public comment. The report was up for public comment until January 13, 2023. Comments provided at the stakeholder meetings as well as the comments submitted in writing during the commenting period were reviewed and considered. Stakeholder comments and feedback, as well as the project team's responses, are located within an Appendix in the final report.

4.0 SUMMARY

The importance of stakeholder engagement in providing information for the completion of the Bass Lake Causation Study and for the protection of the health of Bass Lake cannot be understated. A robust consultation plan was prepared in support of the Study efforts. In addition to efforts to keep stakeholders up to date, two public meetings and a survey were undertaken to compile comments and address issues of concern. Furthermore, comments were welcomed throughout the project timeline. The draft final report of the Study was posted to the Engage Muskoka website where stakeholders and the general public were able to access the online draft and provide any questions or comments to the project team. This commenting period was extended in order to provide more time for stakeholders and the general public to thoroughly read through the document to digest the report and compile any questions or comments. Public comment and questions were then addressed within the final Study report.

All comments and data received throughout the consultation program were distributed to, and considered by, the project team. Many of the comments informed the study design and conclusions or, at minimum, were used to corroborate the results of the study. Furthermore, comments and questions posed during the Stakeholder Meetings and within the commenting period are summarized and responded to in the final report.



We trust this report adequately summarized the consultation that has occurred on the project. Thank you for the opportunity to assist with this scientific effort.

Respectfully Submitted,

ECOVUE CONSULTING SERVICES INC.

A handwritten signature in blue ink, appearing to read "B. Saunders", is written over a light blue horizontal line.

B. Saunders, B.Sc., M.Sc.
Planning Supervisor



Appendix C. Public Meeting Presentations





Hutchinson

Environmental Sciences Ltd.

Causation Study for Bass Lake

Stakeholder Meeting #1 – Project Introduction

April 30th, 2021



Project Team

- ▶ Hutchinson Environmental Sciences Ltd. (HESL)
- ▶ EcoVue Consulting
- ▶ District of Muskoka staff
- ▶ Stakeholders



Project Roles

- ▶ District staff – First point of contact for stakeholders
- ▶ EcoVue – Consultation
- ▶ HESL – Technical expertise



House Keeping

- ▶ Chat function will be monitored throughout the presentation – *please feel free to post questions there.*
- ▶ Participants will be muted throughout the presentation, please raise your hand if you have a question.
- ▶ A Q and A section will follow the presentation where people will be unmuted.

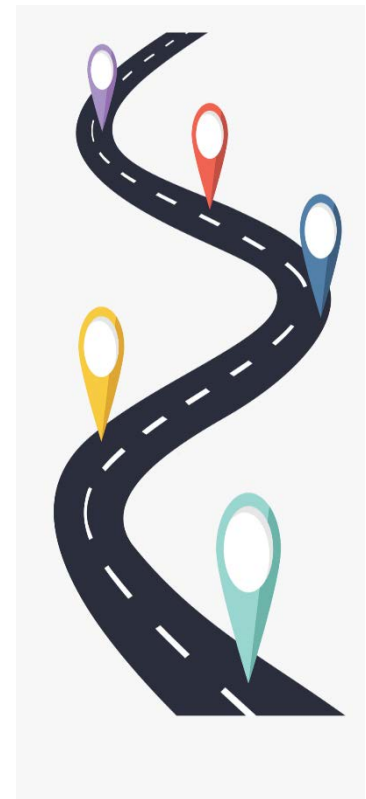
Poll

Please tell us which best describes you:

- ▶ Year round resident on Bass Lake
- ▶ Seasonal resident on Bass Lake
- ▶ Owner of a business located on Bass Lake
- ▶ I don't live/work on Bass Lake but I'm interested in this study

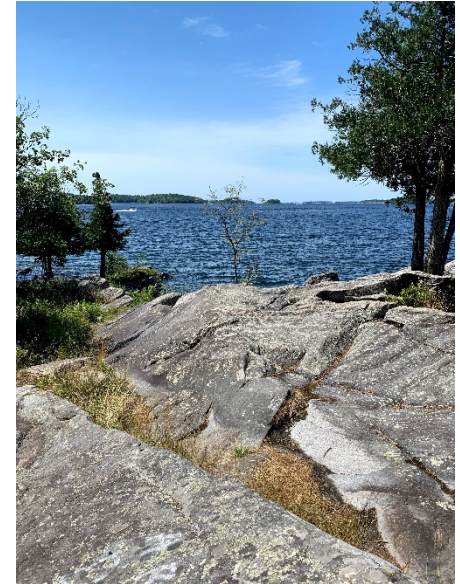
Today's Roadmap

- ▶ Presentation from both EcoVue and Hutchinson
 - Background on causation studies
 - Bass Lake study
 - Next steps
- ▶ Question and Answer
- ▶ We want to hear from you!



What is a Causation Study?

- ▶ Determine causes of a lake's vulnerability
- ▶ May be more than one contributing cause – relative factors
- ▶ Each lake is different, but a watershed perspective is also important
- ▶ The concurrent studies may lead to broader conclusions and recommendations that could be applied watershed-wide
- ▶ Informs future policy and program changes



Causation Study Process

1. Assess the existing water quality conditions
2. Look at historical water quality and/or algal abundances
3. Model and quantify the sources of nutrients
4. Determining if water quality is deteriorating and/or algal composition/communities are changing
5. Attributing a specific cause(s) or contributing factors to the water quality indicator



What is a vulnerable lake?

- ▶ Lakes are identified as vulnerable for water quality based one or more of three criteria:
 1. High long-term phosphorus levels
 2. Increasing phosphorus levels
 3. Confirmed blue-green algae bloom
- ▶ Why are these important factors?
- ▶ Vulnerable lakes are eligible for causation studies



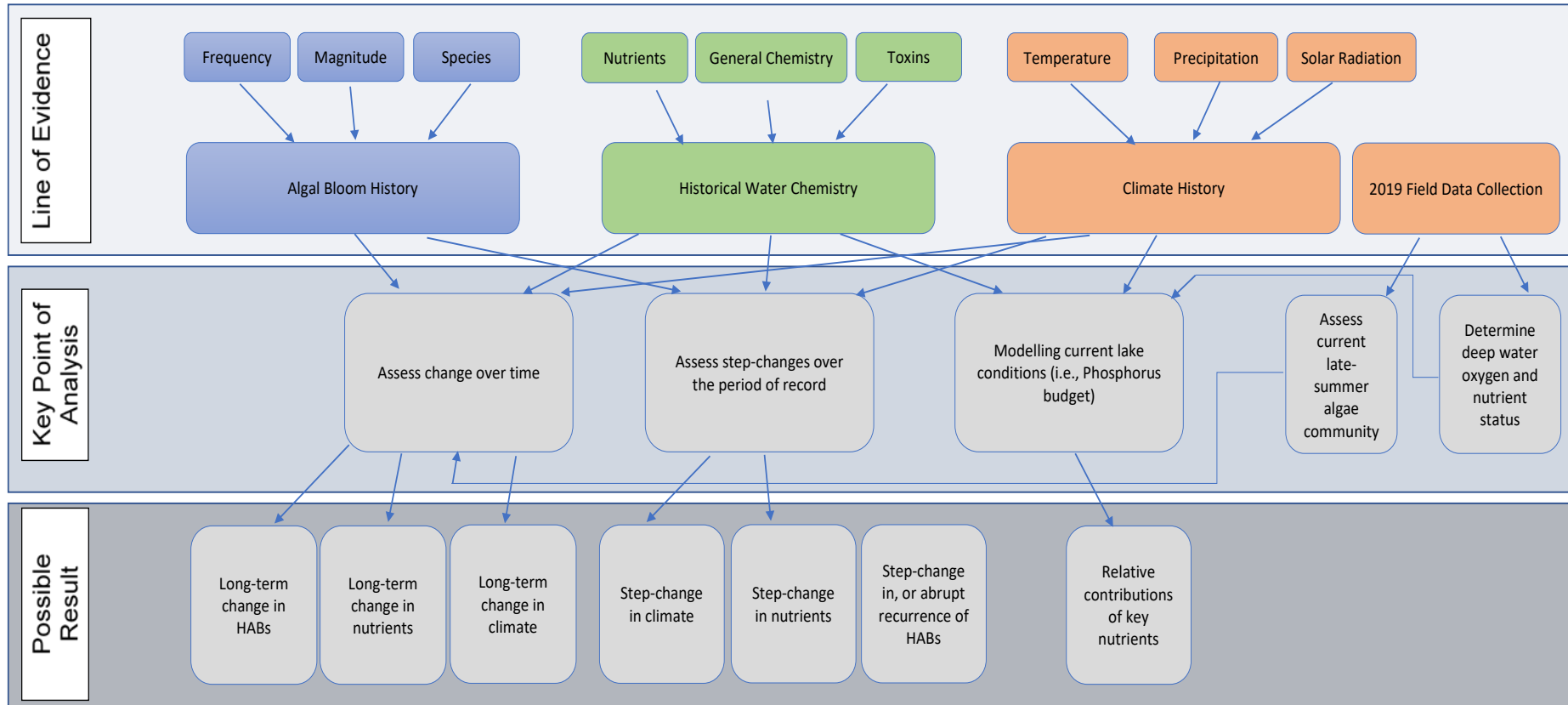
Previous Causation Study

- ▶ A pilot causation study for Peninsula Lake in 2020.
- ▶ HESL developed a Causation Study Framework using a **weight of evidence approach**
- ▶ Focused on estimating the relative importance of ecology, climate and development on the proliferation of cyanobacteria blooms



HESL

Weight of Evidence Approach



Additionally the Causation Study on Bass Lake will look at:

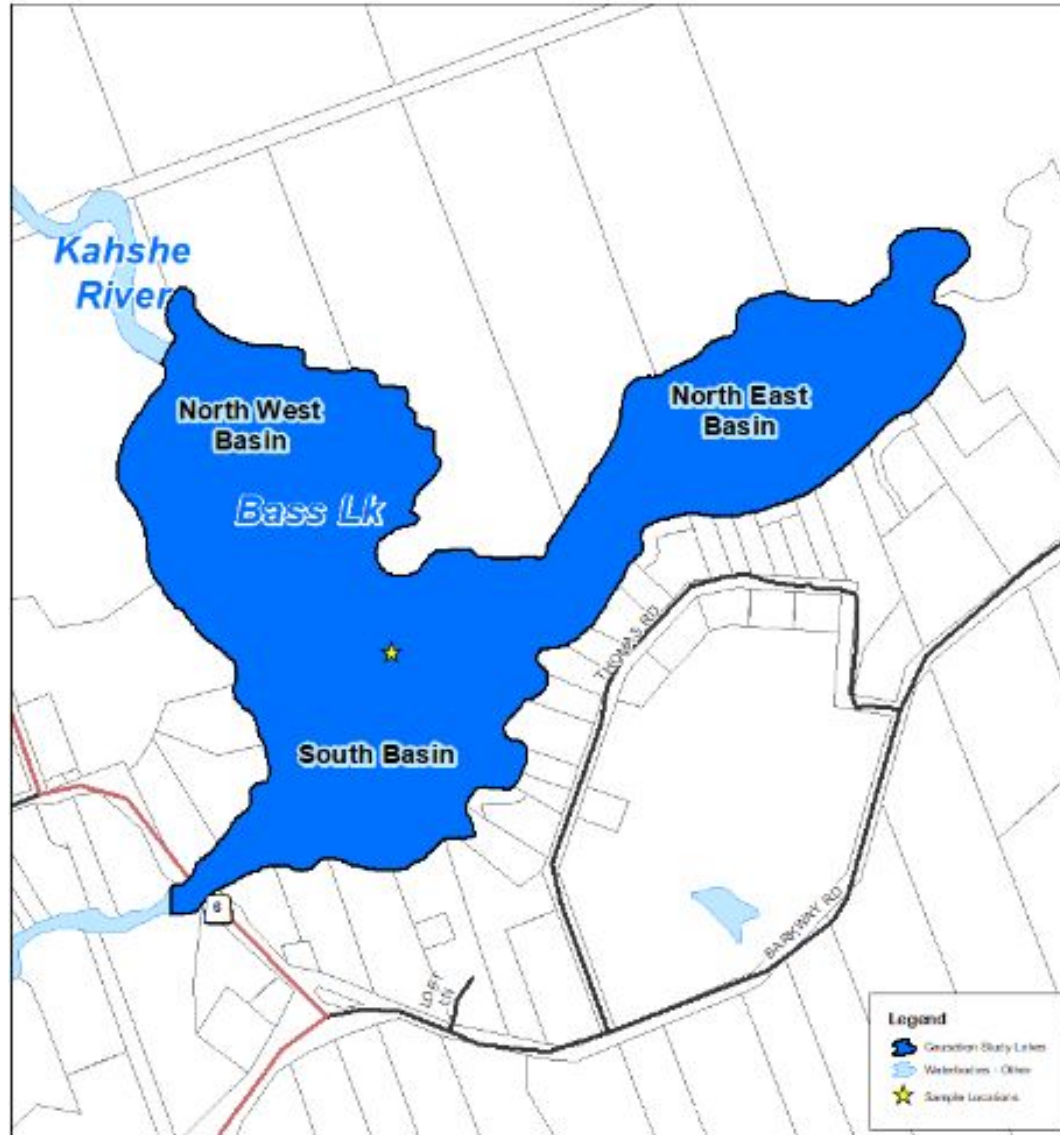
- ▶ Review of existing water quality monitoring data
- ▶ Additional water quality sampling and data collection
- ▶ The need for future targeted sampling or other activities (e.g. septic inspection)
- ▶ **All contributions from stakeholders**



Bass Lake

- ▶ Long-term average phosphorus concentration was 26 $\mu\text{g/L}$
- ▶ Five-year mean exceeds 20 $\mu\text{g/L}$
 - TP concentrations triggered Causation Study
- ▶ 2019 Shoreline Assessment
 - ~25% of the shoreline had been altered based on 32 shoreline areas classified
- ▶ Receives input from Fawn, Doe, and Buck Lakes to the North basin
- ▶ 2019 data showed low dissolved oxygen concentrations in August ($<1 \text{ mg/L}$)

Bass Lake



Possible Causes of High P Levels

- ▶ Internal loading from sediments
- ▶ Overland run-off from the catchment
- ▶ Inputs from upstream waterbodies
- ▶ Inputs from development (e.g., septics)
- ▶ Naturally occurring due to geology and geography of the area

What can you expect from this Causation Study?

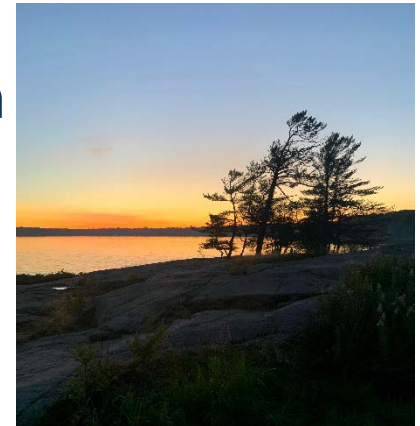
- ▶ A review of all available scientific data
- ▶ Defensible conclusions and recommendations
- ▶ Change is future forward – we all have a role
- ▶ What a causation study is not:
 - An original research project
 - A site by site review of development on the lake
 - All encompassing, may be unanswered questions that require further work



HESL

What can you expect from this Causation Study?

- ▶ Conclusions of the study will be both micro and macro level – specific to Bass Lake or for the entire watershed
- ▶ The project team's conclusions may include:
 - Actionable recommendations for each citizen
 - Actionable recommendations for the District
 - Actionable recommendations for the wider community

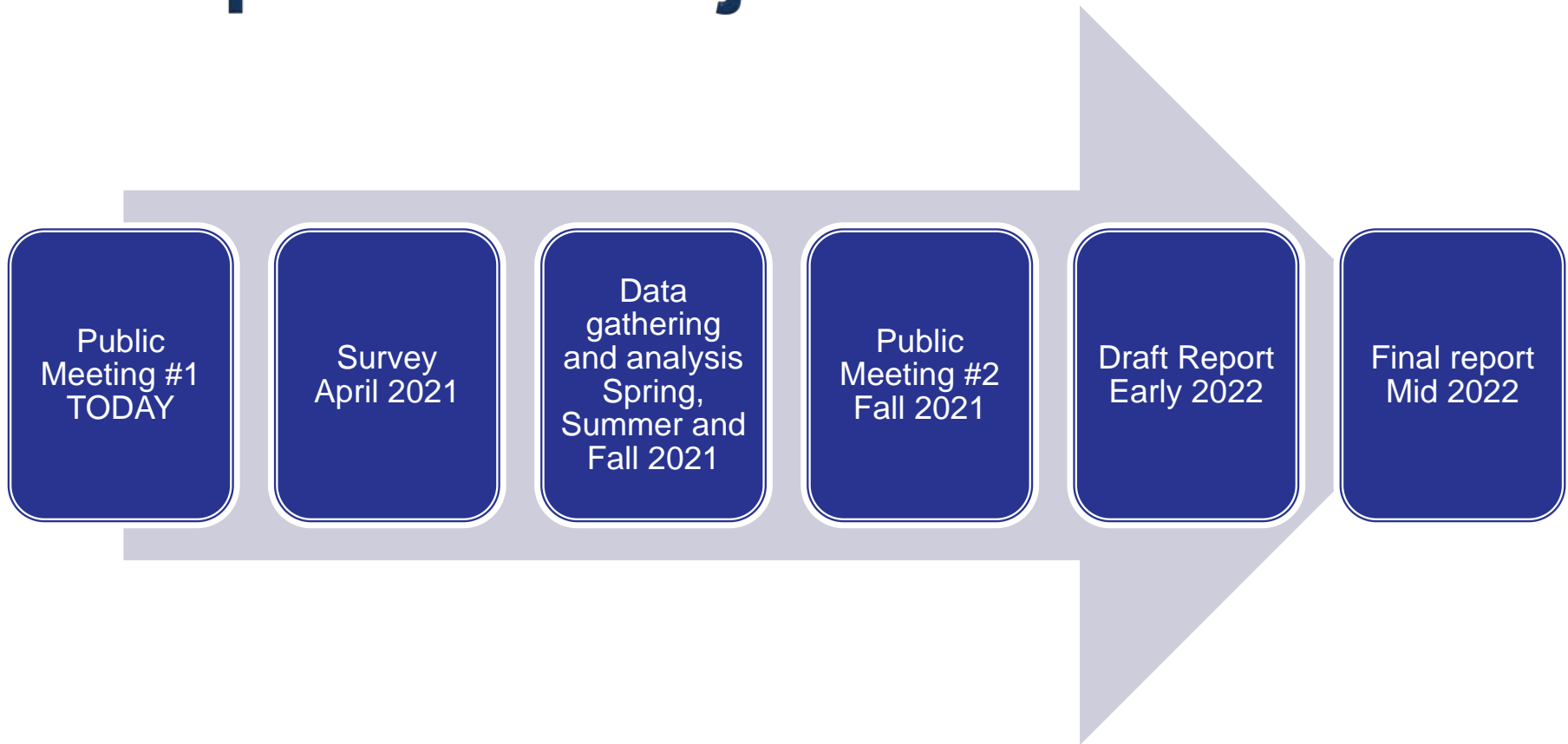


HESL

Progress to Date

- ▶ RFP issued and awarded
- ▶ Start-up meeting – consultants and District
 - Plan the project and confirm roles
 - Plan the consultation process
- ▶ Receive data and information
- ▶ Identify past studies and existing data
- ▶ Identify initial gaps in data

Proposed Project Timeline



How can you help?

- ▶ We need local knowledge of your lake
- ▶ The Terms of Reference for the project will incorporate your feedback
- ▶ Specifically we will be looking for:
 - Any data you have on historical weather patterns
 - Water quality sampling data or lake specific studies
 - Information on point sources of nutrients
 - Historical observations on water quality changes
 - Observations on weather patterns
 - Lake plan
 - Photos



HESL

What is the best way to share my data?

- ▶ Survey launched yesterday
- ▶ Contact the District to submit data
- ▶ Continue to monitor this summer, send data and observations to the District
- ▶ Visit Engage Muskoka and subscribe for project updates



HESL

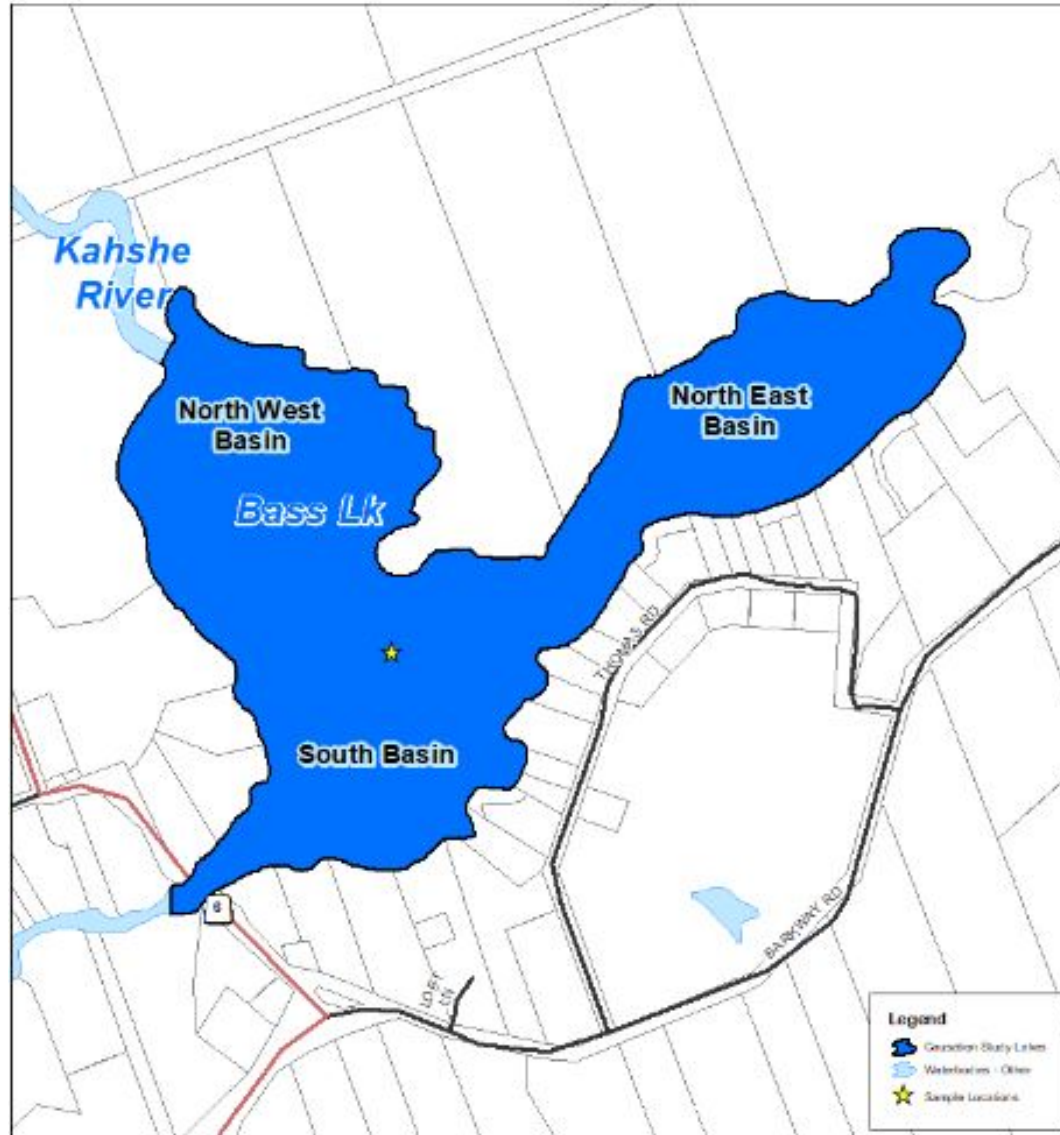
How to stay in touch

- ▶ Engage Muskoka – www.engagemuskoka.ca
 - Click on “Protecting Muskoka’s Vulnerable Lakes: Causation Studies” Project
 - Scroll down and click on Bass Lake to access the Causation Study page
- ▶ Jacquie Evans, Project Coordinator at District of Muskoka
jacquie.evans@muskoka.on.ca



HESL

Bass Lake





Hutchinson

Environmental Sciences Ltd.



Bass Lake Causation Study

Stakeholder Meeting

November 29, 2022

Kris Hadley (Hutchinson Environmental Sciences Ltd.) and
Beverly Saunders (EcoVue Consulting Ltd.)
In collaboration with the District Municipality of Muskoka

Project Team

- ▶ Hutchinson Environmental Sciences Ltd. (HESL)
- ▶ EcoVue Consulting
- ▶ District of Muskoka staff
- ▶ Stakeholders



House Keeping

- ▶ Chat function will be monitored throughout the presentation – *please feel free to post questions there.*
- ▶ Participants will be muted throughout the presentation, please raise your hand if you have a question.
- ▶ Question and answer section will follow the presentation where people will be unmuted.

Today's Roadmap

- ▶ Presentation by Hutchinson and EcoVue
 - Progress to date
 - Causation Study results (primary focus)
 - Explanation of next steps
- ▶ Question and Answer Period
 - We want to answer any questions or concerns you have

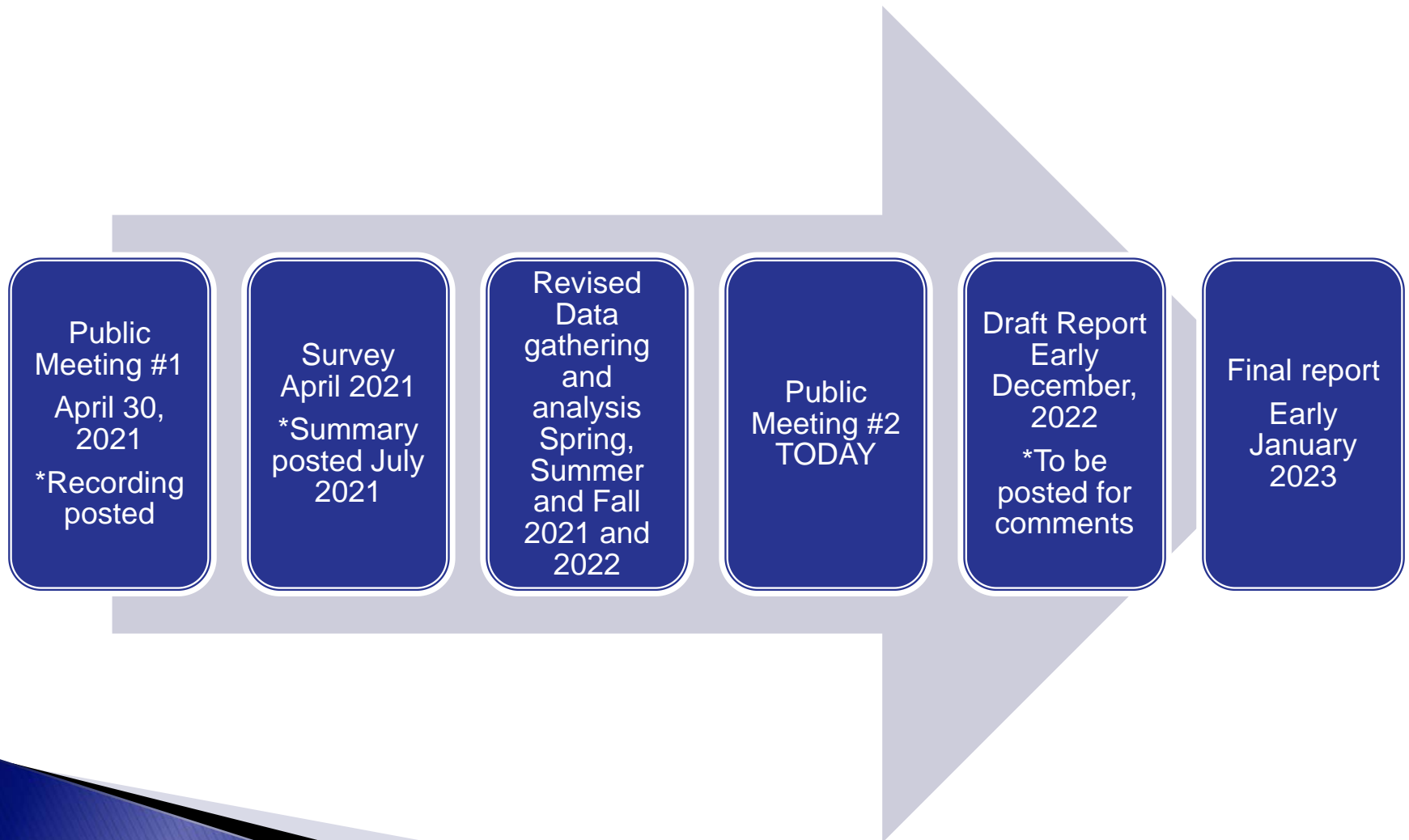
Progress to Date

- ▶ Start-up meeting – consultants and District
 - Plan the project and consultation process
- ▶ Receipt of data and information
 - Identified past studies and existing data
 - Identified initial gaps in data
- ▶ Hosted first stakeholder meeting on April 30, 2021
 - Posted on Engage Muskoka for reference.

Progress to Date (continued)

- ▶ Survey launch in April 2021
 - Survey results compiled and posted July 2021
- ▶ Data collection and fieldwork in 2021 and 2022
- ▶ Completion of draft Bass Lake Causation Study in November 2022
- ▶ Second Stakeholder Meeting (today)
 - Presentation of Causation Study results
 - Discussion of results with stakeholders

Project Timelines (Revised)



Consultation Touch Points – How Your Input Was Used

1. Initial stakeholder meeting feedback

- Identified data sources and potential research question (e.g., episode of “rust” colored water and discussion of comparison to other lakes)

2. Past and Ongoing correspondences and background sent to District Staff, including past studies, inquiries, and datasets

- All correspondences were forward and reviewed
- Used and referenced throughout the research

3. Public Survey

- Used to corroborate background information provided, including review of photos submitted

Bass Lake Causation Study Results

Kris Hadley (Hutchinson Environmental Sciences Ltd.)

Background

- ▶ Goal was to develop an evidence-based, defensible approach to determine the cause(s) and contributing factors that are impacting total phosphorus concentrations in Bass Lake



Scope of the Study

- ▶ Compile and review existing information
 - Historical data review
 - Stakeholder engagement
 - Initial Stakeholder meeting
 - Stakeholder survey
- ▶ Field program
 - Water quality sampling (spring and late–fall 2021)
- ▶ Assessing the Phosphorus budget of the lake
- ▶ Determine what, if any, additional information may be required

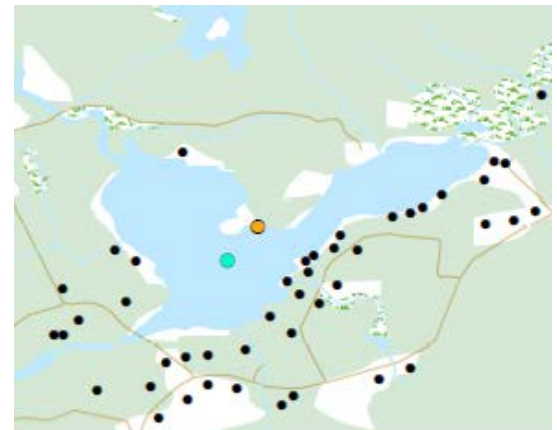
Field Program

- ▶ Goal:
 - Establish oxygen status of the deep water and determine if internal loading is a factor in Bass Lake
 - Collect data on incoming nutrients from the main watercourses
- ▶ Water Quality Sampling
 - Sampling Locations
 - 1 sampling locations on Bass Lake, deep spot
 - Gartnersnake Creek and Kahshe River
- ▶ Sampling was targeted for spring high flow and the end of the stratified season
 - May 23rd, 2021 and October 12th, 2021

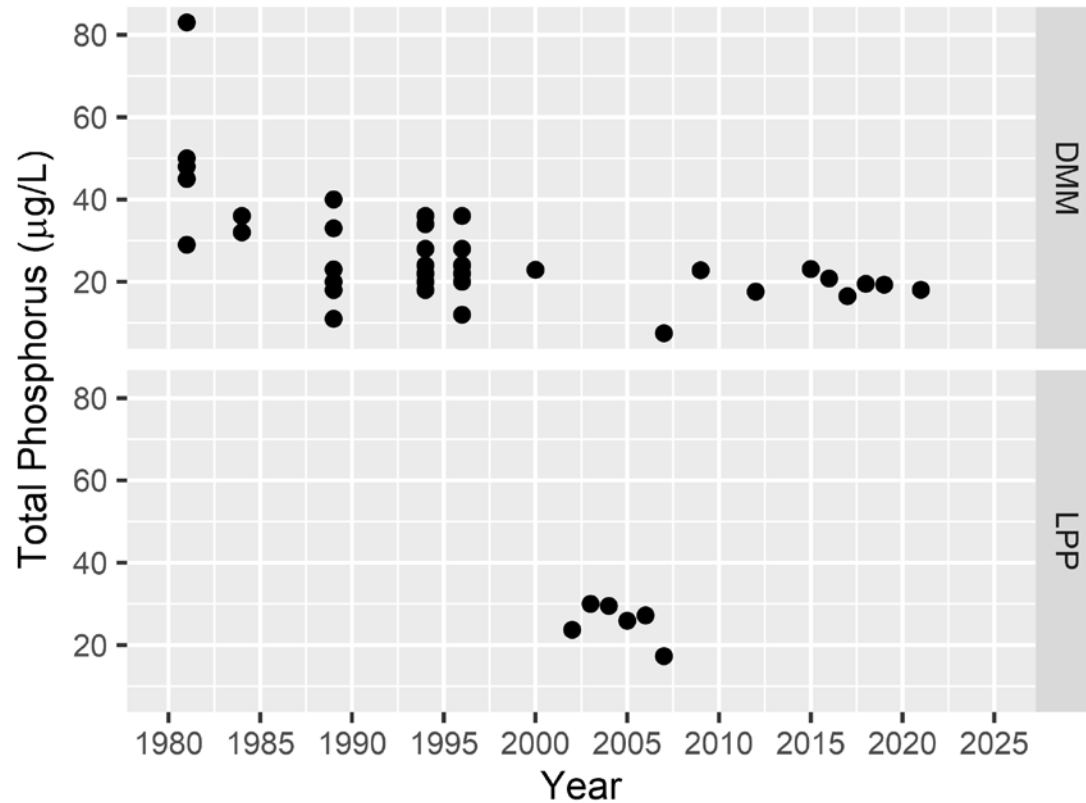


Monitoring Plan

- ▶ Water Quality Parameters
 - Field measurements of pH, conductivity, temperature and dissolved oxygen
 - General chemistry, nutrients and metals
 - Phosphorus and iron from bottom waters if dissolved oxygen is low

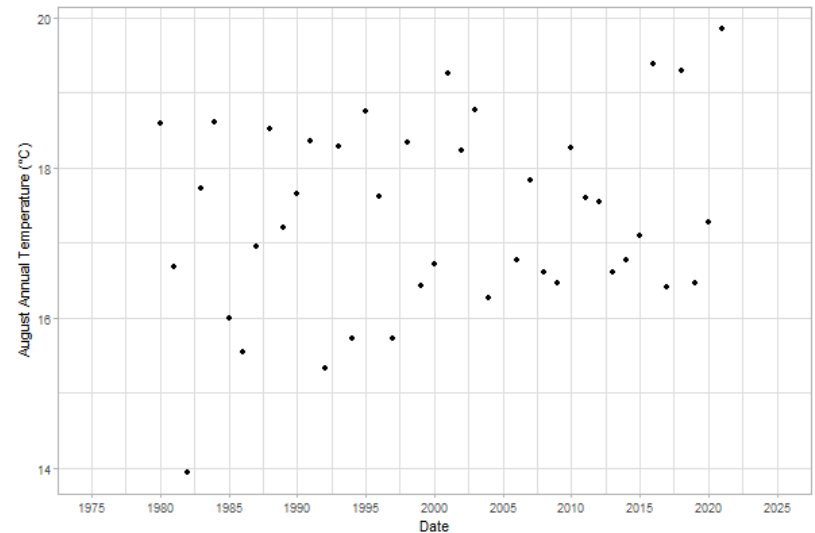
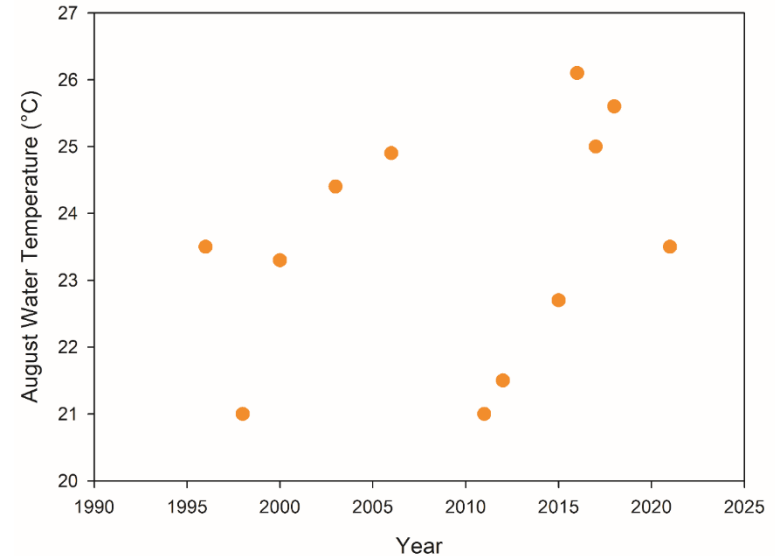


Long-term Total Phosphorus

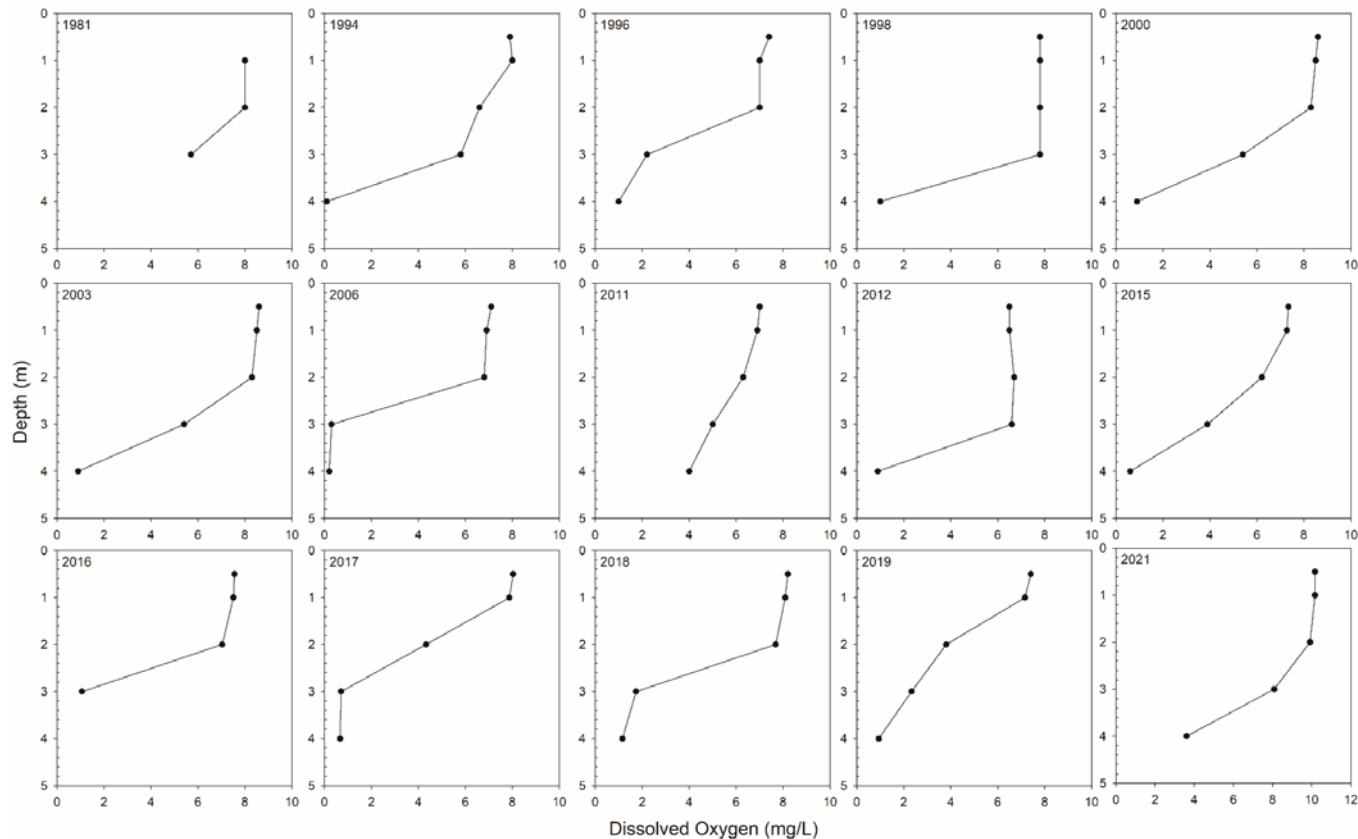


Water and Air Temperature

- ▶ Warm water suggests a more stable water column
- ▶ Gradual but insignificant increase in air temperature over the period of record, with substantial annual variation



Dissolved Oxygen Profiles



- ▶ Historical records showed that dissolved oxygen concentrations fell below 2.0 mg/L consistently (12 of 15 years on record).

Phosphorus budget

- ▶ Monitoring data show no recent changes factors contributing to internal loading
- ▶ A phosphorus budget for Bass Lake was reviewed to determine the relative contributions of other sources to the P to the lake and to assess how/if those have changed in response to development
- ▶ Overland runoff contributed an estimated <0.2% of the total phosphorus load to Bass Lake

Source	Revised Lot Count	Percent	Lot Count (2018) Developed/ Vacant	Old Lot Count	Percent	Lot Count (1997) Developed/ Vacant
	kg/yr			kg/yr		
Natural (Watershed and Precipitation)	1197.57	96.68		1197.57	97.09	
Upstream Sources	884.47			884.47		
Overland Runoff – Cottage	1.02	0.08	30/11	0.71	0.06	21/13
Overland Runoff – Other	0.44	0.04		0.44	0.04	
Septic Systems	16.24	1.31		11.37	0.92	
Upstream Developed	23.38	1.89		23.38	1.90	
Total	1238.65	100.0		1233.47	100.0	

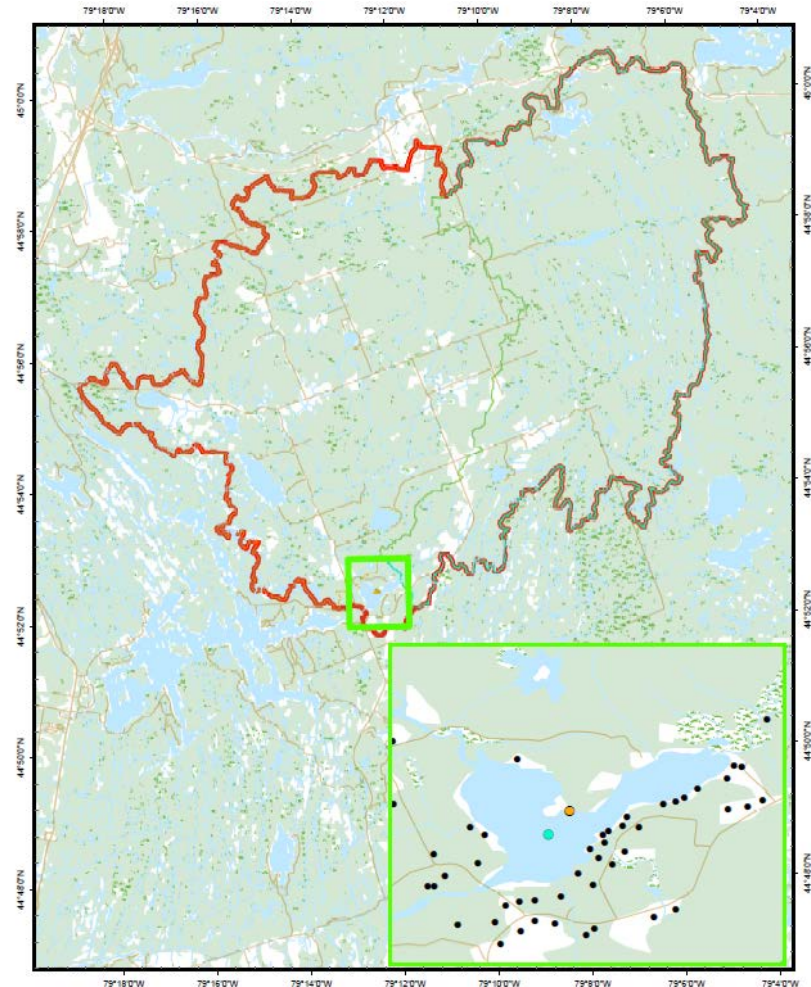


Watershed sources

- ▶ No evidence of elevated phosphorus concentrations in the incoming watercourses was noted during spring sampling



	Units	Kahshe River at Cooks Road	Gartersnake Creek
Physical Parameters			
Total Suspended Solids	mg/L	<3.0	<3.0
Anions and Nutrients			
Alkalinity	mg/L	<10	6.1
Total Ammonia as N	mg/L	<0.010	0.010
Total Kjeldahl Nitrogen	mg/L	0.410	0.380
Total Phosphorus	μg/L	14.5	13.4
Chlorophyll a	mg/L	3.61	2.32



Summary of the Science

- We observed elevated air temperature at the Beatrice Meteorological Station in post-2015 data and a general increase since the 1980s, while long-term regional monitoring by the MECP shows reduced wind speed in the Muskoka area.
- Periods of sustained low wind speed and high air temperature lead to increased water column stability and reduced mixing; these factors can promote internal loading of phosphorus. Long-term data on potential anoxia showed low deep-water oxygen (<2.0 mg/L) in 12 of 15 years, indicating that there is the potential for an internal load of phosphorus from sediments, but data did not suggest anoxia has increased over time.
- The potential for overland runoff is increased in more severe rainfall events, such as is predicted for a changing climate. However, overland runoff from waterfront properties does not represent a significant contribution to the phosphorus budget of Bass Lake.
- We did not document any significant long-term changes in total phosphorus concentrations in the lake over time, nor any abnormalities in recent monitoring that could explain the elevated nutrients that triggered the Causation Study. Total phosphorus concentrations have been relatively elevated over the entirety of the historical dataset.

Conclusions

- ▶ Elevated nutrient concentrations in Bass Lake may be the result of:
 - the natural influence of
 - A large watershed to lake ratio
 - nutrient loading to a drainage lake (i.e., a lake with inflowing streams and rivers) increases with as the ratio of the watershed area to the lake area increases
 - Prolonged periods of hypolimnetic anoxia and internal phosphorus loading
 - Data in Bass Lake do not indicate an increase in the frequency of the occurrence of anoxia during the monitoring record
 - Influence of catchment wetlands and lake hydrology (i.e., a significant contribution of phosphorus from upstream sources);
 - Dissolved organic carbon (DOC) concentrations measured by HESL in 2021 suggest that the wetland is a key source of DOC (and likely phosphorus) to the lake and this influence is seasonal and occurs outside the typical monitoring period.
 - Shallow depth of Bass Lake
 - Shallow lakes are susceptible to a variety of mechanisms that support internal loading of phosphorus where phosphorus is recycled from sediments such as wave and wind induced suspension of phosphorus-laden sediment and decomposition of organic matter
 - shoreline development that occurred prior to the monitoring period of record (and thus no trends are detectable in the available dataset).

Gap Analysis and Recommendations

- ▶ Stream and river sampling is generally underrepresented in the watershed
 - Our field sampling of incoming water courses represents only a single point in time and information on incoming phosphorus from these watercourses could be improved with expanded sampling
 - Targeted storm sampling, to better understand the impact of runoff events and flushing of nutrients and DOC from wetlands following significant precipitation events
- ▶ Currently, no septic system data is available from Bass Lake, while survey results from stakeholders have suggested that septic leakage and grey water leakage are a concern on the lake
 - Alternatively targeted nearshore sampling in areas of concern could identify potential septic issues without the need for a lake-wide survey and may identify manageable sources of phosphorus.
- ▶ Phosphorus concentrations prior to development are unknown
 - Paleolimnological analysis (using algae preserved in sediments to reconstruct phosphorus concentrations over time) may be a valuable tool in determining if the nutrient concentrations in Bass Lake have change over the past 100–150 years.

Recommendations

- ▶ **Algae blooms are not currently an identified problem on Bass Lake**
 - Anecdotal observations (uncovered via our resident survey) suggest that blooms may have been an issue on Bass Lake in the past

Recommendation:

- **Develop a watershed-wide, citizen science-based bloom watch program to collect and archive detailed data on cyanobacteria (and other nuisance algae) blooms.**



Next Steps (what now)?

- ▶ Finalize the draft report based on stakeholder feedback at this meeting and follow up discussions
 - Report to be posted for your comment within one week of this meeting
- ▶ Prepare and present final report, with a response to comments received
 - To be posted for your review (target date January 9th)
- ▶ Presentation to Community Planning Committee (and potentially council)
 - Any council presentation to be recorded and posted



Bass Lake Causation Study Results Discussion and Question Period

Questions? Concerns? Let's discuss.

How to Stay Informed

- ▶ Engage Muskoka
www.engagemuskoka.ca/stewart-lake-causation-study
- ▶ Cassie Emms, Planner at District of Muskoka
cassie.emms@muskoka.on.ca

Thank you

Appendix D. Water Quality Summary Statistics



Parameter	25%	50%	75%	Max	Mean	Min	n
Alkalinity	5	6.5	6.81	9.24	6.248889	3.21	9
Alkalinity; Total Fixed Endpt	7.095	8.15	8.46	9.41	7.48875	3.7	8
Aluminum	101	110	124	204	119.6111	80.5	9
Ammonium Nitrate	24	28	34.5	56	30	14	8
Anions	0.2275	0.245	0.26	0.28	0.215	0	8
Antimony	0	0	0	0.5	0.071429	0	7
Arsenic	0.2	0.2	0.2	1	0.285714	0	7
Barium	11.6	11.6	12.2	16	12.13333	11	9
Beryllium	0	0	0.01	0.5	0.058889	0	9
Boron	4	4	4	10	4.285714	0	7
Cadmium	0	0	0.38	0.9	0.197778	0	9
Calcium	2.295	2.41	2.77	2.84	2.47	2	8
Cations	0.2625	0.285	0.3	0.31	0.24875	0	8
Chloride	2	2.3	2.43	2.71	2.266667	1.94	9
Chromium	0.23	0.3	0.4	5	0.836667	0	9
Cobalt	0.1	0.2	0.2	1.67	0.26	-1.13	9
Conductivity	28.2	31	32.9	34.4	30.43333	23.6	9
Conductivity Estimated	27.55	30.7	31.5	32.5	29.52857	25.4	7
Copper	0.5	0.6	1.01	7.47	1.842222	0	9
Dissolved Inorganic Carbon	1.835	2.03	2.105	2.24	1.956667	1.54	6
Dissolved Organic Carbon	7	7.2	7.9	8.7	7.444444	6.7	9
Ion Balance Calculation	14	17	22	29	17.15714	2.1	7
Iron	400	469	520	554	454.7778	310	9
Langeliers Index Calculation	-3	-3	-2.5	-1	-2.6	-3.2	7
Lead	0.1	0.2	0.5	11.3	2.217778	0	9
Magnesium	0.7175	0.765	0.7925	1	0.76	0.57	8
Manganese	30	37.5	40.2	46.3	34.91111	20.9	9
Molybdenum	0	0	0.1	1.1	-0.02	-1.98	9
Nickel	0.4	0.4	0.78	2.86	0.837778	0	9
Nitrate	9	20	26	50	20.25	4	8
Nitrogen; Total	0.39	0.39	0.45	0.47	0.34	0	5
Phosphorus, Total	20	23.7	32	83	27.21444	7.5	45
Potassium	0.34	0.355	0.385	0.47	0.33	0	8
Potential of Hydrogen (pH)	6.54	6.71	6.92	7	6.604444	5.79	9
Saturation pH Estimated	9.905	9.96	10	10.3	9.984286	9.82	7
Secchi Depth	1.25	1.6	2.05	3	1.712712	0.8	59
Selenium	0	0.1	0.1	5	0.757143	0	7
Silicon	1	1.16	1.28	1.88	1.24	0.98	9
Silver	0	0	0	0.5	0.071429	0	7
Sodium	1.9875	2.01	2.03	2.2	1.98375	1.62	8
Solids; Dissolved Estimated	12.95	14.3	15	15.9	14	11.9	7
Strontium	21.1	23.5	25.3	27.9	23.24444	17.8	9
Sulphate	2.1	2.4	3.1	4.25	2.668889	1.87	9
Thallium	0	0	0	0.5	0.071429	0	7
Titanium	2	2.2	3.26	8.43	3.265556	1.9	9
Total Kjeldahl Nitrogen	381	385.5	438	479	407.25	352	8
True Colour	71.35	82.6	84.2	89.3	74.8	31.6	11

Uranium	0	0	0	0.5	0.071429	0	7
Vanadium	0.4	0.5	0.53	1	0.523333	0.28	9
Zinc	4.3	4.9	5	24.6	6.776667	3.2	9

Appendix E. Summary of Stakeholder Data Use



Data	Use	Comment if data was not used.
DMM Chemistry Data	Used to inform on lake conditions	None
LPP Total phosphorus data	Used to confirm and support DMM Data	None
DMM Limits to Growth Assessment	Used to confirm changes in development	None
Kahshe River Sampling – R. Pearson Data Near-Shore Water Sampling Project –2021	Reviewed and used to provide local context for water quality.	These data were downstream of Bass Lake and therefore were not immediately relevant to the inputs to the lake but were used for context of local water quality and water quality in the Kahshe River between Bass and Kahshe Lakes.
Survey photos provided by stakeholders	Reviewed and not used	As no blooms were confirmed by the MECP this investigation was focused on phosphorus concentrations in Bass Lake. Photos of small localized algae growth were not relevant to our assessment.
4 Stakeholder Emails and Attachments	Emails informed the collection of samples from the inflows to Bass Lake.	None

2018 Benthic Data	Reviewed but not used	Benthic data are a good indicator of lake health but were not relevant to the investigation of phosphorus concentrations in Bass Lake.
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Appendix F. Stakeholder Comments and Replies



Date Received	Comment	Consultant Response
6-Dec-22	In the second paragraph reference is made to a Figure 1 to show watershed inputs via the Kahshe and Gartersnake Rivers; however, the figure is not included in the report. The only other figure available for review is the attached 2020 Causation Study Locations; however, this figure does not provide any information pertaining to watershed boundaries or sampling locations.	Map has been included with the final report.
6-Dec-22	This section makes reference to water quality sampling undertaken by HESL in 2021 on October 13 at the mid-lake site and on May 12, 2021 at the mouth of the Kahshe and Gartersnake Rivers; however, Figure 1 is not provided for review, and the figure that is provided does not show the location of any of the HESL sampling locations.	Map has been included with the final report.
6-Dec-22	This overview section would benefit by a more clearly stated purpose for the HESL late-summer sampling of water quality in the deep waters which were sampled earlier by the DMM at this location on August 16, 2001. Even a brief reference to the rationale for this sampling which was covered in the more specific detail in Section 2.2 would be helpful.	Section 2.2 provides the goal of the Fall field sampling.
6-Dec-22	In this section, it is suggested that stakeholder observations of brown water suggest a proliferation of chrysophytes, which typically comprise an increasing percentage of the algal community in the fall. While the proliferation of chrysophytes is certainly possible, it is not the only possible causal agent. The appearance of orange-brown water in the Kahshe River between Bass and Kahshe Lakes has been reported by property owners along the river in both 2021 and 2022, and may be associated with noticeably higher iron levels in the Bass L water (vs. Kahshe L). These elevated iron levels could be triggering accelerated growth of iron bacteria in the slow moving waters of the Kahshe River, as these organisms can result in the development of an orange-brown colour to the water as they derive their energy from the oxidation of dissolved ferrous iron. The chart below was incorporated in the 2021 Kahshe and Bass Lake Steward Report and demonstrates a noticeable difference in iron levels between Bass and Kahshe Lakes over the entire DMM sampling period from 2006 through 2021.	Bacteria growth is another possible cause for the stakeholders observations, however monitoring data on bacteria were not available and therefore conclusions could not be drawn. By contrast data on chrysophyte were available in the data available to HESL and therefore were the focus of our discussion.
6-Dec-22	In Section 3.2.1.1, the report describes the results of the Muskoka Watershed's 2019 Shoreline Assessment Report generated by the Love Your Lake program. As such, it is not clear why the attached Bass Lake Land Use Survey dated June 2015 is attached rather than the more recent 2019 survey findings.	This was likely a mistake made when the report was published online for review.
6-Dec-22	The text describing available total phosphorus concentrations generated by the DMM and MECP's Lake Partner Program (LPP) would benefit from some additional descriptors of how these concentrations compare to the DMM's existing benchmark system of 'Background' and 'Threshold' levels of 20.6 and 30.9 µg/L, respectively. These existing benchmarks also could be added to Figure 2 to give the reader a better perspective of how the DMM has evaluated total phosphorus in terms of development activity. Alternatively, the text could be modified to inform the reader that a more complete description of the total phosphorus evaluation system can be found in Section 4.	Long-term (10-year average) comparison to the 20 µg/L water quality objective replaced the former DMM Background+50% method during the revision to the Official Plan and is the focus of the DMM's water quality reporting.
6-Dec-22	In Section 3.2.2.3 (Other Water Quality Parameters), reference is made to statistical analysis of the full suite of DMM water quality data in Appendix D; however, this information could not be reviewed as the contents of Appendix D were not provided.	Appendices are included with the final report.
6-Dec-22	In Section 3.2.2.4, the discussion of dissolved oxygen (DO) levels would benefit from a brief description/reference for the value of 2.0 mg/L of DO. The incorporation of this indicator in the yearly DO charts provided in Figure 6 also would provide additional clarity to the relevance of the measured DO concentrations over the full time period of DMM sampling. The incorporation of the PWQO of 5.0 mg/L also would give the reader a better idea as to the significance of these findings with respect to potential impacts on sensitive aquatic organisms.	Reference Added for 2.0 mg/L DO. PWQO for dissolved oxygen is not relevant to the Causation Study which is focused on Cyanobacteria growth.
6-Dec-22	In Section 3.2.2.4, the report indicates that the regular DMM sampling of DO was conducted in July, before the period of hypolimnetic anoxia developed. Our records show that the DMM sampling of Bass L was conducted on August 16 in 2021.	Corrected.
6-Dec-22	In Figure 6, the footnote should be modified to indicate that the DMM sampling in 2019 and 2021 was conducted in July and August, respectively.	Corrected.

6-Dec-22	Near the bottom of page 4, the authors estimate that the phosphorus contributions associated with cottages increased from 0.71 to 1.02 kg/yr based on a more updated number of cottage properties on the lake. While this is reflective of the model output provided in Table 1, it captures only the overland runoff associated with cottage development. The contribution from septic sources associated with cottage development via leaching and below-ground flow in groundwater should be included in this estimate, as it represents a much greater input to the lake (16.4 vs 1.02 kg/year).	An additional sentence was added on the septic load change. The interpretation is not affected by this change.
6-Dec-22	A more thorough description of the sub-surface groundwater flow associated with septic systems and the assumption of an attenuation factor of 1.0 needs to be provided, as it is not clear how this attenuation assumption affects the outcome of the model prediction. Detail on other parameters that were utilized in the phosphorus budget model also would help improve the reader's understanding of how this model generates phosphorus input concentrations to lake water. This is of even greater importance given the potential impact of increased intensity of precipitation events associated with a changing climate. This is important as the flushing of 'legacy' phosphorus which has been attenuated over the years down-gradient of septic leaching beds represents a major source of phosphorus input that needs to be evaluated or at least more thoroughly discussed in the report. In environmental modelling situations like this, there may be an advantage of running a Monte Carlo type of input parameter simulation to evaluate the impact of different components of the model on the generation of predicted output levels. At the very least, the model parameters need to be identified and discussed in terms of their relevance to the water chemistry of the lake.	Leaching of legacy phosphorus cannot be addressed within the report as no data has been collected for analysis by HESL as a part of the long-term monitoring of the lake. No changes were observed in phosphorus concentrations during the duration of monitoring.
6-Dec-22	In Section 4.1, the units for total phosphorus should be modified from mg/L to µg/L to be consistent with how phosphorus concentrations are reported in Table 2 and other parts of the report as well as in the MECP's PWQO document.	Revised to µg/L.
6-Dec-22	In Section 4.1, the reference to a PWQO of 0.03 mg/L (30 µg/L) is misleading, as this is only one (the highest) of three interim PWQOs for total phosphorus. PWQOs of 20 and 10 µg/L also are provided, and a more realistic option for inclusion in this report would be the PWQO of 20 µg/L to avoid nuisance concentrations of algae in lakes.	0.03 mg/L is the appropriate guideline as the paragraph is discussing Rivers. 0.01 and 0.02 mg/L pertain to lakes.
6-Dec-22	In the discussion of total phosphorus concentrations in the spring sampling of both water courses flowing into Bass L, it is indicated that information on incoming phosphorus from these watercourses could be improved with expanded sampling, including targeted storm sampling, to better understand the impact of runoff events and flushing of nutrients and DOC from wetlands following significant precipitation events. Given that this was a 'Causation Study' to explore the unique situation of a lake with total phosphorus concentrations above 20 µg/L, it is not clear why additional sampling of these inflow sources could not have taken place at additional times in 2021 and in 2022, as the cost to generate this additional information would have been minimal and the data generated from this sampling would have enabled a more substantive conclusion regarding the importance of this source.	Collecting and analyzing data from multiple nearshore sites to quantify storm events goes beyond what was possible as part of the causation study scope of work. These studies, although delayed due to unforeseen circumstances, were designed to be complete within a limited time and budget. A detailed nearshore sampling program would require multiple years of data to account for inter-annual variability and therefore could not realistically be completed within the Causation Study design.
6-Dec-22	The field sampling and laboratory methods for the data presented in Table 2 need to be presented, to give additional perspective on tributary flow, depth, distance from the shore and other physical parameters relative to where the samples were collected. It is also important to identify whether the collection of the samples was into laboratory digestion tubes for analysis at the MECP laboratory in Dorset, as if not, then the phosphorus data may under characterize the levels of total phosphorus as private laboratories in Ontario do not provide clients with their laboratory digestion tubes and as such, phosphorus in water samples is lost due to the use of glass sampling bottles.	Additional information on sampling has been added.

6-Dec-22	In the last bullet of this section, the impact of more intense rainfall associated with a changing climate is discussed and it is concluded that overland runoff from waterfront properties resulting from a changing climate does not represent a significant contribution to the phosphorus budget of Bass Lake. While we are in general agreement with this conclusion, this is not the only pathway for phosphorus input to the lake associated with waterfront property development, as it does not take into consideration the accelerated leaching and release of normally attenuated 'legacy' phosphorus associated with the operation of septic systems. It also fails to consider other factors that can negatively impact the attenuation of phosphorus in soils within the groundwater table down-gradient of septic systems. These include the trend towards longer recreational occupancy periods and septic usage and the impact of increased water usage resulting from showering, laundry and dishwasher use which decrease residency periods within the septic chambers and moves only partially settled septic effluent into leaching	No long term changes in total phosphorus were detected in the data available to support water property development as a substantial source of phosphorus in Bass Lake. Were increased recreational occupancy and septic usage resulting in increased phosphorus concentrations in Bass Lake we would expect to see and increase in the long-term concentrations over time.
6-Dec-22	The third bullet of this section makes reference to fall sampling of the lake demonstrating that wetland inputs result in marked seasonal changes in DOC concentrations in the lake. However, the reviewer could find no tabular or graphic summary of the fall sampling results or any comparative graphic to support this conclusion. It is also not clear at what depth the sampling was conducted, what analysis was performed or where in the lake the samples were taken.	DOC is discussed in Section 3.2.2.2. Fall DOC is represented by a single value and therefore was presented in the text in comparison to the typical spring values. More data would be needed to confirm the DOC dynamics of the lake.
6-Dec-22	The authors conclude that "the cause for the elevated phosphorus concentrations at Bass Lake cannot be reliably determined with the current information". With all due respect, it was our understanding that the primary reason for conducting a causation study was because the cause of the elevated phosphorus levels could not be reliably determined with the available historical information. As such, we have difficulty understanding why a more robust water sampling program was not developed and undertaken to advance the understanding of how potential phosphorus inputs were contributing to the elevated total phosphorus levels in Bass Lake.	Collecting and analyzing data from multiple nearshore sites goes beyond what was possible as part of the causation study scope of work. These studies, although delayed due to unforeseen circumstances, were designed to be complete within a limited time and budget. A detailed nearshore sampling program would require multiple years of data to account for inter-annual variability and therefore could not realistically be completed within the Causation Study design.

6-Dec-22	<p>The summary goes on to highlight a number of possible phosphorus input contributors, but the certainty associated with the role of these potential contributing factors is limited by the absence of a more robust and site-specific database to verify the application of a phosphorus budget model specific to conditions on Bass Lake. Additional comments on the description of possible long term phosphorus inputs to the lake follow:</p> <p>a) Large watershed to lake ratio: we concur with the report finding that a large watershed area draining to a small, shallow lake has the potential to increase phosphorus concentrations. With that being the case, we are surprised that the study limited the sampling and analysis of incoming water to a single event in May 2021. As such, any conclusions regarding phosphorus input via this source are at best speculative. Even a monthly sampling or a post-rainfall event sampling during the 2021 ice-free period would have given some perspective regarding the relevance of the 13-14 µg/L total phosphorus concentrations that were detected in the two rivers in May. This may also have provided a more site-specific input parameter for the operation of the phosphorus budget model.</p> <p>b) Prolonged periods of hypolimnetic anoxia and internal phosphorus loading: Again, without any site-specific sampling of bottom water or sediment at the water:sediment interface during the ice-free period, the general conclusion reached that this is a potential source of phosphorus based on published literature from other studies.</p> <p>c) Influence of catchment wetlands and lake hydrology: While it is recognized that the determination of phosphorus input via wetland sources based on site-specific sampling and analysis is likely beyond the scope of a Causation Study, some type of water sampling gradient (temporal and/or spatial) during or even beyond the ice-free period would have helped to increase the certainty of any conclusions related to this potential phosphorus input source.</p> <p>d) Shallow depth of Bass Lake: Again, the general conclusion that the shallow lake status of Bass L could be a factor in the generation of internal loading would have benefited from some actual sampling as noted above.</p>	<p>Additional detailed sampling programs beyond the DMM data would require multiple years of data to account for inter-annual variability and therefore could not realistically be completed within the Causation Study design. These studies, although delayed due to unforeseen circumstances, were designed to be complete within a limited time and budget.</p>
6-Dec-22	<p>The reviewer agrees that the five site-specific sampling/analysis items identified in this section will provide improved certainty with respect to the cause of the elevated phosphorus concentrations in Bass L. And while not specifically noted above, targeted near-shore sampling would have also helped to identify failing septic-related phosphorus input. These are the types of sampling and analysis we were expecting to see in this DMM-funded Causation study.</p>	<p>Collecting and analyzing data from multiple nearshore sites goes beyond what was possible as part of the causation study scope of work. These studies, although delayed due to unforeseen circumstances, were designed to be complete within a limited time and budget. A detailed nearshore sampling program would require multiple years of data to account for inter-annual variability and therefore could not realistically be completed within the Causation Study design.</p>
6-Dec-22	<p>Another component of environmental studies initiated by the DMM back in 2016 when Bass L was first identified as a 'Transitional Lake' was the conduct of Benthic Assessment Studies. Two sites (as shown in the figure aside) were established with benthic sampling being undertaken at both Sites 1 and 2 in 2016, at Site 1 in 2017 and at Site 2 in 2018. We have no record of these sites being further sampled in 2019 or 2021, but given they were initiated and conducted by the DMM, it is not clear why they have not been included in the review of historical Bass L data.</p>	<p>Limited benthic data were available on the lake, however given the timing of collection and the focus of the project on factors contributing to cyanobacterial blooms they were not included in the analysis. These limited data would not be expected to yield information on the long-term nutrient status of the lake.</p>