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Environmental Sciences Ltd.

Muskoka Lakes Association

Preserving Muskoka for Future Generations

Muskoka Lakes Association 2021 Water Quality Initiative Report

Prepared for: Muskoka Lakes Association
Job #: J210048

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Final Report

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Dedication

We are saddened to hear of the death of John Curran on November 5, 2021. We offer our condolences on his death along with our celebration of his life to his wife Liz, his family and friends and the Muskoka Lakes Association. John was the original champion of the MLA's Water Quality Program and Dr. Hutchinson enjoyed working with him designing the first program in 2002 and implementing it in 2003. John's vision, unflagging enthusiasm and his ability to motivate volunteers from within MLA contributed to the long-term success of the program, as documented in this report.

Executive Summary

The Muskoka Lakes Association (MLA), Canada's oldest lake association, was founded in 1894 to represent the lakeshore residents in the Muskoka Region. It has operated "The MLA Water Quality Initiative", (WQI) a monitoring program focussed on Lakes Rosseau, Joseph and Muskoka and including many smaller surrounding lakes, since 2002. The MLA's water quality efforts are concentrated on:

- Protecting and promoting water quality through their monitoring program and
- Promoting responsible land use

The MLA Environment Committee manages over a hundred volunteers to collect annual water quality data and retained Hutchinson Environmental Sciences Limited (HESL) in 2021 to analyze their data and to provide recommendations and program modification/development options. This Water Quality Report presents the most recent data collected in 2021 and compares it to data collected from 2002 to the present.

The MLA and their volunteers monitored 55 areas within 18 lakes and rivers for a total of 687 samples between May and October in 2021. Each sampling area represents a geographic location encompassing a group of WQI monitoring sites, usually focussed on a river, lake or embayment of interest to the MLA. Samples were collected for analysis of Total Phosphorus (TP) and bacteria (*E. coli* and total coliform) and Secchi depths were recorded at each site.

The MLA WQI Program was suspended in 2020 due to limitations on travel and sampling as a result of the COVID pandemic. COVID also impacted the start of the sampling program, which was delayed by 3 weeks due to government restrictions. Any impact of the delay on spring overturn phosphorus data will be considered when additional data are collected in 2022. Changes to the areas and sites monitored by the MLA WQI Program in 2021 were minor. An additional site was added at Leonard Lake (LEO-12 @ 45°04'16.1"N, 79°27'09.7"W) on the west shore to address concerns over a recent algal bloom. In addition, at Bruce Lake, BRU-1 was sampled for the first time since 2016 and Skeleton Lake rejoined program in 2021 after absence since 2008. Finally, no samples were collected in 2021 at Bass Lake, which left the program.

Detailed summaries of 2021 data for mean Secchi depth, spring and annual average total phosphorus and annual geometric mean of *E. coli* and total coliform bacteria counts are included in the Area Reports (Appendix A). Long-term trend analyses for total phosphorus concentrations at all monitoring sites were

included at sites where more than 5 years of data are available. Significant increasing trends were detected at 1 site which has been discussed in Section 3.6 and within the area report for Willow Beach. All trend analysis plots have been provided in Appendix B.

Without exception, Secchi depths recorded in 2021 remained within the range of variability of the long-term dataset. We noted that the Secchi depth data analysis methodology currently only includes comparison of the current years data against the long-term range of values collected at a sampling site. We believe water clarity data currently collected by the MLA WQI could include additional analyses to assess long-term change. Trends in Secchi data were last assessed by HESL in 2017 at a limited number of sampling sites, an updated assessment of the long-term trends in Secchi data may be a valuable addition to the MLA WQI Program.

Deep-water phosphorus concentrations at all sampling areas within the Lake Joseph, Lake Muskoka and Lake Rosseau were below the MECP Interim PWQO's of 10 and 20 µg/L for inland lakes[1], however nearshore phosphorus concentrations were elevated at sites within several sampling areas. We noted that in the majority of cases this was the result of samples collected during "Moderate" or "Heavy" storm events in which runoff or sediment disturbance may have suspended particulate phosphorus in the water column. In some cases, we found that 3 or more of the phosphorus samples collected were collected during storm events. While nearshore samples may provide insights into sources of phosphorus, they may bias estimates of the mean annual concentration. Storm sampling can be useful to identify sources of phosphorus and therefore should be collected, however HESL recommends that results of storm event samples be reported separately from non-storm event samples in the future and that the MLA update their methodology to consistently define storm events.

Trend assessment of spring phosphorus concentrations found a significant increasing trend at Willow Beach – Lake Muskoka, specifically the WLB-3 station. Concentrations at this location were the highest recorded to date and continued an ongoing pattern of steady increase in phosphorus at the site since monitoring began in 2005.

Cyanobacterial blooms were recorded in 2020 and 2021 at Muskoka Lake (Weismiller Bay), Leonard Lake, Three Mile Lake, Bass Lake, Bruce Lake, Brandy Lake, and Silver Lake (Port Carling). These were reported to the MECP, and causation is investigated through the District Municipality of Muskoka program. Additional blooms in the Muskoka region at lakes and embayment's not sampled by the MLA WQI program included Georgian Bay (Southeast Shoreline), Little Lake, Stewart Lake, Paint Lake, Lake St. John, Kahshe, Lake Mary, Lake Menominee Lake and Fawn Lake in 2021. In 2020 blooms outside the MLA WQI program were noted on Kahshe Lake, Black Lake, Cooks Bay (Lake Simcoe), Stewart Lake, Little Lake, Ril Lake, Ten Mile Bay (Lake of Bays), Little Lake Park, Lake St. John, Sparrow Lake and Otter Lake.

E. coli counts exceeded 50 cfu/100 mL in 41 (18%) of 232 sampling events in 2021. Re-tests were not completed in 28 of the 41 sampling events that exceeded the 50 cfu/100mL MLA benchmark. Sampling

[1] *To avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 µg/L; A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration for the ice-free period of 10 µg/L or less. This should apply to all lakes naturally below this value; Excessive plant growth in rivers and streams should be eliminated at a total phosphorus concentration below 30 µg/L.*

areas where *E. coli* counts were elevated in 2021 included Beaumaris (BMR-4 and 10), Brandy Lake (BDY-1, 2, 3, 5, and 6), Bruce Lake (BRU 1, 3, 4, 5 and 6), Clear Lake (CLR-5), Foot's Bay (FTB-3 and 5), Gull Lake (GUL-1, 2, 3, and 4), Indian River (IND-2, 4, 7, and 8), Minett (MIN-1, 6 and 9), Moon River (MOO-12), Muskoka Sands (MSN-2, 3 and 6), Taylor Island (TAY-2) and Windermere (WIN-4 and 5). The areas which exceeded the MLA Yellow Light Benchmark (i.e., a geometric mean of 30 cfu/100mL) in 2021 were Bruce Lake (BRU), Gull Lake (GUL), Indian River (IND), Minett (MIN), and Windermere (WIN). Elevated bacteria at many sites in 2021 coincided with an increase in sampling during recorded storm events.

In 2021, 55 areas were sampled, 43 of which were assigned green lights, while eleven yellow lights and one red light were assigned based on the MLA criteria. Yellow lights at four of the eleven sampling areas were the result of elevated bacteria concentrations, while five sampling areas (Boyd Bay, Bala Bay, Brandy Lake, Silver Lake (Port Carling) and Leonard Lake) experienced cyanobacterial blooms in 2018 - 2021 for which a causation study has not yet been completed. Blooms documented in 2021 did not exceed the MLA threshold of 20 μg/L and were therefore assigned a yellow light. Bruce Lake exceeded yellow light triggers for algae blooms and bacteria concentrations. Gullwing Lake was assigned a yellow light as a result of a 3-year average total phosphorus concentration that exceeded the 20 μg/L thresholds, however this was heavily impacted by an elevated concentration in 2021 which should be confirmed with follow-up sampling in 2022

HESL has formulated several recommendations which we believe will improve the program moving forward. These include:

1. maintaining consistent sampling at long-term sites whenever possible.

2. limiting storm event sampling as a part of the MLA WQI Methodology or presenting and interpreting storm event samples separately from non-event samples.

3. A reminder for sample volunteers about retesting protocols for bacteria samples above the 50 cfu/100 mL threshold.

4. A review of the Secchi data to eliminate anomalous data if present, and an updated assessment of any long-term trends.

5. Focussed sampling at Willow Beach, Minett, Bruce Lake, Indian River and Windermere where elevated levels of bacteria and/or phosphorus were identified in 2021.

6. Continued sampling at Gullwing Lake in 2022 including a duplicate spring phosphorus sample in response to the anomalous value recorded in 2021.

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1. Introduction

There is a need for high quality, long-term data to support effective science-based management of freshwater resources (Smol 2008). This becomes increasingly important as the magnitude and number of environmental stressors grows (e.g., intensification of human land-use, exotic species' invasions and climate change). A region of particular interest in Canada is the lake-rich Muskoka-Haliburton region of south-central Ontario where, despite its relatively remote location, lakes have been influenced by multiple environmental stressors during the past several decades (Hall and Smol 1996, Paterson et al. 2004, DeSellas et al. 2008, Yan et al. 2008). Although distant from major urban and industrial centres, the Muskoka-Haliburton region is a popular destination for recreational activities, and is home to many cottages, resorts and golf courses. As a result, lakes in the region are susceptible to both regional-scale stressors, such as climate change, as well as local, catchment-scale stressors associated with increased shoreline development.

The Muskoka Lakes Association (MLA), Canada's oldest cottage association, was founded in 1894 to represent the lakeshore residents in the Muskoka Region and has operated The MLA Water Quality Initiative (WQI), a monitoring program focussed on Lakes Rosseau, Joseph and Muskoka and including many smaller surrounding lakes, since 2002. The MLA's water quality efforts are concentrated on:

- Protecting and promoting water quality through their monitoring program and
- Promoting responsible land use

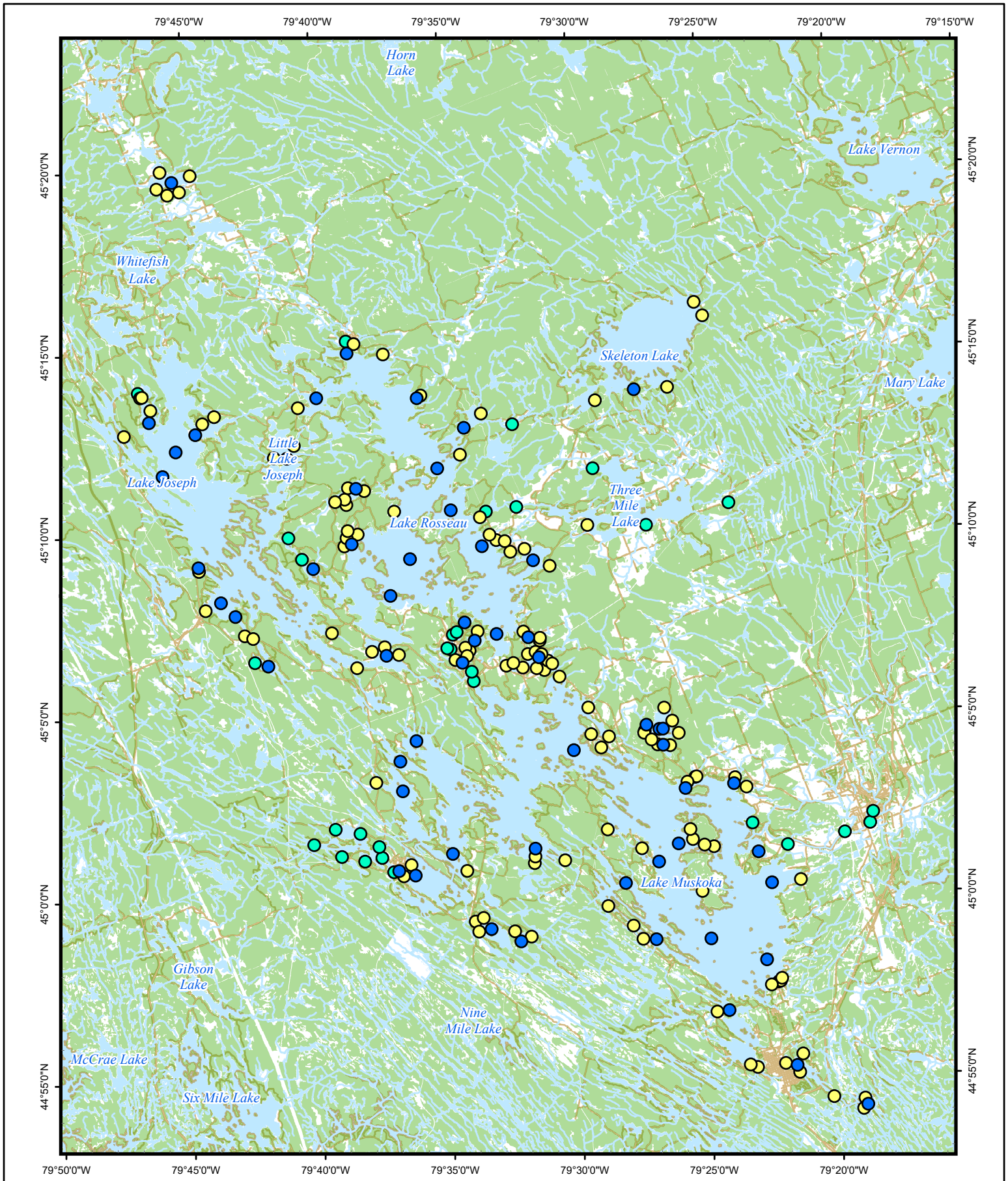
The MLA Environment Committee manages over a hundred volunteers to collect annual water quality data and retained Hutchinson Environmental Sciences Limited (HESL) in 2021 to analyze their data and to provide recommendations and program modification/development options. This Water Quality Report presents the most recent data collected in 2021 and compares it to data collected from 2002 to the present.

2. Water Quality Monitoring Program

2.1 Regional Setting

The study lakes are located in the Muskoka region of south-central Ontario, Canada, situated on the Precambrian Shield (Figure 1). The Shield is characterized by thin, poorly developed soil with abundant bedrock exposures. Catchments are mainly forested, dominated by sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch (*Betula lutea*), red maple (*Acer rubrum*), eastern hemlock (*Tsuga canadensis*), and white and red pine (*Pinus strobus* and *Pinus resinosa*).

A key objective of the MLA program is to determine if the amount and nature of shoreline development has altered key water quality indicators: Total Phosphorus (TP, an indicator of lake productivity), water clarity (influenced by algal growth and catchment runoff and measured as Secchi depth) and bacteria as an indicator of potential water borne pathogens (See Section 2.3). Shoreline development varies greatly between and within lakes. Sampling sites have generally been selected based on community concern and are therefore focused on moderately and heavily developed areas which may be influenced by inputs from urban and seasonal recreational (cottages, resorts, golf course) activities.



Station Type

- Deep Basin
- Nearshore
- Watercourse

- Watercourses
- Wooded Area
- Roads
- Waterbodies

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00.51 2 3 4 5 km

Scale = 1:250,000

N

Project #:	210048	Projection:	UTM Zone 17N
Drafted:	K. Hadley	Datum:	NAD 1983
Reviewed:	B. Parsons	Date:	Nov 22, 2021

Figure 1

Sampling Stations

2.1.1 The Role of Climate

The Muskoka region is situated within the boreal ecozone with a temperate climate. Average monthly air temperature from March to August in 2021 varied between -1.3 and 19.8 °C (Table 1) and monthly precipitation was between 14.9 and 136.2mm (Table 2). Marked increases in precipitation in June and July of 2021 represent the highest rainfalls observed in those months in the last 5 years, while precipitation in May was the lowest and well below the long-term average. Maximum daily air temperatures in 2021 ranged from 18.4 in March to 30.3 °C in June (Table 3), exceeding the average monthly maxima recorded between 1981 and 2010. Analysis of long-term climate records show a marked and significant ($p<0.05$) increase in average annual air temperature since the 1980s (Figure 2). Long -term total annual precipitation varied significantly but no significant long-term trend was noted. (Figure 3).

Spring freshet in 2021 was more similar to typical long-term average conditions than the extreme high-water levels that were noted in 2019. Peak water levels at the Beaumaris Water Survey of Canada Station (02EB018) in both 2020 (9.72 m), when no sampling occurred due to the Covid-19 pandemic, and 2021 (9.67 m) were well below the 10.5 m recorded in 2019 that produced historic flooding conditions (Figure 4).

Table 1. Average Temperatures Recorded at the Beatrice Climate Station (6110607).

	Mean Temperature (°C)						
Month	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1981-2010 Average**
March	-1.5	-5.9	-3.3	-6.2	-0.9	-1.3	-3.8
April	1.6	6.3	-0.2	3.3	2.7	5.9	4.4
May	11.0	10.1	13.3	9.1	9.9	10.0	11.0
June	15.5	15.4	15.5	14.2	16.4	17.4	15.8
July	18.6	17.9	19.5	19.3	20.5	17.6	18.2
August	19.4	16.4	19.3	16.5	17.3	19.8	17.3

Table 2. Total and Average Monthly Rainfall at the Beatrice Climate Station (6110607).

	Total Monthly Precipitation (mm)						
Month	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1981-2010 Average**
March	182.3	87.5	31	62.4	98.1	43.4	75.2
April	64.4	155.6	103.8	133.3	73.6	72.1	76.8
May	56.3	130.2	27.6	100.8	68.3	14.9	97.9
June	41.3	151.6	25.5	101.1	100.9	135.9	87.7
July	72.6	79.6	57	23.9	81.8	136.2	94.3
August	195.5	211.2	196.1	75.3	129.4	88.2	87.7

Table 3. Maximum Daily Air Temperatures Recorded at the Beatrice Climate Station (6110607).

	Maximum Temperature (°C)						
Month	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**1981-2010**
March	12.7	9.5	8.6	9.9	12.3	18.4	2.4
April	22.4	27.1	17.9	18.9	15.5	24.4	10.7
May	30	28.4	30.9	21.4	31.2	29.8	18.1
June	29.6	27.7	30	27.7	30.3	30.3	22.6
July	30	28	33.9	30.6	32.4	28	24.9
August	33.3	27.5	30.4	27.9	29	30.1	23.8

Figure 2. Long-term Trends in Average Annual Air Temperature at the Beatrice Climate Station (6110607).

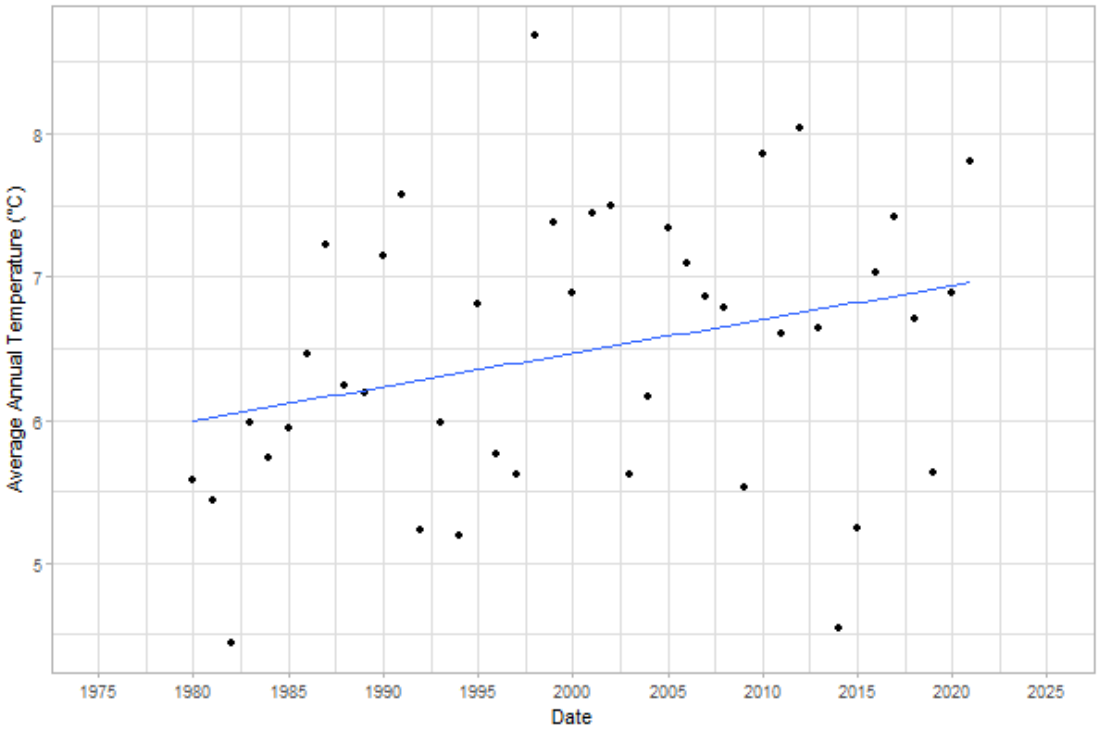


Figure 3. Long-term Records of Total Annual Precipitation at the Beatrice Climate Station (6110607).

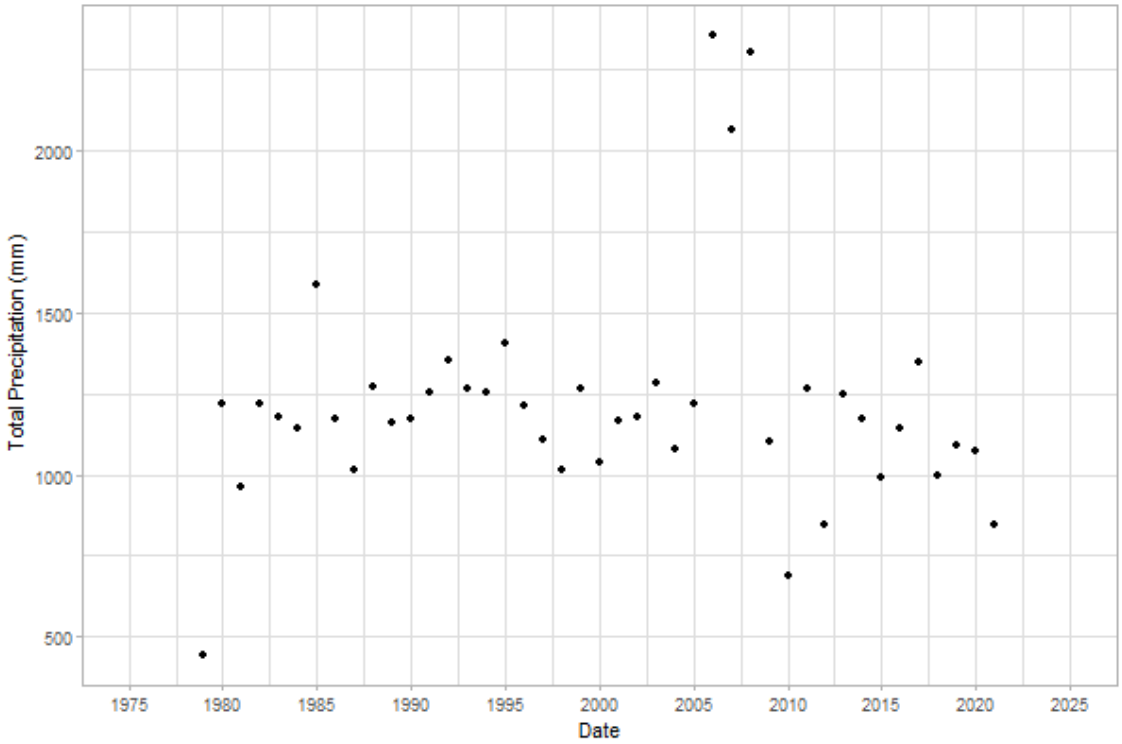
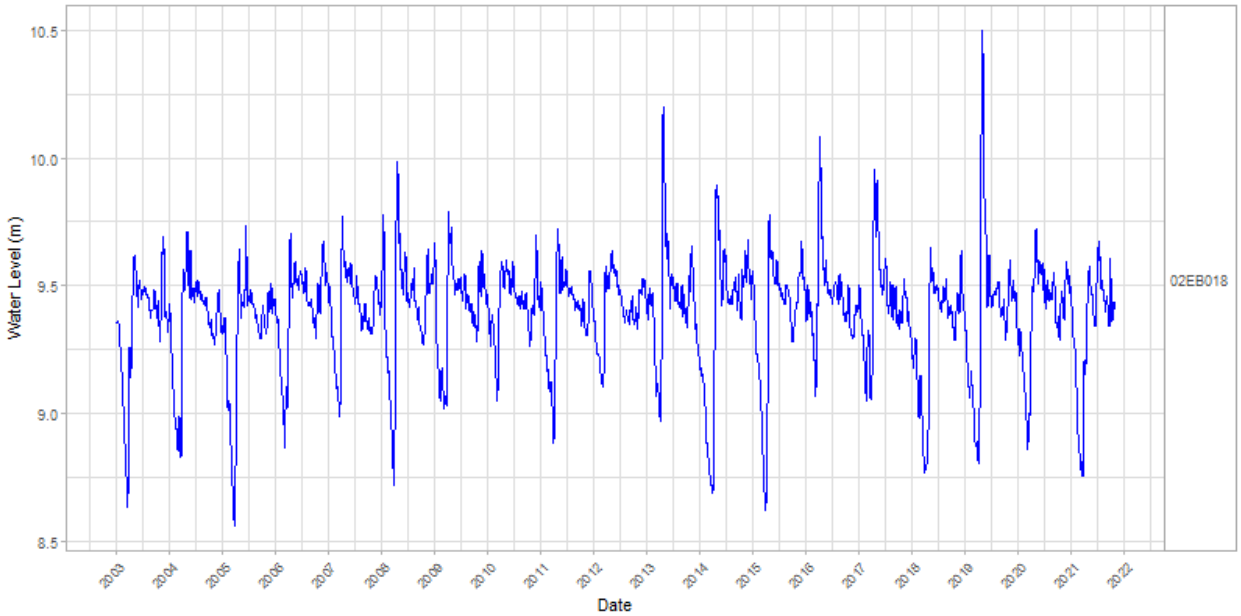


Figure 4. Long-term Water Level at Beaumaris Water Survey of Canada Station (02EB018).



2.2 Study Areas and General Methods

The MLA WQI monitoring program study area includes Lakes Muskoka, Rosseau, and Joseph and several smaller affiliate lakes and rivers in the Muskoka Region. The study area is divided into targeted sampling areas which include lakes, bays, and rivers. Within each sampling area the MLA maintains several sampling stations, normally this includes a deep-water station (to represent average sampling conditions), one or more nearshore sampling stations and, where applicable, watercourse sampling stations.

Details of the sampling protocols are provided in the MLA Water Quality Initiative Methodology Report (http://www.mla.on.ca) and these standard protocols were followed in 2021.

2.3 Water Quality Parameters

The MLA WQI is focussed on total phosphorus concentrations, Secchi disk depth measurements and *E. coli* bacteria sampling. For recreational lakes on the Precambrian Shield water quality concerns are most often associated with nutrient enrichment due to increased human phosphorus sources. Phosphorus is often the primary limiting nutrient in freshwaters in support of macrophyte and algal growth. Phosphorus enters lakes via external loading from the watershed, precipitation and, in certain conditions, through internal loading from sediments at the lake bottom. Effluent from sewage treatment systems and stormwater runoff may have particularly high loadings and as a result phosphorus concentrations are commonly used to assess the impacts of development on water quality. Excessive growth of plants and algae and subsequent decomposition can result in lowering of dissolved oxygen concentrations in deep hypolimnetic waters due to the oxygen requirements of bacteria and this may degrade fish habitat and in extreme cases result in “fish kills”, a phenomenon where water temperature near the surface of the lake is too warm and oxygen concentrations of the water near the bottom are too low to support fish resulting in a mass die-off.

Secchi disk depth provides a measure of water clarity which is one indication of the productivity of the lake. For Precambrian Shield lakes, Secchi depth is primarily determined by the amount of dissolved organic carbon (DOC) in the water (Dillon et al. 1986), and this is a function of the amount of wetland in the watershed (Dillon and Molot 1997). High algae growth, however, reduces the penetration of light through the water column and reduces the measured Secchi depth beyond that related to DOC. Decreases in Secchi depth over time may therefore be indicative of increased productivity by, for example shoreline disturbance and development activities that increase total suspended solids or phosphorus loading from the watershed.

E. coli are a species of fecal coliform bacteria that comes from warm-blooded animals, including humans and are a useful indicator of potential pathogens in the water. They are the primary organism used by Health Canada in determining the safety of recreational waters for swimming and bathing.

2.4 Updates in the 2021 Program

Changes to the areas and sites monitored by the MLA WQI Program in 2021 were minor. An additional site was added in the Leonard Lake Sampling Area (LEO-12 @ 45°04'16.1"N, 79°27'09.7"W) on the west shore to address concerns over a recent algae bloom. In addition, at Bruce Lake, BRU-1 was sampled for

the first time since 2016. Finally, no samples were collected in 2021 at Bass Lake, which has opted out of the MLA WQI Program in 2021.

3. 2021 Monitoring Methods and Results

3.1 Background

The MLA and their volunteers monitored 55 areas within 18 lakes and rivers for a total of 687 samples between May and October in 2021. Each sampling area represents a geographic location encompassing a group of WQI monitoring sites, usually focussed on a river, lake or embayment of interest to the MLA.

Detailed summaries of 2021 data for mean Secchi depth, spring and annual average total phosphorus and annual geometric mean of *E. coli* and total coliform bacteria counts are included in the Area Reports (Appendix A). Long-term trend analyses for total phosphorus concentrations at all monitoring sites were included at sites where more than 5 years of data are available. Significant increasing trends were detected at 1 site and discussed within the area report and Section 3.6. All trend analysis plots have been provided in Appendix B. Area descriptions have been updated in 2021 to reflect Schedule E2 classification under the District of Muskoka Official Plan which identifies lakes which are considered vulnerable to changes in water quality. A visual indication of the overall water quality at each Area is presented by means of a traffic light symbol. The meaning of each symbol is described below:

Green Light
Water quality remains consistently good.

Yellow Light
Further investigation is recommended to maintain good water quality.

Red Light
Remedial action is recommended to improve water quality.

In 2019, the MLA developed new thresholds to align monitoring under the WQI Program with the District Municipality of Muskoka's recently adopted Official Plan amendment - OPA 47 (Table 4). The water quality thresholds defined in DMM Policy C.2.6.3.2 are:

i. 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.

ii. 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

iii. A blue-green algal (cyanobacteria) bloom confirmed and documented by the Province and/or Simcoe-Muskoka District Health Unit.

If conditions (i) or (ii) have been identified in three consecutive monitoring years or condition (iii) has been confirmed to be present, the waterbody is classified as vulnerable and added to Schedule E2. Under the Official Plan, lakes listed under Schedule E2 are subject to a causation study to determine what role, if any, that development has in the measured nutrient enrichment or algae bloom and to recommend management actions.

Beginning in 2019, the MLA has assigned a yellow light threshold for phosphorus concentrations that are either:

- >20 µg /L (latest 3-year spring turnover average);
- show an increasing trend in spring measurements over the last 3 years; or
- have an annual average TP that exceeds spring TP.

A red light threshold for phosphorus concentrations is triggered if:

- concentrations exceed 20 µg/L (latest 5-year spring turnover average); or
- a statistically increasing trend in spring measurements over the last 5 years (or longer).

In addition, a red light occurs for study areas where a confirmed cyanobacterial bloom is detected in the current monitoring year, while a yellow light is assigned if a bloom has been confirmed in the past three years or if microcystin concentrations of a current bloom are below 20 µg/L. A green light for Harmful Algae Blooms is assigned in study areas that have never had a blue-green algal bloom, or that have had 3 years since the last bloom.

E. coli thresholds were established in 2018 using Health Canada and the Ministry of Health and Long-Term Care Operational Approaches for Recreational Water Guideline (2018) for recreational water use at public beaches and waterfronts and are based on a geometric mean of levels of *E. coli*. Health Canada guidelines deems a site unsuitable for swimming and bathing when *E. coli* counts exceed 200 cfu/100mL, based on a minimum of five samples per site collected within a one-month period, which is not currently possible under the MLA WQI program. The MLA has, however, adopted their own, lower, thresholds in recognition of the high water quality in Muskoka's lakes, with the green light established for annual means below 30 cfu/100 ml, yellow for counts between 30 and 199 cfu/100 ml and red where annual means exceed the Health Canada threshold of 200 (Table 4). The MLA *E. coli* geometric mean is calculated annually (ideally, 1 sample per month over 4 months). Individual *E. coli* samples that exceed 50 cfu/100ml require volunteers to re-sample the site weekly. Where additional samples are collected, all data were used to calculate the annual geometric mean.

HESL will review traffic light thresholds with the MLA Environment Committee annually. HESL added the Interim Provincial Water Quality Objectives for TP to our comparisons for each Area Report in 2021. These

guidelines are generally applied to ice-free average phosphorus concentrations, however we have assessed both spring and, where available, annual data against the guidelines to provide an additional assessment of current water quality. These additional guideline comparisons are not incorporated into the MLA Stoplight Thresholds.

Table 4. MLA Thresholds for Assigning Traffic Light Limits for Area Summaries.

Traffic Light	*E. coli* Yearly Geometric Mean (cfu/100 ml)	Phosphorus Trend Associated with all Sampling Years	Harmful Algae Blooms (HAB's)
	0 – 30	Flat or decreasing visual trend	No bloom ever, or 3 years since last bloom
	31 – 199	a) >20 µg /L (latest 3-year spring turnover average); b) show an increasing trend in spring measurements over last 3 years; OR c) yearly mean TP exceeds spring TP	Bloom within last 3 years, or if available, bloom in current year with toxic component (microcystins) measured <20 µg /L
	>200 geometric mean for a series of 5 samples per site per month	a) >20 µg/L (latest 5-year spring turnover average); OR b) statistically increasing trend in spring measurements over last 5 years (or longer).	Bloom in current year

3.2 Secchi Disk Depth

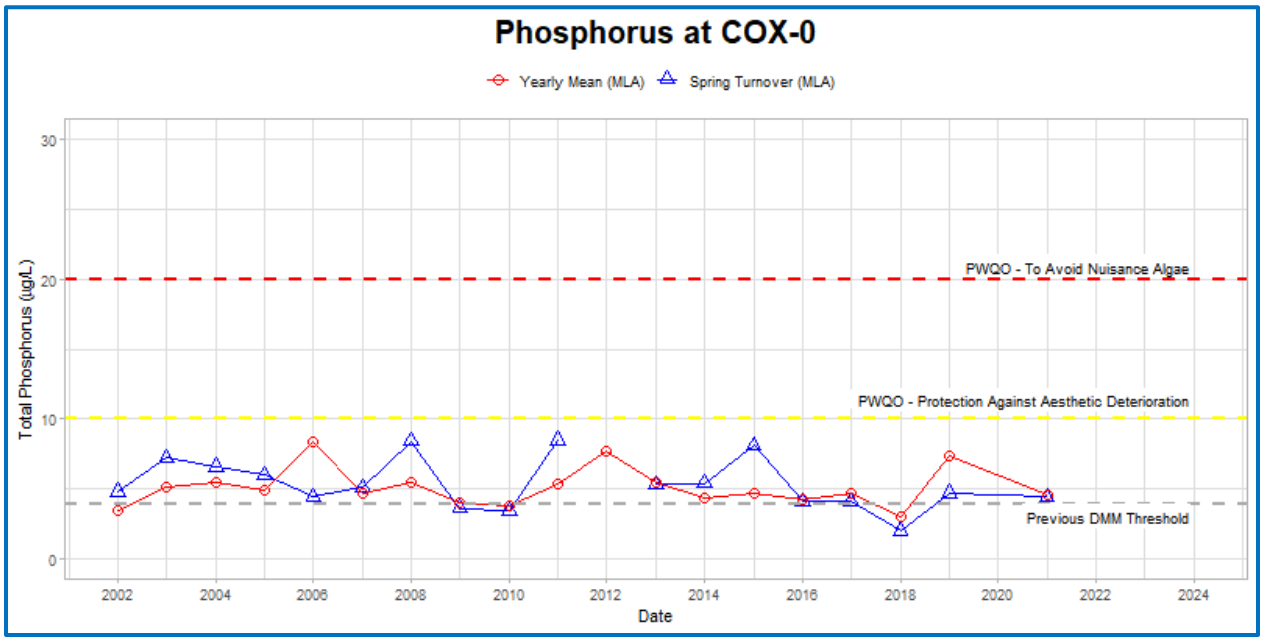
Mean Secchi depth measurements at all deep-water stations are provided for each sampling area in the Area Summary Sheets (Appendix A). Without exception, Secchi depths recorded in 2021 remained consistent with the depths reported historically. We noted that the Secchi depth data analysis methodology currently only includes comparison of the current years data against the long-term range of values collected at a sampling site. We believe water clarity data currently collected by the MLA WQI could include additional analyses to assess long-term change. Trends in Secchi data were last assessed by HESL in 2017 at a limited number of sampling sites, an updated assessment of the long-term trends in Secchi data may be a valuable addition to the MLA WQI Program.

3.3 Total Phosphorus Concentrations

Spring total phosphorus concentrations have been collected since monitoring began from the deep-water sampling station within each sampling area and are presented in the Area Summary Reports (Appendix A). In addition, where available, annual average phosphorus data are also presented (e.g., Figure 5). Phosphorus data were compared against Provincial Water Quality Objectives (PWQO) for Protection Against Aesthetic Deterioration (10 µg/L, Yellow Line) and Prevention Against Nuisance Algal Growth,

which coincides with the DMM threshold adopted in OPA 47 (20 µg/L, Red Line), and, where available, previous District of Muskoka Thresholds based on background + 50% (Grey Line). Nearshore phosphorus concentrations were not collected consistently at all nearshore monitoring stations in the MLA WQI Program, in some cases only bacteria were sampled. Where nearshore phosphorus data were collected, we compared spring overturn and annual average nearshore phosphorus concentration against long-term nearshore monitoring data.

Figure 5. Example of the Presentation of Long-term Phosphorus Monitoring Figures.



In 2021, we have added long-term analysis of total phosphorus concentrations at all deep-water and nearshore stations with sufficient data (> 5 years). Figures for all trend analyses completed in 2021 have been included in Appendix B. When a significant trend is identified, we will include the trend analysis figure and discussion within the Area Report and in the Technical Report discussion (Section 3.3.2). Visual analyses of changes in deep-water and nearshore phosphorus concentrations were also performed to assess the MLA yellow light trigger as described in Section 3.1.

Spring overturn phosphorus concentration from samples collected by the Lake Partner Program and District of Muskoka are available at some sampling stations which are also monitored by the MLA. Based on our understanding with the Environment Committee, these data will be reviewed by HESL and included as a technical memo or addendum to this report when they become publicly available.

3.3.1 Quality Control

A total of 59 duplicate phosphorus samples were collected in 2021 and 17 bad splits were identified that were either >30% different or had an absolute difference of >5 µg/L. If a bad split was identified, the higher of the two values was discarded. Outlier assessment followed previous methods using the Grubb's Test to identify outliers in the spring and annual average total phosphorus data. Unlike previous years, data that

were identified as an outlier were retained in the Area summary plots unless it could be clearly identified as contamination. All outliers, even those identified as potential contaminated samples, are retained in the long-term data set and will be re-evaluated each year when new data is collected. Three samples collected in 2021 were outliers (BRM-10, BRA-3 and STI-2).

3.3.2 2021 Total Phosphorus Results

Deep-water phosphorus concentrations at all sampling areas within Lake Joseph, Lake Muskoka and Lake Rosseau were below PWQO's for inland lakes (Figure 6, 7, 8). Nearshore phosphorus concentrations were elevated at sites within several sampling areas (i.e., BRA, MIN, BMR, MSN, STI, WLB), however we noted that in the majority of cases this was the result of sample collected during "Moderate" or "Heavy" storm events. Sampling during storm events is useful to help capture the full range of variability at a sampling station and to identify potential areas or sources of concern, however in some cases we found that 3 or more of the phosphorus samples collected were collected during storm events. This could bias results and make long-term trend assessments more difficult. HESL recommends that samples collected during storm events be kept separate for purposes of analysis and interpretation, and that they be compared with samples collected outside of storm events. These, and other recommendations will be discussed with the MLA Environment Committee prior to sampling in 2022.

Brandy Lake and Gullwing Lake had spring phosphorus concentrations above the PWQO for Protection Against Aesthetic Deterioration (Figure 9), however, based on long-term data, phosphorus concentrations in Brandy Lake appear naturally elevated and were below the historic DMM threshold in 2021. In Gullwing Lake, an anomalously high spring phosphorus concentration of 39.8 μg/L will require additional sampling in 2022 to confirm. BMR-10 and 12 were both elevated in spring of 2021, and were not associated with a precipitation event, confirmatory sampling in 2022 is recommended at those stations.

Spring phosphorus concentrations showed a significant increasing trend at Willow Beach on Lake Muskoka, specifically the WLB-3 station (Figure 10). Concentrations at this location are the highest recorded to date and continue an ongoing pattern of steady increase in phosphorus at the site since monitoring began in 2005. The magnitude of the long-term increasing trend in total phosphorus concentrations at WLB-3 was ~0.98 μg/L/year. The WLB-3 station is located in a heavily developed area adjacent to two resorts and near the inflow of a creek which drains a golf course and agricultural lands. Sampling of this creek in the future may provide information on the phosphorus load arriving from the watershed and support discussions with the District on potential mitigation options to reduce the concentrations of phosphorus entering the lake at this site. The WLB-3 site also highlights a potential weakness of the current stop light assessment system, as despite the long-term significant trend in total phosphorus detected at this site, at no time in the past 7 years would it have qualified for a yellow light threshold (i.e., three consecutive years of increasing phosphorus concentrations).

3.3.3 Watercourse Stations

Watercourse sampling stations do not make up a significant portion of the MLA WQI Program, however long-term records of water quality have been collected from Muskoka River (MRV), Joseph River (JOR), Indian River (IND), Hamer Bay (HMB-8) and Windermere sampling stations (WIN-7 and WIN-8). Phosphorus concentrations within river stations were frequently elevated (Figure 7, 8 and 10) as seasonal

changes in flow impact Dissolved Organic Carbon and suspended sediment loads in the water column and thus impact nutrient concentrations. Phosphorus concentrations at these stations were compared against the PWQO for the Elimination of Excessive Plant Growth in Rivers and Streams (30 µg/L) and, where appropriate, are discussed within the Area Reports.

3.4 Harmful Algal Blooms

Harmful algae blooms are generally characteristic of nutrient enriched lakes but are becoming an increasingly common occurrence in lakes in the Muskoka region and across Ontario (Winter et al. 2011). In the past decade algae blooms in low nutrient lakes have become significantly more prevalent. In 2020 and 2021 numerous algae blooms were reported on MLA monitored lakes (Table 5). In the absence of enriched or increasing phosphorus concentrations, the increased blooms are thought to be associated with changes associated with the warming climate (Pick 2015, Reini et al. 2021). Causation of documented algal blooms is addressed under the Lake System Health Program of the District Municipality of Muskoka.

Table 5. Summary of Recent Harmful Algae Blooms in MLA Monitoring Lakes.

2020	2021
Leonard Lake	Three Mile Lake
Three Mile Lake	Leonard Lake
Bass Lake	Bass Lake
Bruce Lake	
Brandy Lake	**Outside MLA WQI Program**
Silver Lake (Port Carling)	Kahshe Lake
Muskoka Lake (Weismiller Bay)	Black Lake
	Cooks Bay (Lake Simcoe)
Outside MLA WQI Program	Stewart Lake
Georgian Bay (Southeast Shoreline)	Little Lake
Little Lake	Ril Lake
Stewart Lake	Ten Mile Bay (Lake of Bays)
Paint Lake	Little Lake Park
Lake St. John	Lake St. John
Kahshe Lake	Sparrow Lake
Mary Lake	Otter Lake
Menominee Lake	
Fawn Lake	

3.5 Bacteria

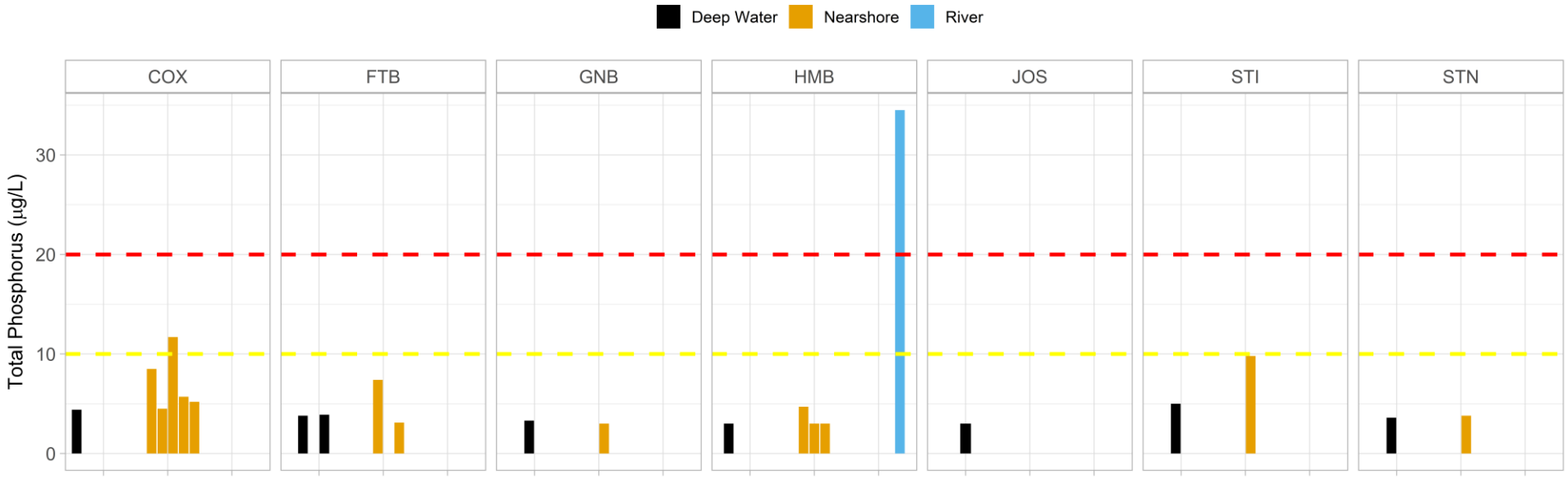
Under the current MLA WQI Methodology, bacteria (*E. coli* and total coliform) levels were compared to the stop light limits developed by the MLA based on Ministry of Health and Long-Term Care Operational Approaches for Recreational Water Guideline (2018) for recreational water use at public beaches and waterfronts (200 cfu per 100 mL for *E. coli*). In addition, we included the PWQO for *E. coli* is 100 cfu per 100 mL on all Area Report summary figures (e.g., Figure 11).

Total coliform and *E. coli* measurements below the detection limit of 3 cfu/100 mL were assigned a value of 1 cfu/100 mL to calculate geometric means, which were calculated using all available data including any retests.

Total coliform counts from samples collected in 2021 are summarized in the Area Summary Reports. Total coliforms samples collected in 2021 did not exceed the 1000 cfu/100mL guideline at any site. Elevated concentrations were frequently associated with precipitation events described by volunteers in their sampling notes.

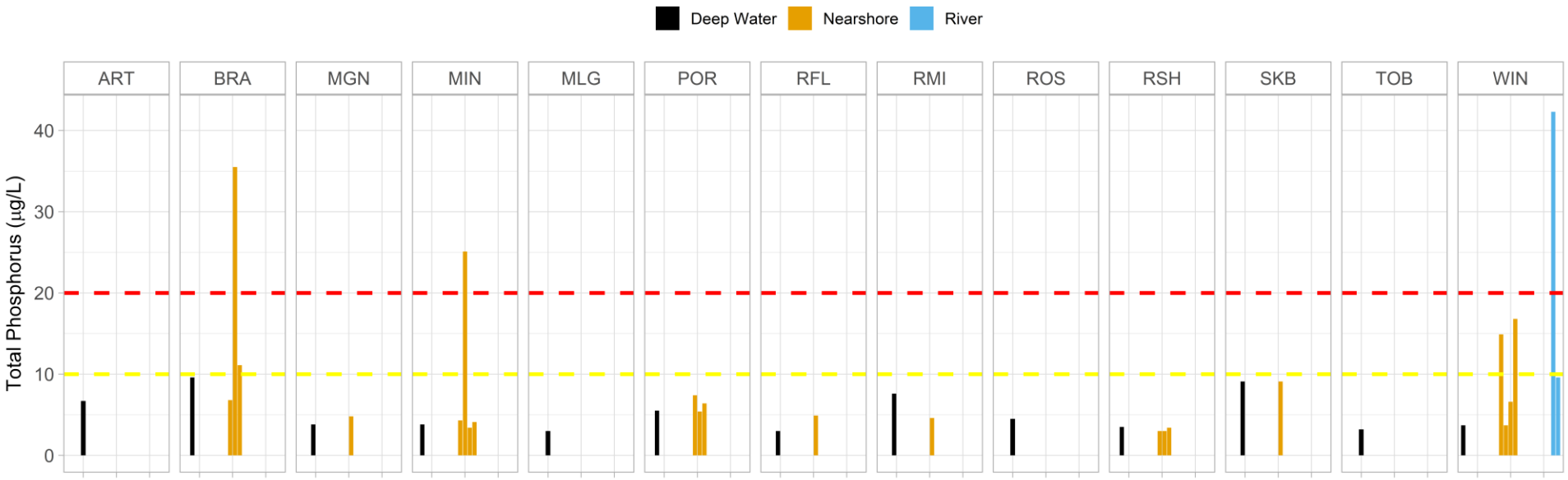
As noted in Section 3.1, the MLA WQI field protocols require volunteers to re-sample a site if *E. coli* counts are greater than 50 cfu/100mL. *E. coli* counts exceeded 50 cfu/100 mL at 41 (18%) of 232 sampling events for E. coli in 2021. This frequency exceeded those recorded in the past five years (4.6% in 2019, 9.2% in 2018, 8.0% in 2017, and 8.7 % in 2016). Re-tests were not completed in 28 of the 41 sampling events that exceeded the 50 cfu/100mL limit.

Figure 6. Summary of the 2021 Spring Total Phosphorus Results from Lake Joseph Sampling Areas.



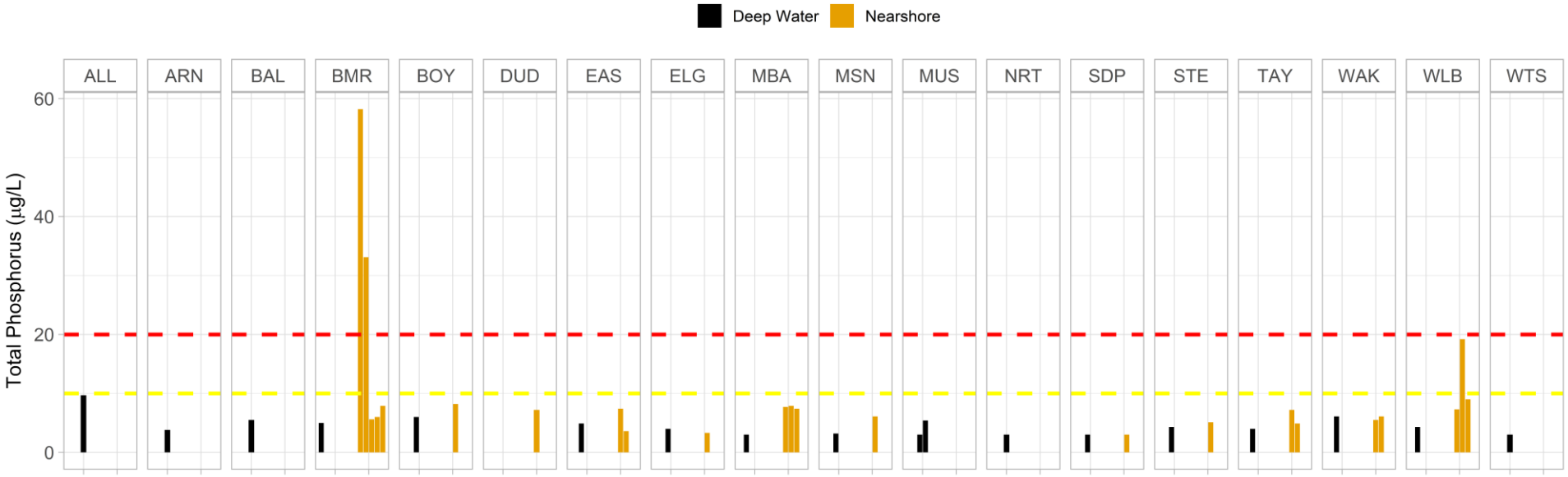
Note: COX = Cox Bay; FTB = Foot's Bay; GNB = Gordon Bay; HMB = Hamer Bay; JOS = Lake Joseph; STI = Stills Bay; STN = Stanley Bay

Figure 7. Summary of the 2021 Spring Total Phosphorus Results from Lake Rosseau Sampling Areas.



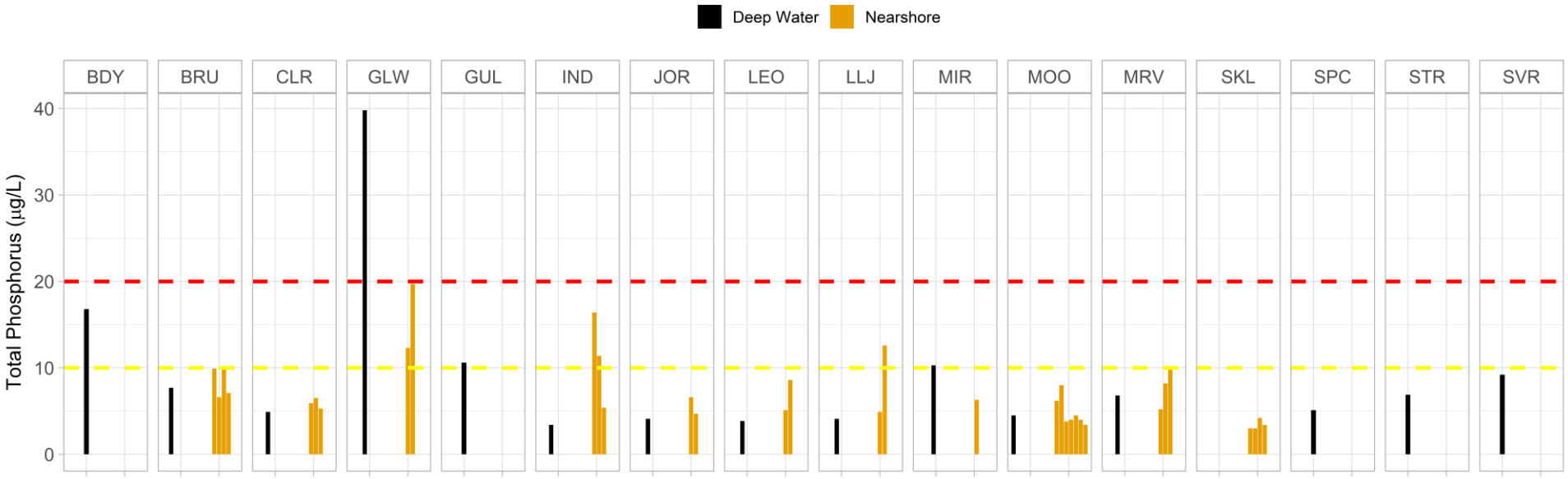
Note: ART = Arthurlie Bay; BRA = Brackenrig Bay; MGN = Morgan Bay; MIN = Minett, MLG = Muskoka Lakes Golf; POR = East Portage Bay; RFL = Rosseau Falls; RMI = Royal Muskoka Island; ROS = Lake Rosseau; RSH = Rosseau North; SKB = Skeleton Bay; TOB = Tobin Island; WIN = Windermere

Figure 8. Summary of the 2021 Total Phosphorus Results from Lake Muskoka Sampling Areas.



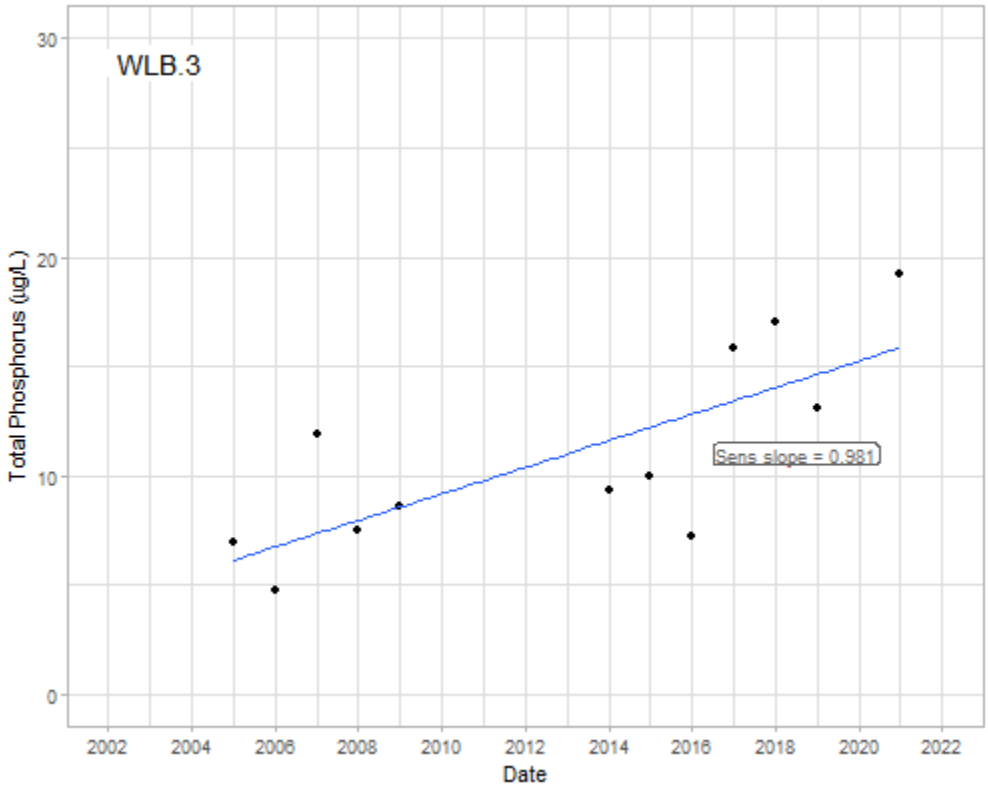
Note: ALL = Alport Bay; ARN = Arundel Lodge; BAL = Bala Bay; BMR = Beaumaris; BOY = Boyd Bay; DUD = Dudley Bay; EAS = East Bay; ELG = Eilean Gowan Island; MBA = Muskoka Bay; MSN = Muskoka Sands; MUS = Lake Muskoka; NRT = North Bay; SDP = Sandy Point; STE = Stephens Bay; TAY = Taylor Island; WAK = Walkers Point; WLB = Willow Beach; WTS = Whiteside Bay.

Figure 9. Summary of the 2021 Spring Total Phosphorus Results from Affiliate Lake and River Sites.



Note: BDY = Brandy Lake; BRU = Bruce Lake; CLR = Clear Lake; GLW = Gullwing Lake; IND = Indian River; JOR = Joseph River; LEO = Leonard Lake; LLJ = Little Lake Joseph; MIR = Mirror Lake; MOO = Moon River; MRV = Muskoka River; SKL = Skeleton Lake; SPC = Silver Lake (Port Carling); STR = Star Lake; SVR = Silver Lake (Gravenhurst)

Figure 10. Trends in Long-term Phosphorus Concentrations at WLB-3.



Note: WLB.3 = Willow Beach Nearshore Site #3.

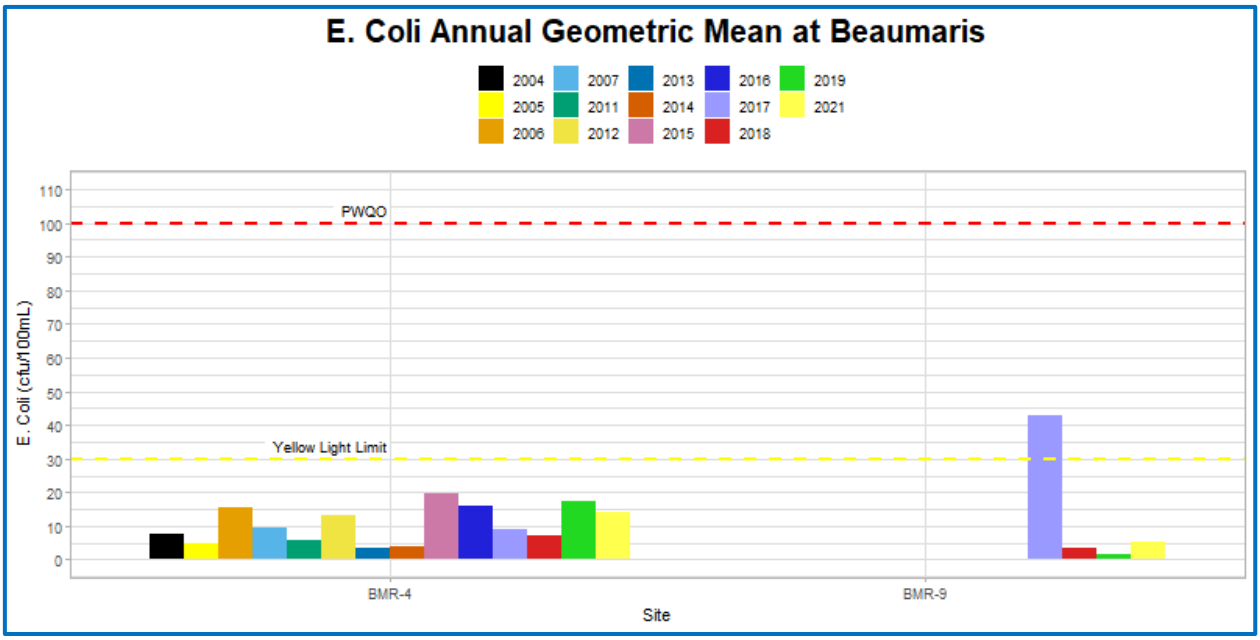
Sampling areas where *E. coli* counts were elevated (>50 cfu/100ml) in 2021 include Beaumaris (BMR-4 and 10), Brandy Lake (BDY-1, 2, 3, 5, and 6), Bruce Lake (BRU 1, 3, 4, 5 and 6), Clear Lake (CLR-5), Foot's Bay (FTB-3 and 5), Gull Lake (GUL-1, 2, 3, and 4), Indian River (IND-2, 4, 7, and 8), Minett (MIN-1, 6 and 9), Moon River (MOO-12), Muskoka Sands (MSN-2, 3 and 6), Taylor Island (TAY-2) and Windermere (WIN-4 and 5). Despite elevated concentrations during some sampling events many of the sites listed did not exceed the yellow light threshold for *E. coli* in 2021. The nearshore areas which exceeded a geometric mean of 30 cfu/100mL in 2021 were Bruce Lake (BRU), Gull Lake (GUL), Indian River (IND), Minett (MIN), and Windermere (WIN).

Bruce Lake was flagged for additional focus in 2019 (Beacon 2020) due to "substantially higher" phosphorus concentrations at BRU-3 (7.9 μg/L in 2019) relative to the deep-water station (BRU-0; 7.2 μg/L), though we suspect that BRU-6 (19.2 μg/L) was the intended site. Yearly mean phosphorus concentrations at Bruce Lake did not differ substantially in 2021, however elevated bacteria concentrations are a concern with three of five nearshore stations exceeding the yellow light trigger suggesting a continued focus on nearshore sampling at Bruce Lake is warranted.

Indian River has been flagged an area of concern due to the MLA yellow light trigger for *E. coli* bacteria being exceeded at three of the six nearshore sampling stations. All three bacteria samples collected at IND-2 in 2020 were storm event samples and bacteria counts can vary significantly both in space and over time.

Therefore, we recommend standard sampling continue at Indian River sites in 2022, however if early 2022 results suggest elevated *E. coli* additional sampling (i.e., 5 samples in one month) should be considered.

Figure 11. Example of the Presentation of Long-term *E. coli* Monitoring Figures.



3.6 Summary and Conclusions

The MLA Water Quality Initiative Program assigns stoplights to each sample area based on the annual monitoring and long-term data collected as described in Section 3.1. In 2021, 55 areas were sampled, 43 of which were assigned green lights, while eleven yellow lights and one red light were assigned based on the MLA criteria (Table 6). Yellow lights at four of the eleven sampling areas were the result of elevated bacteria concentrations, while five sampling areas (Boyd Bay, Bala Bay, Brandy Lake, Silver Lake (Port Carling) and Leonard Lake) experienced cyanobacterial blooms in 2018 - 2021 for which a causation study has not yet been completed. Blooms documented in 2021 did not exceed the MLA threshold of 20 µg/L and were therefore assigned a yellow light. Bruce Lake exceeded yellow light triggers for algae blooms and bacteria concentrations. Gullwing Lake was assigned a yellow light as a result of a 3-year average total phosphorus concentration that exceeded the 20 µg/L thresholds, however this was heavily impacted by an elevated concentration in 2021 which should be confirmed with follow-up sampling in 2022.

A single red light was assigned in 2021 to Willow Beach (WLB-3), where we identified a long-term statistically significant increasing trend in phosphorus concentrations. Additional sampling and investigation to assess the sources of phosphorus at this location and consideration of mitigation options is recommended. Results in 2021 were similar to those recorded in 2019 when 10 yellow and 1 red light were recorded.

Elevated bacteria at many sites in 2021 coincided with an increase in sampling during recorded storm events. This impact was also observed in some nearshore phosphorus sampling areas (e.g., BRA, MIN,

MSN, STI). Four samples are typically collected at sites during the course of the year, one per month, although in some cases only three were collected due to logistical challenges. Within several sampling areas 75-100% of the samples collected were collected during Moderate to Heavy storm events, which has not consistently been the case in past sampling years based on our review of the database. Storm sampling will almost certainly affect the phosphorus and bacteria concentrations measured, particularly at nearshore monitoring stations. Developing and maintaining a protocol for sampling during storm events as a part of the ongoing program is recommended to ensure interannual and long-term comparisons do not become subject to significant sampling bias.

Table 6. Summary of MLA WQI Threshold Exceedances in 2021.

Area	Site	*E. coli*	Total Phosphorus	Cyanobacteria Bloom	Stoplight
Bala Bay	BAL-0			2020	Yellow
Boyd Bay	BOY-0			2018	Yellow
Brandy Lake	BDY-0			2019, 2020	Yellow
Bruce Lake	BRU-4, BRU-5, BRU-6	>30 cfu /100 mL		2020	Yellow
Gull Lake	GUL-4	>30 cfu /100 mL			Yellow
Gullwing Lake	GLW-0		3-yr avg >20 μg/L		Yellow
Indian River	IND-2, IND4, IND8	>30 cfu/ 100 mL			Yellow
Leonard Lake	LEO-0			2020, 2021	Yellow
Minett	MIN-1, MIN-6	>30 cfu/ 100 mL			Yellow
Silver Lake	SPC-0			2020	Yellow
Windermere	WIN-5	>30 cfu/100 mL			Yellow
Willow Beach	WLB-3		5-year increase		Red

The MLA WQI field protocols require volunteers to re-sample a site if *E. coli* counts are greater than 50 cfu/100mL, however we found that consistent resampling was not performed in 2021. *E. coli* counts exceeded 50 cfu/100 mL at 41 (18%) of 232 sampling events and retests were not completed in 28 of those events. Maintaining sampling protocols is recommended to ensure anomalous data can be confirmed and to maintain consistency, as much as is possible, between current and historical samples.

4. Recommendations

As part of our first year assisting the MLA with their ongoing Water Quality Initiative Monitoring Program, HESL has formulated several recommendations which we believe will improve the program moving forward. These have been discussed within the technical report and are briefly summarized below.

1. Review of the sampling sites by the Environment Committee has been an annual part of the MLA WQI Program and should continue prior to sampling in 2022. We recommend maintaining consistent sampling at long-term sites whenever possible. Trend analyses in 2021 were performed

on sites with a minimum of 5 years of data, which represent the absolute minimum number of samples to reasonably draw conclusions on trends over time. Additional data at long-term monitoring stations would strengthen trend analyses and benefit the program in the future.

2. HESL recommends that any sampling for phosphorus during storm events be done in addition to routine non – event sampling and result interpreted separately in order to distinguish trends over time from specific storm or source-related causes.

3. The current methodology for total phosphorus does not specify a minimum number of sample on which an annual mean should be based. HESL recommended that the MLA establish a protocol to ensure annual phosphorus concentrations are calculated consistently.

4. The current methodology states that "volunteers assess the amount of rainfall over the 24-hour period prior to sampling and record it as Heavy, Moderate, Light, or None. Rainfall data is occasionally used to assess the significance of high bacteria counts". It may be useful to establish thresholds for each category for consistency over time in the sampling program.

5. Retesting of bacteria samples that exceed the MLA Sampling Protocol threshold of 50 cfu/100 mL should be maintained. It is possible that a lack of sampling in 2020 has created the need to remind sample volunteers about some of the sampling protocols, HESL will work with the Environment Committee to determine the best way to address this issue prior to sampling in 2022.

6. Water clarity (i.e., Secchi Disk Depth) data that are currently collected under the WQI Program are highly variable. A thorough review of the Secchi data collected by the MLA to date may help eliminate anomalous data if present, while an updated assessment of the long-term trends in Secchi depth may be a valuable addition to the MLA WQI Program.

7. Willow Beach has been identified as an area of concern based on long-term increasing trends in phosphorus since monitoring began. Additional monitoring within the watershed (e.g., the creek along Ziska Rd.) may be warranted to assess phosphorus sources and mitigation possibilities.

8. Minett continues to be an area of concern due to historically elevated bacteria counts at MIN-1 and yellow stoplight exceedances at MIN-1 and MIN-6 in 2021. Furthermore, the spring phosphorus concentration in Wallace Bay (MIN-6) in 2021 was the highest recorded to date, however this sample was collected during a storm event making it more difficult to put into a long-term context.

9. Bruce Lake was flagged for additional focus in 2019 due to "substantially higher" phosphorus concentrations at BRU-3 (7.9 μg/L in 2019) relative to the deep-water station (BRU-0; 7.2 μg/L), though we suspect that BRU-6 (19.2 μg/L) was the intended site. Yearly mean phosphorus concentrations at Bruce Lake did not differ substantially in 2021, however elevated bacteria concentrations are a concern with three of five nearshore stations exceeding the yellow light trigger suggesting a continued focus on nearshore sampling at Bruce Lake is warranted.

10. Continued sampling at Gullwing Lake in 2022 is recommended to determine if the recent anomalous spring phosphorus concentration recorded in 2021 is a reason for concern or a

potentially contaminated sample. We recommend that Gullwing Lakes spring phosphorus sample be collected as a duplicate to allow additional QA/QC at that site.

11. Indian River has been flagged an area of concern due to the MLA yellow light trigger for *E. coli* bacteria being exceeded at three of the six nearshore sampling stations. All three bacteria samples collected at IND-2 in 2020 were storm event samples and bacteria counts can vary significantly both in space and over time. Therefore, we recommend standard sampling continue at Indian River sites in 2022, however if early 2022 results suggest elevated *E. coli* additional sampling (i.e., 5 samples in one month) should be considered.

12. Windermere has been flagged as an area of concern in 2021. Nearshore phosphorus concentrations, particularly at WIN-5 near Parker's Marina and the inflow of a small creek, continue to be elevated relative to other locations within the watershed. Bacteria concentrations have also exceeded the yellow light threshold at WIN-5.

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