Sherbrooke Lake

2019 Water Quality Monitoring Report

Prepared for

Municipality of Chester

Municipality of the District of Lunenburg

Sherbrooke Lake Stewardship Committee

By

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Executive Summary

Water quality has been monitored at Sherbrooke Lake since 2017, in response to concerns regarding the development of a public access site and the increased recreational usage of the lake. The Sherbrooke Lake Stewardship Committee was created by both the Municipality of the District of Lunenburg and the Municipality of Chester. This committee oversees the Sherbrooke Lake Monitoring Program which is managed by Coastal Action and executed by committee members and trained volunteers. The 2019 field season represents the second of five years of planned monitoring.

Water temperatures for the lakes and streams pose minimal threat to aquatic life. Water temperatures exceeded the recommended 20°C thermal threshold for cold-water fish once – in August. No stream sites exceeded the temperature threshold. A thermocline formed at both Lake 1 and Lake 2 sites during the summer months, with deeper waters providing thermal refuge for organisms; however, the thermocline present at Lake 1 was minimal, with only 3.9°C difference between surface and bottom waters.

Dissolved oxygen concentrations for Sherbrooke Lake and its tributaries were within acceptable ranges for aquatic life. No lake or stream site fell below the 6.5 mg/L Canadian Council of Ministers of the Environment (CCME) minimum requirement for aquatic life. The thermocline present at Lake 1 and Lake 2 did result in the stratification of oxygen. Lake 1's weak thermocline resulted in higher dissolved oxygen within the profile, with hypoxic conditions occurring below 1 m depth, while Lake 2 displayed reductions in dissolved oxygen throughout the depth profile with hypoxic conditions beginning 10-m above the lake bottom.

pH in Sherbrooke Lake does not pose a risk to aquatic organisms and appears to buffer the acidity of the seven monitored tributaries. Although no lake sites had pH measurements below CCME's 6.5-pH minimum threshold, all stream sites fell below this guideline. In September 2019, several sites fell below the 5.0-pH threshold for the protection of fish eggs, which may impact native fish species using these headwater streams for spawning.

Nutrients in Sherbrooke Lake were below suggested thresholds; however, concentrations have increased since 2018. Total phosphorus concentrations fell below Ontario's Ministry of Environment and Climate Change (MOECC) guideline of 0.02 mg/L at all lake sites, and all but one stream sample. All lake and stream sites fell below the 0.9 mg/L Dodds & Welch (2000) threshold for freshwater environments, with only one lake sample exceeding the 0.3 mg/L threshold for oligotrophic lakes (Underwood and Josselyn, 1979). Although phosphorus concentrations at depth were equal to or higher than surface water concentrations, the ratio of bioavailable orthophosphate was low, limiting the potential for internal loading. Similarly, nitrogen concentrations at-depth were below those measured at the surface, indicating minimal risk for nutrient enrichment during the lake turnover. Both nitrogen and phosphorus concentrations increased in the tributary streams following the Hurricane Dorian rainfall event; however, the elevated concentrations did not appear to impact lake water quality, as no lake concentrations increased.

E. coli concentrations fell below both primary and secondary Health Canada (2012) recreational limits within the lake, but not its tributaries. No lake sites had more than 20 CFU/100 mL of *E. coli*, well below

the 400 CFU/100 mL and 1000 CFU/100 mL primary and secondary thresholds, respectively. Stream sites fell below both thresholds for all except one sample – 720 CFU/100 mL at Pine Lake Brook in September. The exceedance of Pine Lake Brook's bacteria sample coincided with other elevated bacteria concentrations from other sites due to the Hurricane Dorian rainfall event. Although all streams displayed elevated *E. coli* concentrations, no negative effects were observed at the lake sites, as no site exceeded 20 CFU/100 mL. Flushing of pollutants into nearby waterways is common following heavy rainfall events.

Sediment collected from Lake 1, Lake 2, Lake 4, and Zwicker Brook indicated a moderate level of contamination. All three lake sites exceeded CCME arsenic and cadmium guidelines, with Lake 1 also exceeding mercury guidelines, and Lake 2 exceeding mercury and manganese guidelines. Zwicker Brook did not exceed any metal guidelines.

Sherbrooke Lake's low productivity places it along the oligotrophic-mesotrophic boundary. This trophic status is the same as 2018; however, nutrient concentrations and the frequency of algal bloom reporting have increased in 2019. Continued water quality monitoring is necessary to track changes within the lake, in coordination with an educational component and a communications plan.

1. Introduction

1.1. Sherbrooke Lake Background

Sherbrooke Lake (SL) is located in the headwaters of the LaHave River watershed, in Southern Nova Scotia. Sherbrooke Lake covers 16.94 km^2 – the largest waterbody within the LaHave watershed – and has a 285 km^2 drainage basin (Figure 1). Although SL is fed by 14 inlet streams, many are less than 1 km in length. Sherbrooke River is the largest inlet stream feeding SL, while North Branch is the only outlet stream of the lake - located on the southwest side of the lake.

The water quality of the LaHave River watershed has been monitored by Coastal Action since 2007. The program monitors 15 sites throughout the watershed, including the Sherbrooke River which feeds the lake, and the lake's outlet downstream. A water quality index (WQI) report card on the status of the watershed and the individual sites is reported annually and available on the Coastal Action website (www.coastalaction.org).

Forestry, silviculture, and agriculture dominate the LaHave River watershed and SL drainage area. Rural communities are also located throughout, with cottages and camps found along the edge of SL.

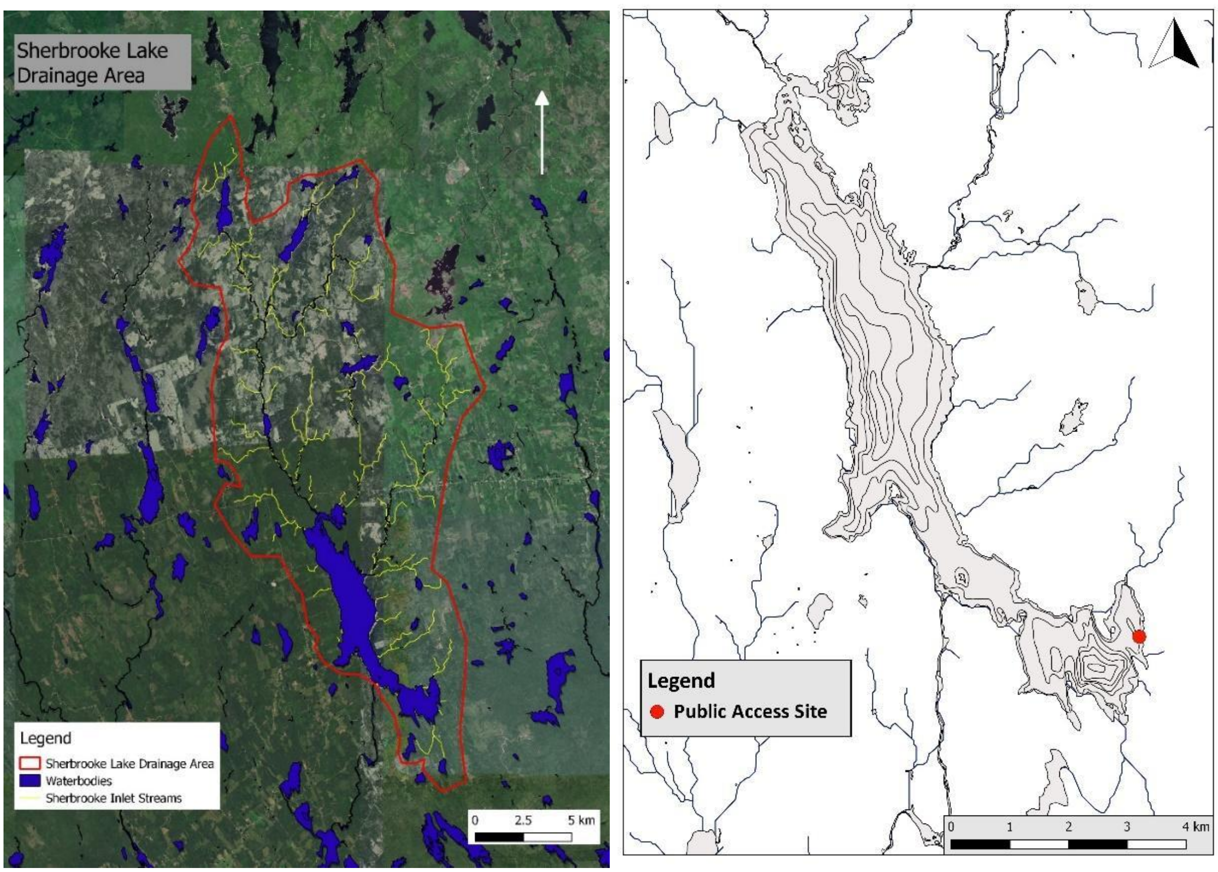

Figure 1: Left - Streams (yellow) and drainage boundary (red) of Sherbrooke Lake. Right – Bathymetry of Sherbrooke Lake and proposed public access site (red circle).

In 2015, the Municipality of the District of Lunenburg (MODL) began investigating ways to allow public access to the lake by appointing the Sherbrooke Lake Access Advisory Committee (SLAAC). SLAAC was to present options for accessing SL, and to obtain community advice and input throughout the process. After public consultations, held by UPLAND Planning + Design, a section of land on the south-eastern side of the lake was selected for the public access site (Figure 1). In the report provided to SLAAC by UPLAND Planning + Design, the implementation of a water quality committee for Sherbrooke Lake was recommended.

1.2. Program Background

As a result of the planned public access site at SL, the Sherbrooke Lake Stewardship Committee (SLSC) was formed. The SLSC, a joint commitment between MODL and the Municipality of Chester (MOC), is comprised of one Coastal Action staff, two residents of MODL, two residents of MOC, a water quality expert, and supporting municipal staff. The SLSC was tasked with developing and implementing a water quality monitoring program to: determine a baseline understanding of water quality conditions within SL prior to construction of the public access site, monitor water quality during and after the construction, and provide evidence-based advice to MODL and MOC regarding ways to address water quality changes and concerns within the lake.

The SLSC developed a water quality monitoring program to track the baseline and changes in water quality conditions within SL. Coastal Action acts as technical support for a set of trained volunteers, who conduct the monthly and rainfall-dependent sampling for the program. Although a preliminary monitoring program was implemented in 2017, the full Sherbrooke Lake Water Quality Monitoring Program was conducted in 2018 and 2019.

Further details on the program can be found in the *Sherbrooke Lake Water Quality Monitoring Program*, and previous program results are found in the *Sherbrooke Lake Water Quality Monitoring Report* (2018); all are available upon request from either the Municipality of Chester or the Municipality of the District of Lunenburg.

1.3. Review of the 2018 Sherbrooke Lake Water Quality Monitoring Report

The trophic state of SL in 2018 was calculated for two different sites: Lake 1 and Lake 2. Both had a trophic state of borderline oligotrophic-mesotrophic. The borderline status indicates that the lake has low phosphorus concentrations but has a moderate presence of biological activity and, therefore, remains vulnerable to outside influences which may degrade water quality.

Thermal and oxygen profiles were conducted at both Lake 1 and Lake 2 sites. Thermal stratification of the lake was observed at Lake 2, with a weak thermocline at Lake 1. Due to the presence a thermocline, stratification of dissolved oxygen was also observed at both sites. Depletion of oxygen in the deeper waters at both locations indicates minimal mixing between surficial and deep waters, with concentrations less than 2 mg/L in the bottom waters posing a threat to aquatic organisms.

Nutrients in SL fell below literature guidelines for both nitrogen and phosphorus for most samples. Stream sites had higher concentrations of both nutrients, indicating nutrient loading from surrounding sources. Spikes in nutrients and bacteria following rainfall events highlight the role of overland flow in flushing nutrients and bacteria from nearby sources into the streams and lake.

Concentrations of metals within the lake sediment exceeded Nova Scotia guidelines. Arsenic, cadmium, lead, and mercury exceeded their guidelines, with manganese and selenium approaching their respective thresholds. Continued sediment monitoring was recommended to monitor metal concentrations and changes in loading to the lake as development continues.

1.4. Changes to the 2019 Sherbrooke Lake Water Quality Monitoring Program

Several changes were applied to the Water Quality Monitoring Program for the 2019 season (Figure 2, Table 1):

- A weather station was installed on a private property at Sherbrooke Lake, to monitor the lake's microclimate.
- The Fecal Indicator Bacteria species was switched from fecal coliform to Escherichia coli (*E. coli*) at all sites to adhere to Health Canada standards for bacteria monitoring in freshwaters.
- Two summer-only sites (Chl 1 and Chl 2) were dropped from the sampling program.
- Sediment sampling was added to the monitoring program for Lake 1.
- Sediment sampling was to be rotated annually to capture concentrations from all seven primary inlet streams, with 2019 sampling at Zwicker Brook.
- Hydrocarbon sampling was removed from the monthly lake water samples and added to the list of parameters in the one-time sediment samples.
- All water chemistry parameters, except for *E. coli*, were removed from sampling at Lake 3.
- Lake 4 was upgraded to a full site, tested monthly for *E. coli*, total suspended solids (TSS), nutrients (nitrogen and phosphorus), and physical water parameters (using the multi-parameter YSI probe and a Secchi disk).
- As the rainfall sampling and September sampling occurred on the same day, the September bimonthly stream sites were not sampled as to avoid duplication from the rainfall-dependent stream samples. The costs for four saved samples were used to offset the costs of Coastal Action staff installing the Sherbrooke Lake weather station.
- A communications plan was added to the program to help share results and encourage conservation and protection of local waterbodies. The communications plan included:
    - A full technical 2019 Sherbrooke Lake Water Quality Monitoring Report.
    - A brief two-page overview of the 2019 Sherbrooke Lake Water Quality Monitoring Report.
    - A Frequently Asked Questions document regarding the SLSC and the monitoring program.
    - An article to be included in the Municipal Matters and Municipal Insight newsletters.
    - A Carolyn's Corner article to be included in the South Shore Breaker.

- An article to be included in Coastal Action's quarterly Coastal Chronicle newsletter.
- Various social media posts to be shared by the MOC, MODL, and Coastal Action.

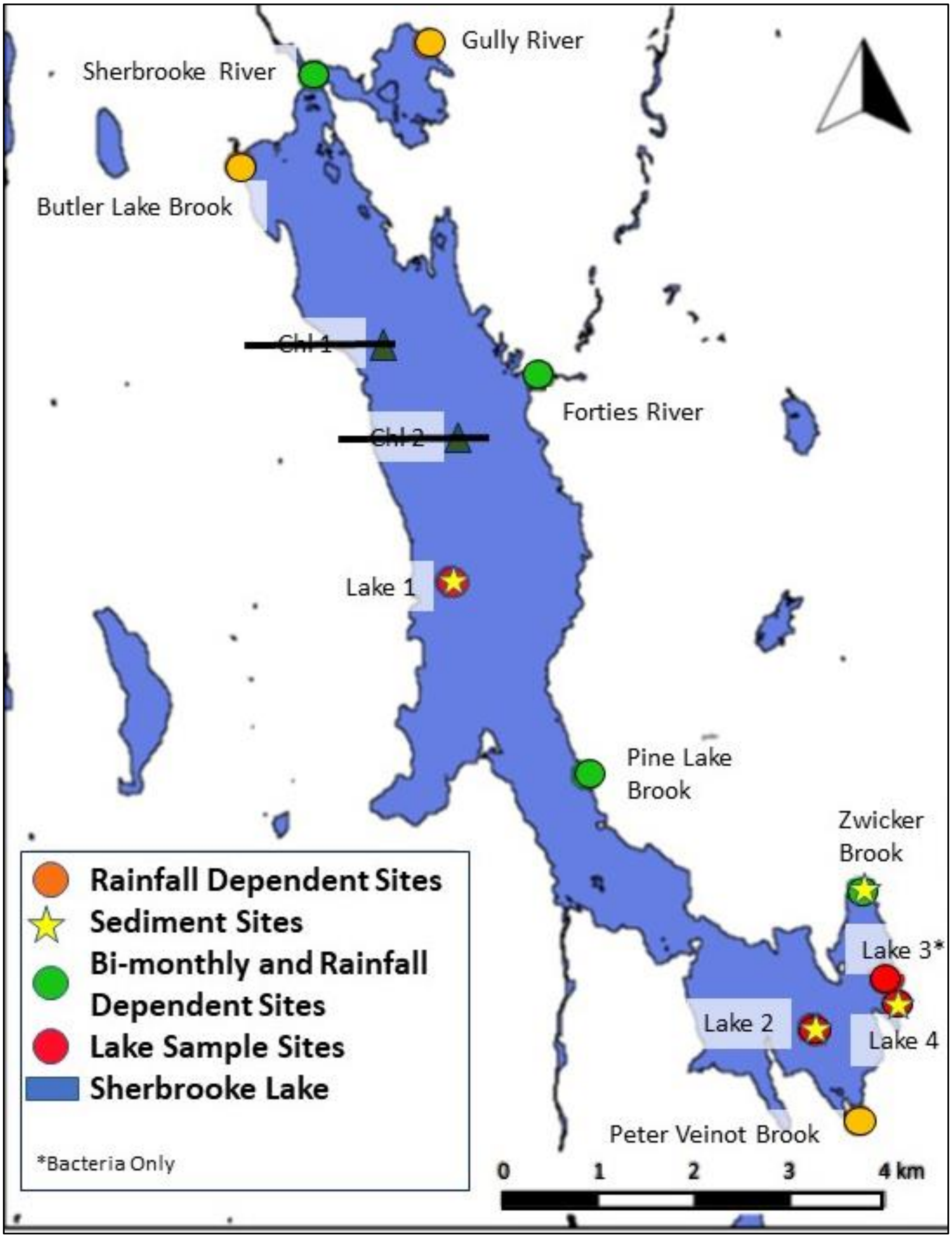

Figure 2: Sherbrooke Lake 2019 Water Quality Monitoring Program sampling locations. Crossed out sampling sites represent discontinued sampling sites; Chl 1 and Chl 2 were discontinued for the 2019 program.

Table 1: Monitoring program parameters, site locations, and sampling frequencies for the 2019 Sherbrooke Lake Water Quality Monitoring Program. GPS coordinates to access river sites via road are in blue.

Sample Site Name	Site Coordinates (UTM Zone 20T)	Sampling Frequency	Parameters Sampled
Lake 1	372287 E, 4947688 N	Monthly (May-Oct.)	YSI[+], hydrocarbons, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a*, Secchi disk depth. One-time depth profile, nutrients at-depth, and sediment grab.
Lake 2	376072 E, 4943018 N	Monthly (May-Oct.)	YSI, hydrocarbons, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a*, Secchi disk depth. One-time depth profile, nutrients at-depth, and sediment grab.
Lake 3 (Public Access)	376831 E, 4943540 N	Monthly (May-Oct.)	YSI, *E. Coli*, Secchi disk depth.
Lake 4 (Public Access Boat Launch)	376844 E, 4943371 N	Monthly (Sept-Oct.)	YSI, hydrocarbons, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.* One-time depth profile and sediment grab.
Butler Lake Brook	370079 E, 4952036 N	One-time, rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.*
Sherbrooke River	369774 E, 4954072 N	Bi-monthly (May, July, Sept.) & rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.*
Gully River	372246 E, 4953404 N	One-time, rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.*
Forties River	373539 E, 4949823 N	Bi-monthly (May, July, Sept.) & rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.*
Pine Lake Brook	373705 E, 4945670 N	Bi-monthly (May, July, Sept.) & rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.*
Zwicker Brook	376582 E, 4944469 N	Bi-monthly (May, July, Sept.) & rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.* One-time dept profile and sediment grab.
Peter Veinot Brook	376507 E, 4941558 N	One-time, rainfall-dependent	YSI, total suspended solids, total phosphorus, total nitrogen, *E. Coli,* chlorophyll *a.*

[+]YSI is a multi-parameter water quality device that measures the physical characteristics (temperature, dissolved oxygen, pH, total dissolved solids, salinity, pressure, and specific conductivity) of the water at the time of sampling.

1.5. Objectives and Scope of Work

The objective of this program is to provide a water quality overview for Sherbrooke Lake, which can help the SLSC provide evidence-based advice to both MODL and MOC. Within the SLSC, Coastal Action's scope of work included:

- Designing and writing the Sherbrooke Lake 2019 Water Quality Monitoring Program;
- Ordering and ensuring correct sampling bottles and analysis from Maxxam Analytics;
- Creating and printing waterproof field sheets for each sampling month;
- Ordering and installing a weather station at Sherbrooke Lake;
- Ordering and downloading sampling locations to a new GPS;
- Calibrating and caring for the MODL/MOC-owned YSI monthly;
- Ensuring volunteers obtained all required field equipment for field work;
- Organizing algal bloom sampling as needed with volunteers, Nova Scotia Environment;
- Conducting one-time field sediment and nutrient at-depth sampling with volunteers;
- Transferring data from field sheets and Maxxam into a database and analyzing data;
- Downloading and analyzing weather data from the Sherbrooke Lake weather station;
- Attending SLSC meetings and presenting water quality results;
- Writing communications regarding the Sherbrooke Lake Water Quality Monitoring Program and its results; and
- Preparing this report to summarize results and recommendations for water quality related to Sherbrooke Lake.

2. Sherbrooke Lake Monitoring Results

2.1. Sherbrooke Lake Weather

Following the installation of a weather station at Sherbrooke Lake, the microclimate conditions at Sherbrooke Lake were monitored from May 15 to October 11, 2019. Air temperatures at Sherbrooke Lake ranged from -0.5°C to 33.1°C (Figure 3). Minimal rainfall accumulated at the lake during the hottest months – July and August (Figure 4). The largest rainfall occurred on September 8, 2019 during Hurricane Dorian, with >100 mm rainfall falling within 36 hours. As the weather gauge is protected on two sides by forest, wind speed and direction are considered skewed and are not included in this report.

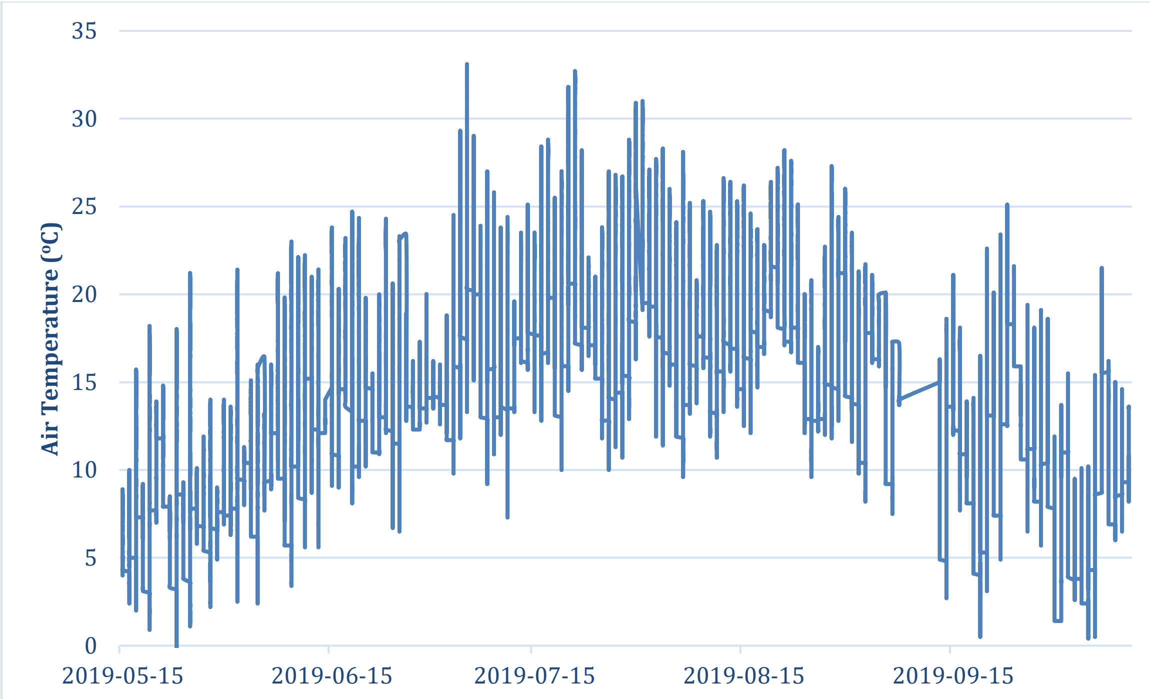

Figure 3: Daily air temperature data at Sherbrooke Lake, from May-October 2019.

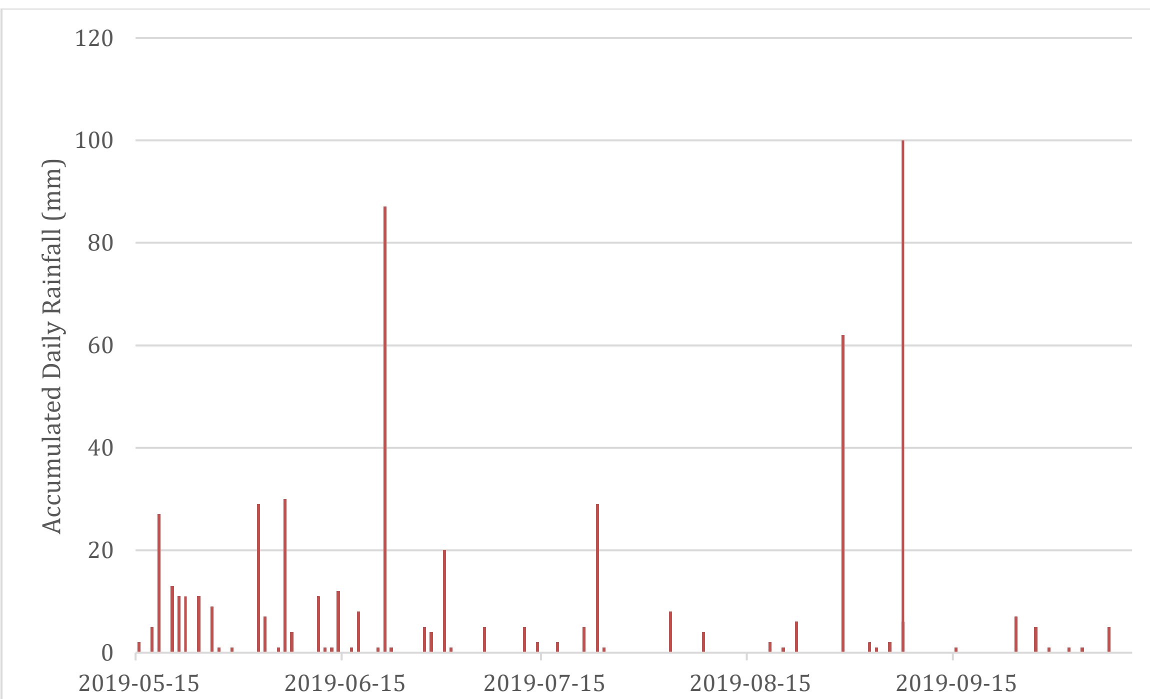

Figure 4: Daily accumulated rainfall at Sherbrooke Lake, NS from May-October 2019. Rainfall data from August 27th was removed and labelled a misread by the weather station, and data was added to September 8th to account for rainfall which fell when the station went offline during Hurricane Dorian.

2.2. Physical Water Parameters

2.2.1. Surface Water Temperature

Water temperature is a key parameter in understanding and assessing the health and productivity of an aquatic environment, as it directly impacts organisms, while also affecting other physical and chemical parameters. Water temperature can impact the presence and survival of fish, where temperatures outside of a species' optimal range can negatively affect fish survival (NSSA, 2014); 20°C is the maximum acceptable temperature for salmon and trout (Alabaster and Lloyd, 1982). In addition, increased water temperature decreases a waterbody's capacity to hold oxygen, thereby limiting available oxygen to aquatic organisms.

In the lake sites, temperatures ranged from 9.0-23.2°C, while streams ranged from 7.4-16.3°C (Figures 5 and 6). The lake sites only exceeded 20°C during August 2019, while the stream sites never exceeded 20°C during the 2019 monitoring period. Lake temperatures have remained comparable to 2018 values; stream temperatures have fallen compared to the 2018 values. Sherbrooke and Forties River had the highest recorded water temperatures in 2018, with exceedances of 20°C occurring in both July and August. Although no streams were measured in August 2019, both Sherbrooke and Forties River were at least 3.7°C lower in July 2019 compared to their July 2018 counterparts. The shift in 2019 data towards cooler temperatures may be explained by the earlier start of sampling – sampling at the beginning of each month instead of the end – and collecting the rainfall-dependent sample in September rather than August. These two changes resulted in minimal summer sampling, with no sampling during the hottest period of the summer (no sampling was conducted in August), skewing the data to represent cooler conditions.

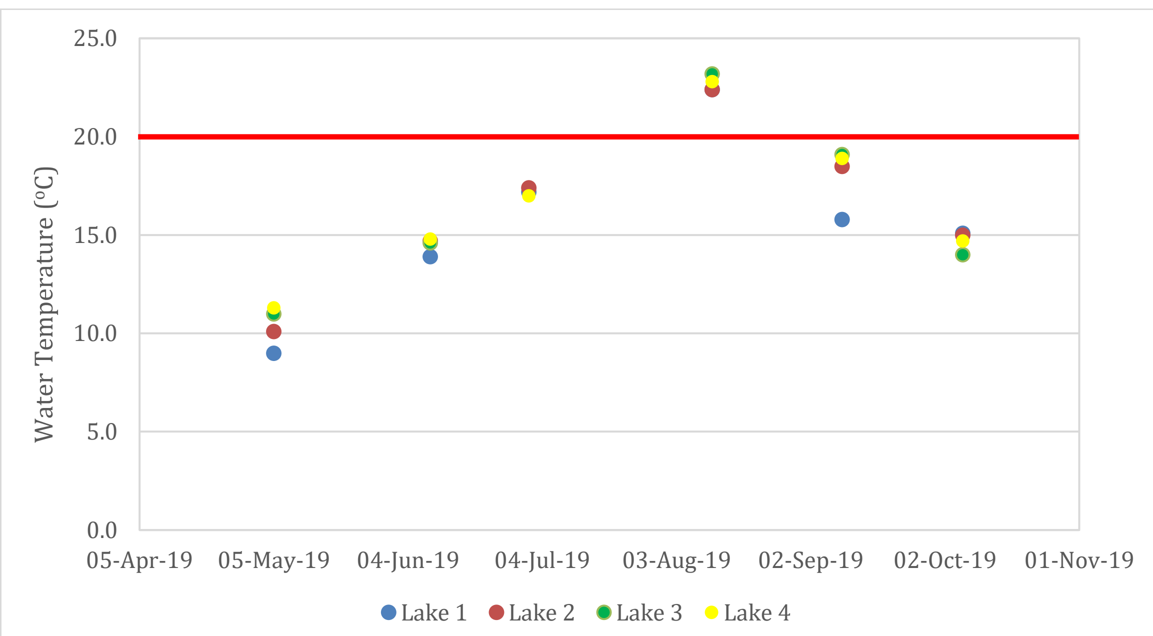

Figure 5: Water temperatures at four monthly lake sites (Lake 1-4) during the May-October 2019 SL water quality field season. Red line indicates the 20°C limit for survival of aquatic organisms.

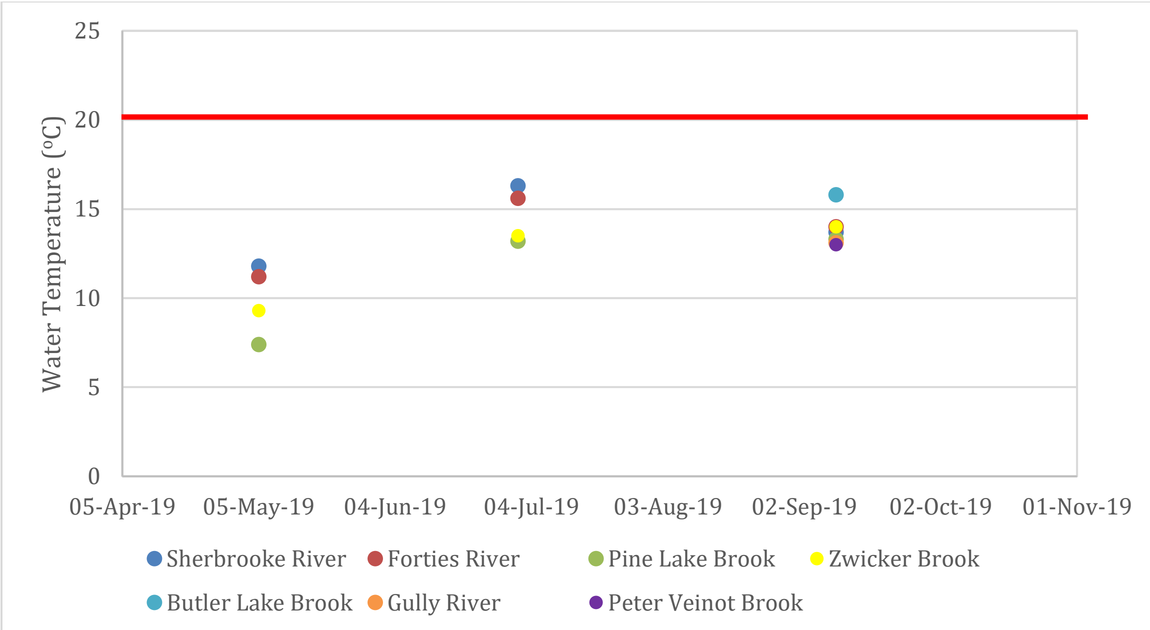

Figure 6: Water temperatures at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season. Red line indicates the 20°C limit for survival of aquatic organisms.

2.2.2. Surface Dissolved Oxygen

Dissolved oxygen (DO) is another key physical water parameter, as it is required for the survival of aquatic organisms and affects how nutrients are cycled and released within lake waterbodies. The Canadian Council of Ministers of the Environment (CCME) set a guideline of ≥6.5 mg/L for the protection of aquatic life for cold-water species – species found in lakes such as Sherbrooke (CCME, 1999). DO not only affects aquatic organisms but is also controlled by organisms (due to consumption), water temperature, and the waterbody's ability to mix and engulf DO (wind and waves increase dissolved oxygen into the water).

No lake or stream site dropped below the 6.5 mg/L CCME aquatic threshold during the 2019 field season (Figures 7 and 8). DO concentrations drop throughout the summer, at both lake and stream sites, coinciding with increased biological demand. DO concentrations are higher than in 2018 (Table 2), possibly a skewed trend due to a shift in sampling timing, which captured cooler periods which would have higher oxygen dissolution capacity. Although it appears that Lake 3 is the only site where 2018 values are higher than 2019 values, this is misleading, as the site was only added in fall 2018 and therefore the 2018 mean does not represent the full 2018 year. In addition, as Butler Lake Brook, Gully River, and Peter Veinot Brook are rainfall-dependent samples, their mean values are not representative of the entire field season as they are only sampled once per season.

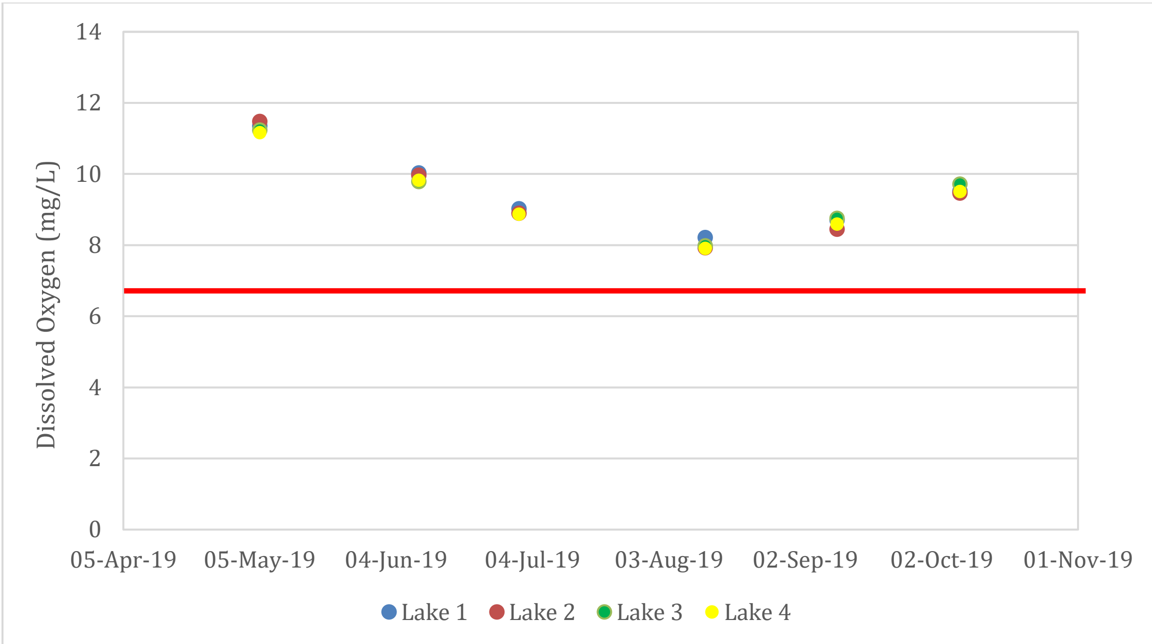

Figure 7: DO at four monthly lake sites (Lake 1-4) during the May-October 2019 SL water quality field season. Red line indicates CCME's 6.5 mg/L DO minimum-threshold for survival of aquatic organisms.

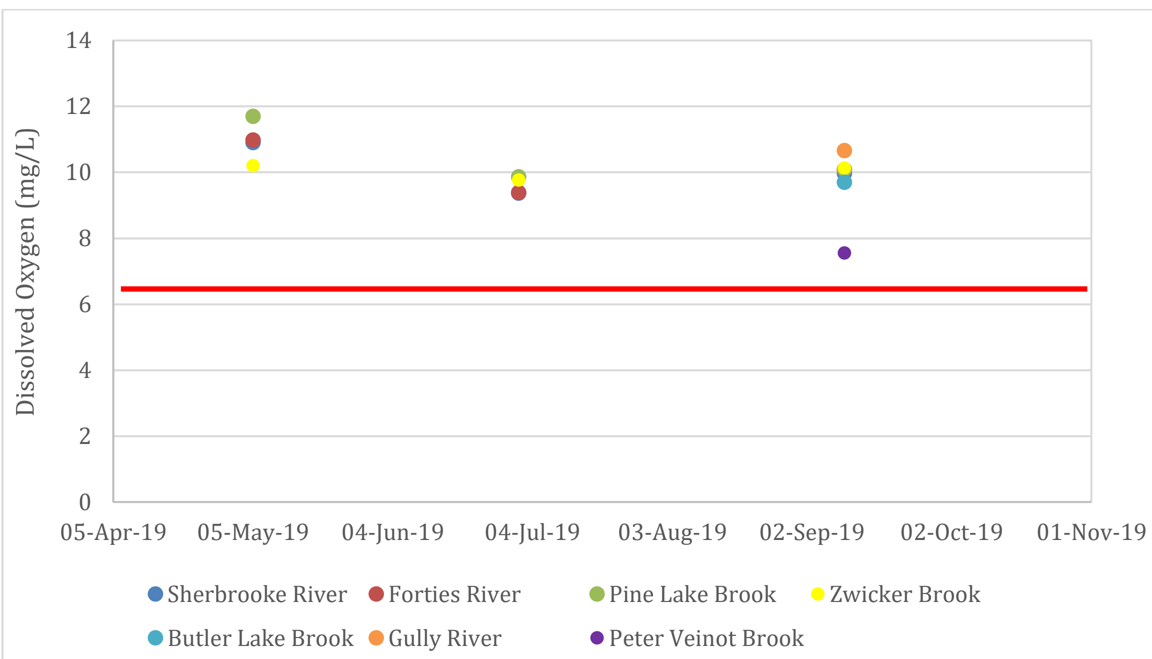

Figure 8: DO at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook). Red line indicates CCME's 6.5 mg/L DO minimum-threshold for survival of aquatic organisms.

Table 2: Mean DO concentrations for the four lake sites and seven stream sites of the Sherbrooke Lake Monitoring Program for the 2018 and 2019 field seasons.

Site Type	Site	Mean DO (mg/L)	
		2018	2019
Lake	Lake 1	8.91	9.50
	Lake 2	8.87	9.37
	Lake 3	8.94	9.50
	Lake 4	9.50	9.30
	Sherbrooke River	8.86	10.09
	Forties River	8.85	10.15
Stream	Pine Lake Brook	9.36	10.55
	Zwicker Brook	8.47	10.04
	Butler Brook	8.99	9.70
	Gully River	9.0	10.66
	Peter Veinot Brook	6.41	7.56

2.2.3. Depth Profiles

2.2.3.1. At-Depth Water Temperature

The water profile at lake sites 1 and 2 in August 2019 indicate that both sites have a thermal stratification; however, Lake 1 has a more pronounced, established thermocline compared to Lake 2 (Figure 9). The difference in thermocline strengths for 2019 is comparable to those observed in 2018. Stratification at Lake 1 starts at 7 m depth, with a thermocline layer of approximately 4 m and a temperature change of 3.9°C. For Lake 2, stratification starts at a shallower depth – 5 m – and has a greater thermocline thickness and temperature change, 10 m and 12.5°C, respectively. Water temperatures fell below the 20°C threshold for aquatic life at depths below 8 m at Lake 1 and 6 m at Lake 2. The Lake 1 and Lake 2 2019 profiles are similar to the 2018 profiles, with only a small increase in temperature observed at the lower depths of the two sites differentiating the two years.

The presence of a thermocline at both lake sites indicates that the nutrient-rich, cold deep waters are not mixing with the nutrient-limited, warm surface waters during the summer months; mixing and redistribution of nutrients within the lake is therefore only occurring during spring and fall turnover, when water temperature is uniform at all depths and no density differences prevent mixing.

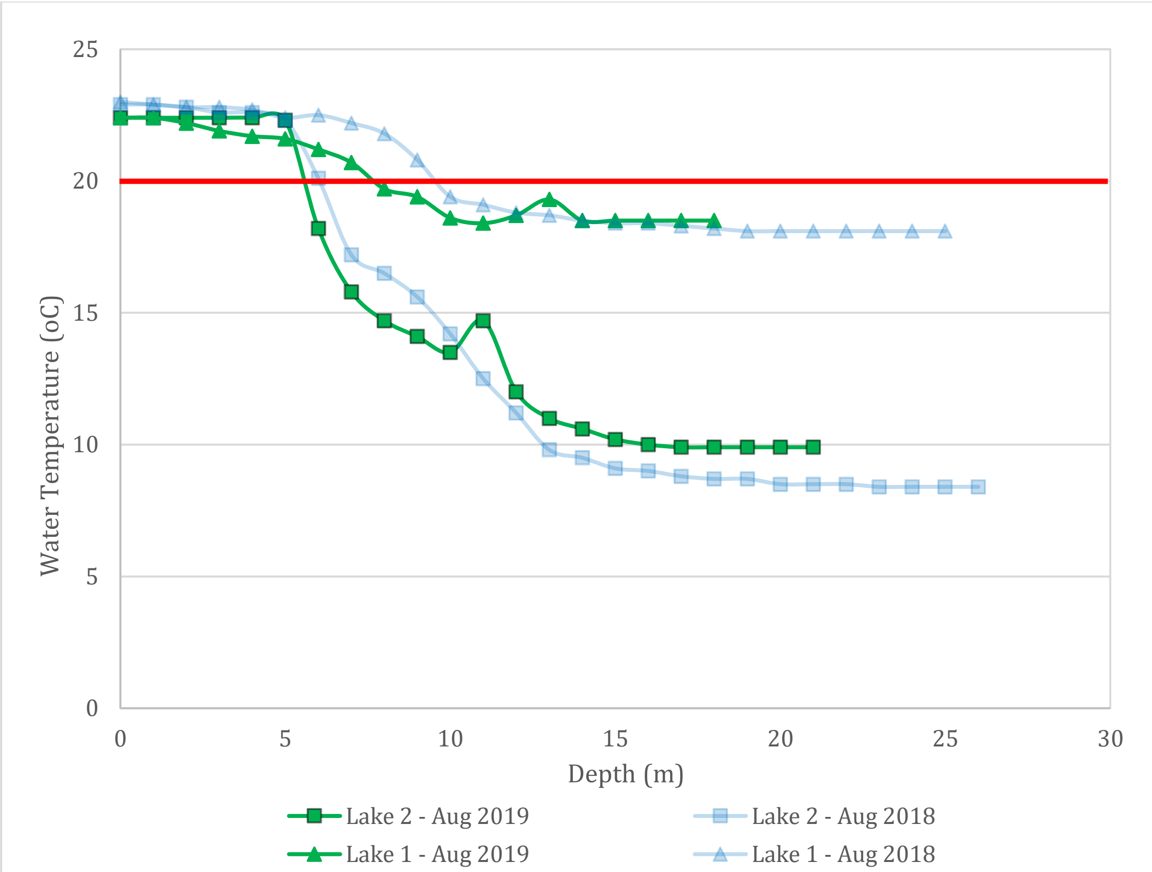

Figure 9: Water temperature depth profiles from two lake sites sampled in August 2018 (blue) and 2019 (green). Red line indicates the 20°C limit for survival of aquatic organisms.

2.2.3.2. At-Depth Dissolved Oxygen

In addition to the thermocline that is present in the lake sites' depth profiles, DO is also stratified at the two sites (Figure 10). Of the four common DO profiles in lakes (Figure 11), both sites appear to have a negative heterograde curve. Negative heterograde curves have a distinct reduction in DO at depth – this may be due to increased organic matter trapped within the thermocline, acting as a source of food for microbes and increasing DO depletion from microbial decomposition. DO increases past the decomposition depth due to the lack of food encouraging microbial decomposition. Although the negative heterograde curve is consistent for Lake 2 with 2018, this profile is new for Lake 1, which had a clinograde curve in 2018. The presence of microbial decomposition at depth for both sites may be linked to the increased algal blooms observed within the lake throughout the summer; however, even with the increased microbial decomposition, DO concentrations for both sites are higher than those recorded in 2018. The drop in DO at Lake 2 is consistent with 2018 and is linked with high oxygen consumption of microbial activity along the sediment surface.

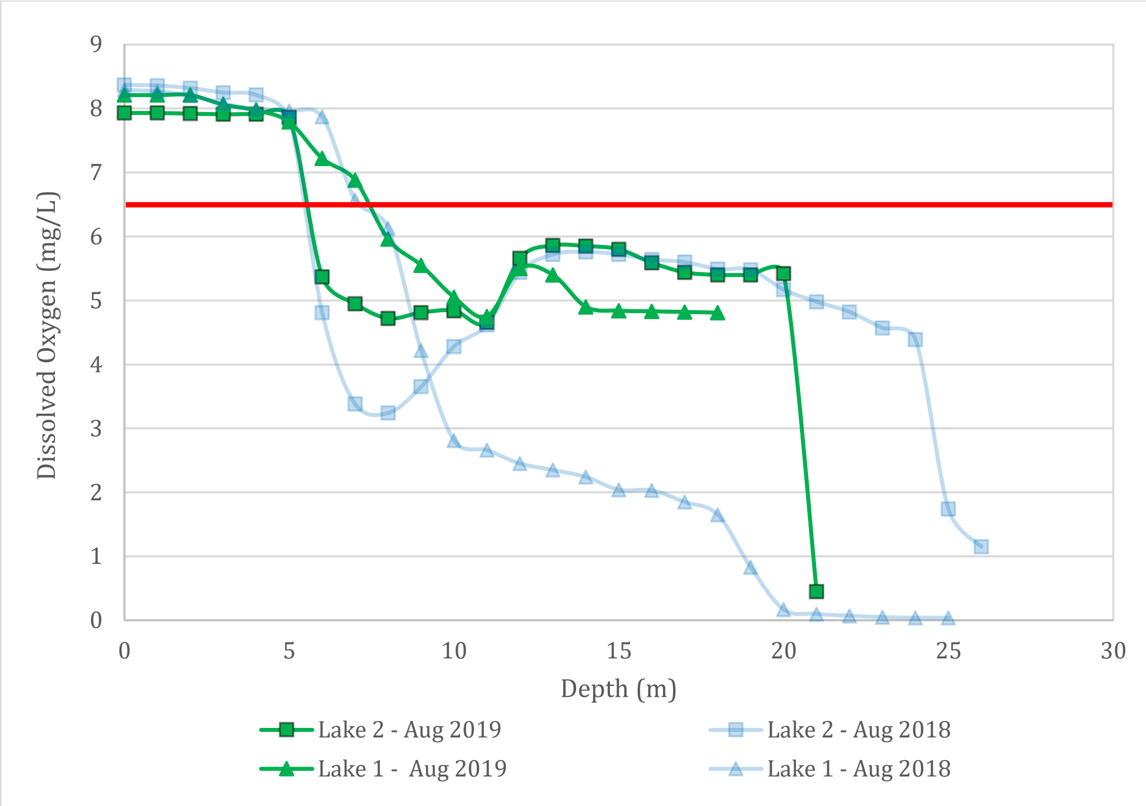

Figure 10: DO depth profiles from two lake sites sampled in August 2018 (blue) and 2019 (green). Red line indicates CCME's 6.5 mg/L DO minimum-threshold for survival of aquatic organisms.

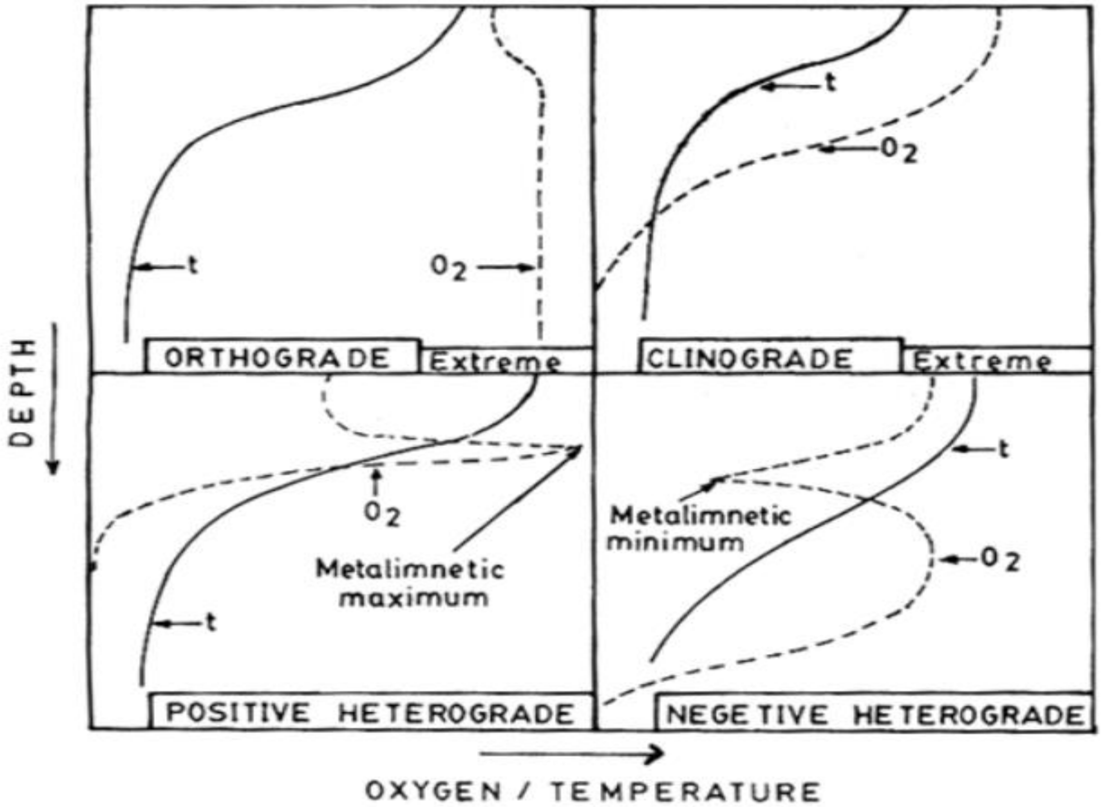

Figure 11: Four common water temperature and DO depth profiles, from Hutchinson, 1957.

Due to the stratification of the lake sites 1 & 2, no summer mixing occurs, resulting in a finite supply of DO for organisms below the thermocline until fall turnover. At depths below 7 m for Lake 1, DO falls below the CCME 6.5 mg/L guideline, while depths below 5 m at Lake 2 also have <6.5 mg/L of DO. As microbes continue to consume the finite supply of DO in the deep lake waters, the stress of low-DO on aquatic organisms will only increase until DO is replenished during fall turnover.

It appears at the bottom of the lake at Lake 2, waters become hypoxic (<2 mg/L) and anoxic (<1 mg/L) and have decreased capacity to support aquatic life (USGS, 2014; Brylinsky, 2004). Similar hypoxic and anoxic conditions were observed for both Lake 1 and Lake 2 in 2018. As oxygen is necessary for aquatic life, anoxic conditions can be harmful and even kill organisms that pass through anoxic waters. In addition, anoxic conditions can cause phosphorus locked in the sediment to change states and be released into the water column, potentially over-enriching the waters with new nutrients and causing algal blooms.

2.2.4. pH

pH is a parameter used to assess the acidity of a substance, with pH being the negative logarithmic of the hydrogen ion concentration of the solution (Equation 1). The pH scale ranges from 0 (most acidic) to 14 (most basic), with 7 being the neutral point. In natural waters, due to the dissolution of carbon dioxide, water pH is slightly more acidic than neutral (~6.5), with geology, organic materials, and rain inputs also affecting the water's natural pH state; due to such natural variations, the CCME has set a pH range of 6.5-9.0 as a guideline for the protection of aquatic life (CCME, 2007).

Equation 1: $$pH = -\log([H^+])$$

Particularly in Nova Scotia, natural organic matter, acid rock drainage from specific bedrock formations, and decades of acid precipitation have lowered the pH of waters in the province and negatively affected fish populations. Although the CCME has set a threshold of 6.5, many aquatic organisms have adjusted to Nova Scotia's acidic waters, with trout species surviving in waters as low as 4.7 (NSSA, 2014). Although organisms can survive in acidic conditions, Harvey and Lee (1982) reported fish kills associated with exposure to highly acidic waters from hours to days, while Courtney and Clements (1998) reported significant reductions in invertebrates after seven days of exposure to acidic conditions (pH 4.0).

pH within the lakes and rivers of the 2019 SL monitoring program varied between 4.52-7.09 (Figures 12 and 13). All lake sites' pH measurements fell within past site-specific pH ranges; no lake site dropped below 5.7-pH. The October Lake 4 sample measured a pH of 6.18, this is almost 3-pH units higher than the October 2018 sample, supporting the SL 2018 Report's hypothesis that the low October 2018 pH measurement was an anomaly. Of the stream sites, the lowest recorded pH was 4.52 at Pine Lake Brook – Pine Lake Brook also had the lowest pH in 2018 and was consistently one of the lowest pH sites during the 2018 and 2019 field seasons. As with dissolved oxygen, the rainfall-dependent samples' data - Butler Lake Brook, Gully River, and Peter Veinot Brook – for 2018 and 2019 are not representative of the sites' entire field seasons due to minimal sampling.

Low pH within the SL system may pose a threat to aquatic life. All seven streams and all lake sites in 2019, except the Lake 2 August measurement, have pH values below the CCME 6.5-pH threshold. Even when using the lower 5.0-pH threshold which is considered adequate for the survival of fish and invertebrates (Morris *et al.*, 1989), we still observe stream measurements below the threshold. Although most SL streams' pH minima have increased from 2018, all stream mean pH values have decreased (Table 3). As the length of the low-pH conditions are unknown – due to the monthly sampling frequency of the program – it is unclear if these conditions pose short-term or long-term concerns to aquatic life; however, it is clear that the SL tributaries are acidic and may be negatively influencing in-stream aquatic organism survival.

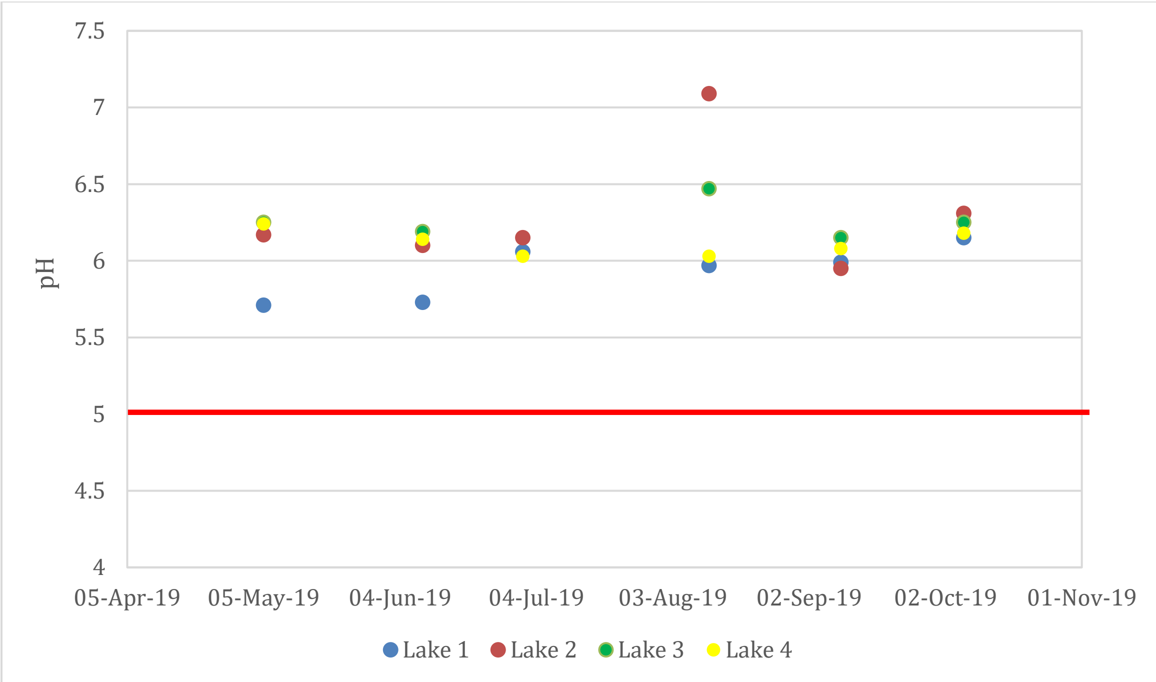

Figure 12: pH at four monthly lake sites (Lake 1-4) during the May-October 2019 SL water quality field season. Red line indicates the 5.0-pH minimum threshold for survival of fish and invertebrates (Morris et al., 1989).

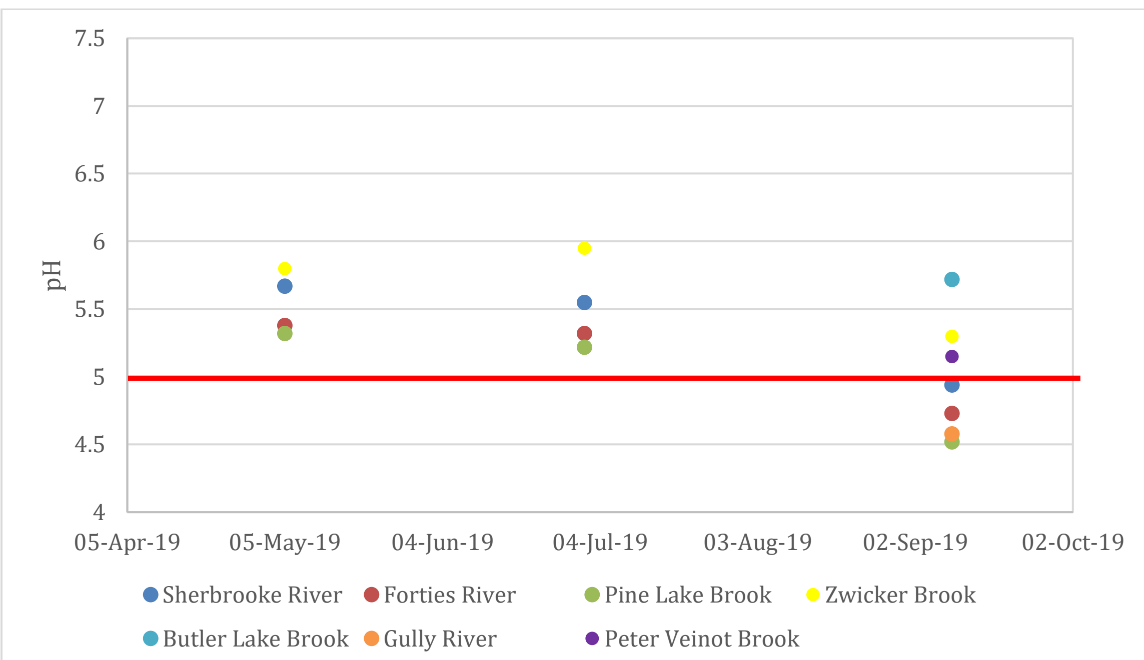

Figure 13: pH at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season. Red line indicates the 5.0-pH minimum threshold for survival of fish and invertebrates (Morris et al., 1989).

Table 3: Mean pH for the four lake sites and seven stream sites of the Sherbrooke Lake Monitoring Program for the 2018 and 2019 field seasons.

Site Type	Site	Mean pH	
		2018	2019
Lake	Lake 1	6.02	5.90
	Lake 2	5.92	6.30
	Lake 3	6.36	6.26
	Lake 4	4.80	6.10
Stream	Sherbrooke River	5.96	5.39
	Forties River	5.75	5.14
	Pine Lake Brook	5.33	5.02
	Zwicker Brook	5.79	5.68
	Butler Brook	5.79	5.72
	Gully River	5.62	4.58
	Peter Veinot Brook	5.27	5.15

2.2.5. Total Dissolved Solids

Total dissolved solids (TDS) – a measurement of dissolved materials in water – is an invaluable parameter. TDS can be influenced by construction, deforestation, sewage effluent, urban and agricultural run-off, industrial waste, road salts, forest fires, and rainfall/flooding events, and therefore provides insight into potential pollution issues affecting the water. Although there is no CCME guideline for TDS, high concentrations of TDS can affect water's taste, colour, and clarity (NSSA, 2014), and reductions in clarity can decrease the depth of light penetration and affect rooted vegetation. For most of Nova Scotia's lakes, TDS ranges from 5 to 235 mg/L (Nova Scotia Lake Inventory Program, 2017).

TDS of the six SL lake sites never exceeded 20.0 mg/L, while most streams had TDS concentrations >20 mg/L (Table 4, Figures 14 and 15). Of the four bimonthly stream sites monitored, all sites indicated an increase in TDS during the rainfall sampling event, suggesting an increase in solids due to overland flow. As the rainfall-dependent samples are only collected during rainfall events, it is unclear whether their values represent normal or elevated conditions due to the rain. In addition, although the seven streams had high TDS concentrations during the rainfall event, the influence on lake water quality appears minimal, as lake site TDS concentrations did not exceed their normal ranges. Butler Brook had the highest recorded TDS concentration (33 mg/L), which is consistent with its 2017 preliminary data (33.8 mg/L) and 2018 data (39 mg/L), suggesting that the brook has naturally high TDS concentrations. TDS concentrations from SL fall along the lower end of the TDS range for Nova Scotia's lakes.

Table 4: Mean and maximum TDS concentrations from lake and river sites during the 2018 and 2019 SL field seasons.

Site Type	Site	Mean TDS (mg/L)		Maximum TDS (mg/L)	
		2018	2019	2018	2019
Lake	Lake 1	18.8	16.7	20.0	17
	Lake 2	18.2	16.3	19.0	17
	Lake 3	18.2	16.2	19.0	17
	Lake 4	18.5	16.5	19.0	17
Stream	Sherbrooke River	21.3	16.3	23	19
	Forties River	19.0	19.3	24	29
	Pine Lake Brook	17.9	18.3	21	28
	Zwicker Brook	19.0	17.3	23	24
	Butler Brook	-	-	39	33
	Gully River	-	-	14	20
	Peter Veinot Brook	-	-	21	24

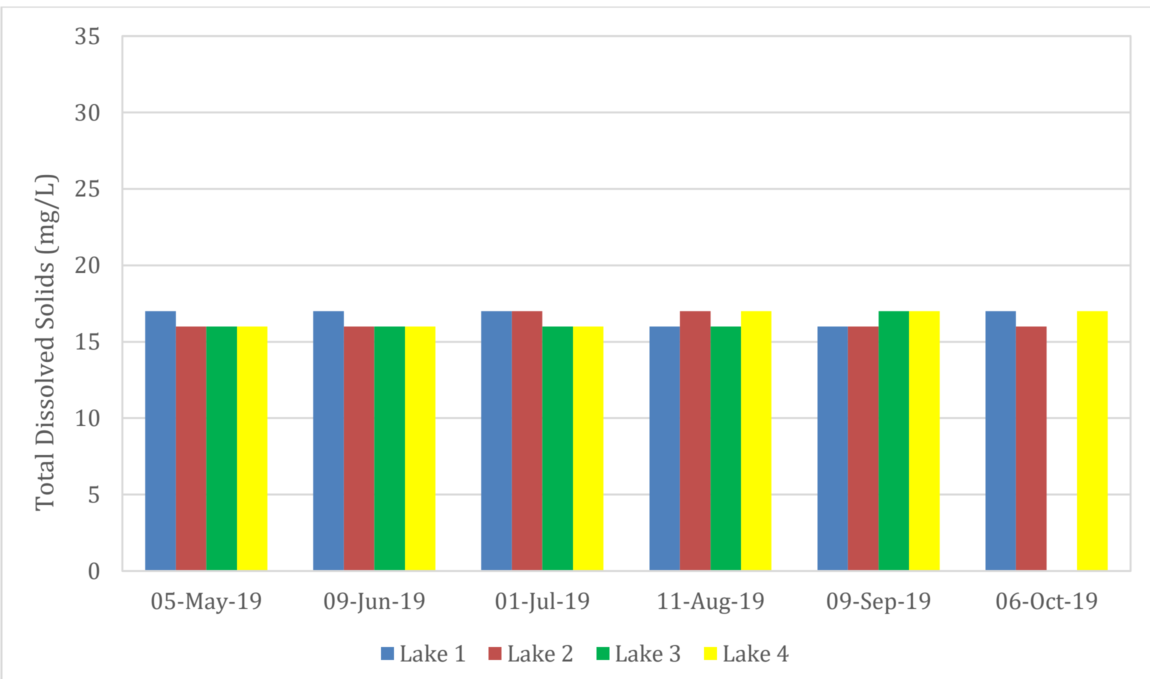

Figure 14: TDS at four monthly lake sites (Lake 1-4) during the May-October 2019 SL water quality field season.

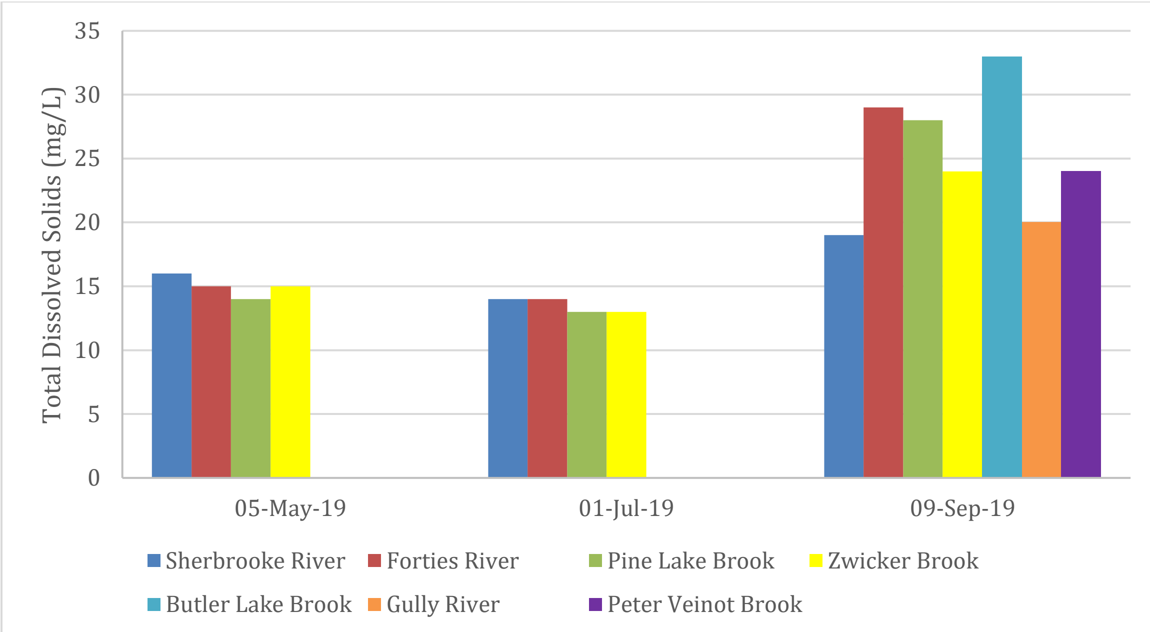

Figure 15: TDS at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season.

2.3. Chemical Water Parameters

2.3.1. Total Suspended Solids

Total suspended solids (TSS) is a measurement of all suspended materials in the water column. Increases in TSS can be natural due to erosion or general disturbance of land upstream or can be unnatural (release of substance from deforestation, mining, etc.). According to the Nova Scotia *Environment Act* (1994-95), '*No person shall release or permit the release into the environment of a substance in an amount, concentration or level of at a rate of release that causes or may cause adverse effect, unless authorized by an approval of the regulations*'; by monitoring and obtaining an initial reference point of TSS and other water quality parameters prior to future potential land disturbances, the SLSC can address and mitigate any possible substance release events.

TSS concentrations ranged from <1 mg/L to 11 mg/L for SL lake and river sites (Table 5, Figures 16 and 17). Most lake sites had <1 mg/L of TSS during the field season, with one outlying measurement of 5.6 mg/L at Lake 1 on July 1st, 2019. It appears no stream is consistently higher than others feeding into SL, with the 11 mg/L July 1st, 2019 sample at Pine Lake Brook appearing to be an anomaly. It is unclear what caused the Pine Lake Brook and Lake 1 anomalies for July 2019.

No stream or lake sites increased outside of normal site-specific TSS ranges during the rainfall sampling event. This is similar to what was observed during the 2018 rainfall-dependent sampling event, when six of the seven streams observed no difference in TSS concentrations. In Nova Scotia, TSS in lakes ranges from 0.8 to 15 mg/L (Nova Scotia Lake Inventory Program, 2017); SL TSS concentrations fall along the lower end of this range, except for the Pine Lake Brook July 2019 anomaly.

Table 5: Mean TSS concentrations from lake and river sites during the 2018 and 2019 SL field seasons. As Lake 3 only sampled bacteria in 2019, no data are available for TSS for 2019.

Site Type	Site	Mean TSS (mg/L)	
		2018	2019
Lake	Lake 1	1.1	2.3
	Lake 2	1.1	1.4
	Lake 3	1.0	-
	Lake 4	1.1	1.5
Stream	Sherbrooke River	1.6	1.9
	Forties River	1.4	1.7
	Pine Lake Brook	1.3	4.6
	Zwicker Brook	1.6	1.1
	Butler Brook	1.8	1.0
	Gully River	1.0	1.0
	Peter Veinot Brook	1.0	1.0

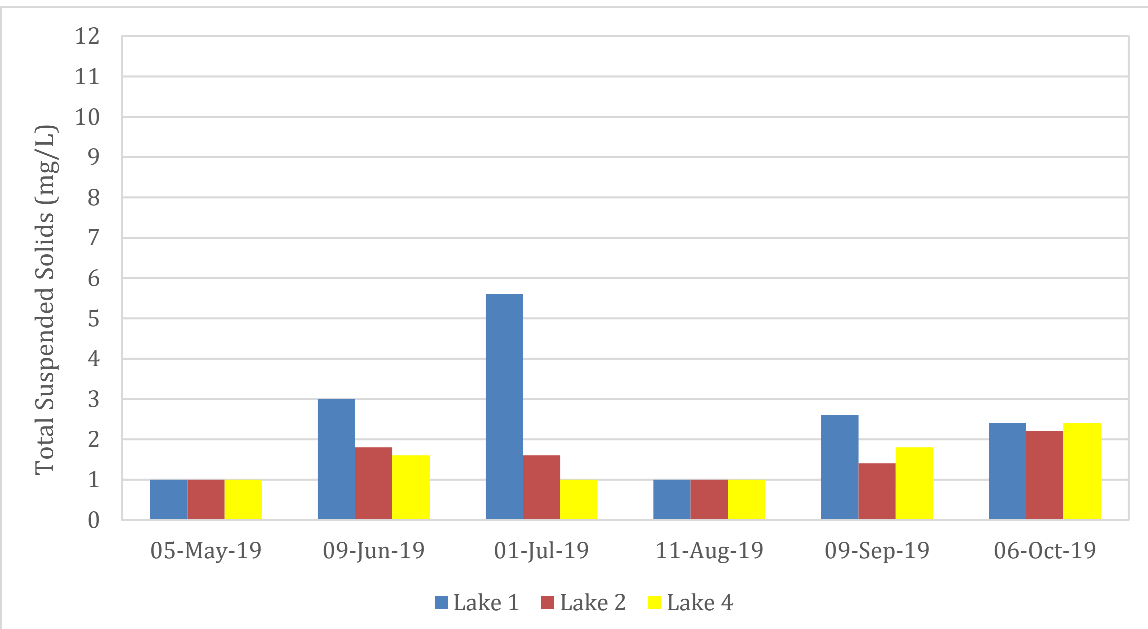

Figure 16: TSS at three monthly lake sites (Lake 1, 2, and 4) during the May-October 2019 SL water quality field season. As Lake 3 only sampled bacteria in 2019, no data are available for 2019 and therefore Lake 3 is not included.

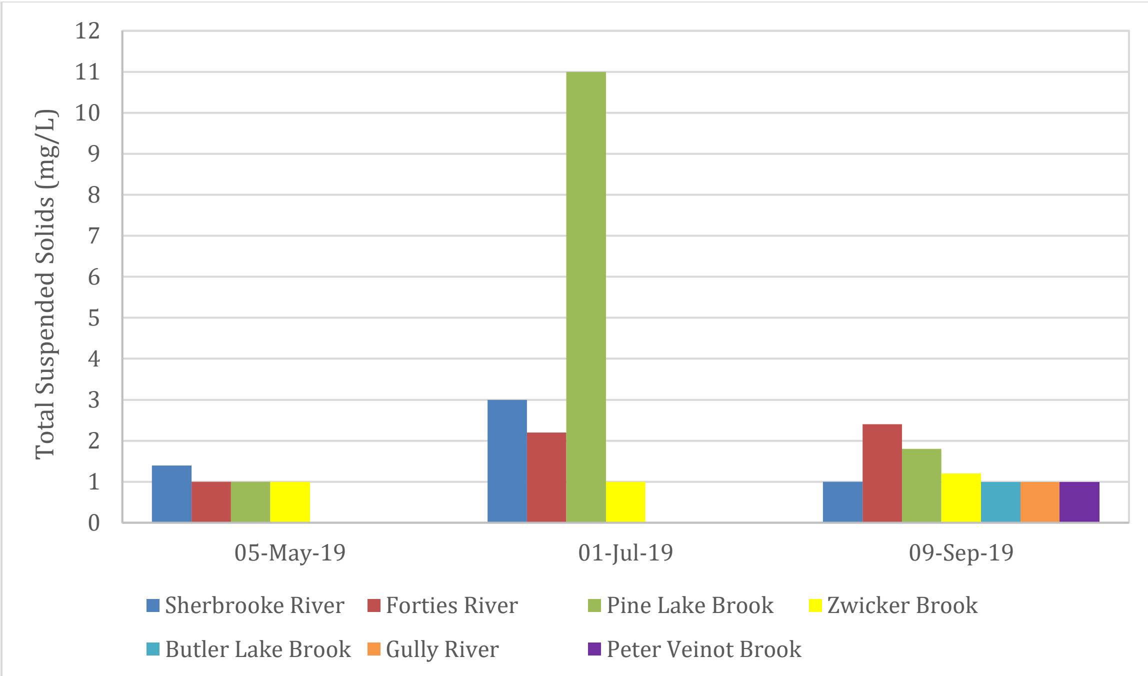

Figure 17: TSS at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season.

Secchi disk depth – the depth to which a black and white disk is just barely visible within a waterbody – can act as a proxy for TSS in lakes. In SL, Secchi disk depths were measured for sites Lake 1-4 (Table 6). Lake 2 had the clearest water, with a maximum depth of 4.05 m. The clarity of Lake 2 has increased since the max depth of 2.84 m in 2018. The clarity of Lake 2 has been greater than Lake 1 for both 2018 and 2019. Both Lake 3 and 4 have maximum depths down to the lake bottom. Although Secchi depth provides an indication of light penetration into waterbodies, the measurements can be skewed due to the depth of the site, an individual's eyesight, and different individuals performing the measurement on different days.

Table 6: Maximum and mean Secchi disk depths from lake sites during the 2018 and 2019 SL field seasons. No maximum Secchi depth is available for Lake 3 and 4, as both are visible down to the lake bottom.

Site Type	Site	Mean Secchi (m)		Maximum Secchi (m)	
		2018	2019	2018	2019
Lake	Lake 1	2.21	2.10	2.65	3.55
	Lake 2	2.43	2.55	2.84	4.05
	Lake 3	1.78	1.46	-	-
	Lake 4	2.38	2.60	-	-

2.3.2. Total Phosphorus

Phosphorus concentrations (both organic and inorganic) are extremely important in healthy ecosystems; phosphorus acts as a nutrient to various organisms and plants within watersheds. Due to minimal natural sources of phosphorus and a high demand by plants, phosphorus concentrations are low in aquatic environments and therefore a growth-limiting factor. As phosphorus is a key nutrient in freshwater environments, and not considered a toxic substance, the CCME does not have set guidelines; however, Ontario's Ministry of Environment and Climate Change (MOECC) has set a total phosphorus guideline of ≤0.02 mg/L for lakes, and ≤0.03 mg/L for rivers and streams (MOE, 1979). By monitoring phosphorus, pollution sources can be identified due to 'pockets' of elevated phosphorus concentrations. In addition, by monitoring phosphorus below a lake's thermocline, we can assess how nutrients are being used/supplied in deeper waters, and if nutrient-enrichment will be a problem once the waters mix during fall and spring turnover.

On average, lake sites were consistently lower than streams (Figures 18 and 19, Table 7). Lake phosphorus concentrations ranged from <0.004 mg/L to 0.017 mg/L, while streams ranged from 0.012 mg/L to 0.032 mg/L. No lake phosphorus concentrations exceeded the MOECC lake guideline of 0.02 mg/L, while only one stream site – Pine Lake Brook – exceeded the MOECC stream guideline of 0.03 mg/L. Phosphorus concentrations increased at the four bimonthly streams during the rainfall event. Phosphorus concentrations were also elevated at the three rainfall-dependent sites, but as these sites were not sampled more than once, it is unclear if these phosphorus concentrations are elevated or natural. Due to the increase in phosphorus in the bimonthly streams, it is reasonable to assume that the rainfall caused increased flushing of phosphorus into the streams. The water quality of the lake appears to be minimally affected by the rainfall-induced increased stream inputs, as phosphorus concentrations did not increase at any lake sites; however, effects on the lake may be delayed due to the lag between pollutants reaching the streams, and the travel of the pollutants downstream to the lake.

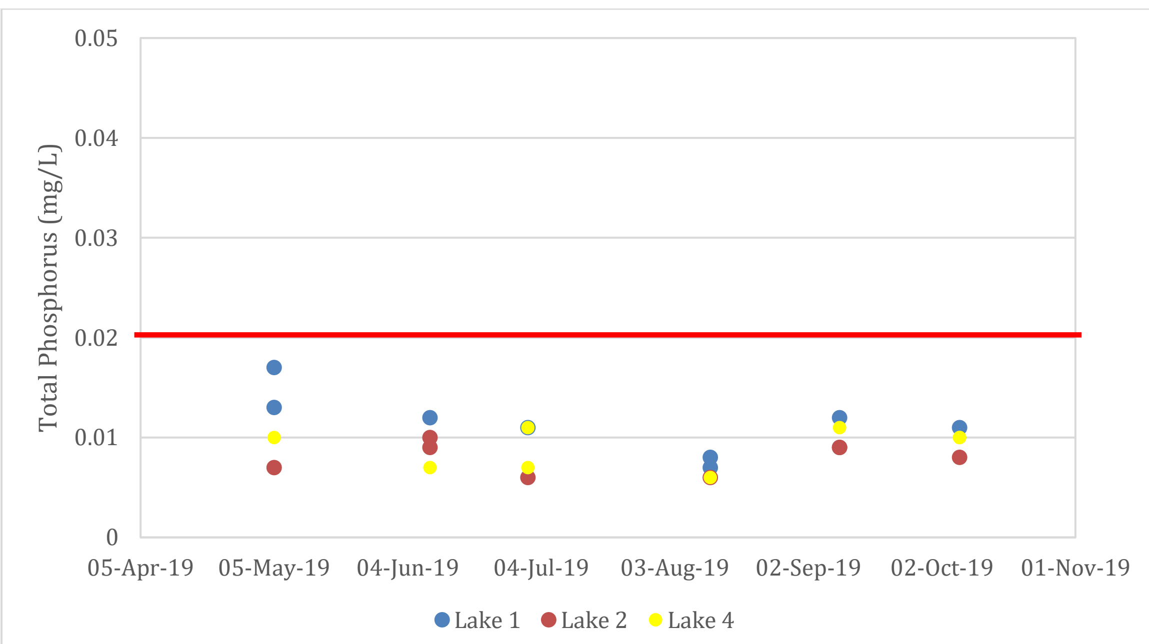

Figure 18: Total phosphorus at three monthly lake sites (Lake 1, 2, and 4) during the May-October 2019 SL water quality field season. Red line indicates the MOECC 0.02 mg/L guideline for phosphorus in lakes. As Lake 3 only sampled bacteria in 2019, no data are available for nutrients and therefore Lake 3 is not included.

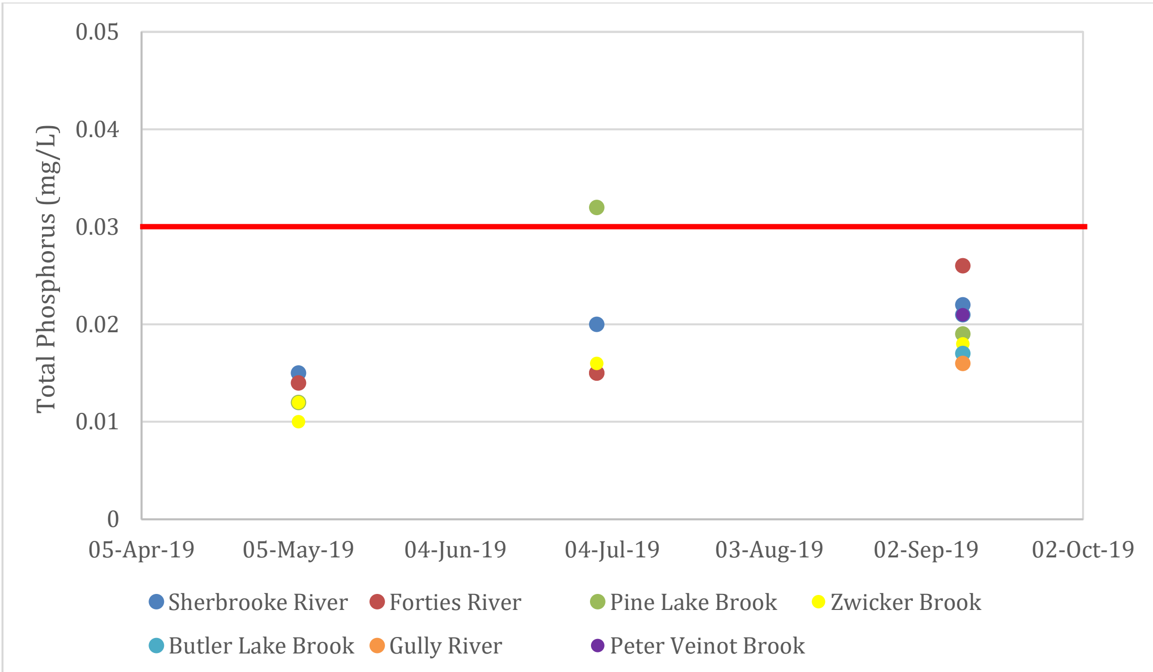

Figure 19: Total phosphorus at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season. Red line indicates the MOECC 0.03 mg/L guideline for phosphorus in streams.

Phosphorus concentrations during the 2019 field season are comparable to those of 2018 (Table 7). Minimum phosphorus concentrations within the lake sites have increased from 2018 values, while the four bimonthly stream sites remain consistent with 2018 concentrations. Two of the three rainfall-dependent stream sites – Butler Lake Brook and Gully River – had lower phosphorus concentrations than the 2018 rainfall event, while Peter Veinot Brook concentrations increased by 0.001 mg/L compared to 2018.

Table 7: Range in total phosphorus concentrations between 2018 and 2019; July-September for lake and stream samples. As Lake 3 only sampled bacteria in 2019, no data are available for total phosphorus for 2019.

Site Type	Site	Total Phosphorus Range	
		2018	**2019**
Lake	Lake 1	0.004-0.008	0.007-0.012
	Lake 2	0.004-0.009	0.006-0.009
	Lake 3	0.004-0.005	-
	Lake 4	0.004	0.006-0.011
Stream	Sherbrooke River	0.015-0.04	0.02-0.022
	Forties River	0.017-0.04	0.015-0.026
	Pine Lake Brook	0.015-0.03	0.019-0.032
	Zwicker Brook	0.018-0.04	0.016-0.018
	Butler Lake Brook	0.03	0.017
	Gully River	0.03	0.016
	Peter Veinot Brook	0.02	0.021

Elevated phosphorus concentrations below the thermocline may indicate a possible nutrient-enrichment event during fall turnover, with a potential for eutrophication and algal blooms. In SL, phosphorus concentrations below the thermocline ('phosphorus at-depth') were equal to or higher than surface concentrations (Table 8), indicating that the deeper lake waters are nutrient enriched. As phosphorus concentrations were higher at-depth, it appears that there is minimal assimilation of phosphorus below the thermocline; however, as orthophosphate concentrations were below detection limits (0.01 mg/L), the bioavailable fraction of phosphorus is minimal, reducing the risk of nutrient enrichment from internal loading during SL's fall turnover.

Table 8: Total phosphorus concentrations from two lake sites, obtained both at the surface and below the thermocline, taken in August for the SL 2018 and 2019 Water Quality Monitoring Programs, in addition to orthophosphate concentrations taken below the thermocline in 2019.

Site	Surface Phosphorus (mg/L)		Phosphorus At-Depth (mg/L)		Orthophosphate At-Depth (mg/L)	
	2018	2019	2018	2019	2018	2019
Lake 1	0.008	0.007	0.007	0.007	-	<0.01
Lake 2	0.004	0.006	0.025	0.008	-	<0.01

2.3.3. Total Nitrogen

Like phosphorus, nitrogen is also a limiting nutrient for plants and other organisms in freshwater environments. No CCME guidelines exist for nitrogen; however, Dodds and Welch (2000) have established a ≤0.9 mg/L guideline for freshwater environments, while Underwood and Josselyn (1979) reported a guideline of ≤0.3 mg/L for oligotrophic waterbodies.

Lake nitrogen concentrations ranged from 0.215 mg/L to 0.327 mg/L, while stream nitrogen concentrations ranged from 0.219 mg/L to 0.784 mg/L (Figures 20 and 21, Table 9). Total nitrogen, like total phosphorus, was lower in lake sites than stream sites. In addition, the nitrogen concentrations for all lake sites were higher in 2019 than 2018. No stream or lake site exceeded the Dodds and Welch (2000) 0.9 mg/L threshold; however, the Lake 1 site did exceed the Underwood and Josselyn (1979) 0.3 mg/L threshold for oligotrophic waterbodies on one occasion – 0.327 mg/L on August 11th, 2019.

Nitrogen concentrations increased following the Hurricane Dorian rainfall event. Of the bimonthly streams monitored during the sampling program, all four streams had increases in total nitrogen during the rainfall-dependent sampling. The three rainfall-only stream sites had similar levels as 2018 – as these are only monitored during rainfall-only events, the range of nitrogen concentrations outside these rainfall events is unknown. Like phosphorus, no lake sites had increases in nitrogen following the rainfall event – this may indicate minimal impact on the lake or may be due to the lag between flushing of nutrient pollutants into the streams and eventual transportation of these waters into the lake.

Elevated nitrogen concentrations in the 2019 lake sites, in addition to increases at all seven streams during the rainfall event, suggests that nitrogen pollution is an issue in SL. Although the oligotrophic threshold was only exceeded once in 2019, the increase in nitrogen concentrations within SL from 2018 to 2019 increases the risk of eutrophication within the lake.

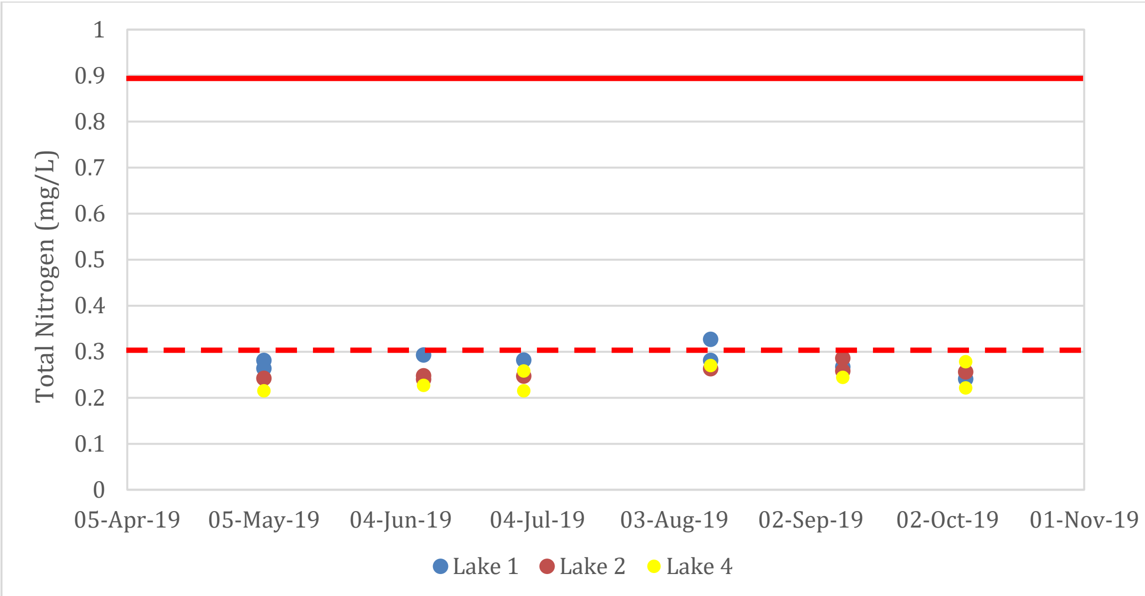

Figure 20: Total nitrogen at three monthly lake sites (Lake 1, 2, and 4) during the May-October 2019 SL water quality field season. Red solid line indicates the Dodds and Welch (2000) 0.9 mg/L nitrogen threshold for freshwaters, and red dashed line indicates the Underwood and Josselyn (1979) 0.3 mg/L nitrogen threshold for oligotrophic lakes. As Lake 3 only sampled bacteria in 2019, no data are available for nutrients and therefore Lake 3 is not included.

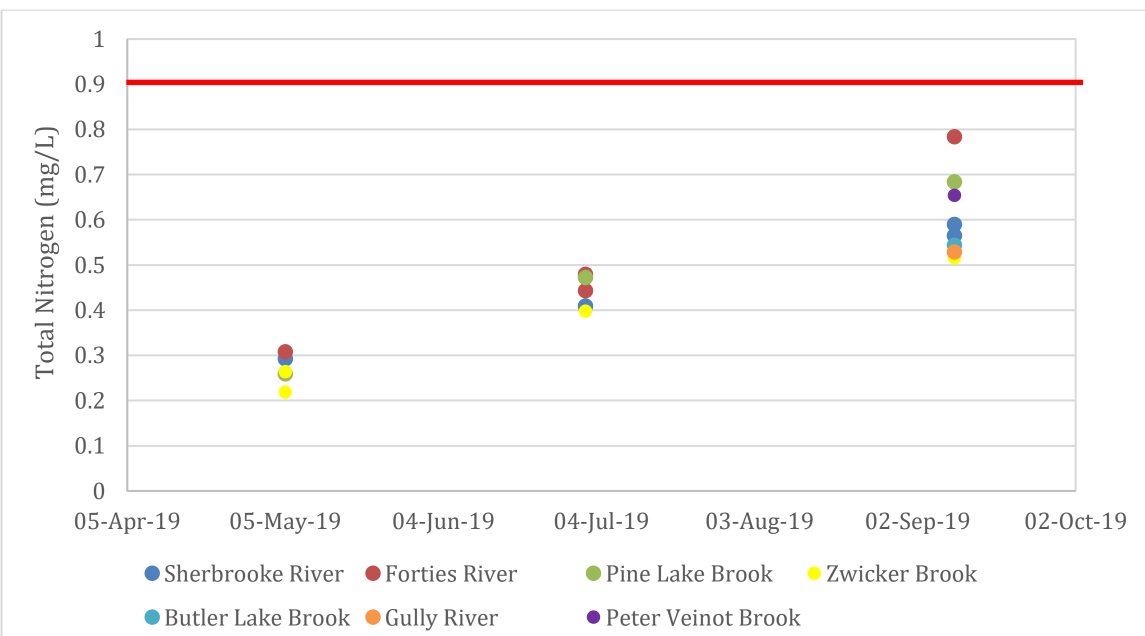

Figure 21: Total nitrogen at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season. Red line indicates the Dodds and Welch (2000) 0.9 mg/L nitrogen threshold for freshwaters.

Table 9: Range in total nitrogen concentrations between 2018 and 2019; July-September for lake and stream samples. As Lake 3 only sampled bacteria in 2019, no data are available for total nitrogen for 2019.

Site Type	Site	Total Nitrogen Range (mg/L)	
		2018	2019
Lake	Lake 1	0.185-0.359	0.267-0.327
	Lake 2	0.18-0.258	0.247-0.286
	Lake 3	0.19-0.29	-
	Lake 4	0.194	0.215-0.27
Stream	Sherbrooke River	0.503-0.714	0.409-0.59
	Forties River	0.534-0.751	0.443-0.784
	Pine Lake Brook	0.497-0.781	0.472-0.684
	Zwicker Brook	0.66-0.711	0.398-0.516
	Butler Lake Brook	0.883	0.544
	Gully River	0.483	0.529
	Peter Veinot Brook	0.66	0.654

Unlike phosphorus, lower nitrogen concentrations below the thermocline limit the potential for a nutrient-enrichment event during fall turnover. In SL, nitrogen concentrations were only slightly lower at-depth than the surface concentrations (Table 10). Lake 1 at-depth nitrogen concentrations were only 0.017 mg/L below those at the surface, while Lake 2 samples were 0.003 mg/L below surface concentrations. Surface nitrogen concentrations have increased since 2018 for both lake sites, while Lake 1 at-depth nitrogen concentrations have increased while Lake 2 at-depth concentrations have decreased since 2018. As nitrogen concentrations are lower at-depth, the deeper SL waters are not a source of internal loading, thereby minimizing the potential for eutrophication and algal blooms in the fall season.

Table 10: Total nitrogen concentrations from two lake sites, obtained both at the surface and below the thermocline, in August for the SL 2018 and 2019 Water Quality Monitoring Programs.

Site	Surface Nitrogen (mg/L)		Nitrogen At-Depth (mg/L)	
	2018	2019	2018	2019
Lake 1	0.263	0.327	0.223	0.31
Lake 2	0.258	0.263	0.46	0.26

2.3.4. Chlorophyll *a*

Chlorophyll *a* is a parameter used as a proxy for biological activity within water and can be an indicator for potential algal blooms if it increases to elevated levels (Stumpf, 2001). For SL, chlorophyll *a* never exceeded 7 µg/L (Figures 22 and 23, Table 11). Chlorophyll *a* concentrations were consistently higher at the lake sites than stream sites, which may be due to the lower velocity of the waters and therefore greater ability for algae to grow and thrive. The lake sites, and three of the four bimonthly stream sites, had lower mean chlorophyll concentrations than 2018 values. All three rainfall-dependent stream samples increased from 2018, but as these are only collected annually, it is unclear whether these increases are beyond the normal streams' chlorophyll *a* range.

2019 chlorophyll *a* concentrations are inconsistent with previous findings. Although the seasonal variations for the 2019 stream sites are consistent with 2018 values, the lake sites diverge from 2018 trends. There is a decrease in chlorophyll *a* concentrations throughout the first three months at the lake sites, as was also observed in 2018; however, there is a subsequent increase come August 2019. The August 2019 increase does not correspond to increases in nutrient availability, as both nitrogen and phosphorus concentrations remain within expected ranges during this period. The August increase also does not appear to be rainfall related, as only 2 mm of rain fell in the three days prior to the August 2019 sampling event. The maintained increase in chlorophyll *a* concentrations during the September and October sampling events is consistent with 2018 values, as rainfall increased and resulted in the flushing of more materials into the lake. It is unclear why chlorophyll *a* concentrations increased in August, while the three earlier months – when various algal blooms were reported within the lake – fell below 3 mg/L. The increase in chlorophyll in the fall months is not consistent with the 2018 data; further sampling is required to understand why concentrations increased.

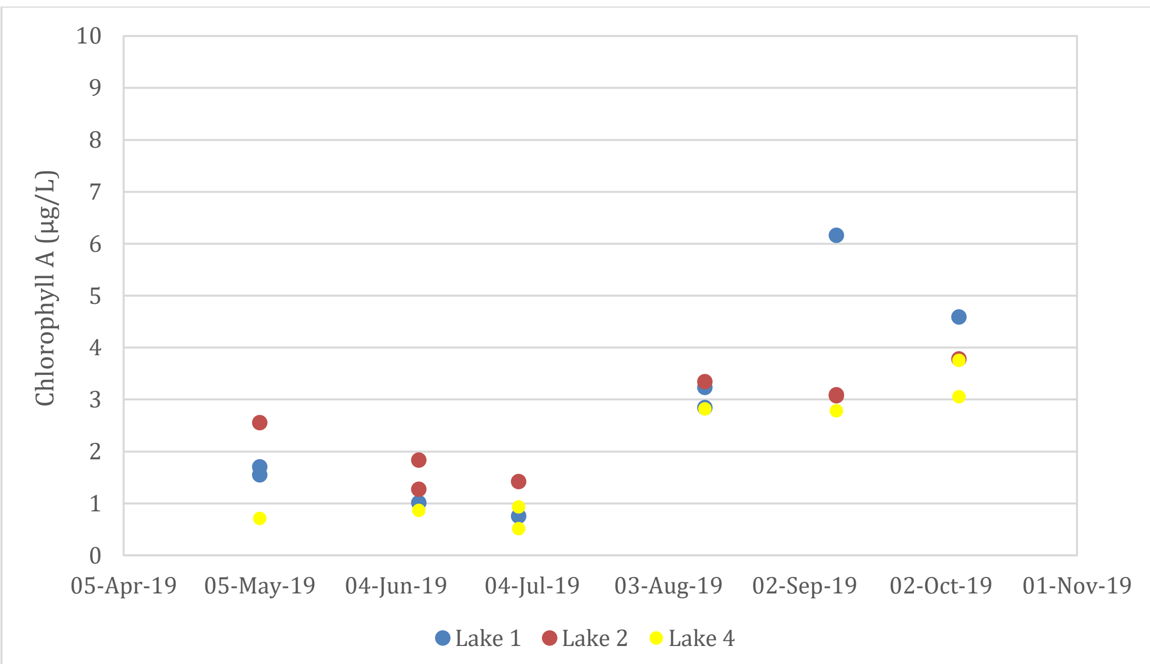

Figure 22: Chlorophyll a at three monthly lake sites (Lake 1, 2, and 4) during the May-October 2019 SL water quality field season. As Lake 3 only sampled bacteria in 2019, no data are available for chlorophyll a and therefore Lake 3 is not included.

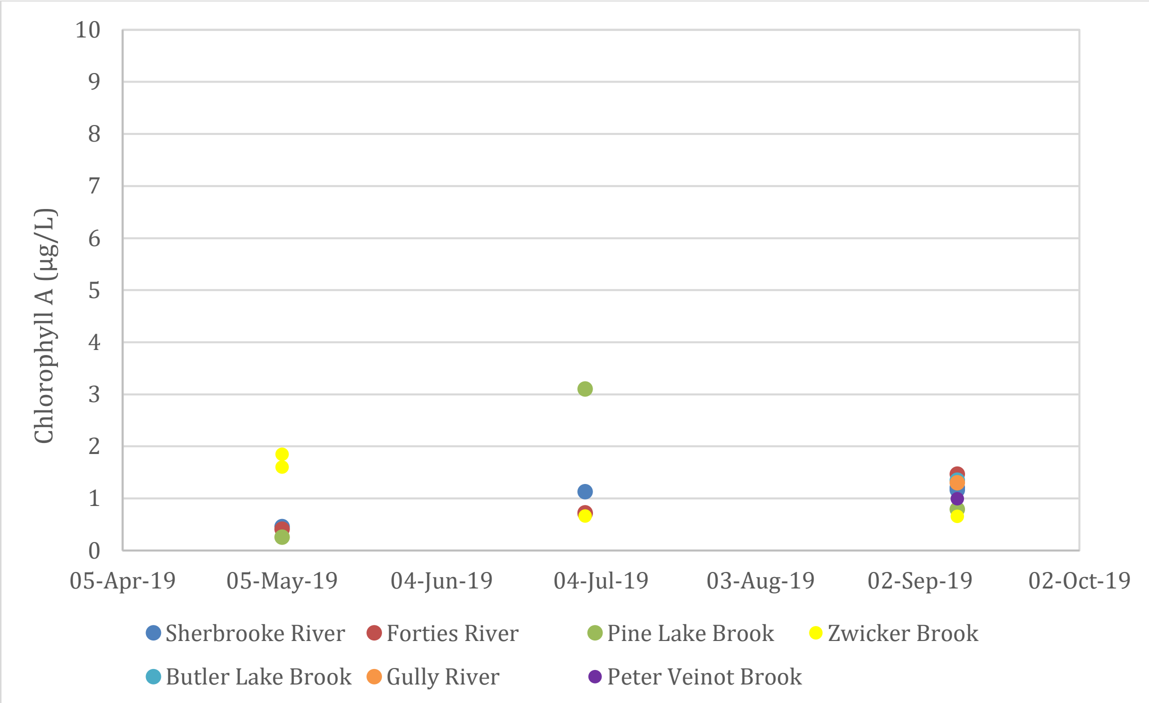

Figure 23: Chlorophyll a at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season.

Table 11: Maximum and mean chlorophyll a from lake and river sites during the 2018 and 2019 SL field seasons. As Lake 3 only sampled bacteria in 2019, no data are available for chlorophyll a for 2019.

Site Type	Site	Mean Chlorophyll a (µg/L)		Maximum Chlorophyll a (µg/L)	
		2018	2019	2018	2019
Lake	Lake 1	3.73	2.70	2.65	3.55
	Lake 2	2.79	2.54	2.84	4.05
	Lake 3	2.11	-	2.3	-
	Lake 4	2.10	1.93	2.63	3.85
Stream	Sherbrooke River	1.72	0.99	3.88	1.21
	Forties River	1.71	0.83	2.97	1.47
	Pine Lake Brook	0.76	1.38	0.94	3.10
	Zwicker Brook	5.18	1.19	17.41	1.85
	Butler Brook	0.89	1.35	0.89	1.35
	Gully River	0.85	1.30	0.85	1.30
	Peter Veinot Brook	0.79	0.99	0.79	0.99

2.3.5. E. Coli Bacteria

Escherichia coli (E. coli) is a species of fecal coliform bacteria which are found in the waste of warm-blooded animals and used as indicators of fecal pollution within freshwater environments. Sources of bacteria can include agricultural lands – due to the spreading of manure on crops, stream crossings by livestock, and livestock feces (Stephenson and Street, 1978; Hunter *et al.*, 1999; Crane *et al.*, 1983), domestic and wild animal feces, leachate from landfills (Maqbool *et al.*, 2011), malfunctioning septic systems, illegal straight-pipes, and stormwater run-off (both urban areas and overland flow in rural regions).

In recreational waters, the presence of fecal pollution presents a risk to the public, as the possible presence of pathogenic microorganisms can infect humans and animals and cause serious illnesses. As testing for the hundreds of disease-causing microorganisms is costly and impractical, this program uses E. coli measured in coliform forming units per 100 mL (CFU/100 mL) as an indicator of fecal pollution. The program switched from testing fecal coliforms in 2018 to E. coli in 2019 to align with Health Canada's standards of using E. coli as the primary indicator bacteria of fecal contamination in freshwaters. For recreational waters, Health Canada has set a limit of <400 CFU/100 mL of E. coli during primary contact activities (activities where the body, face, or trunk are submersed, and it is likely that water will be swallowed, such as: swimming, surfing, canoeing, etc.) (Health Canada, 2012). Although the presence of E. coli indicates the presence of fecal contamination, the absence of E. coli should not be interpreted to mean that all pathogenic organisms are absent.

In the four lake sites and seven inlet stream sites monitored during the 2019 field season, only once was a measurement above the Health Canada primary contact limit (Figures 24 and 25). The highest E. coli count within the lake sites was 20 CFU/100 mL, found at Lake 2 and 3 in September 2019. Samples were below laboratory detection limits for all seven Lake 1 samples (including one replicate sample), six of eight Lake 2 samples (including two replicate samples), four of six Lake 3 samples, and all eight Lake 4 samples (including two replicates). For the streams, concentrations ranged from <10 CFU/100 mL to 720 CFU/100 mL; the bacteria concentrations from 2019 are higher than those of 2018, which ranged from <10 CFU/100 mL to 350 CFU/100 mL. The highest bacteria concentration was recorded at Forties River (720 CFU/100 mL), during the rainfall-dependent event.

Elevated stream bacteria concentrations were recorded following the rainfall event of Hurricane Dorian – these elevated concentrations may be due to flushing of bacteria on land into the streams and was also observed in the 2018 measurements. Increases in bacteria in waterbodies following rainfall is commonly reported in the literature (Rodgers *et al.*, 2003; Hunter, McDonald, and Beven, 1992; Stephenson and Street, 1978); however, it appears that the increases did not greatly affect lake water quality. As the rainfall-dependent sampling of the seven inlet streams coincided with the September sampling event of the four lake sites, the influence of the rainfall and streams can be observed on the lake's water quality. Although all streams had elevated levels of E. coli, only Lake 2 and 3 had increases from the previous month's E. coli levels; however, these increases were minimal, as concentrations never exceeded 20 CFU/100 mL. Caution should still be maintained by the public after rainfall events, to avoid exposure to high fecal bacteria concentrations, especially around streams and where streams and the lakes intersect. In addition, caution should be taken in streams that have known bacteria sources upstream.

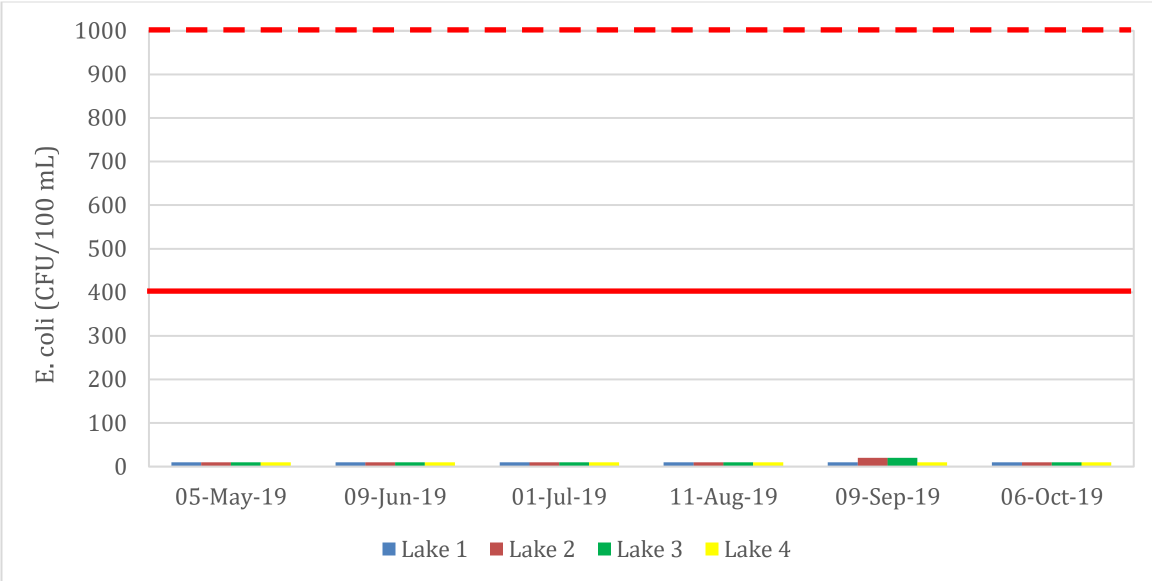

Figure 24: E. coli at four monthly lake sites (Lake 1-4) during the May-October 2019 SL water quality field season. Red solid line indicates Health Canada's primary limit for recreation in freshwaters (400 CFU/100 mL), and red dashed line indicates Health Canada's secondary limit for recreation in freshwaters (1,000 CFU/100 mL).

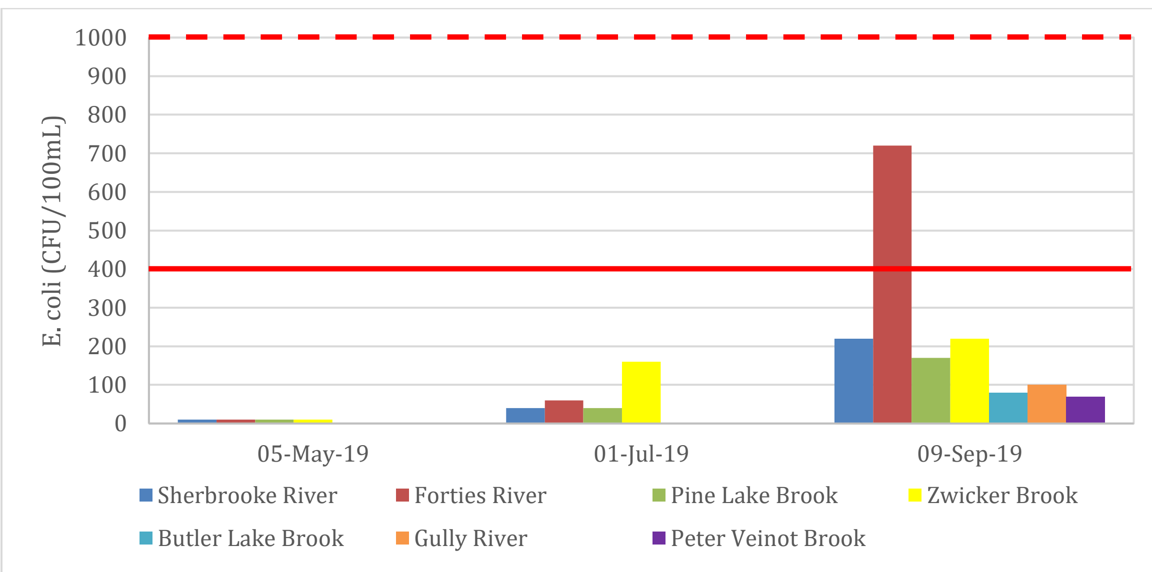

Figure 25: E. coli at four bimonthly and rainfall-dependent stream sites (Sherbrooke River, Forties River, Pine Lake, and Zwicker Brook), in addition to three rainfall-dependent stream sites (Butler Lake Brook, Gully River, and Peter Veinot Brook), during the May-October 2019 SL water quality field season. Red solid line indicates Health Canada's primary limit for recreation in freshwaters (400 CFU/100 mL), and red dashed line indicates Health Canada's secondary limit for recreation in freshwaters (1,000 CFU/100 mL).

2.4. Sediment Sampling

2.4.1. Metals

Sediments can have adverse effects on water quality in lakes and rivers, as sediment acts as a reservoir for metals, nutrients, and organisms. During turbulence in streams, chemicals held within sediment can be released, causing an influx of more than just TSS and TDS, but increases in metals, bacteria, organic matter, and nutrients (Reddy *et al.*, 1999; Brylinsky, 2004) – all of which can negatively affect a lake's fragile chemical equilibrium.

For sediments found at the bottom of lakes, resuspension is less likely; however, sediments can affect bottom-feeding organisms due to high concentrations of metals which settle out of suspension and accumulate on the lake bottom (Guthrie and Perry, 1980). Affecting bottom-feeders thereby affects other organisms due to bioaccumulation of chemicals through the food-chain (Fishar and Ali, 2005; Chen and Chen, 1999). In addition, different forms of phosphorus held in sediments can greatly affect lakes. Orthophosphate is a bioavailable form of phosphorus which tends to be in lower concentrations due to high demand by plants; however, as plants decompose, orthophosphate is released back into the environment (CCME, 2004; Howell, 2010). For phosphorus held into complexes with metals, anoxic conditions facilitate the dissolution of complexes and release of phosphorus from sediments (Hayes, Reid, and Cameron, 1985). Increased levels of phosphorus released from sediments into the water (internal phosphorus loading) can cause nutrient-enrichment and potential eutrophication and algal blooms (Sondergaard, Jensen, and Jeppesen, 2003) – this is particularly susceptible during turnover, when nutrient-rich bottom waters are mixed throughout the lake, providing new food sources for organisms.

High concentrations of metals within the lake bottom sites, unlike the Zwicker Brook site, may negatively affect aquatic life (Table 12). Within the Lake 1, 2 and 4 sites, arsenic and cadmium exceed the CCME interim sediment quality guidelines (ISQG). Lake 1 and 2 also exceed ISQG guidelines for mercury, with Lake 2 also exceeding manganese guidelines. In addition, selenium concentrations at Lake 2 and lead concentrations at Lake 1 appear to be close to CCME sediment guidelines and should be monitored (CCME, 2001). The deepest parts of SL – Lake sites 1 and 2 – have the highest concentrations of heavy metals in sediment. Water depth and slope are associated with increased metal concentrations due to funneling of particulate matter towards deeper lake-bottom pockets, as observed by Hakanson (1977) in Lake Vanern, Sweden.

Most SL lake sediment concentrations are comparable to metal concentrations found in four Kejimkujik lakes monitored from 2000-2009. Sediment samples were collected by Environment and Climate Change Canada from Hichemakaar Lake, Big Dam East, Cobrielle Lake, and Peskowesk between 2000 and 2009 (Kirk, 2018). Although the SL and Kejimkujik lakes have comparable sediment metal concentrations, many of these metals' concentrations exceed CCME guidelines. The high metal concentrations at Lake 1 are greater than the mean metal concentrations found at Kejimkujik for mercury and cadmium (Table 13). In addition, the concentration of cadmium in sediment at Lake 1, 2, and 4 is greater than the maximum cadmium concentration found in the four Kejimkujik lakes. Lake 2 also exceeded the range of manganese found within the Kejimkujik lakes, with a value 1.5 times the maximum concentration measured within the four Kejimkujik lakes.

As Zwicker Brook does not exceed any guidelines, it does not appear to be a significant influence on metal concentrations within the lake sites. It is possible that one (or multiple) of the other 13 inlet streams is affecting metal concentrations within the lake sediments; the lake sediment metals may be accumulating over time from metal inputs from other inlet streams. As the lake acts as a sink for all the various metal inputs, the higher metal concentrations observed within the lake sites compared to Zwicker Brook is reasonable, and consistent with 2018 results, where Forties River had lower metal concentrations than the lake sites. The rotation of sediment analyses from the inlet streams will help determine whether one or multiple streams are influencing lake sediment accumulation quantities.

Table 12: Concentration of metals within site sediment samples sampled on August 27th, 2018 and August 11th, 2019. Interim sediment quality guideline (ISQG) is the recommendation by CCME of total concentrations of chemicals in surficial sediment, while the probable effect level (PEL) is the CCME upper value in which adverse effects are expected (CCME, 2001). Nova Scotia environmental quality standards (NSEQS) are sediment guidelines specifically set by the Nova Scotia Environment (NSE, 2014). Light yellow indicates parameters approaching one of the guidelines, while dark yellow indicates an exceedance of one of the guidelines.

Parameter	Units	Lake 1	Lake 2		Lake 3	Lake 4	Forties River	Zwicker Brook	RDL*		Guidelines		
		2019	2018	2019	2018	2019	2018	2019	2018	2019	ISQG	PEL	NS
Aluminum (Al)	mg/kg	22000	22000	25000	6700	7200	4300	4700	10	10			
Antimony (Sb)	mg/kg	ND*	ND	ND	ND	ND	ND	ND	2	2			
Arsenic (As)	mg/kg	8.4	16	12	8.3	8.1	2.7	ND	2	2	5.9	17	17
Barium (Ba)	mg/kg	49	42	50	26	17	26	18	5	5			
Beryllium (Be)	mg/kg	ND	ND	2.1	ND	ND	ND	ND	2	2			
Bismuth (Bi)	mg/kg	ND	ND	ND	ND	ND	ND	ND	2	2			
Boron (B)	mg/kg	ND	ND	ND	ND	ND	ND	ND	50	50			
Cadmium (Cd)	mg/kg	0.76	1	0.99	1.5	0.76	ND	ND	0.3	0.30	0.6	3.5	3.5
Chromium (Cr)	mg/kg	15	14	14	4.6	5.1	4.7	4.0	2	2	37.3	90	90
Cobalt (Co)	mg/kg	9.0	8.8	11	6.8	4.1	2.3	2.2	1	1			
Copper (Cu)	mg/kg	12	15	10	13	3.1	ND	4.2	2	2	35.7	197	197
Iron (Fe)	mg/kg	14000	14000	15000	10000	9400	8300	6800	50	50			47766
Lead (Pb)	mg/kg	34	49	24	13	13	3.3	3.3	0.5	0.50	35	91.3	91.3
Lithium (Li)	mg/kg	17	10	9.7	11	14	20	21	2	2			
Manganese (Mn)	mg/kg	540	480	1300	1000	290	200	110	2	2			1100
Mercury (Hg)	mg/kg	0.27	0.27	0.20	0.16	ND	ND	ND	0.1	0.10	0.17	0.49	0.486
Molybdenum (Mo)	mg/kg	ND	ND	2.0	ND	ND	ND	ND	2	2			
Nickel (Ni)	mg/kg	10	7.5	6.9	5.7	4.6	2.3	3.1	2	2			75
Phosphorus (P)	mg/kg	1900	1900	2200	400	490	180	190	100	100			
Rubidium (Rb)	mg/kg	11	6.3	6.2	4.7	5.5	17	7.8	2	2			
Selenium (Se)	mg/kg	1.3	1.8	1.8	ND	ND	ND	ND	1	1			2
Silver (Ag)	mg/kg	ND	ND	ND	ND	ND	ND	ND	0.5	0.50			1
Strontium (Sr)	mg/kg	13	13	13	ND	ND	ND	ND	5	5			
Thallium (Tl)	mg/kg	0.26	0.26	0.24	0.34	0.11	0.12	ND	0.1	0.10			
Tin (Sn)	mg/kg	2.5	3	1.5	2	ND	ND	ND	2	1			
Uranium (U)	mg/kg	4.3	5.7	6.5	1.7	2.0	0.52	0.77	0.1	0.10			
Vanadium (V)	mg/kg	23	30	34	11	12	11	9.0	2	2			
Zinc (Zn)	mg/kg	87	93	89	96	66	20	34	5	5	123	315	315
Orthophosphate (P)	mg/kg	0.15	0.067	0.086	0.26	0.24	0.33	0.38	0.05	0.050			

*RDL = Reportable Detection Limit; ND = Not Detected

Table 13: Comparison of 2018 and 2019 sediment metal concentrations from SL lake and river sites to the range and mean metal concentrations from four Kejimkujik Lakes (Hilchemakaar, Big Dam East, Cobrielle, and Peskowesk) monitored from 2000-2009 (Kirk, 2018).

Metal	Unit	Lake 1	Lake 2		Lake 3	Lake 4	Forties River	Zwicker Brook	Kejimkujik Range	Kejimkujik Mean Concentration
		2019	2018	2019	2018	2019	2018	2019		
Acid Extractable Arsenic (As)	mg/kg	8.4	16	12	8.3	8.1	2.7	ND*	3.55-27.1	10.50
Acid Extractable Cadmium (Cd)	mg/kg	0.76	1.0	0.99	1.5	0.76	ND	ND	0.1-0.4	0.26
Acid Extractable Lead (Pb)	mg/kg	34	49	24	13	13	3.3	3.3	43-62.5	48.40
Acid Extractable Manganese (Mn)	mg/kg	540	480	1300	1000	290	200	110	28.7-666	273.40
Acid Extractable Mercury (Hg)	mg/kg	0.27	0.27	0.20	0.16	ND	ND	ND	0.14-0.345	0.22
Acid Extractable Selenium (Se)	mg/kg	1.3	1.8	1.8	ND	ND	ND	ND	1.39-3.17	2.24

*RDL = Reportable Detection Limit; ND = Not Detected

2.4.2. Hydrocarbons

Hydrocarbons are chains of carbon and hydrogen molecules which are the main components of natural gases and petroleum products. Monitoring hydrocarbons provides insight to whether anthropogenic activities are influencing water quality in the region - such as boating and combustion of petroleum products causing atmospheric deposition of polycyclic aromatic hydrocarbons (PAHs) (Das, Routh, and Roychoudhury, 2008; Andren and Strand, 1979).

Hydrocarbon testing was done for sediments rather than water samples for the 2019 field season, as hydrocarbons are known to settle out of the water column and onto the substrate. Of the hydrocarbon chains tested, the low molecular weight (LMW) chains were undetectable; however, the detection limits for these chains were higher than the guidelines set by the CCME for specific LMW chains, therefore, it is unclear whether concentrations pose a risk to the environment. Most high molecular weight (HMW) chains were also non-detectable, but also had detection limits above select CCME HMW guidelines. For the HMW chains between C21 and C32, the lab detected concentrations of 180,000 µg/kg for Lake 2, 87,000 µg/kg for Lake 4, and 28,000 µg/kg for Zwicker Brook. These values fall above the 6.22 µg/kg ISQG and 135 µg/kg PEL for dibenz(a,h)anthracene; however, it is unlikely that dibenz(a,h)anthracene is the only chain detectable between the C21-C32 chains tested, as many natural sources have long carbon chain structures, therefore risks associated with high levels of dibenz(a,h)anthracene are unknown, but should be considered minimal. Due to the lack of a sample available to perform hydrocarbon testing, no data are available for hydrocarbons in the sediment at Lake 1.

Hydrocarbons should continue to be monitored at all lake sites to monitor for changes in detectable amounts of hydrocarbons – especially at Lake 1 and Lake 4. Monitoring Lake 1 would provide information regarding the accumulation of hydrocarbons where no data are available, while Lake 4 is located near the proposed public boat launch, which would see an increase in boat traffic, and by association, increases in the potential for hydrocarbon releases into the lake.

2.4.3. Nutrients

Regarding the phosphorus levels within the lake and river sediment (Table 14), although Lake 2 has the highest amount of phosphorus in sediment, Zwicker Brook has the highest orthophosphate to phosphorus ratio (0.2% orthophosphate). The higher levels of this bio-accessible phosphorus in the stream is similar to what was observed in 2018, where Forties River also had the highest orthophosphate to phosphorus ratio (0.18% orthophosphate). All four 2019 sites had low orthophosphate to phosphorus ratios (≤0.2% each), indicating that the bioavailable orthophosphate is being quickly assimilated by organisms and therefore most of the phosphorus in the sediment is in non-bioavailable forms.

Phosphorus concentrations within SL suggest pollution within the lake. Although there is no sediment phosphorus guideline set by the CCME, Ontario's Provincial Sediment Quality Guidelines have a 600-2000 mg/kg range, where 2000 mg/kg of phosphorus in sediment is the 'severe effect level' (Ontario MOE, 2008). Lake 4 and Zwicker Brook are below the Ontario guidelines, suggesting minimal influence by pollution and no negative effects on aquatic organisms; however, Lake 1 is close to the threshold, while Lake 2 exceeds the 2000 mg/kg severe effect level, and therefore indicates pollution within the lake. For Lake 2, the indication of pollution is greater, as both the concentrations of total phosphorus and orthophosphate have increased from 2018 levels. The elevated phosphorus concentrations within the Lake 1 and 2 sites indicate a potential for internal loading for phosphorus in the lake causing algal blooms. Lake sites 1 and 2 should be considered 'sites of concern' and be continued to be monitored due to high potential for nutrient-enrichment, eutrophication, and algal blooms.

Table 14: Phosphorus concentrations in sediment samples from lake and river sites sampled on August 27th, 2018, and August 11th, 2019.

	Lake 1	Lake 2		Lake 3	Lake 4	Forties River	Zwicker Brook
Parameter (Units)	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Orthophosphate in sediment (mg/kg)	0.15	0.0067	0.086	0.26	0.24	0.33	0.38
Acid extractable phosphorus in sediment (mg/kg)	1900	1900	2200	400	490	180	190

3. Discussion

3.1. Trophic State of Sherbrooke Lake

Trophic states describe the productivity of a waterbody which can aid in tracking how a waterbody changes over time. Trophic states range from oligotrophic (low productivity and minimal biomass) to hypereutrophic (high productivity and maximum biomass). The trophic state index (TSI), proposed by Carlson (1977), uses the depth of transparency (Secchi disk), and concentrations of chlorophyll *a* and phosphorus to apply a number to the waterbody's state (Equations 2, 3, and 4) – associated with its trophic state. Tracking a waterbody's TSI allows comparison between years using the same methods.

Equation 2: $$TSI\ (Secchi\ disk) = 60 - 14.41 \times \ln(Mean\ Secchi\ disk\ [m])$$

Equation 3: $$TSI\ (chlorophyll\ A) = 30.6 + 9.81 \times \ln\left(Mean\ chlorophyll\ A\ \left[\frac{\mu g}{L}\right]\right)$$

Equation 4: $$TSI\ (total\ phosphorus) = 4.15 + 14.42 \times \ln\left(Mean\ total\ phosphorus\ \left[\frac{\mu g}{L}\right]\right)$$

In SL, the lake's TSI could be based on sites Lake 1, Lake 2, and Lake 4, therefore a TSI was created for all three sites (Table 15; Figure 26). All sites have oligotrophic levels of phosphorus, indicating low productivity. The phosphorus TSI scores have increased from 2018. For chlorophyll *a*, Lake 1 has mesotrophic levels, while Lake 2 and 4 indicate oligotrophic levels of chlorophyll *a*. All three sites have mesotrophic levels of transparency (calculated using Secchi disk depths). Concern should be minimal for the Secchi disk/water transparency indices, as water transparency is not an exact indication of a waterbody's productivity, and can be influenced by factors other than biomass, such as suspended particles within the water column (NSSA, 2014; EPA, 2002). In general, SL can be labelled primarily oligotrophic; however, the increase in TSI phosphorus scores indicates the lake's productivity may be changing and being influenced by nutrient loading.

Table 15: Carlson (1977) 2018 and 2019 SL TSI scores and trophic states for total phosphorus, chlorophyll A, and Secchi disk for Lake 1 (red), Lake 2 (blue), and Lake 4 (yellow – for 2019 only).

TSI Score	Trophic State	Phosphorus		Chlorophyll A		Secchi Disk	
		2018	2019	2018	2019	2018	2019
< 40	Oligotrophic	33.3	39.21		39.76		
		28.6	34.14		37.03		
			35.83				
40-50	Mesotrophic			42.3	40.45	48.6	49.31
				40.7		47.38	46.51
							46.24
> 50	Eutrophic						

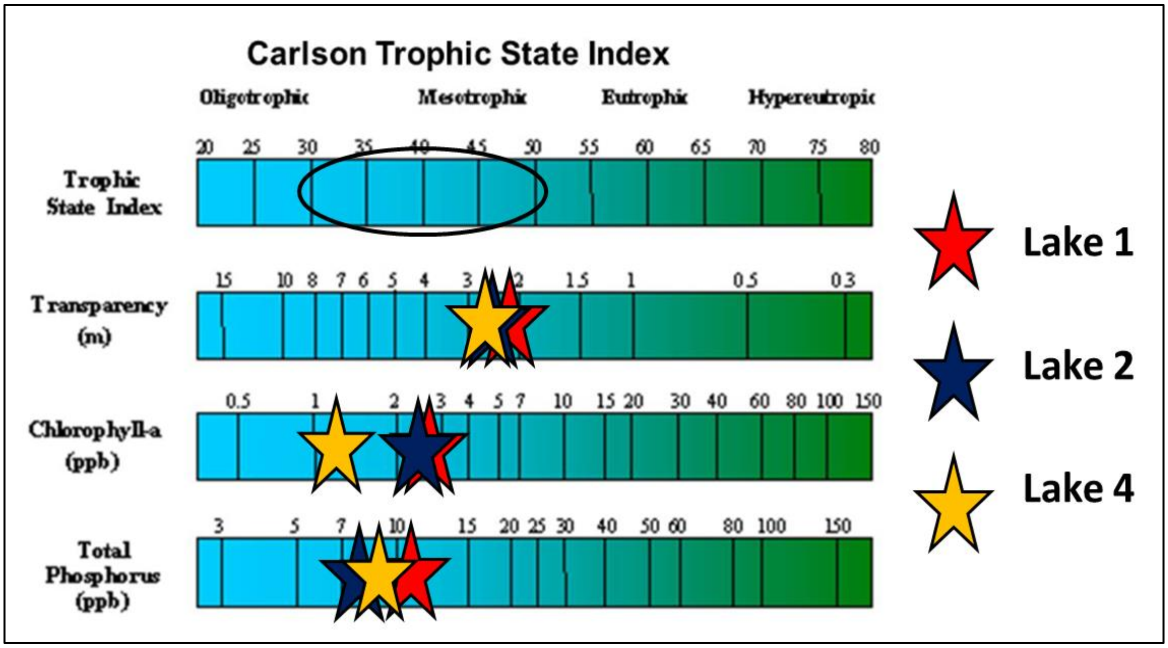

Figure 26: Carlson TSI for lakes, with TSI ranks for SL Lake 1 (red star), Lake 2 (blue star), and Lake 4 (yellow star). Transparency determined using Secchi disk depth. From Carlson (1977).

3.2. Algal Blooms

An algal bloom is the rapid increase and accumulation of microscopic plankton algae (phytoplankton) in waterbodies and can be detrimental to ecosystems (Hallegraeff, 2003). Ecosystems have a fragile balance, where biomass is sustained and limited by available nutrients; however, when excess nutrients enter an ecosystem, biomass can expand (Heisler *et al.*, 2008). In waterbodies, excess nutrients allow algae to flourish, exceeding normal densities and assimilating all nutrients. The increased biomass presence causes decreased water transparency – blocking off the depth of which sunlight penetrates a waterbody – and as the algae decay, increased microbial decomposition reduces dissolved oxygen – leading to hypoxic and anoxic conditions (Paerl *et al.*, 2001).

In addition to the detrimental environmental effects, algae blooms can pose a risk to humans and animals if they consist of cyanobacteria. Cyanobacteria, commonly referred to as blue-green algae, can emit toxins into the water, causing serious illness and even death in humans (Lawton and Codd, 1991). Aside from humans, cyanobacteria blooms have also been associated with fish kills (Rodger *et al.*, 1994), and the death of dogs (Backer *et al.*, 2013). Although not all cyanobacteria are toxic, it is important to test each bloom to confirm which strains are present and if toxins are a threat within the waterbody.

In 2019, SL experienced several algae blooms (Figure 27). These blooms were reported throughout the lake, with no one singular source or location, indicating that algae growth appears to be a lake-wide issue. From the sighting reports, blooms occurring along the north-eastern side of the lake disappated overnight, with blooms then occuring the following day along the south-western side of the lake, suggesting that wind and wave action may be partially responsible for the movement of blooms within SL. The influence of wind and waves on bloom dispersion allows for greater distribution of blooms throughout the lake, thereby affecting a greater portion of residents of SL.

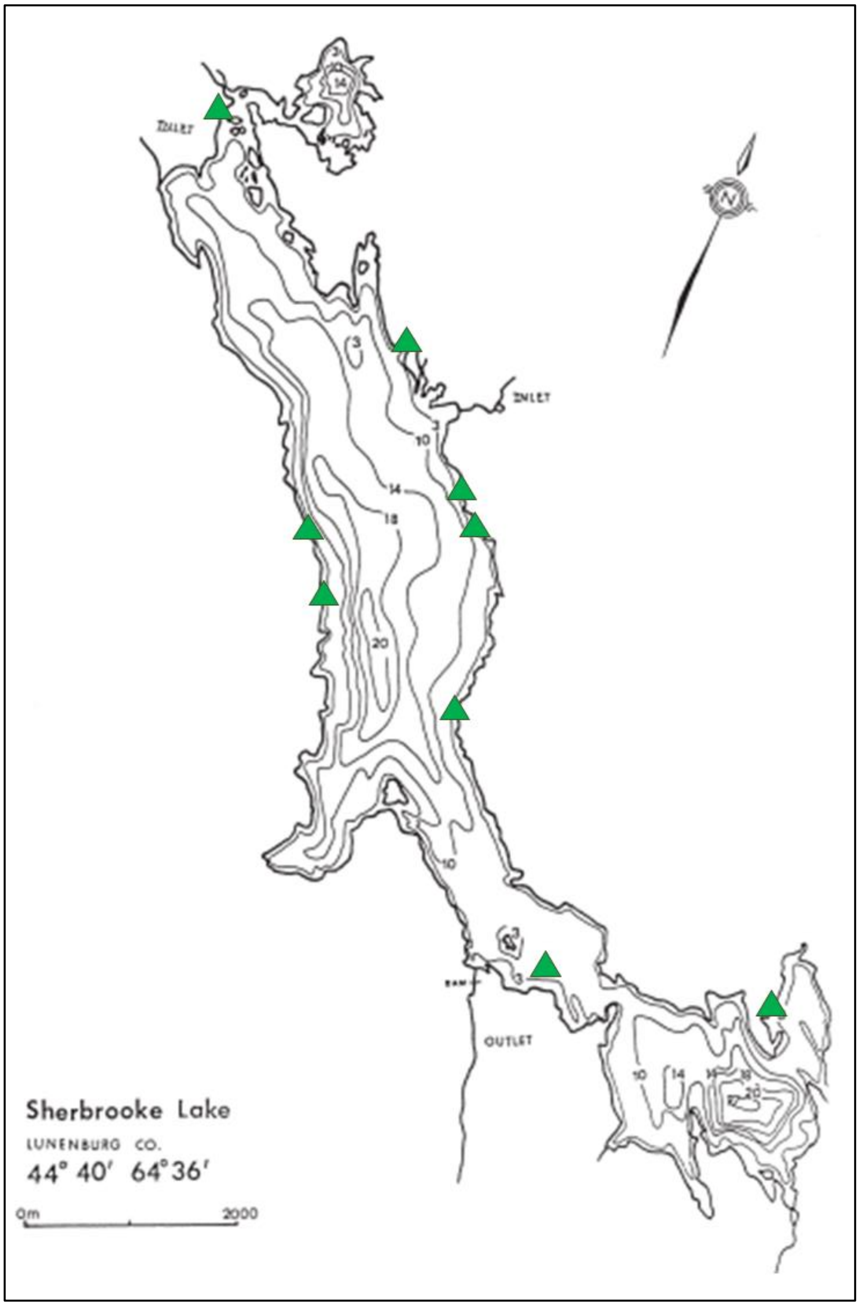

Figure 27: Reported algae bloom locations (green triangles) within Sherbrooke Lake during the 2019 field season.

Of the reported blooms, two were sampled and sent to Maxxam Analytics to be tested for microcystins – the toxin associated with cyanobacteria. For recreational use, total microcystins should be less than 20 µg/L (Health Canada, 2012); the two SL samples had levels below instrument detection limits, indicating that the water was safe for recreation. In addition to the microcystin samples, an algae sample was also sent to Dalhousie to identify the algae species present in the water. The predominant form of algae was green algae – a non-toxic species. The increase in this species compared to previous years may be linked to the higher concentrations of nutrients (nitrogen and phosphorus) measured within the lake in 2019 compared to 2018.

Bloom sightings have increased from 2018 when no bloom was reported, to nine sightings reported to Coastal Action within the months of June and July 2019. The increase in blooms in SL is not a localized phenomenon, as studies have observed an increase in both size and frequency of algae blooms globally, with potential for further increases in the future (Ho *et al.*, 2019; Michalak *et al.*, 2013). Although the increases in algal blooms have been linked to climate change and increasing temperatures (Ho *et al.*, 2019), land-use practices, such as the removal of natural filters – wetlands, vegetative buffers – and the increased application of nutrient-rich fertilizers, have also been discussed as catalysts increasing bloom occurrences (Huisman *et al.*, 2018). Increased bloom sightings at SL may also be attributed to a greater awareness of lake water quality and monitoring activities through the efforts of the SLSC. Although the source of the blooms in SL is unclear, management of nutrients into SL is necessary, as its oligotrophic state is easily influenced by excess nutrient loading, as observed with the increase in the lake's phosphorus TSI values, which can lead to an increase in the presence of algae blooms – and the potential for toxic cyanobacteria blooms – in the lake.

3.3. Pollution

Nutrients and bacteria are two pollutants common in SL and its tributaries. Although both pollutants are present in the natural environment, their concentrations increase with human activities. The increased presence of nutrients poses a threat to both human and aquatic life, as nutrients can increase the lake's productivity, shifting its trophic status from oligotrophic to eutrophic, which increases the risk of the formation of algal blooms. The increased presence of bacteria poses a risk for human health, as recreation within waters with high counts of bacteria increases the risk of exposure to harmful bacteria, viruses, and protozoa. Human activities can influence the levels of these pollutants via pollution inputs – straight pipes, malfunctioning septic systems, lawn and crop fertilization, etc. – and the removal of pollutant control measures – riparian zones in particular. Addressing the high levels of the nutrients and bacteria within SL and its tributaries requires action regarding both human activity types.

As observed in 2018, rainfall events appear to be detrimental to the water quality of the SL tributaries. The rain flushes pollutants from land-based sources towards nearby waterbodies. Spikes in both nutrients and bacteria were observed following Hurricane Dorian at the seven inlet streams; however, lake water quality was minimally affected. A settling time of 24 hours is advised prior to recreation within the SL waters following a rainstorm event.

Heavy metals also appear to be pollutants within the lake, due to contaminated levels of metals found within the lake sediment. Although heavy metals do have natural sources, and the metal concentrations from SL sediment are comparable to nearby sediment in Kejimkujik, concentrations for mercury, arsenic, cadmium, and manganese exceed CCME guidelines for aquatic life. The accumulation of heavy metals in SL sediment may be exacerbated by development and atmospheric inputs originating from industry.

Although SL is considered an oligotrophic lake, its status is fragile. The lake is being influenced by sources of nutrients and bacteria, while also experiencing long-term sediment contamination. Continued pollutant inputs into the lake will affect the lake's water quality, and it is important to continue monitoring and highlighting these changes to develop management plans for the lake and encourage the application of best management practices.

4. Recommendations

The following recommendations are suggested for the SL Water Quality Monitoring Program, based on the 2019 water quality results:

- The SL Water Quality Monitoring Program should continue in 2020 and beyond, as construction of the public access site - and increased lake usage - is expected to continue into future years, and this program was developed to establish a water quality baseline to aid in evidence-based decisions concerning the development of the property acquired by MODL for public use.
- Sampling of the seven inlet streams should continue during rainfall-dependent events, to determine how rainfall events are affecting inlet streams. Overlapping monthly lake sampling with the rainfall-dependent event is also advised, to assess how rainfall-induced changes in stream water chemistry affect the lake.
- The stream sediment sample should continue to be rotated and sampled from a different inlet stream each year, to gather more spatial information about nutrient and metal loading from the different streams discharging into the lake. This will help determine if any inlet streams are contributing excess pollutants and having an influence on lake sediment.
- In conjunction with the Sherbrooke Lake Communications Plan, both municipalities should continue to create and distribute educational pieces to inform the public about water quality protection and stewardship.
- There is a need for more consistency between MODL and MOC's websites in regard to the SL Water Quality Monitoring Program and how the information is provided. A link to each other's websites would be beneficial as well.
- There is a need for continued communication between the Sherbrooke Lake Stewardship Committee and the Sherbrooke Lake Park Advisory Committee. It is recommended that these two groups keep each other apprised of their activities and meet on a somewhat regular basis once development of the public access site begins.
- Residents of SL should continue to be supplied with lab-certified bottles and sampling procedures for the collection of water samples during an algae bloom.
    - There should be a greater emphasis on algal bloom education, focused on increasing awareness of what blooms are, how they occur, what they look like, and how to report them. Information should be shared with lake residents and at the public access site for visitors of the lake.
    - A procedure should be created and shared by both municipalities to inform citizens of the proper steps to take when they observe a potential algae bloom. Potential blooms should be reported to Nova Scotia Environment, as the authority responsible for assessing the bloom's presence and risk to the public. Bloom sightings should also be reported to the SLSC – for the purpose of tracking and analyzing bloom occurrences for the water quality monitoring program.

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