2023

HALLS & HAWKS LAKE PROPERTY OWNERS ASSOCIATION

WATER QUALITY MONITORING REPORT

PREPARED BY

U-Links Centre for Community-Based Research

Table of Contents

Contents

Project Overview

Haliburton County is located 200KM north-east of the Greater Toronto Area at an elevation of 325-440 metres above sea level (ASL), a high elevation point of the Canadian Shield, encompassing over 4000 square kilometres of forests and over 600 lakes [1]. The current geographic landscape of Haliburton County was primarily influenced by glacial melting. These natural amenities attract tourism which drives the local economy.

It is acknowledged that Haliburton County is located on Treaty 20 Michi Saagiig territory and in the traditional territory of the Michi Saagiig and Chippewa Nations, collectively known as the Williams Treaties First Nations [1].

Acting on information requests from Haliburton County Lake Associations in 2021, Woodlands and Waterways EcoWatch (WWEW), a division of U-Links Centre for Community-Based Research, initiated a pilot water quality monitoring program which has been developed to be able to expand to lakes across Haliburton County. The pilot program started in 2022, and in 2023, WWEW and Lake Association citizen scientists sampled water quality parameters from 37 sites on 25 lakes (for purposes of this program, Paddy's Bay – on the north shore of Kennisis Lake is a recognized sample location). This program represents a broadscale monitoring objective of having water quality data that is comparable across lakes within Haliburton County and with neighbouring regions. The goals of this pilot program are:

- to develop water quality monitoring protocols and practices specific to the aquatic health concerns in the region.
- to develop and grow a database of water quality measurements that will provide long-term information on lake health in Haliburton County.

This information will be useful for decision-makers as they attempt to develop legislation that will ultimately maintain water quality in the County's freshwater resources.

Stocking Lake, which is located ~25km North from the HHLPOA Lakes (Figure 1), was used as a reference lake for this program; it was selected based largely on the absence of seasonal and permanent dwellings except for a small collection of cabins used for research purposes. Motorized vehicles are not permitted on the water and shorelines have retained their natural state.

A Haliburton Water Quality Summit was held in 2022 during program development, where a number of limnology experts were consulted to select and optimize the physical and chemical water quality parameters to measure. This program has been funded in part by the County of Haliburton, grants sourced from Federal and Provincial agencies, Canoe FM, the Haliburton County Development Corporation, and participating Lake Associations. Many thanks to the Lake Association volunteers who provided sampling support, boat transportation and coordination of Association participants as citizen scientists.

Figure 1 Stocking Lake (Reference) in relation to HHLPOA Lakes (Sampled)

Report Overview

This report documents physical and chemical water quality parameters that were measured on Big Hawk Lake, Little Hawk Lake and Halls Lake in 2022 and 2023, and provides an update to the 2022 report prepared for the Halls & Hawk Lakes Property Owners Association (HHLPOA) [2].

Water Quality Measurements and Methods

SITE LOCATION

Field measurements and samples were collected from Big Hawk Lake (Site BHAW-WQ-01), Little Hawk Lake (Sites LHAW-WQ-01 and LHAW-WQ-02), and Halls Lake (Site HALL-WQ-01) in 2022 and 2023. In 2022, sampling occurred twice, on July 22nd and September 6th, with samples collected from the deepest points within lake basins (Figure 2). The deepest point was chosen for its better representation of the entire lake water, with lesser influences from shorelines and shoreline activity.

In 2023, the sampling frequency was maintained with sampling dates being: June 29th, and October 3rd. Ice-on testing was conducted on the HHLPOA lakes in 2023 but program expansions will seek to initiate this testing in 2024 onward.

These adjustments in the sampling schedule aimed to enhance the temporal resolution of data collection and capture potential seasonal variations in water quality. The inclusion of ice-on testing contributes valuable insights into winter conditions The HHLPOA Lakes, as upper reservoir lakes in the Trent system, are impacted by controlled drawdown and fluctuating lake levels. Winter ice-on testing is suggested to determine whether these fluctuating levels impact water quality measurements. The continued focus on the deepest points within lake basins ensures a consistent and representative approach to monitoring water quality.

Site Coordinates

- BHAW-WQ-01: 45.1633, -78.7357
- LHAW-WQ-01: 45.1595, -78.7027
- LHAW-WQ-02: 45.15152, -78.70792
- HALL-WQ-01: 45.10494, -78.73642

Figure 2 Water quality sampling locations on the HHLPOA Lakes

Methods

To gather data and gain the insight necessary to complete this report, industry standard sampling protocols were followed with the use of various monitoring tools in the field to collect measurements. The sampling protocol is available as a separate document: *Woodlands and Waterways EcoWatch - Lake Sampling Procedures* [3].

As part of the program, several on-site water quality measurements were recorded (pH, conductivity, Secchi depth, dissolved oxygen, temperature, and alkalinity). Water samples were collected through the water column down to the determined Secchi depth. This allows for the measurement of nutrients present within the entire **photic zone**. Water samples were collected at each site and shipped to the ALS Environmental Analysis Laboratory based in Waterloo, Ontario. Weather observations were also noted at the start of every sampling event.

To measure alkalinity, test strips for freshwater (Water Rangers branded) were dipped into a surface water sample. Conductivity and pH were measured using an Oakton PCTS-50 multi-meter that was placed into a surface water sample. A depth profile for dissolved oxygen and temperature was produced, measuring in metre intervals of lake depth (up to 50m) using a YSI PRO-ODO device. All other parameters (ammonia, total Kjeldahl nitrogen, nitrates, nitrites, total phosphorus, and sulfate) were measured at the ALS laboratory using the collected water samples.

An addition to the sampling program for 2023 was offered to Lake Associations, which included a total metals analysis, providing a baseline measurement of 39 analytes (Listed in Results Section-Table 3), allowing for a comparison with the reference lake.

PARAMETERS MEASURED

A detailed description of the program's standard parameters is summarised in Table 1 and the following sections.

Table 1 - Chemical water quality parameter descriptions

ALKALINITY	Alkalinity is indicative of a lakes ability to neutralize acids and its sensitivity to acidic inputs [2]	Alkalinity concentrations come from salts and minerals **leaching** from rocks into lakes, or from wastewater discharge [2]. Recommended limit: 20-200 mg/L. If <10 mg/L = the waterbody is susceptible to acidification [2]
AMMONIA	Ammonia is a form of nitrogen, formed through the fixation of atmospheric nitrogen and hydrogen [3]	Ammonia can be highly toxic to aquatic life. Common ammonia inputs into freshwater systems include run-off from fertilizers, municipal **effluent** discharges and industry processes [3]. Natural sources can include organic waste breakdown, forest fires, animal waste. Recommended limit: 0.019 mg/L [4]
CONDUCTIVITY	Conductivity measures the total **ionic strength** of water, and determines how well an electric current can pass through it [2,5]	Higher levels of conductivity typically mean it contains more dissolved salts [2]. Conductivity also increases as temperatures increase, due to evaporation of surface water [2]. Pure water has very low conductivity. Lakes can range from 0-200 µS, with some major rivers reaching >1000 µS [5]
DISSOLVED OXYGEN	Dissolved oxygen is the measure of the amount of free oxygen present in the water [6]	Dissolved oxygen has a large influence on aquatic organisms, outside of the ideal range, it can inhibit aquatic life and affect water quality and is closely related to lake temperature [6]. Range is highly variable
NITRATES, NITRITES	Nitrates and nitrites are nitrogen compounds that in low concentrations, play an important role in aquatic ecosystem health [2]	If nitrate levels are too high, it can cause algae blooms and **eutrophication** [2]. Elevated levels may be caused by pollution (runoff, sewage). Natural surface water levels are typically <1.0mg/L [6]
PH	pH is a measure of the degree to which water is acidic or basic. On the 0-14 pH scale, 0 = strongly acidic, 14 = highly basic. 7 represents a neutral pH, such as pure water	Most North American freshwater bodies have a pH that ranges from 6.5-8.5, and most fish thrive in water within this range [7]. pH is influenced by local geology (such as the Canadian Shield) and is determined by chemistry components like salts, carbonates and various acids
SULFATE	Sulfate is the most common form of sulfur found in well-oxygenated lakes [2]	Naturally occurring sulfate can be introduced through the breakdown of leaves in the Fall [6], it can also be brought into the lake through acid rain. High levels of sulfate can increase the acidity of a lake, reducing its pH [8]. Recommended limit: <250 mg/L [8]
TOTAL KJELDHAL NITROGEN	Total Kjeldahl Nitrogen is a measure of total organic nitrogen + ammonia [2]	If nitrate levels are too high, it can cause algae blooms and eutrophication [2]. Elevated levels may be caused by input by pollution (runoff, sewage). Natural surface water levels are typically <1.0 mg/L [2]
TOTAL PHOSPHORUS	Phosphorus is an abundant mineral and essential aquatic nutrient, key for plant and algae productivity and biomass [7]	In excess, phosphorus can limit biodiversity, harm sensitive species, cause anoxia and lead to eutrophication. Sources can include fertilizers, animal waste, sewage effluent. Recommended limit: 0.01 mg/L [7]

SECCHI DISK SAMPLING

Secchi disks are weighted, thin, black, and white disks, attached to a line, that gather visual data based on the visual properties that emerge as they are lowered into the water column. The depth in which the sight of the disk is lost gives insight into water colour, transparency, fluorescence, and clarity [9].

The apparent colour is the result of various substances that are either suspended or dissolved in the water column that are typically comprised of three main components: organic particulates (including phytoplankton and zooplankton), inorganic matter (commonly composed of chalk and dissolved minerals) and coloured dissolved organic matter (CDOM) [9].

The results of these components allow for colour comparison correlating to specific water conditions that include the following:

- Colourless – High light penetrations often associated with low nutrient stocks and low rates of biomass primary production.
- Green-blue – Colour tends to be dominated by algae and with moderate levels of dissolved sediment and organic matter.
- Yellow-brown – Waters are subject to high levels of **humification** where CDOM has reached maturity and decomposition of plant remains including aquatic and terrestrial litter has occurred.

The Secchi disk is also used to measure the photic zone, the uppermost layer of water which is penetrated by sunlight. This zone is where plant life can undergo photosynthesis and survive. The depth of this zone is dependent on the amount of suspended matter and particulates [9].

DISSOLVED OXYGEN AND TEMPERATURE

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in the water and available for living organisms, such as fish. Long-term unaddressed organic matter and nutrient introductions can promote the development of **eutrophication** and algal blooms, leading to reduced DO concentrations effectively suffocating aquatic life. Oxygen is a primary controller of lake chemistry and is thus especially important to measure in lakes [10].

DO is sourced by oxygen transfer from Earth’s atmosphere and by photosynthesis (from submerged aquatic vegetation). Aeration from mixing water also promotes oxygen reintroduction, typically at sites containing waterfalls, rapids or during high wind conditions. Temperature is a significant variable affecting DO concentrations, the solubility of oxygen is inversely proportional to temperature so as waters become warmer the DO decreases.

Thermal stratification occurs where a warm water layer remains on top, and a cold-water lies below. Due to the density differences in these two layers, there is no mixing and the atmospheric oxygen present in the top layer does not reach the bottom. Due to photosynthesis in the photic zone, DO concentrations remain high throughout the summer, however, the bottom layer can exhibit declines in DO as organisms consume oxygen.

Depending upon the amount of biological activity, bottom waters can become **anoxic**, nearly free of dissolved oxygen (<5 mg/L). This may lead to fish death and can dramatically affect chemical processes in these waters. Dissolved oxygen levels above 5 mg/L are considered optimal for most aquatic organisms, while fish require levels above 3 mg/L. For cold-water species, such as Lake trout, a minimum of 6 mg/L is needed, along with a temperature below 10°C [10].

Results and Discussion

RECOMMENDED LIMITS

The parameters measured are important indicators of water quality and ecosystem health. However, it is important to note that individual parameters come together to create a cohesive picture as one parameter alone cannot always tell a story. Individual parameters might fluctuate above or below the recommended limits, and this might be natural and expected over the changing seasons. Other very high or low measurements might be problematic but cause for concern will be typically established over multiple rounds of sampling and data, and perhaps further investigation.

Total Kjeldahl Nitrogen (TKN) is a measured parameter that does not have an established ideal limit or range as TKN is the sum of the total nitrogen bound in organic substances plus that nitrogen contained in both ammonia and ammonium [2]. Higher values are considered problematic and lower values are more ideal, the average TKN concentration of Canadian Shield lakes is 0.275 mg/L [21]. Due to this, it is important to measure regularly and identify trends or spikes. Consistency is key as sudden spikes could indicate an issue [5]. To place some context around this parameter, a trend line can be developed with low versus high concentrations based on collected data.

Similarly, Secchi disk depth does not have a specific contextual range and is dependent on various factors including overall lake depth, shoreline composition and vegetation buffer, local rocks and mineral, organic matter, and other natural inputs.

The limits used in this results section have been established by various research institutions, including the Ontario Provincial Water Quality Objectives, the Canadian Councils for Ministers of the Environment (CCME) and the District of Muskoka [4,6,10]. These limits have allowed us to develop an initial set of our own water quality limits which we feel are suitable for the lakes in Haliburton

County in general. However, as these standards are established for either the province of Ontario, or for all of Canada, they may not be exactly appropriate for your lake. In this report, and ins subsequent reporting, we will comment on the appropriateness of the limits, if applicable.

RESULTS

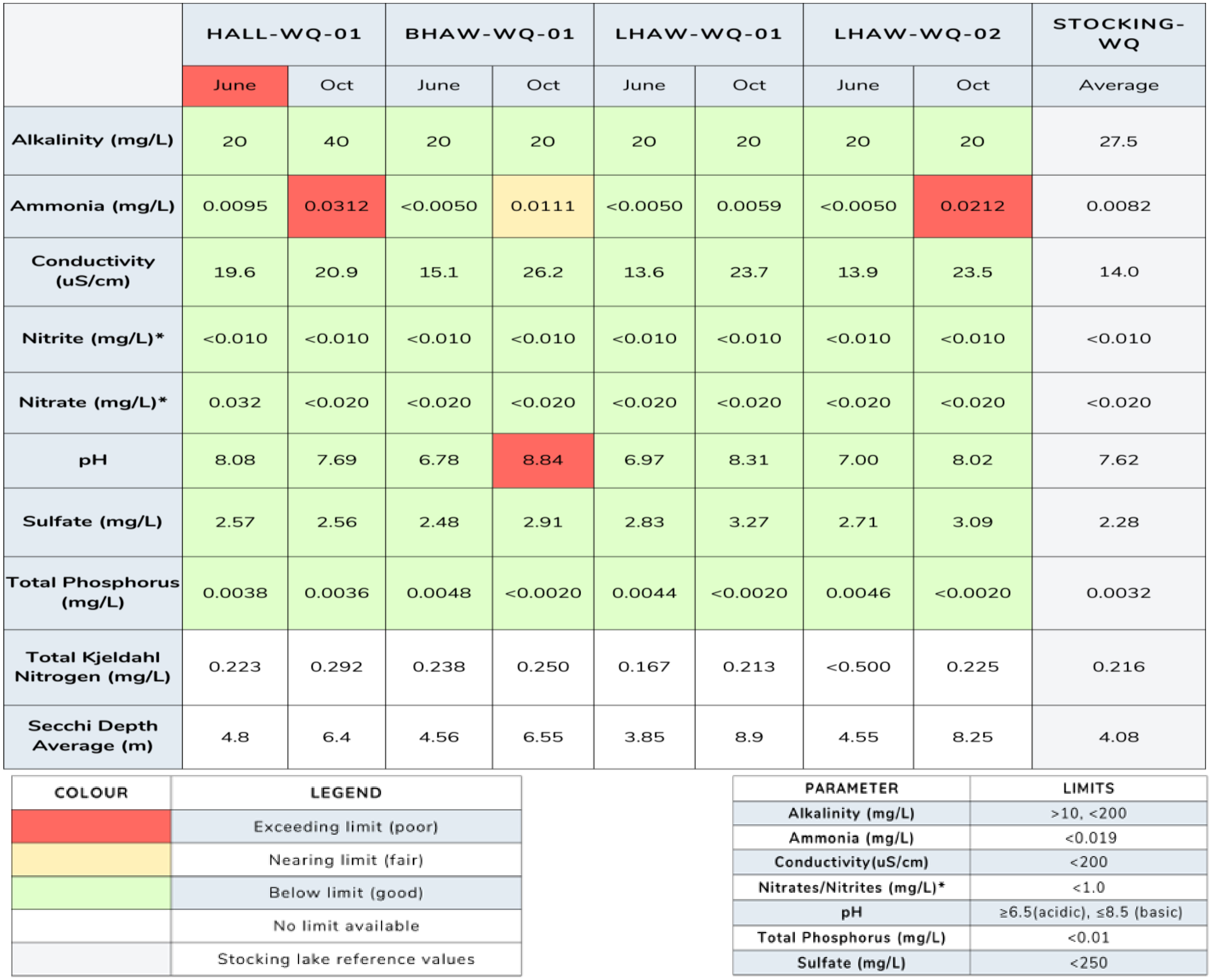
This report provides a comprehensive assessment of physical and chemical water quality parameters that are useful in monitoring lake health. The results presented here provide a comprehensive overview of the chemical parameters measured during this study, offering an interpretation of the findings.

The specific findings for 2023, for the HHLPOA Lakes, including the parameters mentioned, are presented in Table 2, which includes a comparison with results obtained from Stocking Lake, the reference lake. This comparative analysis serves as a critical tool in identifying potential variations and trends, offering valuable insights into the unique characteristics of each lake.

It is important to note that comprehending the "normal" state of these lakes necessitates a longitudinal perspective. As we embark on the second year of our sampling program, the inclusion of multiple years of data becomes fundamental in discerning patterns and establishing a robust baseline for future assessments. This ongoing and extended timeframe not only enhances the reliability of the findings but also facilitates the capture of seasonal variation contributing to a more comprehensive understanding of the lakes' ecological dynamics.

The continuous sampling efforts are integral to the process of building a reliable dataset that can effectively represent the inherent variability within these aquatic ecosystems. Additional years of sampling will further contribute to the refinement of baseline levels, enabling a more informed evaluation of lake health and resilience

Table 2 Results from the HHLPOA Lakes in comparison to Stocking Lake and specific parameter limits



	HALL-WQ-01		BHAW-WQ-01		LHAW-WQ-01		LHAW-WQ-02		STOCKING-WQ
	June	Oct	June	Oct	June	Oct	June	Oct	Average
Alkalinity (mg/L)	20	40	20	20	20	20	20	20	27.5
Ammonia (mg/L)	0.0095	0.0312	<0.0050	0.0111	<0.0050	0.0059	<0.0050	0.0212	0.0082
Conductivity (uS/cm)	19.6	20.9	15.1	26.2	13.6	23.7	13.9	23.5	14.0
Nitrite (mg/L)*	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrate (mg/L)*	0.032	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
pH	8.08	7.69	6.78	8.84	6.97	8.31	7.00	8.02	7.62
Sulfate (mg/L)	2.57	2.56	2.48	2.91	2.83	3.27	2.71	3.09	2.28
Total Phosphorus (mg/L)	0.0038	0.0036	0.0048	<0.0020	0.0044	<0.0020	0.0046	<0.0020	0.0032
Total Kjeldahl Nitrogen (mg/L)	0.223	0.292	0.238	0.250	0.167	0.213	<0.500	0.225	0.216
Secchi Depth Average (m)	4.8	6.4	4.56	6.55	3.85	8.9	4.55	8.25	4.08

COLOUR	LEGEND
🟥	Exceeding limit (poor)
🟨	Nearing limit (fair)
🟩	Below limit (good)
⬜	No limit available
▨	Stocking lake reference values

PARAMETER	LIMITS
Alkalinity (mg/L)	>10, <200
Ammonia (mg/L)	<0.019
Conductivity(uS/cm)	<200
Nitrates/Nitrites (mg/L)*	<1.0
pH	≥6.5(acidic), ≤8.5 (basic)
Total Phosphorus (mg/L)	<0.01
Sulfate (mg/L)	<250

pH

In comparison to the findings of the previous year, the measured chemical parameters for the HHLPOA Lake samplings exhibited results indicating very healthy waters. In the 2022 sampling, all parameters fell within normal limits.

The 2023 sampling reveals a notable changes in pH across most sites throughout the year, specifically for the October sampling event. pH across all sites on Big and Little Hawk Lakes show an increase compared to both events in 2022, signifying an alkaline shift for the waterbodies. It is important to note that while this increase is evident, only one of the sites have surpassed the recommended upper limit of 8.5 (BHAW-WQ-01). LHAW-WQ-01 had a pH value that approached the upper limit, (pH= 8.31). This observed trend emphasises the importance of continuous monitoring to discern patterns and potential shifts in the chemical composition of the lake over time. Further investigation and analysis will be crucial to understanding the underlying factors contributing to these observed changes and their potential implications for the overall health of the HHLPOA Lakes.

Nitrogen

The current laboratory detection limits for nitrate and nitrite, 0.020mg/L and 0.010mg/L respectively, do not allow for the provision of sufficient data for our current program purposes, as these parameters consistently fall below these limits. As the pilot develops there will be an effort to identify ways to reduce this limit in order to provide vital information.

Ammonia levels during the 2022 sampling were negligible across all sites, falling within the normal range of <0.019 mg/L. Detailed laboratory detection limits are provided in Appendix B.

Significant variations have been observed in ammonia levels during the 2023 sampling. Ammonia levels from LHAW-WQ-01 are the exception, maintaining levels comparable to the previous year. However, levels at HALL-WQ-01 and LHAW-WQ-02 exceeded the upper limit in October while all sites were within guideline limits the preceding spring. BHAW-WQ-01 recorded an increase in October, approaching the upper guideline limit at 0.0111 mg/L.

In 2023, nitrate concentrations were detected at one site (HALL-WQ-01) in the spring, in contrast to 2022, when they all fell below the Limit of Reporting (LOR) across all HHLPOA sites. Nitrite values continued to fall below the LOR in 2023. Following consultation with lake monitoring experts, the water quality monitoring program has decided to discontinue the detection of nitrite going forward.

Total Kjeldahl Nitrogen (TKN) at all sites was measured to be <0.3mg/L. The lowest amount measured was <0.500 mg/L in October at LHAW-WQ-02. The highest amount measured was 0.292 mg/L in October at HALL-WQ-01.

The evolving trends in ammonia levels and the changes in nitrate concentrations underscore the dynamic nature of water quality dynamics, reaffirming the necessity for ongoing monitoring and adaptive program adjustments to ensure the effectiveness of the lake monitoring efforts.

Phosphorus

Total phosphorus remained consistently below the recommended limit (<0.010 mg/L) during all sample events in 2022. The highest concentration recorded was 0.0041 mg/L at sites LHAW-WQ-01 in July and LHAW-WQ-02 in September, while the lowest was 0.0029 mg/L at HALL-WQ-01 in July (refer to Figure 3).

In the 2023 sampling, there are notable reductions in total phosphorus concentrations across all sites on Big and Little Hawk Lakes with concentrations all falling below the LOR. HALL-WQ-01 exhibited very little change with a shift from June to October of 0.0038 mg/L to 0.0036 mg/L.

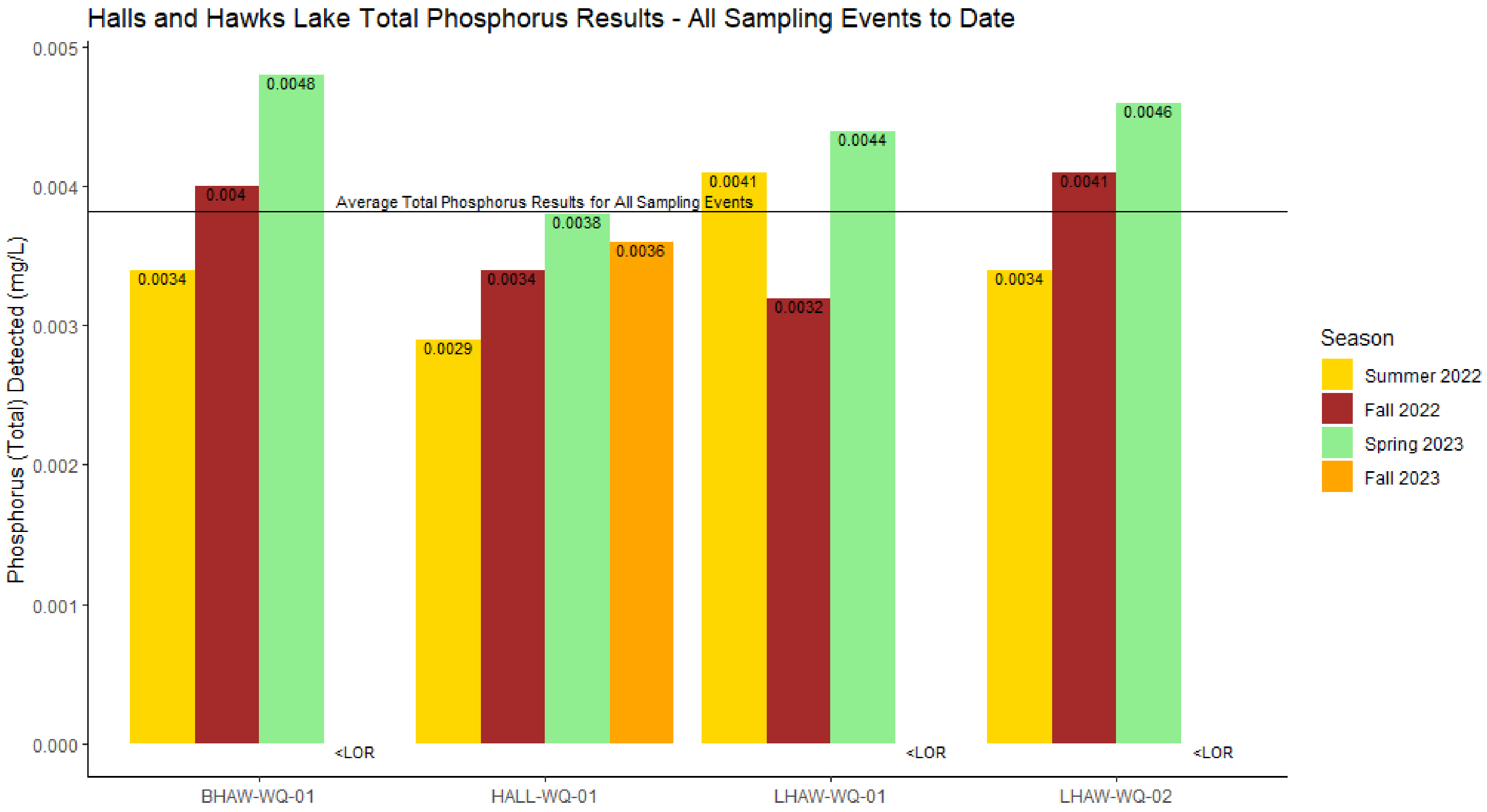


Figure 3 Total Phosphorus concentrations from all sites on HHLPOA Lakes across all sampling events.

Sulfate

Sulfate levels also remained considerably low, with a high of 3.27 mg/L in October at LHAW-WQ-01 and a low of 2.48 mg/L in June at BHAW-WQ-01.

Dissolved Oxygen and Temperature

Understanding the intricate components of the water column in lakes is essential for comprehending the distribution of temperature and dissolved oxygen (DO) throughout the aquatic environment. Lakes exhibit distinct layers: the epilimnion, which is the warm, upper layer; the metalimnion, characterized by the thermocline and transitional properties; and the hypolimnion, the cold lower layer [10]. These layers play a significant role in regulating the dynamics of DO and temperature within the lake. Seasonal variations in DO levels are closely intertwined with biological activity and environmental conditions [23]. Spring brings upon increased solar radiation, stimulating photosynthesis and drives a surge in oxygen production [23]. This abundance of oxygen persists throughout the summer, particularly in the epilimnion, where continuous photosynthesis and atmospheric diffusion contribute to higher levels of DO [23]. However, the stratification common in temperate lakes during summer creates divergent conditions in the hypolimnion [23].

Comparing this to eutrophic lakes which are characterized by high productivity, oxygen becomes depleted in the lower layers due to isolation from oxygen sources and organism respiration [23]. On the other hand, oligotrophic lakes which have lower algal biomass and deeper light penetration in relation to eutrophic lakes, retain oxygen at depth – benefiting from the enhanced solubility in colder water [23].

Winter presents contrasting challenges however, while oligotrophic lakes remain relatively stable, ice-covered eutrophic lakes may experience drastic declines in DO [23][10]. With limited sunlight penetration through an ice layer and lack of atmospheric contributions, microbial decomposition can quickly deplete oxygen availability, leading to “winter kill” events and exacerbating water quality issues [23][10].

The primary purpose of understanding these profiles are to visually illustrate the phenomenon of thermal stratification and the availability of DO to aquatic organisms, such as lake trout. By examining temperature and DO profiles, the presence and characteristics of these layers can be identified which offer crucial insights into the health and dynamics of lake ecosystems. Figure 4 shows the typical seasonal changes of DO and temperature for oligotrophic lakes.

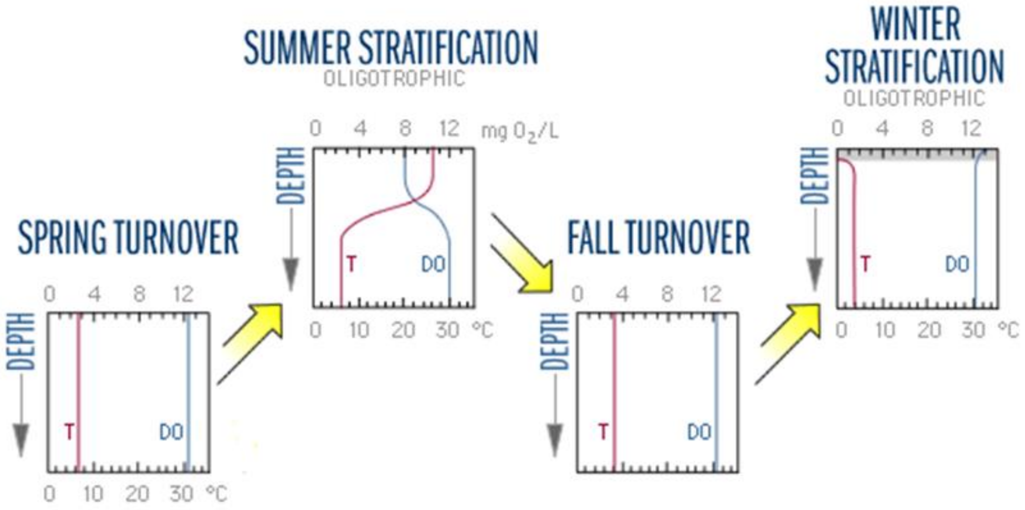
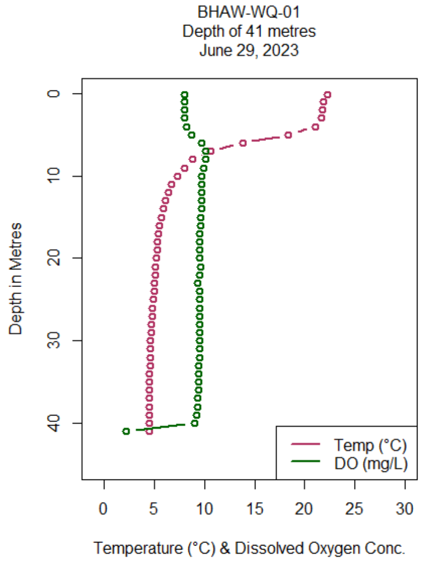
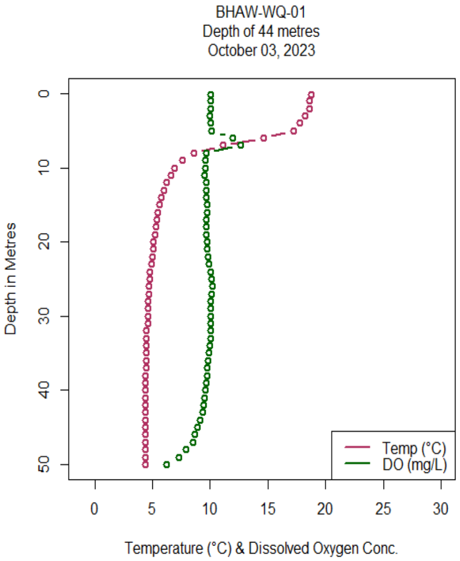


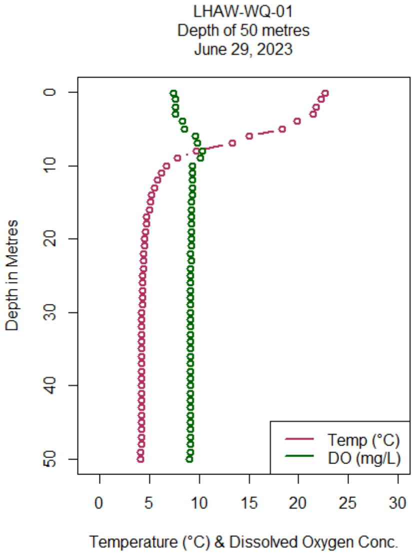
Figure 4 Typical dissolved oxygen and temperature changes across seasons in eutrophic and oligotrophic lakes [23].

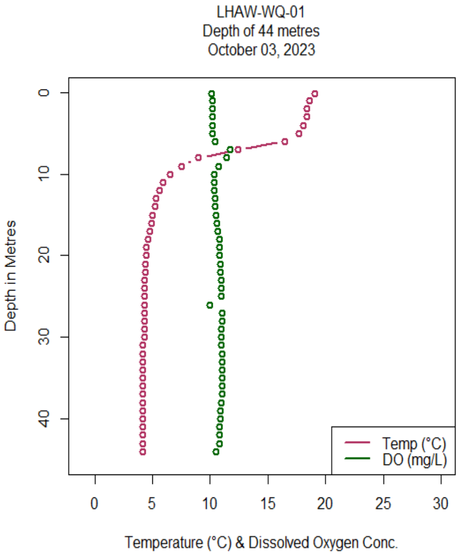
In Figures 5(a-h) the dissolved oxygen and temperature profiles are shown below. These profiles offer a comprehensive insight into the distribution of oxygen levels and temperature gradients across varying depths at each of the sample locations. The data spans from the water surface down to a maximum depth of 50 metres, providing a detailed vertical profile of the water column.

These profiles were developed from data collected during multiple sampling events throughout 2023, specifically in June, and October. Dissolved oxygen levels directly impact the health and viability of aquatic ecosystems. See Dissolved Oxygen portion of Parameters Measured section to review impacts on aquatic ecosystems.


BHAW-WQ-01
Depth of 41 metres
June 29, 2023
Depth in Metres
0
10
20
30
40
0
5
10
15
20
25
30
Temperature (°C) & Dissolved Oxygen Conc.
Temp (°C)
DO (mg/L)


BHAW-WQ-01
Depth of 44 metres
October 03, 2023
Depth in Metres
0
10
20
30
40
50
0
5
10
15
20
25
30
Temperature (°C) & Dissolved Oxygen Conc.
Temp (°C)
DO (mg/L)


LHAW-WQ-01
Depth of 50 metres
June 29, 2023
Depth in Metres
0
10
20
30
40
50
0
5
10
15
20
25
30
Temperature (°C) & Dissolved Oxygen Conc.
Temp (°C)
DO (mg/L)


LHAW-WQ-01
Depth of 44 metres
October 03, 2023
Depth in Metres
0
10
20
30
40
0
5
10
15
20
25
30
Temperature (°C) & Dissolved Oxygen Conc.
Temp (°C)
DO (mg/L)

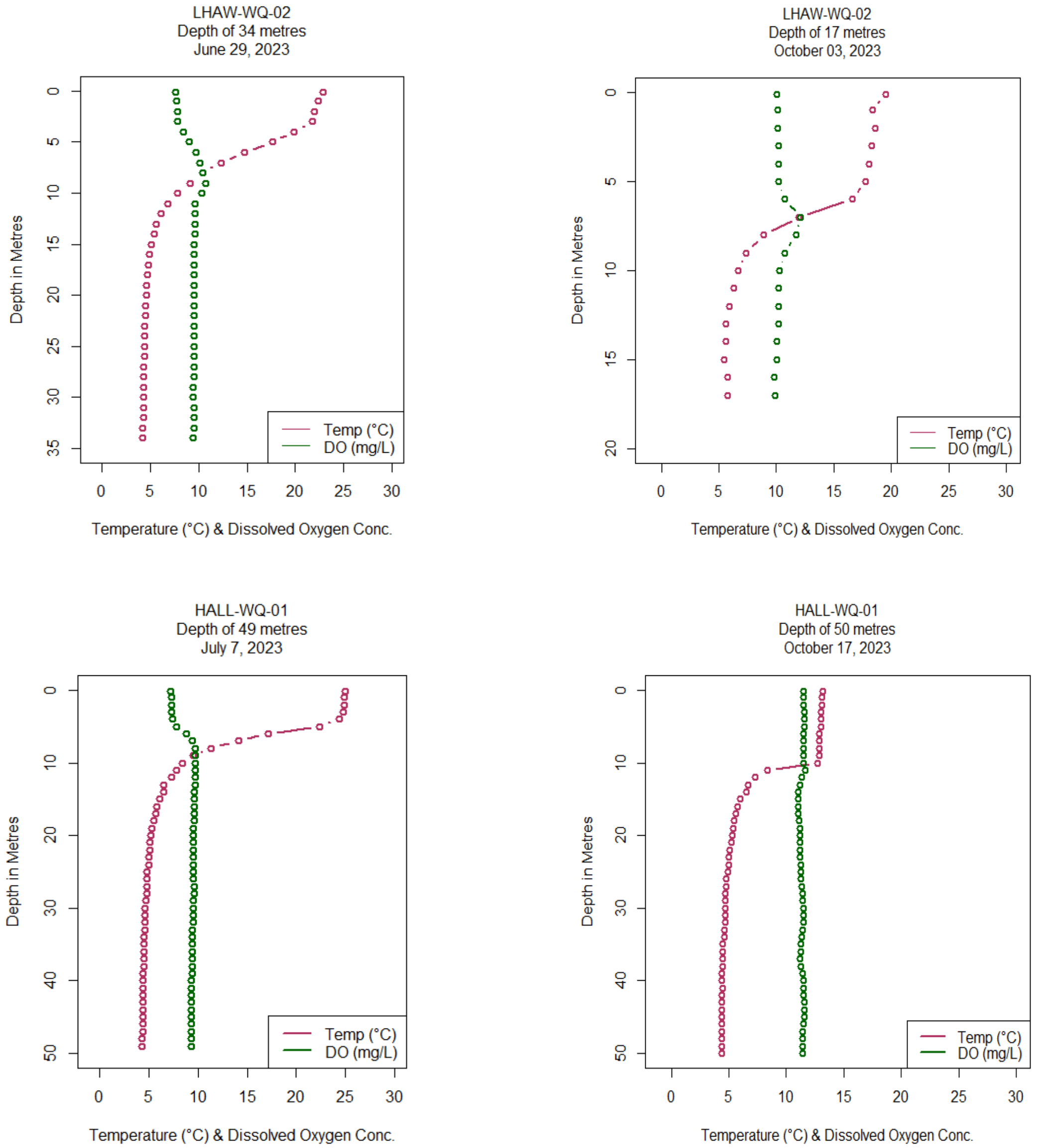


Figure 4a-l Dissolved Oxygen & Temperature profiles from all sites on HHLPOA Lakes (2023)

Table 4 Dissolved Oxygen and Temperature data at depth (to nearest full metre above lake bottom) across June and October sampling events

Sample Location	HALL-WQ-01	BHAW-WQ-01	LHAW-WQ-01	LHAW-WQ-02
June 2023	Normal 9.33mg/L at depth (49m)	Normal 10.74mg/L at depth (44m)	Normal 9.05mg/L at depth (50m)	Normal 9.45mg/L at depth (34m)
October 2023	Normal 11.45mg/L at depth (50m)	Normal 6.20mg/L at depth (50m)	Normal 10.52mg/L at depth (44m)	Very low DO 9.92mg/L at depth (17m)

Cyanobacteria: Blue-Green Algae

There is growing public concern over cyanobacteria, due to an increasing trend in the number of algal blooms in Ontario. These blooms cause an environmental hazard, impacting water quality, and also contain toxins harmful to humans and animals. Blooms mostly occur in late summer in warm shallow waters, but have also been recorded in deeper, cooler, oligotrophic lakes.

Measurements of chemical parameters such as dissolved oxygen and total phosphorus (TP) can provide insight into the probability of cyanobacteria blooms. By regularly measuring these parameters to define normal ranges for each lake, unnaturally high temperatures, low DO, and high TP can give early indication of cyanobacteria occurrence.

Anoxic waters can generate a chemical reaction in which phosphorus is released from sediments into the water column, potentially fuelling algal growth [11]. This nutrient loading would normally occur in the late summer/fall months. To anticipate these occurrences, DO/temperature profiles should be taken consistently in the fall to determine the “normal” state of the lake and to keep an eye out for unusual anoxic conditions. The HHLPOA Lakes were sampled in October; maintaining a timeline that allows sampling later into the fall.

Long-term climate warming is a potential contributing factor to recent blooms. The warming of the water column from longer ice-free periods and warmer atmospheric temperatures can provide ideal conditions for eutrophication and a rise in bloom occurrences.

Short-term climate variability has also been recognized as a trigger for cyanobacteria blooms. Unusually late ice-out, followed by above average air temperature and low wind speeds (for about 2 weeks) can produce rapid thermal stratification leading to a very short spring turnover period [12]. The resulting incomplete oxygen replenishment into the water column at the beginning of summer could lead to anoxia and phosphorus loading over the growing season.

It is important to take note of any unusual weather occurrences that could trigger cyanobacteria growth as well as making sure there are no anthropogenic sources of nutrient loading that could impact water quality. For more information on identifying and reporting blue-green algae blooms visit: ontario.ca/page/blue-green-algae

Trends and Next Steps

As part of this pilot program, compiled historical water quality data from the Lake Partner Program (2002-2022) [13], the Ministry of Environment, Conservation and Park's Water Chemistry data for Lake Trout Lakes (2001-2017) [14], the Ministry of Natural Resources and Forestry's Broadscale Monitoring Water Quality program (2009-2019) [15], and the Lake Health Report completed by the Coalition of Haliburton Property Owners Associations [16] are included. All raw data is provided for your review in an attached excel document. Figure 5 (a-b) represents the trends of total phosphorus for Little Hawk and Halls Lakes. Data from the WWEW program alongside data from the above-mentioned organizations specific to HHLPOA Lakes is included to show long-term changes in phosphorus levels. Moving forward into future reports, the goal is to have more trend graphs available on additional parameters and lake basins.

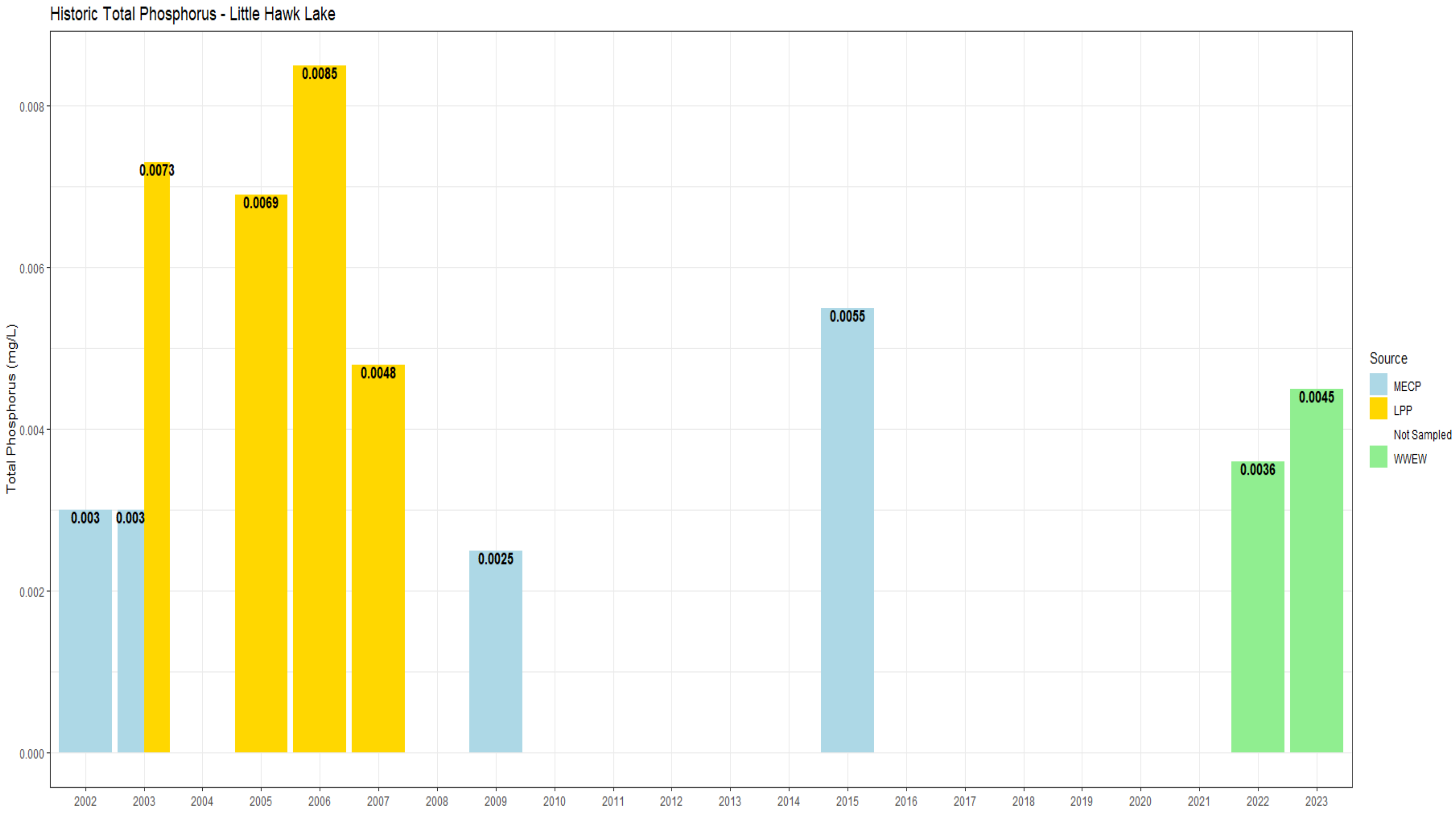


Figure 5 Historic Total Phosphorus concentrations across sampling programs on Little Hawk Lake

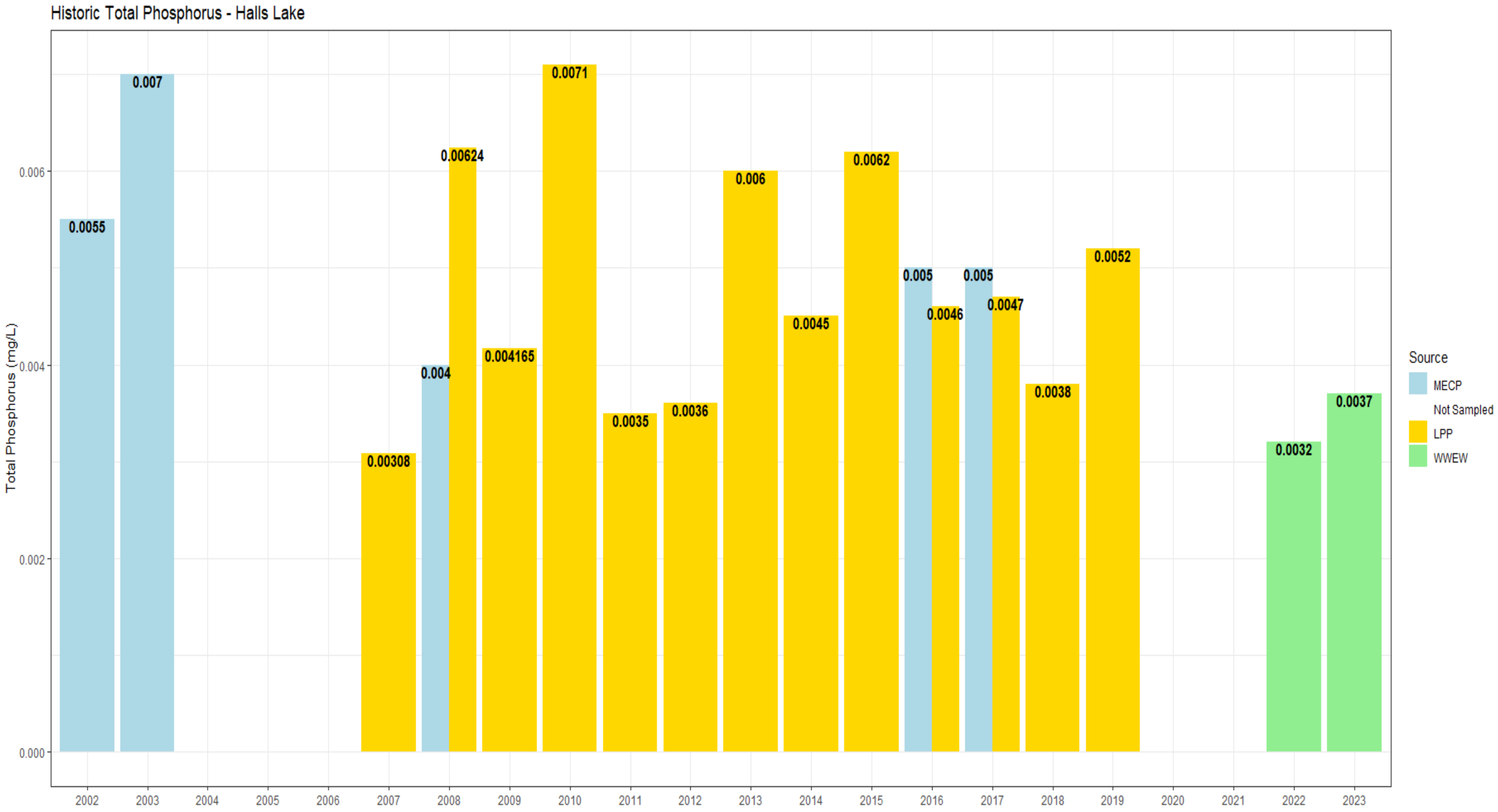


Figure 6 Historic Total Phosphorus concentrations across sampling programs on Halls Lake

Conclusion

The data amassed by WWEW throughout the pilot 2022/2023 sampling seasons and subsequent years holds significant data to be used in identifying trends related to water quality and overall lake health. This information not only enhances our understanding of current and potential hazards but also bolsters our capacity for intervention and mitigation practices. The primary objectives of this pilot program extend beyond the immediate term; they encompass the development and continual refinement of water monitoring protocols tailored to address aquatic concerns specific to the region. Concurrently, the program aims to establish and expand a comprehensive database of water quality measurements, fostering a foundation for sustained, long-term monitoring efforts.

The overarching goals of the pilot program are twofold: firstly, to cultivate and continually enhance water monitoring protocols and practices that are attuned to the unique aquatic challenges prevalent in the region. Secondly, to systematically construct and grow a robust database of water quality measurements that will serve as the cornerstone for enduring, long-term monitoring initiatives.

During the course of this pilot, challenges were encountered in measuring chemical parameters, particularly nitrate and nitrite concentrations, which frequently fell below the limit of reporting for ALS laboratories. In response, WWEW is proactively addressing these challenges for future sampling initiatives. Specific to nitrite as part of our ongoing commitment to refining our sampling protocols, WWEW has decided to discontinue nitrite as a sampled parameter. Additionally, recognizing the need for enhanced data reliability, we are implementing the inclusion of duplicate samples for total phosphorus in future sampling endeavours. Furthermore, to broaden our understanding of water quality dynamics, we intend to expand our reference lake set beyond Stocking Lake to account for the variability of characteristics on lakes participating in this program. Specifically, the focus will extend to incorporating lakes that do not experience controlled water fluctuations, providing a unique opportunity to assess the impact of drawdowns via the Trent Severn Waterway system.

Comparison of the 2022 and 2023 sample data reveals dynamic shifts in the HHLPOA Lake's water chemistry. In 2022, parameters all fell within normal limits, In 2023, a pH increase was observed sites on Big and Little Hawk Lakes, most notably at site BHAW-WQ-01 with a pH value (8.84) in October exceeding the guideline limit. Ammonia levels, negligible in 2022, saw large increases in 2023, notably exceeding limits in the fall at sites HALL-WQ-01, BHAW-WQ-01 and LHAW-WQ-02.

Nitrate was detected in 2023, contrasting 2022's absence. Nitrite detection was discontinued as all previous measurements were below detection limits. Total phosphorus maintained stable concentrations in line with 2022, duplicate sampling for total phosphorus is implemented to further quality control procedures, emulating MECP Lake Trout Lake testing. Sulfate levels remained low, far below guideline limits. Total Kjeldahl Nitrogen varied minimally across sites, maintaining comparison to Canadian Shield average of 0.275 mg/L. In 2024 sampling on ice testing is suggested to capture seasonal variations on HHLPOA lakes more holistically.

References

1. Living in Haliburton County. (2020). County of Haliburton. Retrieved from https://www.haliburtoncounty.ca/en/living-here/living-here.aspx
2. S. Fischer, F. Figuli. (2023). Halls & Hawk Lakes Property Owners Association Water Quality Report. Woodlands and Waterways EcoWatch.
3. S. Fischer, K. Paroschy, C. Pereira, S. Sinclair. (2022). Lake Sampling Protocols. Woodlands and Waterways EcoWatch.
4. District Municipality of Muskoka. (2016). 2015 Lake System Health Water Quality Monitoring Program: Year End Report. *The District Municipality of Muskoka Planning and Economic Development Department.*
5. United States Environmental Protection Agency. (2013). Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater. *US. EPA. Office of Water. Office of Science and Technology. Washington, DC.*
6. Canadian Council of Ministers of the Environment. (2010). Canadian Water Quality Guidelines for the Protection of Aquatic Life: Ammonia. Canadian Council of Ministers of the Environment, Winnipeg.
7. DataStream. (2021). A Water Monitor's Guide to Water Quality: Conductivity. *DataStream.Org*. [PDF]
8. Fondriest Environmental, Inc. "Dissolved Oxygen." Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. Retrieved from https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/ >
9. Ontario. (1994). Water management: policies, guidelines, provincial water quality objectives. Retrieved from https://www.ontario.ca/page/water-management-policies-guidelines-provincial-water-quality-objectives#section-13
10. Meays, C. & Nordin, R. (2013). Ambient Water Quality Guidelines for Sulphate. *Water Protection & Sustainability Branch. Environmental Sustainability and Strategic Policy Divison. BC Ministry of Environment*. Retrieved from

https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/sulphate/bc_moe_wqg_sulphate.pdf

11. L. Ceccaroni, J. Piera, M.R. Wernand, O. Zielinski, J.A. Busch, H.J. Van Der Woerd, R. Bardaji, A. Friedrichs, S. Novoa, P. Thijsse, F. Velickovski, M. Blaas, K. Dubsky. (2020). CitClops: A next-generation sensor system for the monitoring of natural waters and a citizens' observatory for the assessment of ecosystems' status. PLoS ONE 15(3) doi.org/10.1371/journal.pone.0230084

12. Trent Aquatic Research Program (TARP) Water Quality Primer (2021) What's in the water at the lake? A Brief review of water quality and limnology

13. Molot LA, Watson SB, Creed IF, Trick CJ, McCabe SK, Verschool MJ, Sorichetti RJ, Powe C, Venkiteswaran JJ, Schiff SL (2014) A novel model for cyanobacteria bloom formation: the critical role of anoxia and ferrous iron. Freshw Biol 59:1323–1340

14. Favot, EJ, Rühland, KM, DeSellas, AM, Ingram, R, Paterson, AM, Smol, JP (2019) Climate variability promotes unprecedented cyanobacterial blooms in a remote, oligotrophic Ontario lake: evidence from paleolimnology. J Paleolimnol 62:31-52

15. Ministry of Environment, Conservation and Parks (2020) Ontario Lake Partner. Ontario. https://data.ontario.ca/dataset/ontario-lake-partne

16. Data Request to Ontario MECP Kingston Office. Personal Communication – Dana Cruikshank to Jim Prince, June 2022

17. Data Request Ontario MND MNRF Peterborough Office. Personal Communication – Lisa Solomon to Jim Prince, July 2022

18. "The Lake Health Report for the Haliburton Highlands", Coalition of Haliburton Property Owners' Association. May 2019

19. "Get Informed: Drinking Water Contaminants." Know Your H2O Water Research Center. July 2023. https//www.knowyourh2o.com/indoor-3/contaminants

20. “Barium in Drinking Water – Guideline Technical Document for Public Consultation, Ottawa: Health Canada” Health Canada. December 2020. https://www.canada.ca/en/health-canada/programs/consultation-barium-drinking-water/document.html

21. Dietrich, J. Water Quality Baseline Report Update. EcoMetrix Incorporated. November 2020. https://www.iaac-aeic.gc.ca/050/documents/p54755/136845E.pdf

22. Marshall, E.E.M., Larocque, S.M., Reddick, D.T., Midwood, J.D., Doka, S.E. (2021). Temperature, Dissolved Oxygen, Fish, Vegetation, and Substrate Surveys in Lake Ontario Coastal Wetlands. Fisheries and Oceans Canada:1-60

23. “Understanding Lake Ecology”. Water On The Web. June 2004. https://www.waterontheweb.org/under/lakeecology/08_dissolvedoxygen.html

Appendix A - Glossary

Anoxic: the complete absence of oxygen, which occurs in the aforementioned “dead zones”

Cyanobacteria: unicellular, photosynthetic, aquatic bacteria. In ideal conditions, they multiply into extensive growths (blooms)

Effluent: the various types wastewater or liquid byproducts of sewage systems or industry, which often reaches water bodies

Eutrophic lakes (eutrophication): a state that occurs within a lake when nutrient concentrations are high, organic matter increases and decomposes, and the process over-consumes lake oxygen, often leading to “dead zones” where there is a complete lack of oxygen, which is difficult for organisms to survive in

Humification: The process where humic material (organic matter that is decomposing) forms from vegetative matter such as plant remains.

Ionic Strength: Ions are small atoms and ionic strength refers to how many ions there are in the water (concentration). The more ions there are, the greater the ionic strength is. Ionic strength can have negative effects on aquatic life and can decrease their ability to access nutrients, minerals and oxygen in the water

Leaching: the draining away of a chemical or mineral from soil, usually by flowing water

Oligotrophic lakes: lakes with lower concentrations of nutrient concentrations, with higher levels of dissolved oxygen

Overproduction: when excess food is produced and not consumed, leading to high rates of decomposition and high use of oxygen

Photic Zone: the uppermost layer of a body of water that receives sunlight, allowing phytoplankton to perform photosynthesis.

Thermal Stratification: Is the effect when lake water forms individual layers of temperature due to energy intake from the sun; this phenomenon results in three different layers: the epilimnion which is the shallowest and closest to the surface, the hypolimnion which is the deepest and coldest and lastly the metalimnion which is the transition layer between.

Turnover Period: The cooling of lake surfaces makes the water heavier than warm water below in the column causing a mixing effect with cooler water below; this effect can be influenced by wind intensities.

Appendix B - ALS Laboratories Limits of Reporting

The limit of reporting, or laboratory detection limits, are the lowest concentration of an analyte that can be consistently detected with certainty by the lab. Table 3 below summarizes the detection limits from ALS Environmental for the selected study parameters.

Table 3: ALS Environmental analyte detection limits.

Parameter (analyte)	**Detection Limit**
Ammonia	0.0050 mg/L
Nitrate	0.020 mg/L
Nitrite	0.010 mg/L
Sulfate	0.30 mg/L
Total Kjeldahl Nitrogen	0.050 mg/L
Total Phosphorus	0.0020 mg/L

Where a reported less than (<) result is higher than the detection limit, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Appendix C - ALS Chemical Analysis Methodology

Table 4: ALS Environmental methodology

Method	ALS Test Description	Lab Location	Matrix	Method Reference	Methodology Description
Anions and Nutrients (Matrix: Water)					
E235.NO2	Nitrite in Water by IC	Waterloo - Environmental	Water	EPA 300.1 (mod)	Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.
E235.NO3	Nitrate in Water by IC	Waterloo - Environmental	Water	EPA 300.1 (mod)	Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.
E235.SO4	Sulfate in Water by IC	Waterloo - Environmental	Water	EPA 300.1 (mod)	Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.
E298	Ammonia by Fluorescence	Waterloo - Environmental	Water	Method Fialab 100, 2018	Ammonia in water is determined by automated continuous flow analysis with membrane diffusion and fluorescence detection, after reaction with OPA (ortho-phthalaldehyde). This method is approved under US EPA 40 CFR Part 136 (May 2021)
E318	Total Kjeldahl Nitrogen by Fluorescence (Low Level)	Waterloo - Environmental	Water	Method Fialab 100, 2018	TKN in water is determined by automated continuous flow analysis with membrane diffusion and fluorescence detection, after reaction with OPA (ortho-phthalaldehyde). This method is approved under US EPA 40 CFR Part 136 (May 2021).
E372-U	Total Phosphorus by Colourimetry (0.002 mg/L)	Waterloo – Environmental	Water	APHA 4500-P E (mod).	Total Phosphorus is determined colourimetrically using a discrete analyzer after heated persulfate digestion of the sample.
Total Metals (Matrix: Water)					
E420	Total Metals in Water by CRC ICPMS	Waterloo - Environmental	Water	EPA 200.2/6020B (mod)	Water samples are digested with nitric and hydrochloric acids, and analyzed by Collision/Reaction Cell ICPMS. Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.
Method References					
The analytical methods used by ALS are developed using internationally recognized reference methods (where available), such as those published by US EPA, APHA Standard Methods, ASTM, ISO, Environment Canada, BC MOE, and Ontario MOE. Reference methods may incorporate modifications to improve performance					