



*The Alberta Lake Management Society  
Volunteer Lake Monitoring Program*

## Wabamun Lake Report

# 2022

Updated June 23, 2023

Lakewatch is made possible  
with support from:





# ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data from Alberta's Lakes. Equally important is educating lake users about aquatic environments, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch reports are designed to summarize basic lake data in understandable terms for the widest audience, and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch, and readers requiring more information are encouraged to seek those sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments, and particularly those who have participated in the LakeWatch program. These leaders in stewardship give us hope that our water resources will not be the limiting factor in the health of our environment.

If you require data from this report, please contact ALMS for the raw data files.



## ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Sue Styles, Neil Flemming, and Stan Franklin for their commitment to collecting data at Wabamun Lake. We would also like to thank Kurstyn Perrin and Dominic Wong, who were summer technicians in 2022. Executive Director Bradley Peter and Program Manager Caleb Sinn were instrumental in planning and organizing the field program. This report was prepared by Caleb Sinn and Bradley Peter.

BEFORE READING THIS REPORT, CHECK  
OUT [A BRIEF INTRODUCTION TO  
LIMNOLOGY](#) AT [ALMS.CA/REPORTS](https://alms.ca/reports)

## WABAMUN LAKE

Wabamun Lake is a well-known, large lake situated 60km west of Edmonton in the North Saskatchewan watershed. The lake's watershed is approximately 351 km<sup>2</sup>, and the lake itself has a surface area of 79 km<sup>2</sup>, a mean depth of 5.1 m, with the deepest area being approximately 11 m deep.<sup>1</sup> *Wabamun* is Cree for "mirror," and has been the historical name of the lake, but was also called White Whale Lake for most of the 1800s, due to the size of large Whitefish harvested from the lake at that time.<sup>2</sup> The Paul Band reserve is situated on the Eastern edge of the lake, and many other communities line Wabamun's shore. Of them, the Village of Wabamun was established in 1912, and the summer villages of Lakeview and Kapasiwin were some of the first summer villages to be established in Alberta. Other communities across the lake include Fallis, Seba Beach, Betula Beach, and Point Allison, to name just a few. Wabamun Lake Provincial Park is located on the northeast part of the lake, and protects much of the shoreline of Moonlight Bay.



Wabamun Lake, looking towards the north shore. (Photo by Caleb Sinn, 2022)

There is much industrial activity in the watershed. TransAlta currently operates two coal-fired power plants and one coal mine that impact the Wabamun watershed. The Sundance plant is located near the southeast shore within the watershed, and is the largest coal-fired electrical generation plant in Western Canada.<sup>3</sup> While the Keephills plant is located outside of the Wabamun watershed, both Keephills' and Sundance's cooling pond drain into the lake after treatment by the Wabamun Water Treatment Plant.<sup>4</sup> SunHills Mining, a subsidiary of TransAlta, also operates the Highvale Mine located on the south shore of the lake, and stretches southeast to the North Saskatchewan River. TransAlta also operated the Wabamun Power Plant and Whitewood Mine on the northeast shore from 1962 - 2010.<sup>5</sup>

<sup>1</sup> Aquality Environmental Consulting (2013). Wabamun Lake State of the Watershed Report. Wabamun Watershed Management Council.

<sup>2</sup> Mitchell, P. and E. Prepas (1990). Atlas of Alberta Lakes, University of Alberta Press.

<sup>3</sup> TransAlta Corporation (2018). Retrieved from <https://www.transalta.com/facilities/plants-operation/sundance/>

<sup>4</sup> Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.

<sup>5</sup> TransAlta Corporation (2018). Retrieved from <https://www.transalta.com/facilities/mines-operation/whitewood-mine/>

A railway runs along the north shore of the lake, and even crosses over the lake at the mouth of Moonlight Bay. On August 3, 2005, a Canadian National (CN) train travelling west towards Vancouver, BC derailed and spilled approximately 400,000 L of Bunker C oil and 88,000 L of toxic pole treating oil, with unknown quantities of each being released into the lake.<sup>6</sup> Subsequently, oil was spread across the northern, eastern and southern shores of the lake, severely impacting aquatic and riparian habitat for numerous aquatic species, and waterfowl. Cleanup efforts commenced immediately, and a report released by the Alberta Government in 2007 states that bulrush growth was not impacted by the toxic components of the spilt oil, but rather suffered from the treatments used to clean up the oil.<sup>7</sup> Toxic compounds were still detectable in sediments in 2007, although they were below environmental guideline limits.

The relatively shallow lake attracts many avid anglers to catch walleye, lake whitefish, and burbot. See current sportfishing regulations for more information.<sup>8</sup> Sailing is a popular activity due to the strong winds and northwest orientation of the lake. The lake also attracts many boaters and visitors, due to its relatively good water quality and the scenic aspen parkland that surrounds the lake. Since the lake is one of the most extensively monitored lakes in the province, long-term trend analyses performed by the Alberta Government,<sup>9</sup> Associated Environmental and ALMS all confirm that phytoplankton and nutrient levels within the lake are stable at moderate levels (mesotrophic), and even slightly decreasing. Cyanobacteria blooms are relatively rare, however in 2019 Alberta Health Services issued a cyanobacteria bloom beach advisory at Wabamun for the first time. Alberta Health Services' cyanobacteria monitoring program is ever-evolving, and has been in existence only since 2010.<sup>10</sup> Total dissolved solids (TDS) have been increasing in the lake since the lake was first sampled in 1980, likely due to climate impacts and possibly the return of treated water to the lake from the power plant activities within the watershed.<sup>11, 12</sup>



Aerial photo of Wabamun Lake (Alberta Atlas of Lakes: <http://albertalakes.ualberta.ca/>).

The Wabamun Watershed Management Council (WWMC) is an active group that has collectively worked with Alberta Environment and Parks, the North Saskatchewan Watershed Alliance, various consultants, and municipalities on watershed studies, plans, and on-the-ground projects that aim to protect the lake and inform Wabamun Watershed residents. In addition, 2019 was the first year that ALMS collaborated with the WWMC to sample Wabamun as part of its LakeWatch program. A draft watershed management plan was released in 2020 and is available on their website.

<sup>6</sup> QM Environmental (2020). Retrieved from <http://www.qmenv.com/Projects/Wabamun-Lake-Oil-Spill>

<sup>7</sup> Thormann, M. N. and S. E. Bayley (2008). Impacts of the CN Rail Oil Spill on Softstem Bulrush-Dominated Lacustrine Marshes in Wabamun Lake. Alberta Environment and Parks.

<sup>8</sup> <https://albertaregulations.ca/fishingregs/pp2.html>. Accessed May 2022.

<sup>9</sup> Casey, R. (2011). Water Quality Conditions and Long-Term Trends in Alberta Lakes. Alberta Environment and Parks.

<sup>10</sup> Health Protection Branch, Alberta Health (2014). Alberta Cyanobacteria Beach Monitoring, 2010 – 2013. Alberta Health.

<sup>11</sup> Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.

<sup>12</sup> Casey, R. (2003). Wabamun Lake Water Quality, 1982 – 2001. Alberta Environment and Parks.

## WATER CHEMISTRY

*ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-*a* are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 2 for a complete list of parameters.*

The average total phosphorus (TP) concentration for Wabamun Lake was 24 µg/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. This value is in the mid to low-range of historical averages. TP was lowest at the beginning of the season at 17 µg/L during the June 1<sup>st</sup> sampling event, and was highest late in the season at 36 µg/L, during the September 10<sup>th</sup> sampling event (Figure 1).

Average chlorophyll-*a* concentration in 2022 was 9.1 µg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. Chlorophyll-*a* was lowest during the June 1<sup>st</sup> sampling event at 5.3 µg/L, and increased later in the season to a peak of 17.6 µg/L on September 9<sup>th</sup> (Figure 1).

The average TKN concentration was 0.9 mg/L (Table 2) and varied from 0.81 mg/L to 0.96 mg/L, having the highest level during the September 9<sup>th</sup> sampling event (Figure 1).

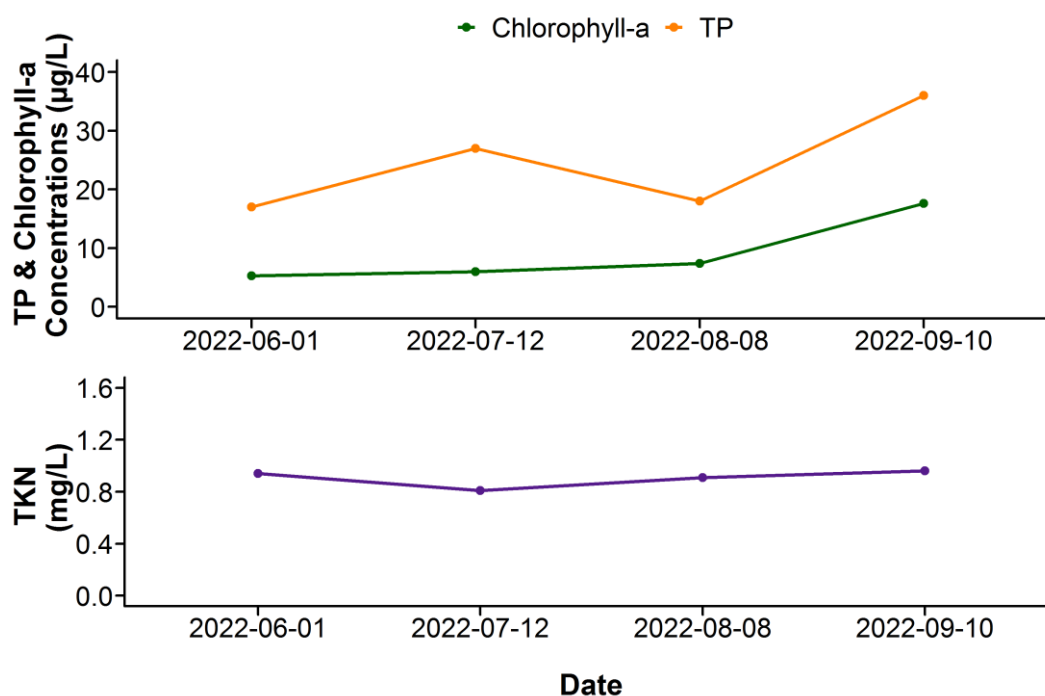


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Wabamun Lake.

Average pH was measured as 8.40 in 2022, buffered by moderate alkalinity (212 mg/L  $\text{CaCO}_3$ ) and bicarbonate (255 mg/L  $\text{HCO}_3^-$ ). Aside from bicarbonate, the dominant ions were sulphate and sodium, which contributed to a moderate conductivity of 630  $\mu\text{S}/\text{cm}$  (Table 2). Wabamun Lake is in the moderate range of ion levels compared to other LakeWatch lakes sampled in 2022 (Figure 2, bottom).

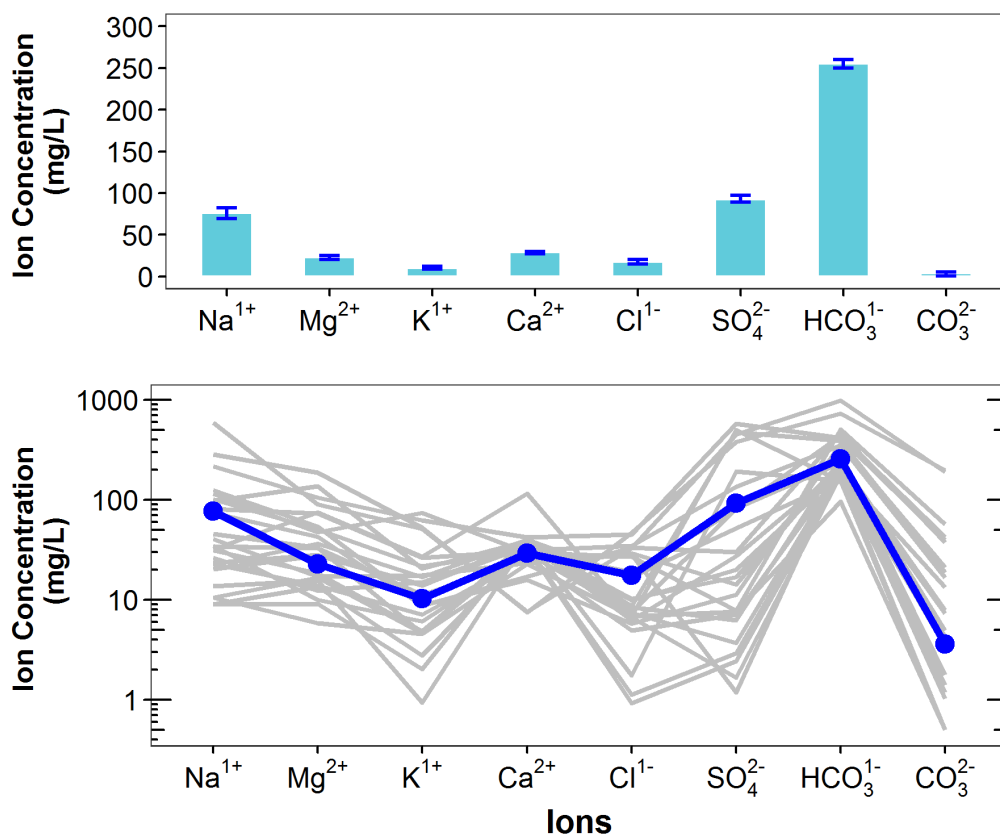


Figure 2. Average levels of cations (sodium =  $\text{Na}^{1+}$ , magnesium =  $\text{Mg}^{2+}$ , potassium =  $\text{K}^{1+}$ , calcium =  $\text{Ca}^{2+}$ ) and anions (chloride =  $\text{Cl}^{1-}$ , sulphate =  $\text{SO}_4^{2-}$ , bicarbonate =  $\text{HCO}_3^{1-}$ , carbonate =  $\text{CO}_3^{2-}$ ) from four measurements over the course of the summer at Wabamun Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Wabamun Lake (blue line) compared to 25 lake basins (gray lines) sampled through the LakeWatch program in 2022 (note log<sub>10</sub> scale on y-axis of bottom figure).

## METALS

*Metals will naturally be present in aquatic environments due to in-lake processes or the erosion of rocks, or introduced to the environment from human activities such as urban, agricultural, or industrial developments. Many metals have a unique guideline as they may become toxic at higher concentrations. Where current metal data are not available, historical concentrations for 27 metals have been provided (Table 3).*

Metals were not measured at Wabamun Lake in 2022, but Table 3 displays historical metal concentrations.

## WATER CLARITY AND EUPHOTIC DEPTH

*Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring, but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi depth. Two times the Secchi depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.*

The average euphotic depth of Wabamun Lake in 2022 was 5.92 m, corresponding to an average Secchi depth of 3.19 m (Table 2) – the euphotic depth average is not double the Secchi depth average because the euphotic depth was equal to the lake bottom depth on June 1<sup>st</sup>. The euphotic depth was deepest during the June 1<sup>st</sup> sampling event at 8.07 m (lake bottom), then decreased through the season to a low of 4.20 m on September 10<sup>th</sup> (Figure 3).

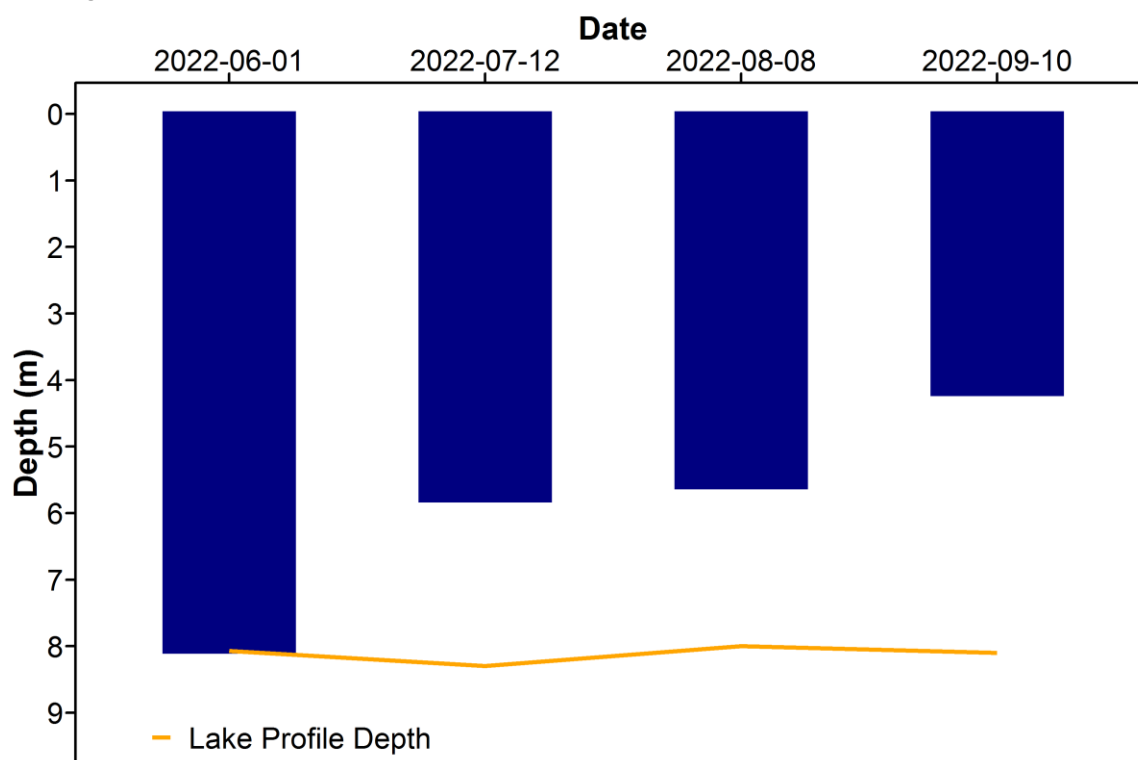


Figure 3. Euphotic depth values measured four times over the course of the summer at Wabamun Lake in 2022.

## WATER TEMPERATURE AND DISSOLVED OXYGEN

*Water temperature and dissolved oxygen (DO) profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.*

Surface temperatures of Wabamun Lake varied throughout the summer, with the August 8<sup>th</sup> sampling date having the warmest temperatures at 20.1°C (Figure 4a). The lake displayed complete mixing during each sampling date. The lake was the coldest during the June sampling event, warmed up through July and August, then cooled down again in September, but was still approximately 3.5°C warmer than during the June sampling event.

Wabamun Lake was well oxygenated in the surface waters on all sampling dates, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b). Slight decreases in oxygen were detected towards the bottom of the lake during each sampling event, but did not fall below 6.5 mg/L. Oxygen levels were appreciably higher throughout the whole water column during the June sampling event.

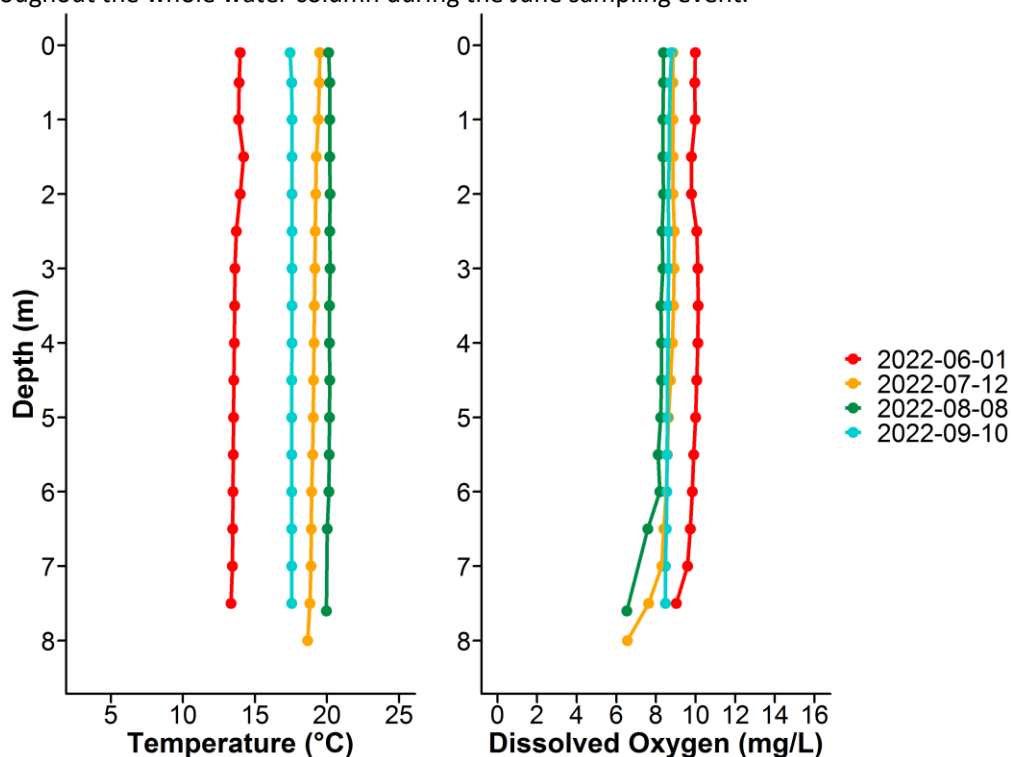


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Wabamun Lake measured four times over the course of the summer of 2022.



## MICROCYSTIN

*Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 10 µg/L. Blue-green algae advisories are managed by Alberta Health Services. Recreating in algal blooms, even if microcystin concentrations are not above guidelines, is not recommended.*

Microcystin levels in Wabamun Lake fell below the recreational guideline of 10 µg/L during every sampling event in 2022 (Table 1), and the seasonal average was below historical averages (Table 2). In addition, microcystin levels from June 1<sup>st</sup> and July 12<sup>th</sup> were below the laboratory detection limit of 0.10 µg/L. A value of 0.05 µg/L is assigned to these dates in order to calculate an average. Even though low levels of microcystin were detected, caution should always be observed when recreating around cyanobacteria.

Table 1. Microcystin concentrations measured four times at Wabamun Lake in 2022.

| Date      | Microcystin Concentration (µg/L) |
|-----------|----------------------------------|
| 1-Jun-22  | <0.1                             |
| 12-Jul-22 | <0.1                             |
| 8-Aug-22  | 0.10                             |
| 10-Sep-22 | 0.39                             |
| Average   | 0.15                             |

## INVASIVE SPECIES MONITORING

*Dreissenid mussels pose a significant concern for Alberta because they impair the function of water conveyance infrastructure and adversely impact the aquatic environment. These invasive mussels can change lake conditions which can then lead to toxic cyanobacteria blooms, decrease the amount of nutrients needed for fish and other native species, and cause millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities. Spiny water flea pose a concern for Alberta because they alter the abundance and diversity of native zooplankton, as they are aggressive zooplankton predators. Through over-predation, they will impact higher trophic levels such as fish. They also disrupt fishing equipment by attaching in large numbers to fishing lines.*

Monitoring involved sampling with a 63 µm plankton net at three sample sites to look for juvenile mussel veligers and spiny water flea in each lake sampled. In 2022, no mussels or spiny water flea were detected at Wabamun Lake.

*Eurasian watermilfoil is a non-native aquatic plant that poses a threat to aquatic habitats in Alberta because it grows in dense mats preventing light penetration through the water column, reduces oxygen levels when the dense mats decompose, and outcompetes native aquatic plants. Eurasian watermilfoil can look similar to the native Northern watermilfoil, thus genetic analysis is ideal for suspect watermilfoil species identification.*

Two watermilfoil specimens were collected from Wabamun Lake on August 8<sup>th</sup>, and both specimens were confirmed to be the native Northern Watermilfoil.

## WATER LEVELS

*There are many factors influencing water quantity. Some of these factors include the size of the lake's drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Alberta Environment and Parks Monitoring and Science division*

Water levels at Wabamun Lake in 2022 were slightly below the historical average (Figure 5) and decreased through the season (Figure 5). Records going back to 1915 indicate that water levels have varied within a 1.5 m range, with only short periods of time with high or low levels. The longest period of prolonged low water lasted approximately 15 years, between the early 1990s and early 2000s.

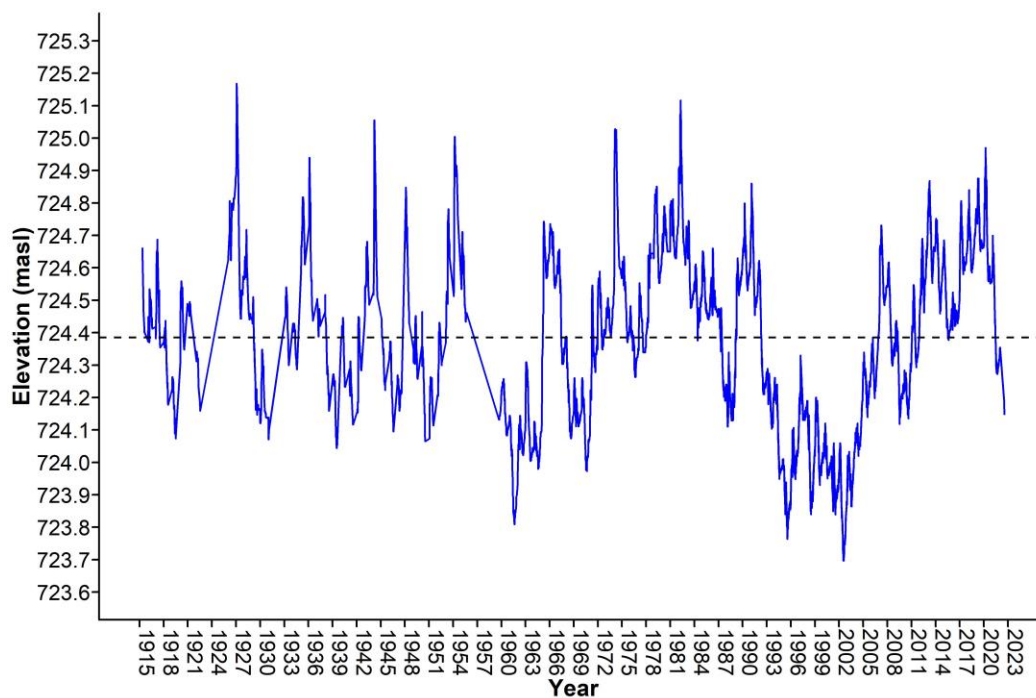


Figure 5. Water levels measured at Wabamun Lake in metres above sea level (masl) from 1915-2022. Data retrieved from Alberta Environment and Parks and Environment Canada. Black dashed line represents historical yearly average water level.

## WEATHER & LAKE STRATIFICATION

*Air temperature will directly impact lake temperatures, and result in different temperature layers (stratification) throughout the lake, depending on its depth. Wind will also impact the degree to which a lake mixes, and how it will stratify. The amount of precipitation that falls within a lake's watershed will have important implications, depending on the context of the watershed and the amount of precipitation that has fallen. Solar radiation represents the amount of energy that reaches the earth's surface, and has implications for lake temperature & productivity.*

Wabamun Lake experienced a warmer, wetter, slightly more windy summer with slightly more solar radiation compared to normal (Figure 6). Despite a prolonged period of higher than normal air temperatures leading up to the September 10<sup>th</sup> sampling event, the lake had cooled substantially from the previous sampling event on August 8<sup>th</sup>.

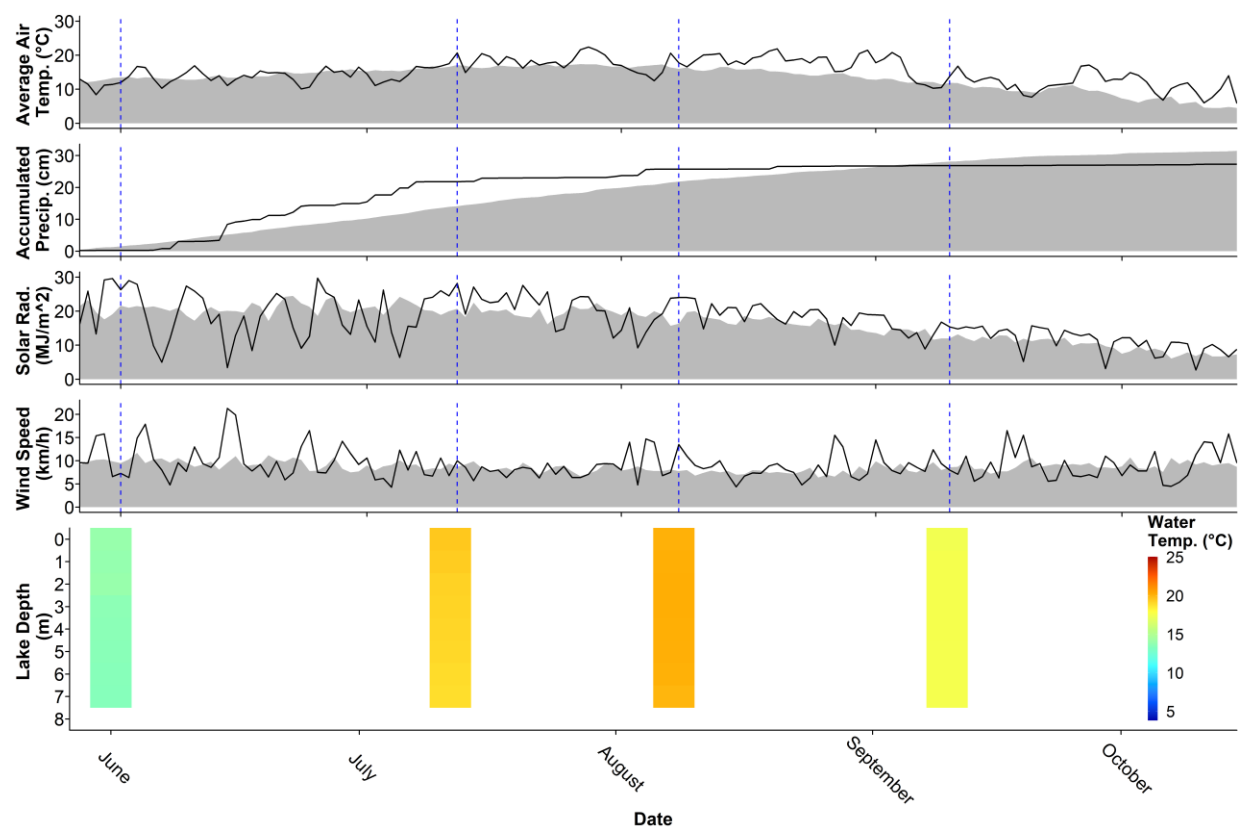


Figure 6. Average air temperature (°C), accumulated precipitation (cm), and wind speed (km/h) measured from 'Tomahawk AGDM', as well as solar radiation (MJ/m<sup>2</sup>) measured from 'Evansburg 2 AGCM,' with Wabamun Lake temperature profiles (°C) at the bottom. Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Wabamun Lake over the summer. Further information about the weather data provided is available in the LakeWatch 2022 Methods report. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) <https://acis.alberta.ca> (retrieved March 2023).



## HISTORICAL DATA

Wabamun Lake has been extensively monitored by Alberta Environment and Protected Areas, and has lake water quality data that dates back to 1980. Over the years, Wabamun Lake has been sampled many ways, likely to answer specific questions. For instance, there are four different codes in the Alberta Government database denoting different spatial samplings of the lake.

There is composite lake data for the East Basin, West Basin and Moonlight Bay, and there is data for the Main Basin, which represents composite data from the entire lake. As this report aims to report data on Wabamun Lake as a whole, the data tables were assembled to represent the most complete, whole lake data. For years where both the East and West basins were sampled at the same time, the values were averaged to capture a more accurate picture of the whole lake. Main Basin data is reported as is, and years where only the East Basin was sampled are also reported as is (this is only the case for 1982, 2014 and 2016). Generally, sampling occurred once per month from May till October, however some years had more or less frequent sampling events. This sort of variability in sampling frequency is typical of water quality data, as well as environmental data in general. The historical water quality dataset for Wabamun Lake is remarkably consistent and complete, with monthly, multi-basin sampling occurring in 39 years of the past 43 years.

Table 2a. Average Secchi depth and water inconsistent between years.

[illegible]



Table 2c. Average Secchi depth and water chemistry values for Wabamun Lake. Historical values are given for reference. Number of sample trips are inconsistent between years.

| Parameter  | 2006 | 2007 | 2008 | 2010 | 2011 | 2012 | 2013 | 2014 | 2016 | 2019 | 2020 | 2021 | 2022 |
|--|------|------|------|------|------|------|------|------|------|------|------|------|------|
| TP (µg/L)  | 21   | 28   | 22   | 34   | 40   | 33   | 36   | *416 | 26   | 27   | 44   | 26   | 24   |
| TDP (µg/L)                                       | 5    | 8    | 7    | 13   | 9    | 14   | 14   | 22   | 6    | 7    | 6    | 7    | 6    |
| Chlorophyll- <i>a</i> (µg/L)                     | 10.8 | 13.9 | 10.3 | 7.9  | 11.5 | 11   | 8.8  | 9.1  | 9.2  | 11.1 | 11.7 | 12   | 9.1  |
| Secchi depth (m)                                 | 2.70 | 2.41 | 2.27 | 1.93 | 1.47 | 2.00 | 1.80 | 2.39 | 2.82 | 2.70 | 2.42 | 2.70 | 3.19 |
| TKN (mg/L)                                       | 1    | 0.9  | 0.9  | 1.1  | 1.1  | 1    | 1    | 0.8  | 0.9  | 0.9  | 1    | 1    | 0.9  |
| NO <sub>2</sub> -N and NO <sub>3</sub> -N (µg/L) | 4    | 4    | 3    | 7    | 2    | 3    | 2    | 26   | 4    | 2    | 2    | 3    | 6    |
| NH <sub>3</sub> -N (µg/L)                        | 48   | 41   | 57   | 12   | 12   | 17   | 11   | 26   | 25   | 15   | 24   | 15   | 13   |
| DOC (mg/L)                                       | 12   | 11   | 10   | 12   | /    | 11   | /    | 10   | 11   | 10   | 10   | 10   | 11   |
| Ca (mg/L)  | 25   | 26   | 26   | /    | /    | /    | /    | /    | 26   | 28   | 29   | 29   | 29   |
| Mg (mg/L)  | 19   | 19   | 20   | /    | /    | /    | /    | /    | 22   | 22   | 22   | 22   | 23   |
| Na (mg/L)  | 69   | 67   | 70   | 77   | 73   | 72   | 73   | 79   | 76   | 75   | 74   | 74   | 76   |
| K (mg/L)   | 10   | 9    | 9    | 10   | 10   | 10   | 9    | 10   | 10   | 10   | 10   | 10   | 10   |
| SO <sub>4</sub> <sup>2-</sup> (mg/L)             | 74   | 75   | 76   | 86   | 80   | 85   | 83   | 84   | 90   | 88   | 87   | 86   | 92   |
| Cl <sup>-</sup> (mg/L)                           | 10   | 10   | 12   | 13   | 13   | 13   | 12   | 14   | 15   | 16   | 16   | 16   | 18   |
| CO <sub>3</sub> (mg/L)                           | 9    | 6    | 10   | 8    | 9    | 7    | 10   | 8    | 7    | 7    | 7    | 11   | 4    |
| HCO <sub>3</sub> (mg/L)                          | 240  | 241  | 238  | 243  | 233  | 245  | 239  | 242  | 252  | 255  | 230  | 238  | 255  |
| pH   | 8.59 | 8.50 | 8.57 | 8.62 | 8.65 | 8.50 | 8.36 | 8.43 | 8.54 | 8.59 | 8.54 | 8.62 | 8.4  |
| Conductivity (µS/cm)                             | 562  | 561  | 577  | 592  | 583  | 602  | 608  | 610  | 623  | 612  | 598  | 630  | 630  |
| Hardness (mg/L)                                  | 140  | 142  | 144  | 141  | 140  | 146  | 153  | 149  | 157  | 158  | 162  | 162  | 168  |
| TDS (mg/L)                                       | 334  | 332  | 343  | 356  | 343  | 353  | 353  | 370  | 372  | 370  | 360  | 365  | 380  |
| Microcystin (µg/L)                               | /    | /    | /    | 0.10 | 0.17 | 0.20 | 0.10 | 0.13 | 0.19 | 0.12 | 0.24 | 0.08 | 0.15 |
| Total Alkalinity (mg/L CaCO <sub>3</sub> )       | 212  | 208  | 211  | 213  | 207  | 212  | 213  | 212  | 217  | 220  | 198  | 212  | 212  |
| Basin Sampled                                    | E, W | E, W | E, W | M    | M    | M    | M    | E    | E    | M    | M    | M    | M    |

\*Note that 2014 TP average contains suspect laboratory results, from July 15<sup>th</sup>, 2014 sampling event.

Table 3. Concentrations of metals measured in Wabamun Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Note that metal sample collection method changed in 2016 from composite to single surface grab at the profile location.

| <b>Metals (Total Recoverable)</b> | <b>2013</b> | <b>2020</b> | <b>Guidelines</b>      |
|-----------------------------------|-------------|-------------|------------------------|
| Aluminum µg/L                     | 30.6        | 15.1        | 100 <sup>a</sup>       |
| Antimony µg/L                     | 0.178       | 0.145       | /                      |
| Arsenic µg/L                      | 2.77        | 3.2         | 5                      |
| Barium µg/L                       | 131         | 128         | /                      |
| Beryllium µg/L                    | 0.0074      | 0.003       | 100 <sup>c,d</sup>     |
| Bismuth µg/L                      | <0.001      | <0.003      | /                      |
| Boron µg/L                        | 921         | 791         | 1500                   |
| Cadmium µg/L                      | 0.0106      | <0.01       | 0.24 <sup>b</sup>      |
| Chromium µg/L                     | 0.493       | <0.1        | /                      |
| Cobalt µg/L                       | 0.0283      | 0.016       | 50,1000 <sup>c,d</sup> |
| Copper µg/L                       | 0.642       | 0.46        | 3.59 <sup>b</sup>      |
| Iron µg/L                         | 18.96       | 13          | 300                    |
| Lead µg/L                         | 0.0624      | 0.045       | 5.93 <sup>b</sup>      |
| Lithium µg/L                      | 39.7        | 38          | 2500 <sup>d</sup>      |
| Manganese µg/L                    | 37.6        | 24          | 180 <sup>e</sup>       |
| Molybdenum µg/L                   | 4.63        | 5.14        | 73                     |
| Nickel µg/L                       | 0.182       | 0.42        | 138.6 <sup>b</sup>     |
| Selenium µg/L                     | 0.148       | 0.3         | 1                      |
| Silver µg/L                       | 0.0185      | <0.001      | 0.25                   |
| Strontium µg/L                    | 402         | 367         | /                      |
| Thallium µg/L                     | 0.0008      | <0.002      | 0.8                    |
| Thorium µg/L                      | 0.0055      | 0.012       | /                      |
| Tin µg/L                          | 0.0423      | <0.06       | /                      |
| Titanium µg/L                     | 1.20        | 0.48        | /                      |
| Uranium µg/L                      | 0.456       | 0.419       | 15                     |
| Vanadium µg/L                     | 0.827       | 0.873       | 100 <sup>c,d</sup>     |
| Zinc µg/L                         | 1.07        | 1.7         | 30 <sup>f</sup>        |

Values represent means of total recoverable metal concentrations.

<sup>a</sup> Based on pH ≥ 6.5

<sup>b</sup> Based on 2020 avg. water hardness (as CaCO<sub>3</sub>) with CCME equation

<sup>c</sup> Based on CCME Guidelines for Agricultural use (Livestock).

<sup>d</sup> Based on CCME Guidelines for Agricultural Use (Irrigation).

<sup>e</sup> Based on CCME Manganese variable calculation ([https://ccme.ca/en/chemical/129#\\_aqf\\_fresh\\_concentration](https://ccme.ca/en/chemical/129#_aqf_fresh_concentration)), using 2020 avg. water hardness (as CaCO<sub>3</sub>) and avg. pH

<sup>f</sup> Based on 2020 avg. water hardness (as CaCO<sub>3</sub>), avg. pH, and avg. DOC with CCME equation

<sup>g</sup> Did not exceed guideline due to effect of relatively lower pH value in 2014 on Manganese variable calculation.

A forward slash (/) indicates an absence of data or guidelines

## LONG TERM TRENDS

Trend analysis was conducted on the parameters total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth to look for changes from 1980 or 1981 to 2022 in Wabamun Lake. Data was excluded from the trend analysis from any year where only one of the East or West basins were sampled. For years where both the East and West basins were sampled at the same time each month, the data was averaged between each basin and included in the trend analysis. These steps were taken to best capture the trends for Wabamun Lake as a whole. In summary, a significant decreasing trend was observed in TP, significant increasing trends were observed in TDS and Secchi Depth, and no significant change was observed in chlorophyll-*a*. Data is presented below as both a line graph (all data points) or a box-and-whisker plot. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes*.

Table 4. Summary table of trend analysis on Wabamun Lake data from 1980 or 1981 to 2022.

| Parameter              | Date Range | Direction of Significant Trend |
|------------------------|------------|--------------------------------|
| Total Phosphorus       | 1981-2022  | Decreasing                     |
| Chlorophyll- <i>a</i>  | 1980-2022  | No Change                      |
| Total Dissolved Solids | 1980-2022  | Increasing                     |
| Secchi Depth           | 1980-2022  | Increasing                     |

### Definitions:

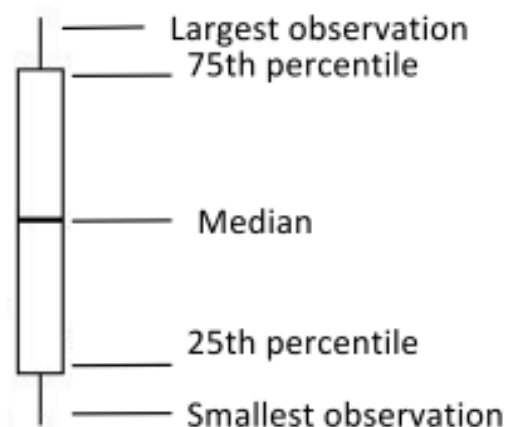
**Median:** the value in a range of ordered numbers that falls in the middle.

**Trend:** a general direction in which something is changing.

**Monotonic trend:** a gradual change in a single direction.

**Statistically significant:** The likelihood that a relationship between variables is caused by something other than random chance. This is indicated by a *p*-value of <0.05. **Variability:** the extent by which data is inconsistent or scattered.

**Box and Whisker Plot:** a box-and-whisker plot, or boxplot, is a way of displaying all of our annual data. The median splits the data in half. The 75<sup>th</sup> percentile is the upper quartile of the data, and the 25<sup>th</sup> percentile is the lower quartile of the data. The top and bottom points are the largest and smallest observations.



## Total Phosphorus (TP)

Trend analysis indicates there has been a significant decreasing trend of TP in Wabamun Lake since 1981 (Tau = -0.16,  $p = 0.007$ ; Table 5).

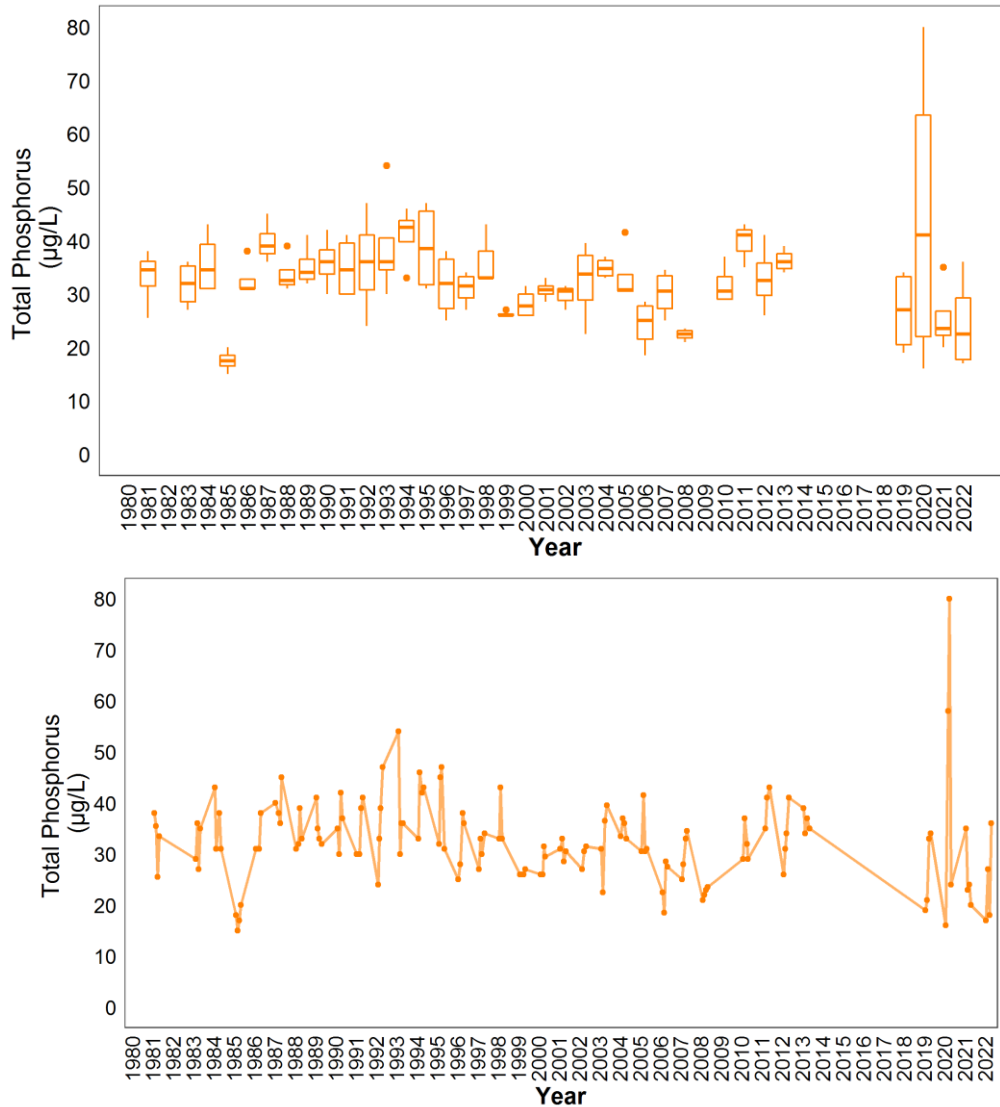


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September on sampling dates between 1981 and 2022 ( $n = 137$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

## Chlorophyll-a

Chlorophyll-a concentrations have not significantly changed in Wabamun Lake since 1980 (Tau = 0.10,  $p = 0.07$ ; Table 5).

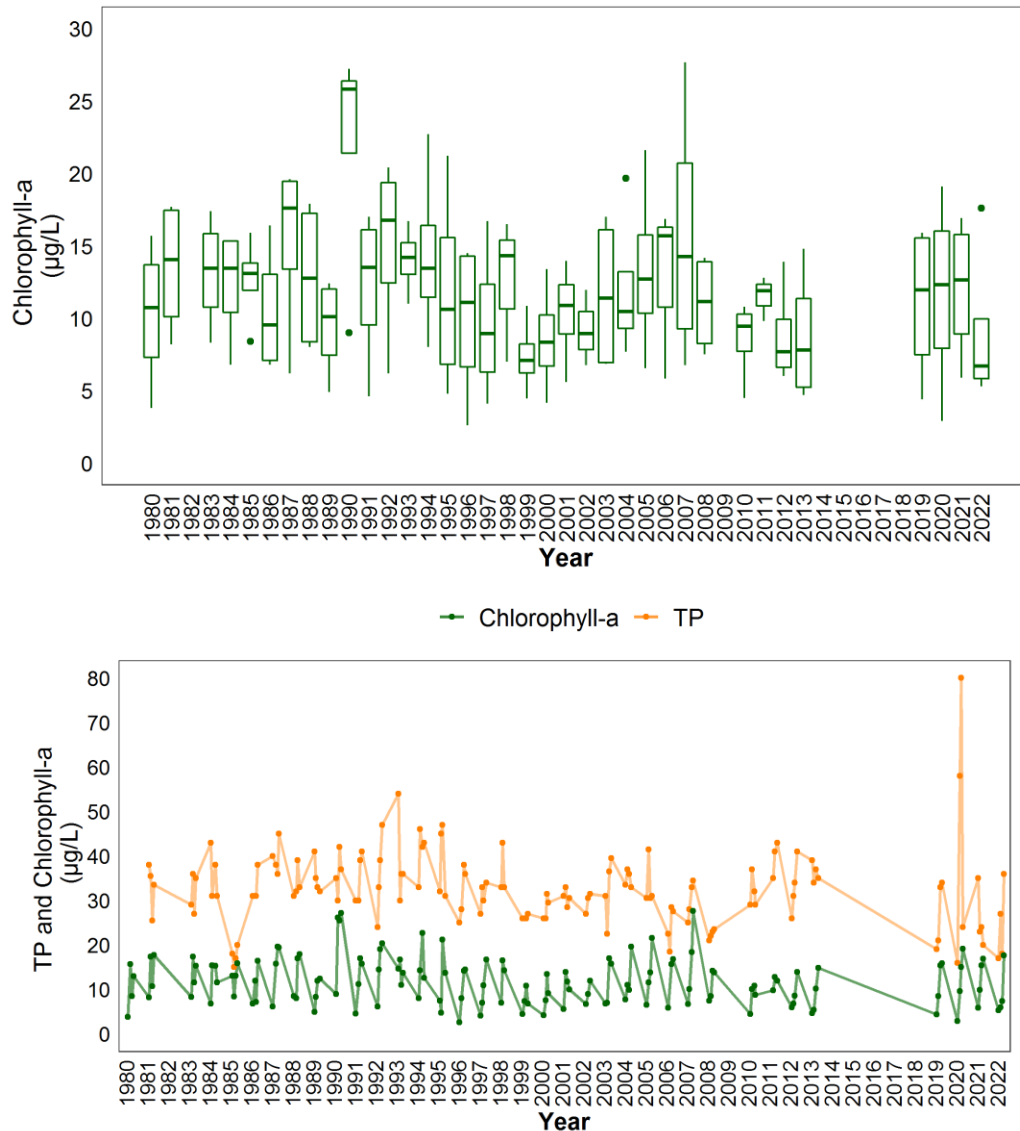


Figure 8. Monthly chlorophyll-a concentrations measured between June and September on sampling dates between 1980 and 2022 ( $n = 140$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

## Total Dissolved Solids (TDS)

Trend analysis showed a significant increasing trend in TDS between 1980 and 2022 ( $\text{Tau} = 0.92$ ,  $p = <0.001$ ) in Wabamun Lake. The magnitude of change is relatively high (slope = 4.05 mg/L per year), with levels of TDS having increased by nearly 160 mg/L since 1980 (Figure 9). Previous trend analysis performed by Alberta Environment and Parks indicates these changes are likely related to the lake receiving treated North Saskatchewan River water.<sup>13</sup> The increasing trend has appeared to slow in recent years, which could be related to the reduction of the volume of treated water entering the lake in starting in 2007.<sup>13</sup>

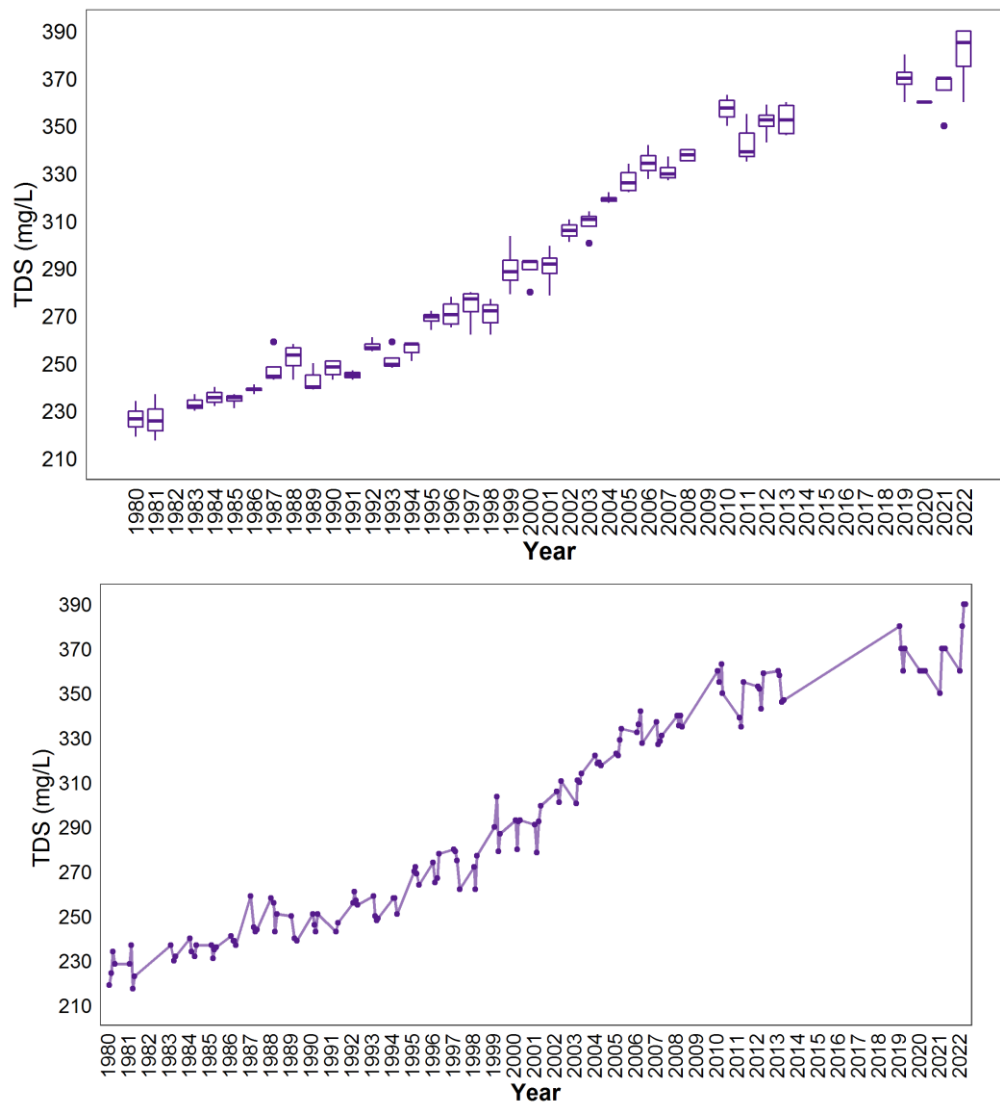


Figure 9. Monthly TDS values measured between June and September on sampling dates between 1980 and 2022 ( $n = 136$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

<sup>13</sup> Casey, R. (2011). Water Quality Conditions and Long-Term Trends in Alberta Lakes. Alberta Environment and Parks.

Due to the significant increasing trend of TDS in Wabamun Lake, exploring the specific major ions which may be driving this trend is important to determine. Trend analysis of major ions at Wabamun Lake indicates that sulphate, sodium, and alkalinity (bicarbonate, carbonate) are likely the key parameters that drove the historical increase in TDS (Figure 10). Most parameters which displayed significant increasing trends (sodium, potassium, sulphate, alkalinity) followed the trajectory of TDS over time and showed an initial level increase, followed by stabilization. Only chloride and magnesium differ as they have appeared to continue to increase in recent years.

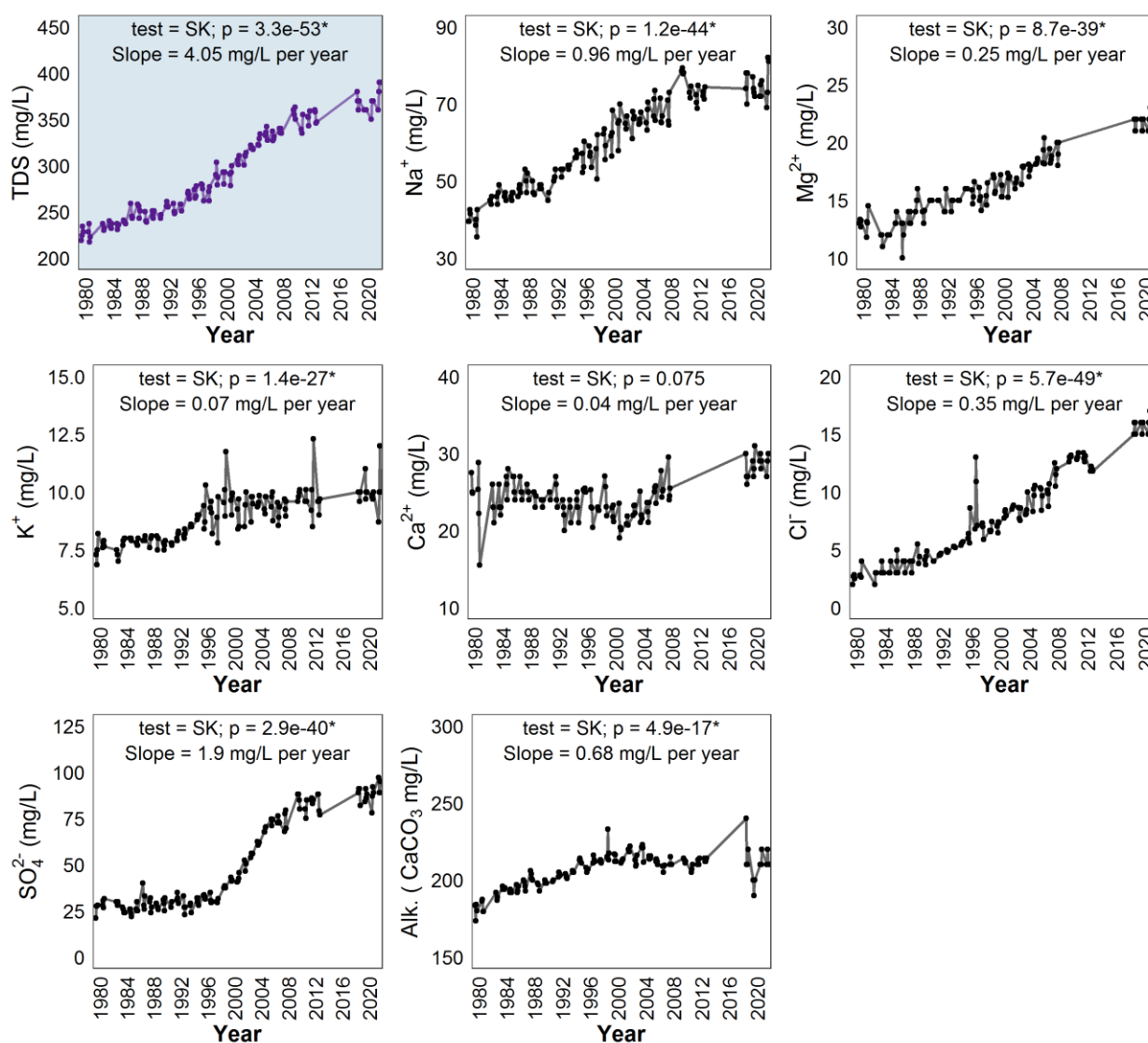


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na<sup>+</sup>, magnesium = Mg<sup>2+</sup>, potassium = K<sup>+</sup>, calcium = Ca<sup>2+</sup>, chloride = Cl<sup>-</sup>, sulphate = SO<sub>4</sub><sup>2-</sup>), and total alkalinity (Alk., as mg/L CaCO<sub>3</sub>) measured monthly between June and September on sampling dates between 1980 and 2022. Also represented is the monotonic trend results for each parameter; test used (MK = Mann Kendall, SK = Seasonal Kendall), significance of test ( $p$ ; assessed as significance when  $p < 0.05$ , marked with “\*” if significant), and the slope of the trend. Test selection follows method outline in the *ALMS Guide to Trend Analysis on Alberta Lakes*. Note that some ions had insufficient data (\*I.D.\*) therefore trends were not calculated. The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

## Secchi Depth

Trend analysis of Secchi depth over time indicates it has significantly increased in Wabamun Lake since 1980 (Tau = 0.15,  $p = 0.01$ ; Table 5).

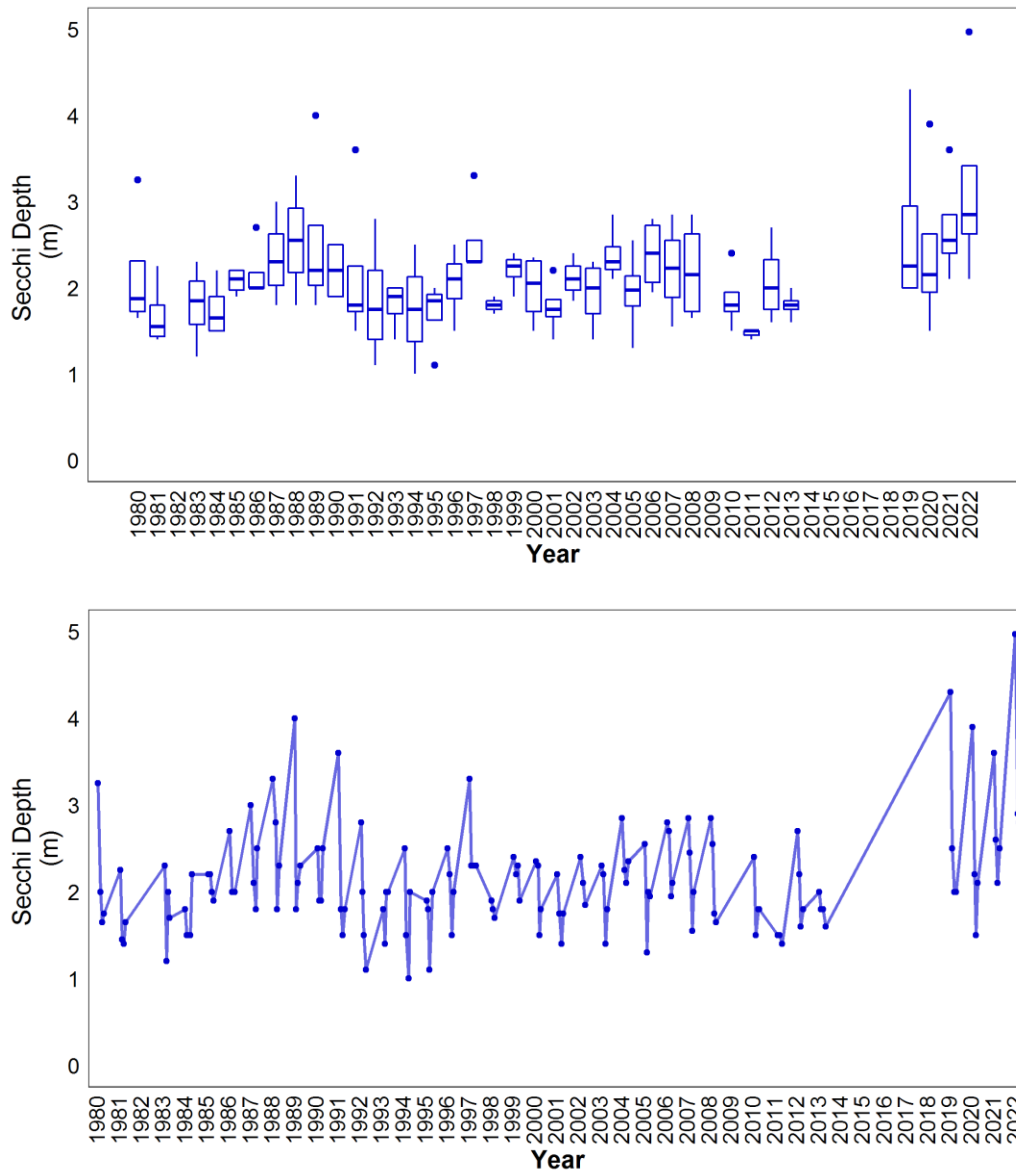


Figure 11. Monthly Secchi depth values measured between June and September on sampling dates between 1980 and 2022 ( $n = 141$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. Results of trend tests using total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS) and Secchi depth data from June and September, for sampled years from 1980 or 1981 to 2022 on Wabamun Lake data.

| Definition  | Unit                   | Total Phosphorus (TP)  | Chlorophyll-a | Total Dissolved Solids (TDS) | Secchi Depth     |
|---|------------------------|------------------------|---------------|------------------------------|------------------|
| Statistical Method  | -                      | Seasonal Kendall       | Mann Kendall  | Seasonal Kendall             | Seasonal Kendall |
| The strength and direction (+ or -) of the trend between -1 and 1 | Tau                    | -0.16                  | -0.10         | 0.92                         | 0.15             |
| The extent of the trend   | Slope (units per year) | -0.18                  | -0.07         | 4.05                         | 0.01             |
| The statistic used to find significance of the trend              | Z                      | -2.69                  | -1.82         | 15.35                        | 2.52             |
| Number of samples included  | n                      | 137                    | 140           | 136                          | 141              |
| The significance of the trend                                     | <i>p</i>               | $7.23 \times 10^{-3*}$ | 0.07          | $3.30 \times 10^{-53*}$      | 0.01*            |

\**p* < 0.05 is significant within 95%