



# Lakewatch

LAKEMATCH

The Alberta Lake Management Society  
Volunteer Lake Monitoring Program

## Wabamun Lake Report

### 2020

Updated April 29, 2021

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 Randall Heil, Carman McNary, Neil Flemming, and Stan Franklin for their commitment to collecting data at Wabamun Lake. We would also like to thank Kyra Ford and Ryan Turner, who were summer technicians in 2020. 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.

## 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 in the northeast part of the lake, and protects much of the shoreline of Moonlight Bay.



Wabamun Lake Watershed. Base data provided by the Government of Alberta under the Alberta Open Data License (2020).

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 Kepphills plant is located outside of the Wabamun watershed, both Kepphills' 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> Although bulrush growth was not significantly impacted by the spilled materials, toxic compounds were still detectable in sediments in 2007, although they were below environmental guideline limits.

The relatively shallow lake attracts many avid fishers to catch Northern Pike, Walleye, Lake Whitefish and Yellow Perch.<sup>8</sup> However, since the spill in 2005, the Alberta Government has mandated a catch-and-release only fishery on the lake.<sup>9</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>10</sup> Associated Environmental and ALMS all confirm that algal 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>11</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>12, 13</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 have 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> Mitchell, P. and E. Prepas (1990). Atlas of Alberta Lakes, University of Alberta Press.

<sup>9</sup> Wabamun Watershed Management Council (2019). Retrieved from <https://www.wwmc.ca/wabamun-fishery>

<sup>10</sup> Casey, R. (2011). Water Quality Conditions and Long-Term Trends in Alberta Lakes. Alberta Environment and Parks.

<sup>11</sup> Health Protection Branch, Alberta Health (2014). Alberta Cyanobacteria Beach Monitoring, 2010 – 2013. Alberta Health.

<sup>12</sup> Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.

<sup>13</sup> Casey, R. (2003). Wabamun Lake Water Quality, 1982 – 2001. Alberta Environment and Parks.

## METHODS

**Profiles:** Profile data is generally measured at the deepest spot in the main basin of the lake. At the profile site, temperature, dissolved oxygen, pH, conductivity and redox potential are measured at 0.5 – 1.0 m intervals. Additionally, Secchi depth is measured at the profile site and used to calculate the euphotic zone. For select lakes, metals are collected at the profile site by hand grab from the surface on one visit over the season.

**Composite samples:** At 10-sites across the lake, water is collected from the euphotic zone and combined across sites into one composite sample. This water is collected for analysis of water chemistry, chlorophyll-a, nutrients and microcystin. Quality control (QC) data for total phosphorus was taken as a duplicate true split on one sampling date. ALMS uses the following accredited labs for analysis: Routine water chemistry and nutrients are analyzed by Bureau Veritas, chlorophyll-*a* and metals are analyzed by Innotech Alberta, and microcystin is analyzed by the Alberta Centre for Toxicology (ACTF).

**Invasive Species:** Invasive mussel monitoring involved sampling with a 63 µm plankton net at three sample sites twice through the summer season to determine the presence of juvenile dreissenid mussel veligers, and spiny water flea. Technicians also harvested potential Eurasian watermilfoil (*Myriophyllum spicatum*) samples and submitted them for further analysis at the Alberta Plant Health Lab to genetically differentiate whether the sample was the invasive Eurasian watermilfoil or a native watermilfoil. In addition, select lakes were subject to a bioblitz, where a concerted effort to sample the lake's aquatic plant diversity took place.

**Data Storage and Analysis:** Data is stored in the Water Data System (WDS), a module of the Environmental Management System (EMS) run by Alberta Environment and Parks (AEP). Data goes through a complete validation process by ALMS and AEP. Users should use caution when comparing historical data, as sampling and laboratory techniques have changed over time (e.g. detection limits). For more information on data storage, see AEP Surface Water Quality Data Reports at [www.alberta.ca/surface-water-quality-data.aspx](http://www.alberta.ca/surface-water-quality-data.aspx).

Data analysis is done using the program R.<sup>14</sup> Data is reconfigured using packages tidy<sup>15</sup> and dplyr<sup>16</sup> and figures are produced using the package ggplot2<sup>17</sup>. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)<sup>18</sup>. The Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life are used to compare heavy metals and dissolved oxygen measurements. Pearson's Correlation tests are used to examine relationships between total phosphorus (TP), chlorophyll-*a*, total kjeldahl nitrogen (TKN) and Secchi depth, providing a correlation coefficient (r) to show the strength (0-1) and a p-value to assess significance of the relationship. For lakes with >10 years of long term data, trend analysis is done with non-parametric methods. The seasonal Kendall test estimates the presence of monotonic (unidirectional) trends across individual seasons (months) and is summed to give an overall trend over time. For lakes that had multiple samplings in a single month, the value closest to the middle of the month was used in analysis.

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<sup>14</sup> R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

<sup>15</sup> Wickman, H. and Henry, L. (2017). tidy: Easily Tidy Data with 'spread ()' and 'gather ()' Functions. R package version 0.7.2. <https://CRAN.R-project.org/package=tidy>.

<sup>16</sup> Wickman, H., Francois, R., Henry, L. and Muller, K. (2017). dplyr: A Grammar of Data Manipulation. R package version 0.7.4. <https://CRAN.R-project.org/package=dplyr>.

<sup>17</sup> Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

<sup>18</sup> Nurnberg, G.K. (1996). Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12: 432-447.

## WATER CHEMISTRY

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

*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 45 µg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. This is the highest average TP for Wabamun Lake on record (Table 2). Detected TP was lowest in June at 16 µg/L, and peaked at 80 µg/L in August, which is also the highest single sampling value of TP on record (Figure 6). Considering the high TP value in August, along with the low TP value in June, 2020 also represents the year with the greatest TP variability on record.

Average chlorophyll-*a* concentration in 2019 was 11.17 µg/L (Table 2), falling into the eutrophic, or highly productive trophic classification. Chlorophyll-*a* was lowest in June at 2.9 µg/L and peaked at 19.1 µg/L in September. Blooms of *Gleotrichia* spp. were observed as early as the July sampling.

The average TKN concentration was 1.0 mg/L (Table 2) with concentrations peaking in September (Figure 1).

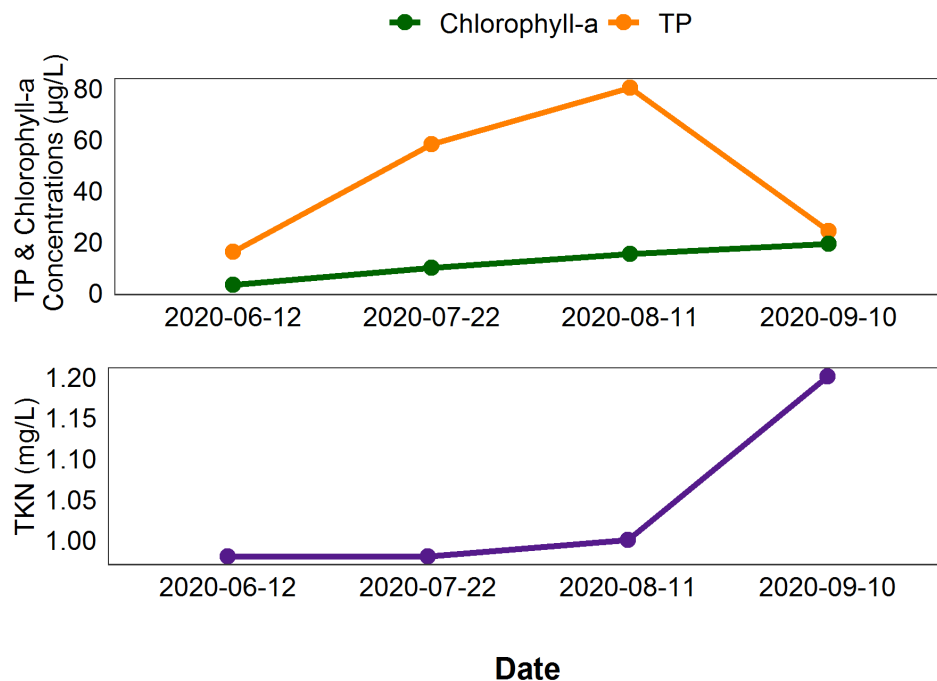


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Wabamun Lake.

Average pH was measured as 8.55 in 2020, buffered by low alkalinity (198 mg/L CaCO<sub>3</sub>) and bicarbonate (230 mg/L HCO<sub>3</sub><sup>-</sup>). Aside from bicarbonate, the dominant ions were sulphate and sodium, contributing to a moderate conductivity of 598 μS/cm (Figure 2, top; Table 2). Wabamun Lake is in the average range of ion levels compared to other LakeWatch lakes sampled in 2020 (Figure 2, bottom).

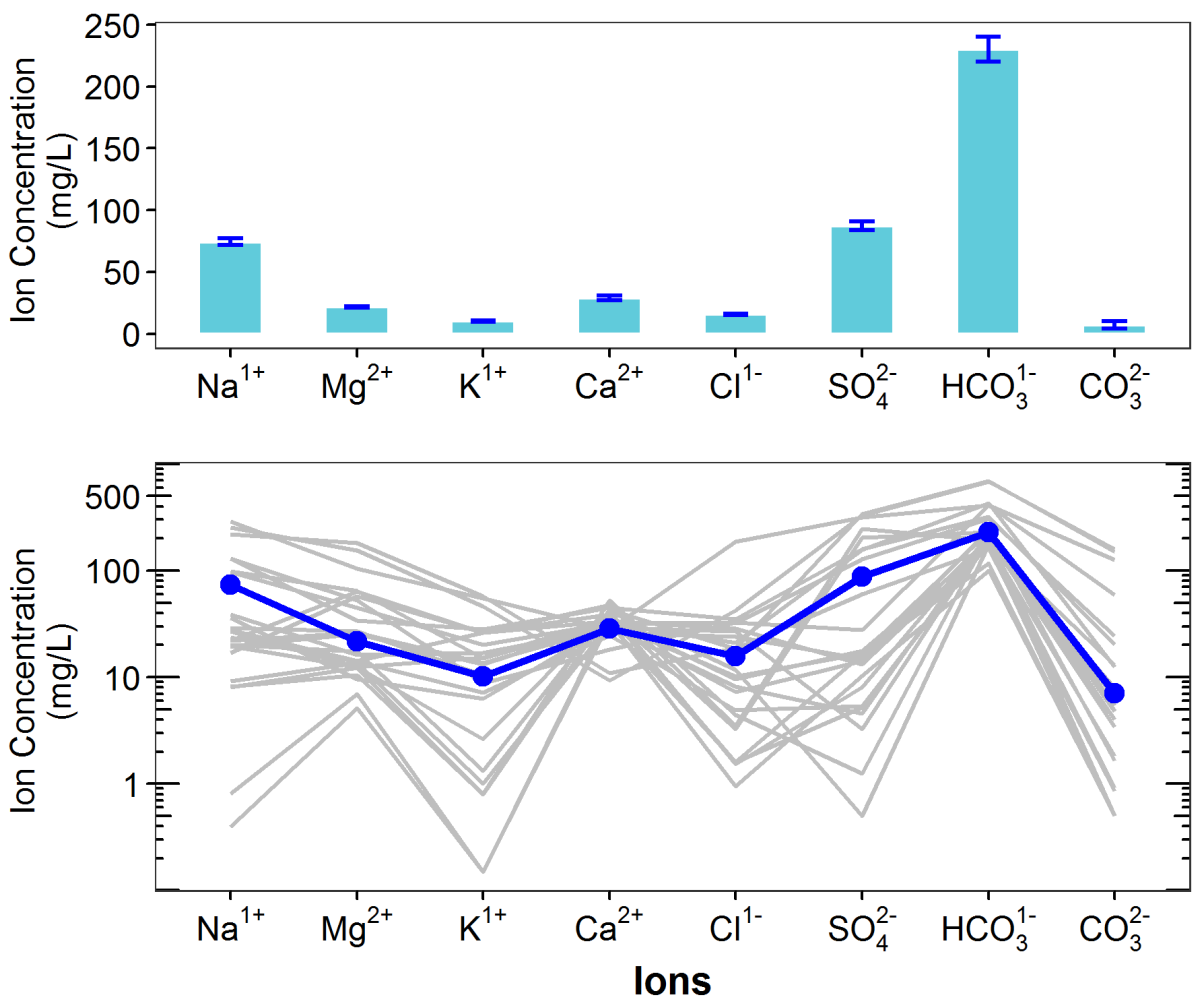


Figure 2. Average levels of cations (sodium = Na<sup>1+</sup>, magnesium = Mg<sup>2+</sup>, potassium = K<sup>1+</sup>, calcium = Ca<sup>2+</sup>) and anions (chloride = Cl<sup>1-</sup>, sulphate = SO<sub>4</sub><sup>2-</sup>, bicarbonate = HCO<sub>3</sub><sup>1-</sup>, carbonate = CO<sub>3</sub><sup>2-</sup>) from four measurements over the course of the summer at Beauvais Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Beauvais Lake (blue line) compared to 25 lake basins (gray lines) sampled through the LakeWatch program in 2020 (note log<sub>10</sub> scale on y-axis of bottom figure).



## METALS

*Samples were analyzed for metals once throughout the summer. In total, 27 metals were sampled for. It should be noted that many metals are naturally present in aquatic environments due to the weathering of rocks and may only become toxic at higher levels.*

A metals sample was collected for Wabamun Lake in 2020 on September 10<sup>th</sup>. Out of the 27 metals, only manganese was above its CCME guideline for the Protection of Aquatic Life (Table 3). Manganese was also above the guideline when the last metals sample was taken in 2013, where it was higher than the value in 2020. Samples for total mercury analysis were collected from the surface and near bottom (7m) also on September 10<sup>th</sup>, 2020. The values for top (0.39 ng/L) and near bottom (0.42 ng/L) were below the Alberta Government's Environmental Quality Guidelines for Alberta Surface Waters (2018) chronic (5 ng/L) and acute (13 ng/L) levels of total mercury for the Protection of Aquatic Life.

## 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 2020, no mussels or spiny water flea were detected at Wabamun Lake.

*Eurasian watermilfoil is 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.*

Samples collected from Wabamun Lake on July 10<sup>th</sup> were confirmed to be the native Northern watermilfoil (*Myriophyllum sibiricum*).



## 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 2020 was 4.73 m, corresponding to an average Secchi depth of 2.43 (Table 2). On June 12, the bottom depth was used as the euphotic depth as light was reaching the bottom sediments – this may skew the average euphotic depth to appear low compared to the average Secchi disk depth. Euphotic depth was greatest during the June 12<sup>th</sup> sampling, being equal to the recorded bottom depth of 7.3 m, and then was the shallowest on August 11<sup>th</sup> at 3.0 m.

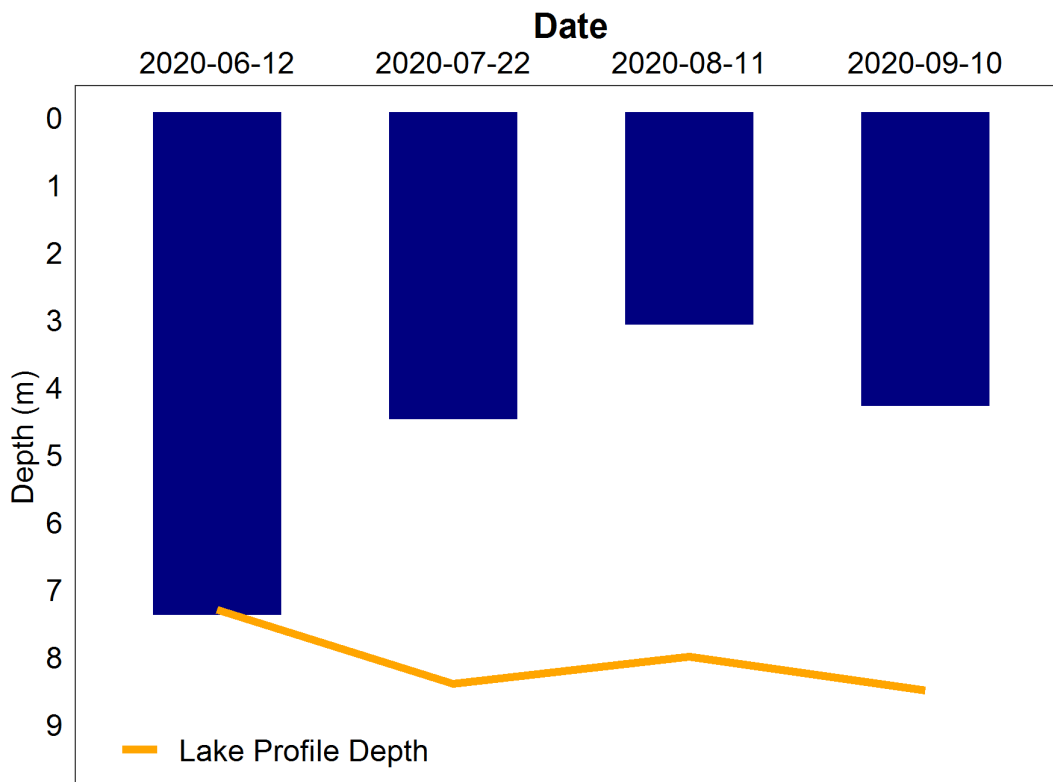


Figure 3. Euphotic depth values measured four times over the course of the summer at Wabamun Lake in 2020.

## 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.*

Water temperatures in Wabamun Lake varied throughout the summer, with a maximum temperature of 19.2°C measured at 0.5 m on July 22<sup>nd</sup>, and a minimum temperature of 14.7°C measured at 7 m, near the bottom of the lake, on June 12<sup>th</sup> (Figure 4a). The lake was not significantly stratified during any of the sampling trips, with temperatures fairly constant from top to bottom. This indicates partial or complete mixing in this basin throughout the season.

Wabamun Lake remained well oxygenated through the water column on all sampling trips, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b). The only exception was during the July 22<sup>nd</sup> sampling event, where dissolved oxygen below 7 m depth was below the CCME guideline. Anoxia, or dissolved oxygen less than 1mg/L, was not observed during any sampling event at Wabamun Lake in 2020.

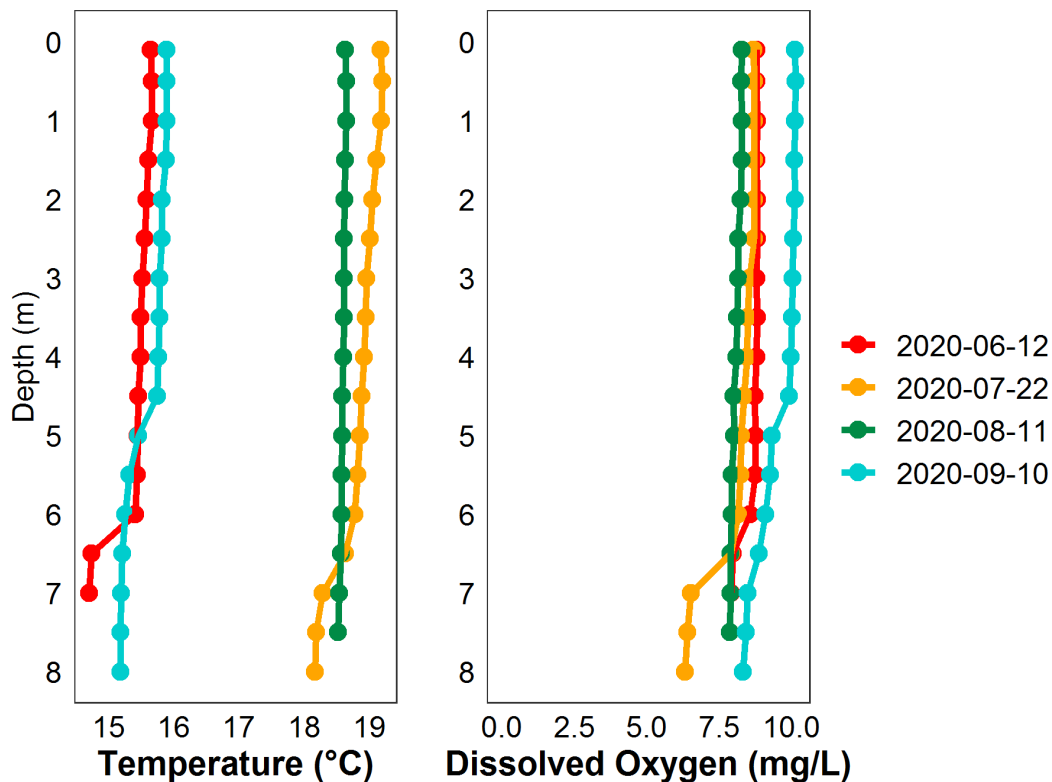


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Wabamun Lake measured four times over the course of the summer of 2020.



## 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 the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 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 20 µg/L at the locations and times sampled at Wabamun Lake in 2020. Microcystin was even below detection limit during the June 12<sup>th</sup> sampling event. A value of 0.05 µg/L is used for the purpose of calculating average concentration in instances of no detection. However, evidence of cyanobacteria blooms were noted at Wabamun Lake in 2020. Despite microcystin concentrations remaining low throughout the summer, caution should be observed when recreating in visible blooms.

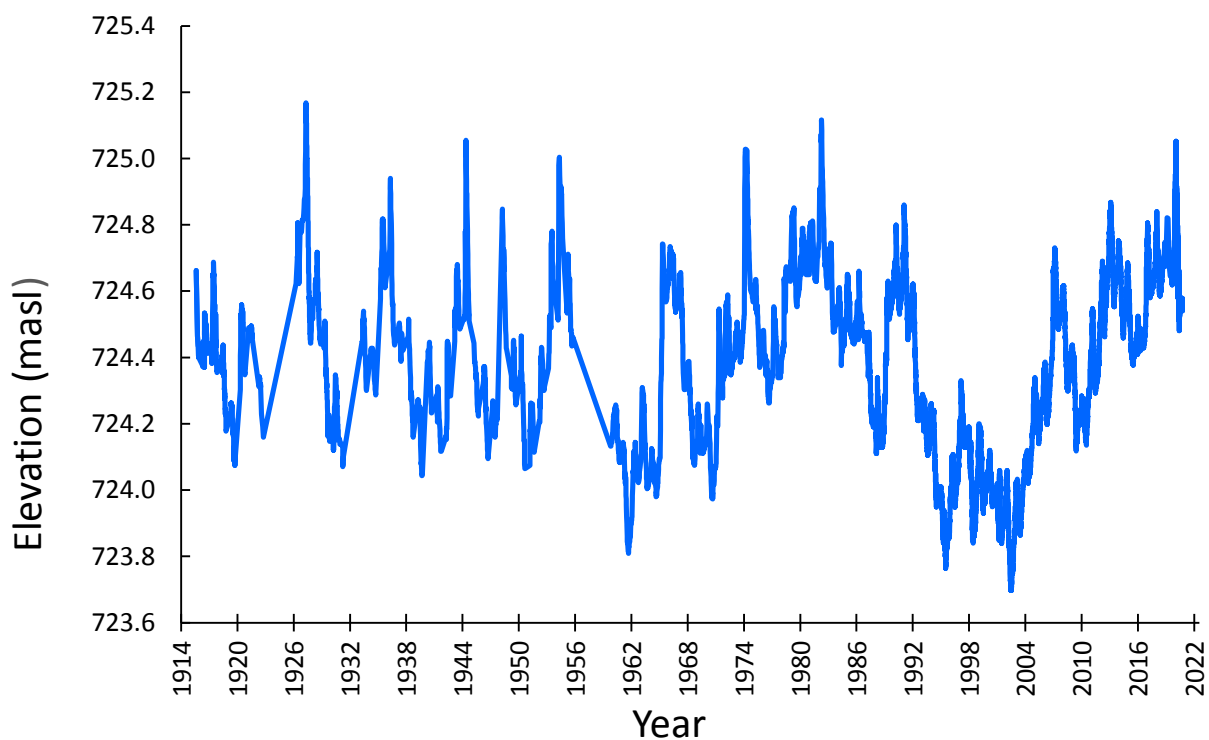
Table 1. Microcystin concentrations measured four times at Wabamun Lake in 2020.

<b>Date</b>	<b>Microcystin Concentration (µg/L)</b>
<b>12-Jun-20</b>	<0.10
<b>22-Jul-20</b>	0.16
<b>11-Aug-20</b>	0.23
<b>10-Sep-20</b>	0.50
<b>Average</b>	0.24

## WATER LEVELS

*There are many factors influencing water quantity. Some of these factors include the size of the lakes 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.*

There is over 100 years of water level data for Wabamun Lake, as levels were first recorded in 1915. A weir was built on the outflow, Wabamun Creek, in 1912. In 1990 the weir was set to only allow outflow above 724.55 masl<sup>19</sup>. In the first half of the 20<sup>th</sup> century, levels seemed to fluctuate on about a 10 year cycle from a high of about 725 meters above sea level (masl), to a low of about 724.1 masl (Figure 5). Then, late in 1961, a low of 723.8 masl was reached, before coming back within the mean historical range through the 1970s and 1980s. Then a prolonged period of low levels occurred in the 1990s and early 2000s, where a historical low of 723.7 masl was recorded in September, 2002. Since then, levels have risen through the 2010s within the average historical range. Declines in the 2000s were likely mitigated by the diversion of water from the North Saskatchewan River into the lake beginning in 1999.<sup>20</sup> The levels in June 2020 are among the highest on record, which goes along with the observations of loss of beach and increase in standing water in certain areas within the watershed, likely due to heavy precipitation.



from Environment Canada (1915 – 2018), and Alberta Environment and Parks (2019 – 2021).

<sup>19</sup> Wabamun Watershed Management Council (2020). Draft Wabamun Lake Watershed Management Plan. Accessed via [www.wwmc.ca](http://www.wwmc.ca) April 23 2021.

<sup>20</sup> Associated Environmental (2018). Water Quality Status and Trends in Wabamun Lake.





## HISTORICAL DATA

Wabamun Lake has been extensively monitored by Alberta Environment, and has composite lake sampling data that dates back to 1980. Over the years, Wabamun Lake has been sampled many different ways, likely to answer specific questions. For instance, there are four different codes in the Alberta Environment 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, and not to differentiate certain areas of the lake, the data tables represent the most complete, whole lake data, with the exception of three years where only the East Basin was sampled. This means that 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 a month from May till October, but some months had multiple samplings during certain years, and in some years sampling did not occur in some months. This sort of variability in sampling frequency is typical of water quality data, as well as environmental data more generally. Otherwise, Wabamun Lake has a remarkably complete dataset with monthly, multi-basin sampling occurring in 37 years of the past 41 years.

Table 2a. Average historical Secchi depth and water chemistry values for Wabamun Lake (E=East Basin, W=West Basin, M=Main Basin).

Parameter	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
TP ( $\mu\text{g/L}$ )	/	34	30	30	33	18	33	37	35	34
TDP ( $\mu\text{g/L}$ )	/	11	10	10	14	6	10	11	13	12
Chlorophyll- $\alpha$ ( $\mu\text{g/L}$ )	10.3	13.0	11.6	10.4	11.8	10.6	10.3	12.5	12.0	11.2
Secchi depth (m)	2.15	1.88	/	2.30	1.87	2.46	2.58	2.74	2.86	2.72
TKN (mg/L)	1.2	1.1	0.9	0.8	0.8	0.8	0.9	0.9	1.0	0.9
NO <sub>2</sub> -N and NO <sub>3</sub> -N ( $\mu\text{g/L}$ )	4	6	1	5	6	3	2	7	2	2
NH <sub>3</sub> -N ( $\mu\text{g/L}$ )	26	62	27	17	22	9	17	19	15	30
DOC (mg/L)	12	13	11	11	11	14	11	11	12	13
Ca (mg/L)	25	24	23	24	23	25	26	26	25	24
Mg (mg/L)	13	13	12	12	12	13	13	13	15	14
Na (mg/L)	41	41	43	45	47	46	47	47	51	49
K (mg/L)	8	8	7	7	8	8	8	8	8	8
SO <sub>4</sub> <sup>2-</sup> (mg/L)	25	30	28	28	26	25	27	30	28	27
Cl <sup>-</sup> (mg/L)	2	3	3	3	3	3	4	4	4	5
CO <sub>3</sub> (mg/L)	/	/	/	7	11	5	9	10	11	5
HCO <sub>3</sub> (mg/L)	/	/	/	217	216	223	219	223	225	228
pH	8.23	8.09	8.60	8.52	8.67	8.56	8.67	8.57	8.67	8.43
Conductivity ( $\mu\text{S/cm}$ )	408	403	406	412	413	421	421	430	439	428
Hardness (mg/L)	120	113	/	108	108	115	117	119	125	118
TDS (mg/L)	224	231	241	233	237	235	241	247	252	245
Microcystin ( $\mu\text{g/L}$ )	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L CaCO <sub>3</sub> )	182	184	187	190	195	192	195	198	203	197
Basin Sampled	E, W	E, W	E	M	M	M	M	M	M	M







Table 2d. Average historical Secchi depth and water chemistry values for Wabamun Lake (E=East Basin, W=West Basin, M=Main Basin).

Parameter	2010	2011	2012	2013	2014	2016	2019	2020
TP ( $\mu\text{g/L}$ )	34	40	33	36	33	33	27	45
TDP ( $\mu\text{g/L}$ )	13	9	14	14	14	12	7	6
Chlorophyll- <i>a</i> ( $\mu\text{g/L}$ )	7.9	11.5	11.0	8.8	9.1	9.1	11.1	11.7
Secchi depth (m)	1.93	1.47	2.00	1.80	2.00	2.33	2.69	2.43
TKN (mg/L)	1.0	1.1	1.0	1.1	1.0	1.0	0.9	1.0
NO <sub>2</sub> -N and NO <sub>3</sub> -N ( $\mu\text{g/L}$ )	7	3	3	3	7	14	2	2
NH <sub>3</sub> -N ( $\mu\text{g/L}$ )	12	12	17	11	11	16	15	25
DOC (mg/L)	12	/	11	/	11	12	10	10
Ca (mg/L)	/	/	/	/	/	/	28	29
Mg (mg/L)	/	/	/	/	/	/	22	22
Na (mg/L)	77	73	72	73	75	75	75	74
K (mg/L)	10	10	10	9	9	9	10	10
SO <sub>4</sub> <sup>2-</sup> (mg/L)	86	80	85	83	81	80	88	87
Cl <sup>-</sup> (mg/L)	13	13	13	12	13	13	16	16
CO <sub>3</sub> (mg/L)	8	9	7	10	10	10	7	7
HCO <sub>3</sub> (mg/L)	243	233	245	239	238	238	255	230
pH	8.62	8.65	8.50	8.36	8.53	8.51	8.59	8.55
Conductivity ( $\mu\text{S/cm}$ )	592	583	602	608	607	608	613	598
Hardness (mg/L)	141	140	146	153	151	150	158	163
TDS (mg/L)	356	343	353	353	353	356	370	360
Microcystin ( $\mu\text{g/L}$ )	0.10	0.17	0.20	0.10	0.13	0.19	0.12	0.24
Total Alkalinity (mg/L CaCO <sub>3</sub> )	213	207	212	213	212	212	220	198
Basin Sampled	M	M	M	M	E	E	M	M

Table 3. Concentrations of metals measured in Wabamun Lake; total recoverable metals have only been determined in 2013 and 2020 for Wabamun Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values above these guidelines are presented in red.

<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	0.26 <sup>b</sup>
Chromium µg/L	0.493	<0.1	/
Cobalt µg/L	0.0283	0.016	1000 <sup>d</sup>
Copper µg/L	0.642	0.46	4 <sup>b</sup>
Iron µg/L	18.96	13	300
Lead µg/L	0.0624	0.045	7 <sup>b</sup>
Lithium µg/L	39.7	38	2500 <sup>e</sup>
Manganese µg/L	37.6	24	5.2
Molybdenum µg/L	4.63	5.14	73 <sup>c</sup>
Nickel µg/L	0.182	0.42	150 <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>d,e</sup>
Zinc µg/L	1.07	1.7	30

Values represent means of total recoverable metal concentrations.

<sup>a</sup> Based on pH ≥ 6.5

<sup>b</sup> Based on water hardness > 180mg/L (as CaCO<sub>3</sub>)

<sup>c</sup> CCME interim value.

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

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

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

\*2012 data is average from July and September sampling events



## LONG TERM DATA

Wabamun Lake has a fairly unique water quality dataset, as explained above in the Historical Data section, and thus has been analyzed slightly differently than other lakes with long term data. For other lakes' long term trend analyses, any historical data used excludes data from May and October sampling trips. This was done because generally, the historical data supplements the ALMS data, where the ALMS datasets are usually more extensive over time, and ALMS does not sample lakes in May and October. If the May and October data from the smaller pre-ALMS datasets were included, the trend analysis may become biased, as lake conditions within these months are generally different than from June to September. For Wabamun, as it was part of the provincial long term lake monitoring program, samplings occurred in May and October for the majority of years, and over a long time span. Therefore, the October and May data were included to improve the analysis' capture of seasonal variability at Wabamun Lake, where the bias is reduced because the majority of years includes those two months. In addition, 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.

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 2020 in Wabamun Lake. In summary, significant decreasing trends were observed in TP and in chlorophyll-*a*, significant increasing trends were observed in TDS, and no change was observed in Secchi depth. 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 2020.

Parameter	Date Range	Direction of Significant Trend
<b>Total Phosphorus</b>	1981-2020	Decreasing
<b>Chlorophyll-<i>a</i></b>	1980-2020	Decreasing
<b>Total Dissolved Solids</b>	1980-2020	Increasing
<b>Secchi Depth</b>	1980-2020	No change

## Definitions:

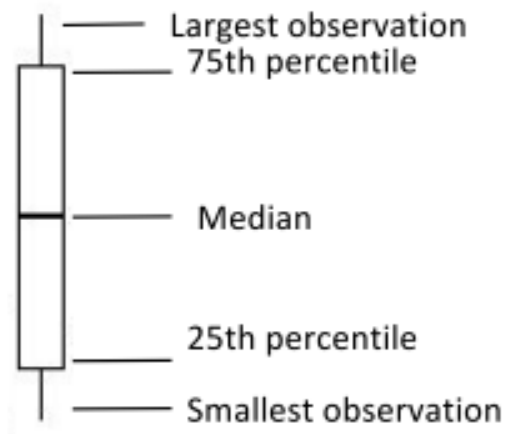
**Median:** the value in a range of ordered numbers that falls in the middle.

**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)

Total phosphorus (TP) decreased significantly between 1981 and 2020 at Wabamun Lake (Tau = -0.15,  $p = 0.0054$ ). However, the slope was only  $-0.17 \mu\text{g/L}$  TP per year, which amounts to a decrease of  $7 \mu\text{g/L}$  of TP over 40 years. So while the decreasing trend is significant, TP has only decreased slightly.

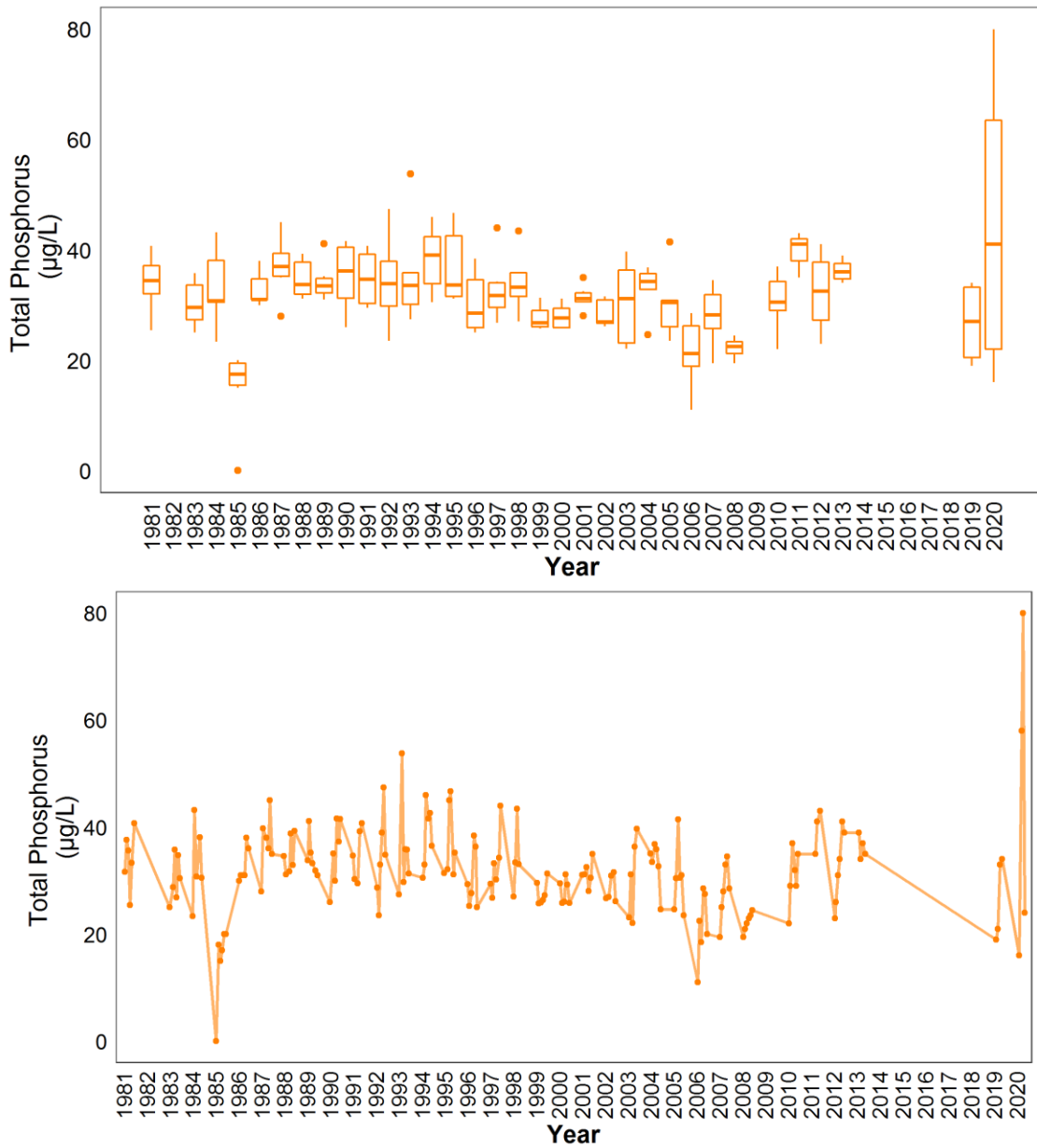


Figure 6. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1980 and 2020 ( $n = 183$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

## Chlorophyll-*a*

Chlorophyll-*a* (Chl*a*) decreased significantly between 1980 and 2020 (Tau = -0.15,  $p = 0.0039$ , Table 2). The decrease is also very slight (slope =  $-0.069 \mu\text{g/L Chl}a$  per year), only  $3 \mu\text{g/L}$  less in 41 years. In addition, TP and Chlorophyll *a* were significantly correlated ( $r = 0.41$ ,  $p = 1.0 \times 10^{-8}$ ).

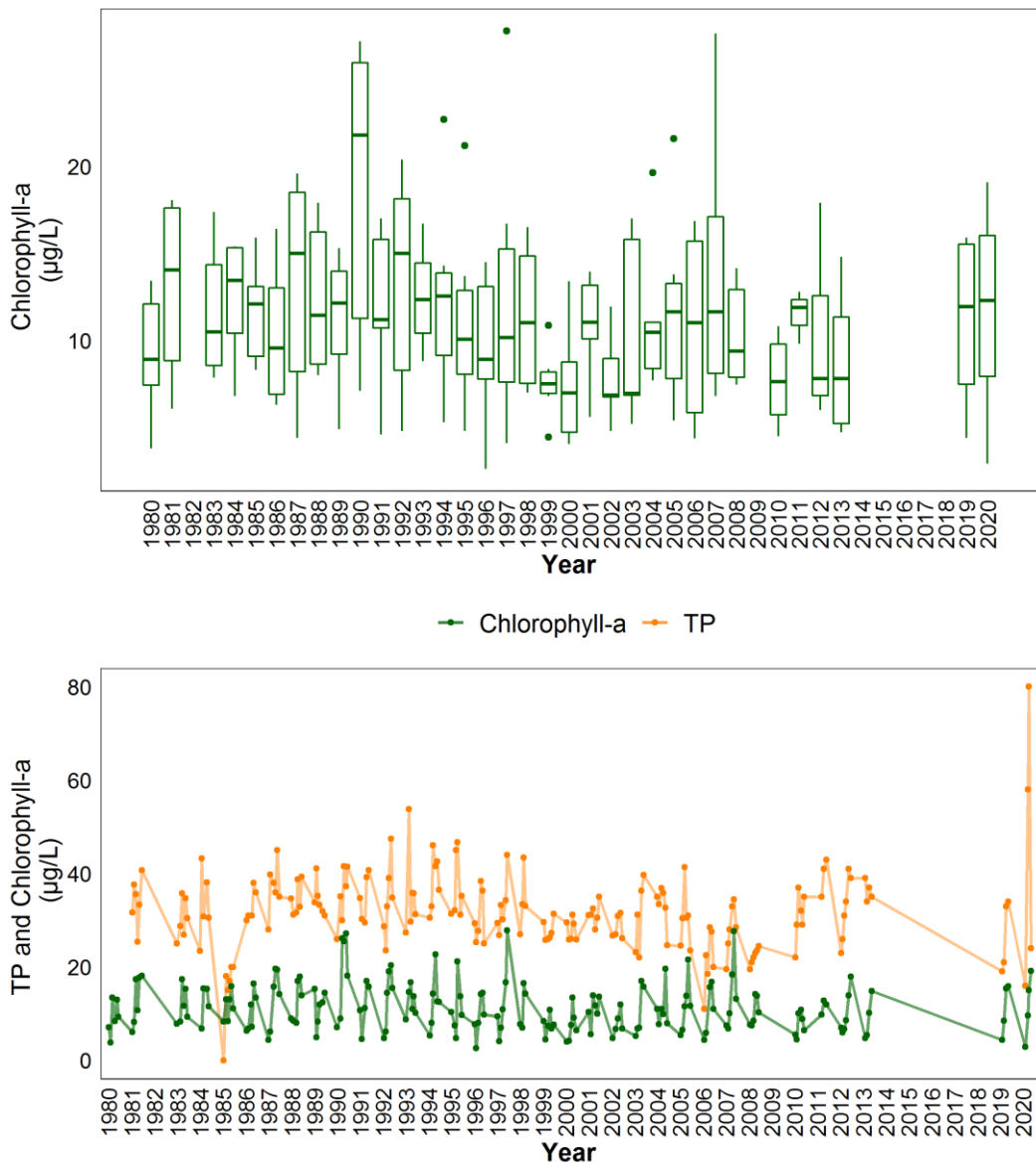


Figure 7. Monthly chlorophyll-*a* concentrations measured between May and October over the long term sampling dates between 1980 and 2020 ( $n = 187$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

## Total Dissolved Solids (TDS)

Total dissolved solids increased significantly between 1980 and 2020 (Tau = 0.91,  $p < 0.001$ , Table 2). The increase was appreciable (slope = 4.19 mg/L TDS per year), where the lake saw an increase in TDS of over 150 mg/L in 41 years.

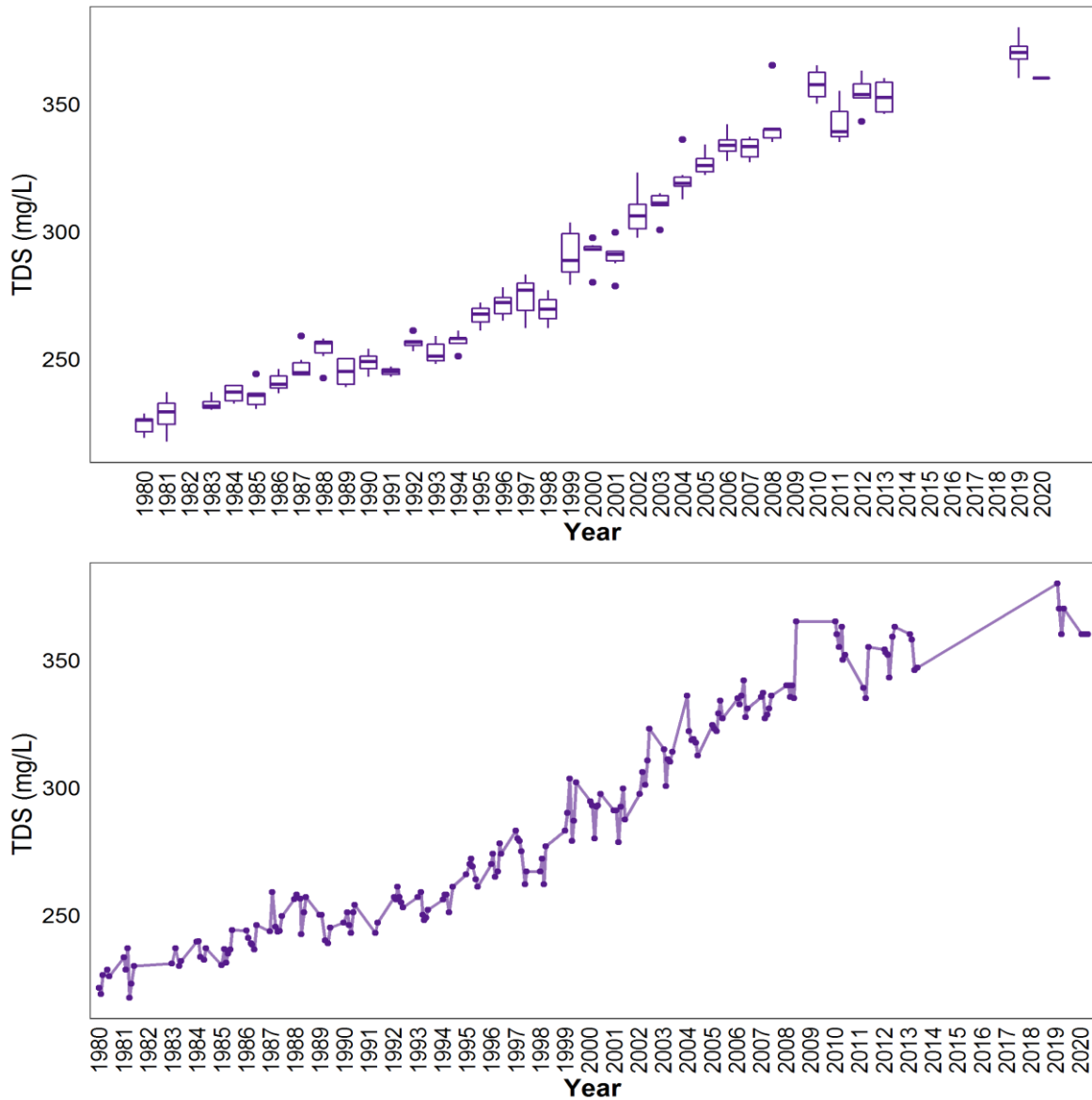


Figure 8. Monthly TDS values measured between May and October over the long term sampling dates between 1980 and 2020 (n = 181). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

## Secchi Depth

Secchi depth did not change significantly between 1980 and 2020 ( $\tau = 0.013$ ,  $p = 0.68$ , Table 2).

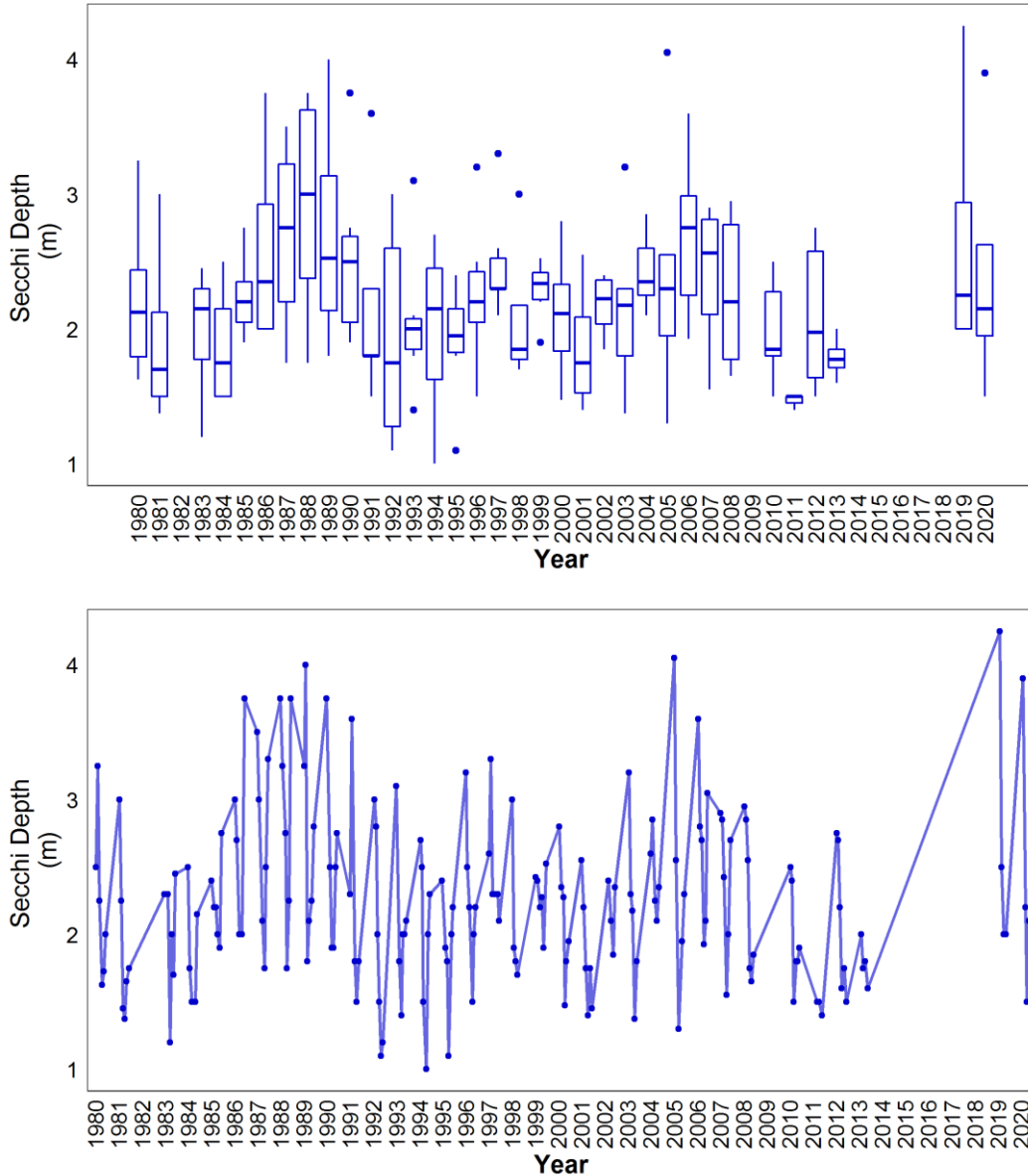


Figure 9. Monthly Secchi depth values measured between May and October over the long term sampling dates between 1980 and 2020 ( $n = 186$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.



Table 6. Results of Seasonal Kendall Trend test using monthly total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS), and Secchi depth data from May to October on Wabamun Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll-a	Total Dissolved Solids (TDS)	Secchi Depth
Statistical Method	-	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall	Seasonal Kendall
The strength and direction (+ or -) of the trend between -1 and 1	Tau	-0.15	-0.15	0.91	0.013
The extent (slope) of the trend	Slope	-0.17	-0.069	4.19	0.00
The statistic used to find significance of the trend	Z	-2.78	-2.89	17.42	0.41
Number of samples included	n	183	187	181	186
The significance of the trend	<i>p</i>	0.0054*	0.0039*	5.86 x 10 <sup>-68</sup> *	0.68

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