



# Lakewatch

The Alberta Lake Management Society  
Volunteer Lake Monitoring Program

## Minnie Lake Report

### 2024

Updated November 13, 2025

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 Garry Kissel for their commitment to collecting data at Minnie Lake. We would also like to thank Katherine Cundict and Jordyn Lajeunesse, who were summer technicians in 2024. Executive Director Bradley Peter and Program Manager Brittany Onsyk were instrumental in planning and organizing the field program. This report was prepared by Brittany Onsyk and Bradley Peter.

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INTRODUCTION TO LIMNOLOGY](#)

## MINNIE LAKE

Minnie Lake is a small lake located west of Bonnyville and northeast of Glendon, within the Beaver River Watershed. The lake is 2 km long and 0.6 km wide, with a surface area of 0.84 km<sup>2</sup>. Mean depth is 8.3 m and maximum depth is about 23 m, though water levels have decreased since these values were calculated.<sup>1</sup>

The shoreline of the lake hosts two municipal campsites, private cabins and recreational properties, agricultural land, and boreal forest. The watershed area for Minnie Lake is 4.43 km<sup>2</sup> and the lake area is 0.67 km<sup>2</sup>, accounting for a lake to watershed ratio of 1:7; the watershed being about 7 times as large as the lake. The watershed is mostly made up of agriculture and oil and gas activities.<sup>2</sup>

Minnie Lake has no in- or out-flow and receives groundwater inputs from a shallow Quaternary aquifer, likely from within the Sand River Formation.<sup>3</sup> Surface run-off from precipitation would also influence water levels.

Historically, Minnie Lake was used as a source of drinking water for the Village of Glendon. Significant declines in water levels were noted in the 80's.<sup>1</sup>

In 2006-2007 the lake experienced a winter fish kill, which decimated stocks of northern pike and yellow perch that previously supported a recreational fishery. Fish populations have not recovered to date.<sup>4</sup>



Bathymetric map of Minnie Lake

<sup>1</sup> Minnie Lake Stabilization Plan Water Quality Assessment. 1986. Trew, D.O. <https://open.alberta.ca/dataset/26db0a0e-7c63-41ca-896a-3a0e5c39be47/resource/1d8deab3-aa80-40b8-a0f2-18aca857d5fb/download/8153.pdf>. Accessed October 22, 2025.

<sup>2</sup> Beaver River State of the Watershed Assessment & Reporting. 2025. Fiera Biological Consulting Ltd. <https://online.fliphtml5.com/bqscp/fuup/?search=land%2520use#p=5>. Accessed October 22, 2025.

<sup>3</sup> Decision 2011 ABERCB 019: Canadian Natural Resources Limited Applications for 15 Well and 8 Facility Licences, Sugden Field. 2011. Energy Resources Conservation Board. <https://static.aer.ca/prd/documents/decisions/2011/2011-ABERCB-019.pdf>. Accessed October 22, 2025.

<sup>4</sup> Anonymous, personal communication.

## 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 Minnie Lake was 25 µg/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. This value falls in the middle of all previously observed historical TP averages going back to 1985 (Table 2). TP ranged from a minimum of 19 µg/L on September 4, to a maximum of 36 µg/L on June 19 (Figure 1).

The average chlorophyll-*a* concentration in 2024 was 6.5 µg/L (Table 2), similarly falling into the mesotrophic, or moderately productive trophic classification. Chlorophyll-*a* was lowest at 4.1 µg/L on September 4 and peaked at 7.9 µg/L on June 19 (Figure 1).

The average total Kjeldahl nitrogen (TKN) concentration was 1.3 mg/L (Table 2). TKN levels were relatively stable all summer (Figure 1).

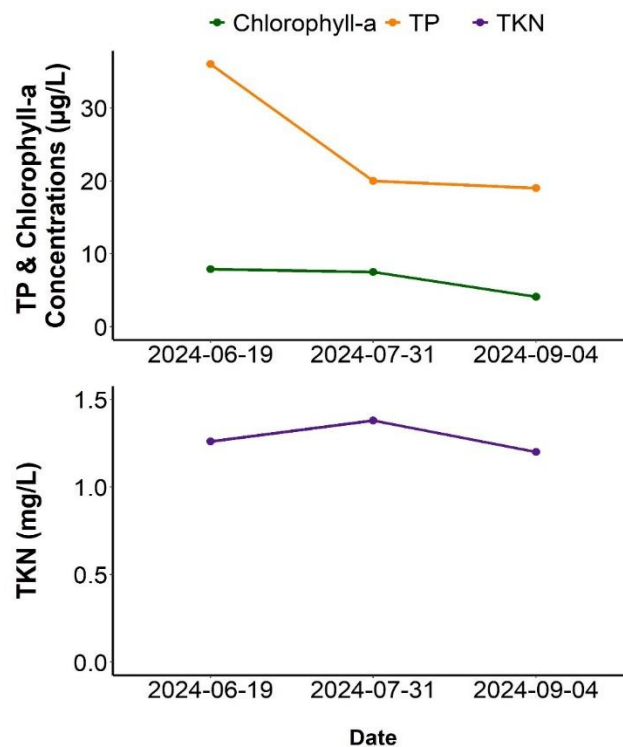


Figure 1. Total Phosphorus, Chlorophyll-*a*, and Total Kjeldahl Nitrogen concentrations measured over the course of the summer at Minnie Lake in 2024.

Average pH was measured as 8.74 in 2024, buffered by an alkalinity (350 mg/L CaCO<sub>3</sub>) and bicarbonate (363 mg/L HCO<sub>3</sub><sup>-</sup>). Aside from bicarbonate, sulphate was the most abundant ion, followed by magnesium and sodium (Figure 2, top). These major ions contributed to a high average conductivity of 1500 µS/cm (Table 2).

Minnie Lake is in the high range of ion levels compared to other LakeWatch lakes sampled in 2024 (Figure 2, bottom). The elevated conductivity (ions), sulphate, and magnesium are likely naturally occurring due to the groundwater influence at Minnie Lake, and have been reflected in water sampling dating back to the 1970's.<sup>1</sup>

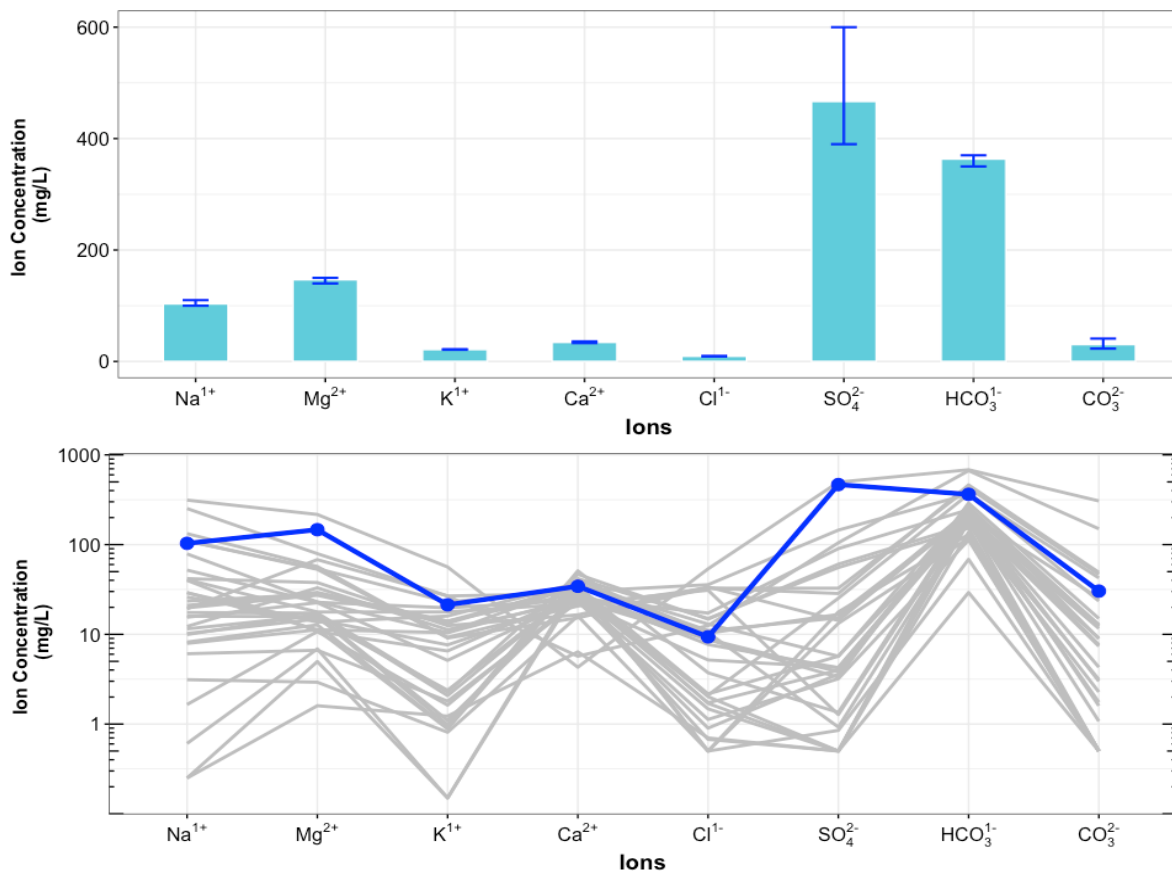


Figure 2. Average levels of cations (sodium = Na<sup>1+</sup>, magnesium = Mg<sup>2+</sup>, potassium = K<sup>1+</sup>, calcium = Ca<sup>2+</sup>) and anions (chloride = Cl<sup>1-</sup>, sulphate = SO<sub>4</sub><sup>2-</sup>, bicarbonate = HCO<sub>3</sub><sup>1-</sup>, carbonate = CO<sub>3</sub><sup>2-</sup>) from 3 measurements over the course of the summer at Minnie Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Minnie Lake (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2024 (note log<sub>10</sub> scale on y-axis of bottom figure).

<sup>1</sup> Minnie Lake Stabilization Plan Water Quality Assessment. 1986. Trew, D.O. <https://open.alberta.ca/dataset/26db0a0e-7c63-41ca-896a-3a0e5c39be47/resource/1d8deab3-ea80-40b8-a0f2-18aca857d5fb/download/8153.pdf>. Accessed October 22, 2025.



## 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 measured at Minnie Lake in 2024 (Table 3). Arsenic was the only metal to exceed the CCME chronic guideline for the protection of aquatic life.<sup>5</sup> Arsenic has been measured above the CCME guidelines since LakeWatch sampling has occurred at Minnie Lake (2008) (Table 3).

The elevated levels of arsenic are likely attributed to the heavy presence of groundwater at Minnie Lake.<sup>1</sup> In Northern Alberta, groundwater is found to be naturally high in arsenic and other heavy metals.<sup>6</sup>

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<sup>1</sup> Minnie Lake Stabilization Plan Water Quality Assessment. 1986. Trew, D.O. <https://open.alberta.ca/dataset/26db0a0e-7c63-41ca-896a-3a0e5c39be47/resource/1d8deab3-ea80-40b8-a0f2-18aca857d5fb/download/8153.pdf>. Accessed October 22, 2025.

<sup>5</sup> Canadian Water Quality Guidelines. 2019. Canadian Council of Ministers of the Environment. <https://ccme.ca/en/resources#>. Accessed October 29, 2025.

<sup>6</sup> Arsenic in Groundwater from Domestic Wells in Three Areas of Northern Alberta. 2000. Alberta Health and Wellness. <https://open.alberta.ca/dataset/a8da31b1-3a3e-40d7-b033-83289b0bfae3/resource/23f0e555-3ce0-457a-a9a0-b6112a7cb5c4/download/arsenic-groundwater-wells-2000.pdf> . Accessed October 29, 2025.

## 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 Minnie Lake in 2024 was 5.07 m, corresponding to a Secchi depth of 2.53 m (Table 2). Euphotic depth varied over the season, ranging from as low as 3.2 m on June 19 to as deep as 6 m on July 31 (Figure 3).

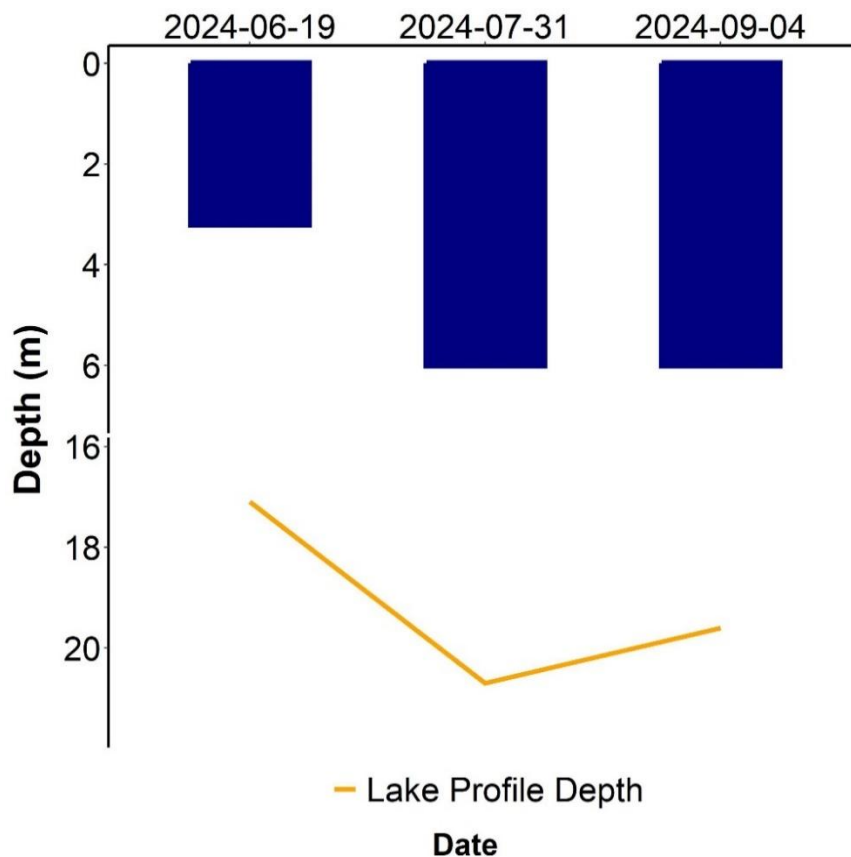


Figure 3. Euphotic depth values measured over the course of the summer at Minnie Lake in 2024.



## 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 Minnie Lake varied throughout the summer, with the August 31 sampling date having the warmest temperatures at nearly 23°C (Figure 4). The lake was strongly stratified during each sampling trip and was especially strong during the August sampling event. During each sampling event, the bottom layer of water (hypolimnion) approached 4°C.

Minnie Lake was well oxygenated in the surface waters on all sampling dates, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen<sup>7</sup> (Figure 4b). During all sampling events, dissolved oxygen can be seen decreasing sharply at the thermocline, or mixing depth, at approximately 6 m (Figure 4).

Minnie Lake was well stratified during each sampling event, meaning there is a clear differentiation between warm surface water and cooler, denser water near the bottom of the lake. This stratification is likely why TP decreased over the summer (Figure 1). As algae and aquatic plants utilized the phosphorus in the surface water to grow and photosynthesize, the strong stratification of the lake prevented lake mixing, and prevented phosphorus from migrating up from the bottom of the lake.

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<sup>7</sup> Canadian Water Quality Guidelines for the Protection of Aquatic Life, Dissolved Oxygen (Freshwater). 1999. Canadian Council of Ministers of the Environment. <https://ccme.ca/en/res/dissolved-oxygen-freshwater-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf>. Accessed October 29, 2025.

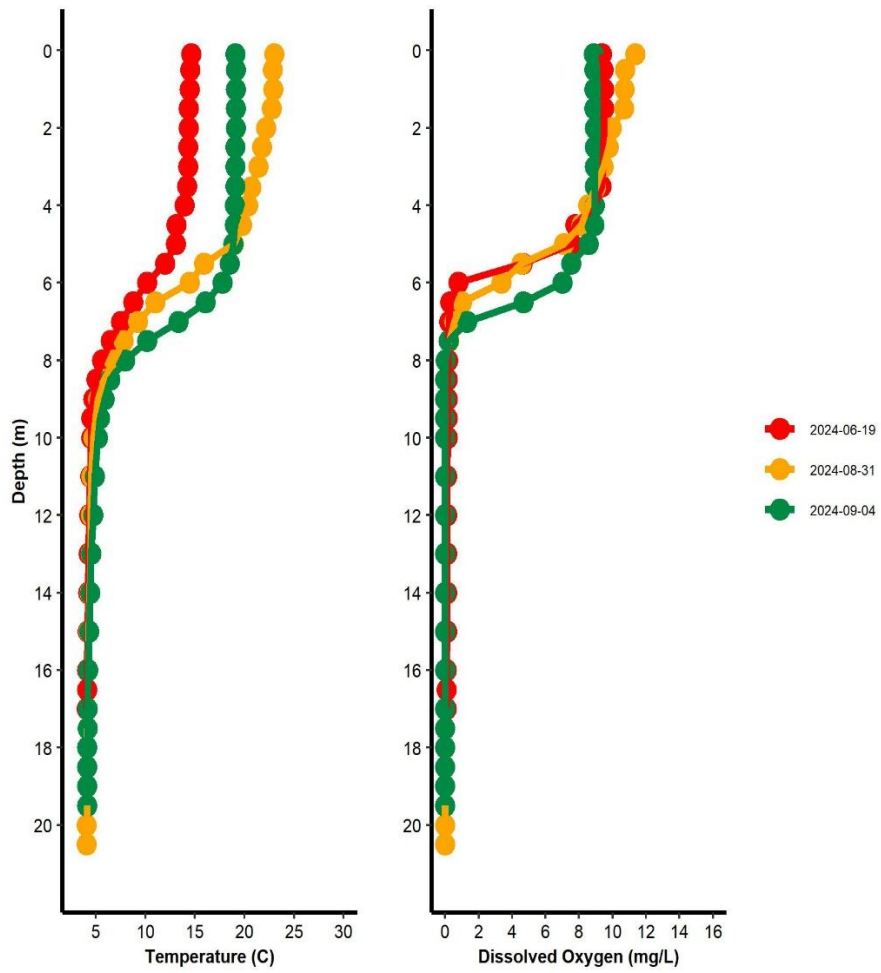


Figure 4. Temperature (°C) and dissolved oxygen (mg/L) profiles for Minnie Lake measured over the course of the summer of 2024.



## 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 Minnie Lake fell below the recreational guideline of 10 µg/L<sup>8</sup> during every sampling event in 2024. Despite low levels of microcystin detected during the three sampling events, caution should be observed in areas of the lake where significant cyanobacteria accumulation occurs.

Table 1. Microcystin concentrations measured four times at Minnie Lake in 2024.

<b>Date</b>	<b>Microcystin Concentration (µg/L)</b>
06/19/2024	0.48
07/31/2024	0.1
09/04/2024	0.12
<b>Average</b>	0.23

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<sup>8</sup> Health Canada. 2022. Guidelines for Canadian Recreational Water Quality.



## INVASIVE SPECIES

*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 for aquatic invasive species involved sampling with a 63 µm plankton net at three sample sites. This monitoring is designed to detect juvenile Dreissenid mussel veligers and spiny water flea. No mussels or spiny water flea were detected at Minnie Lake in 2024.

*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.*

Watermilfoil was not collected at Minnie Lake in 2024.

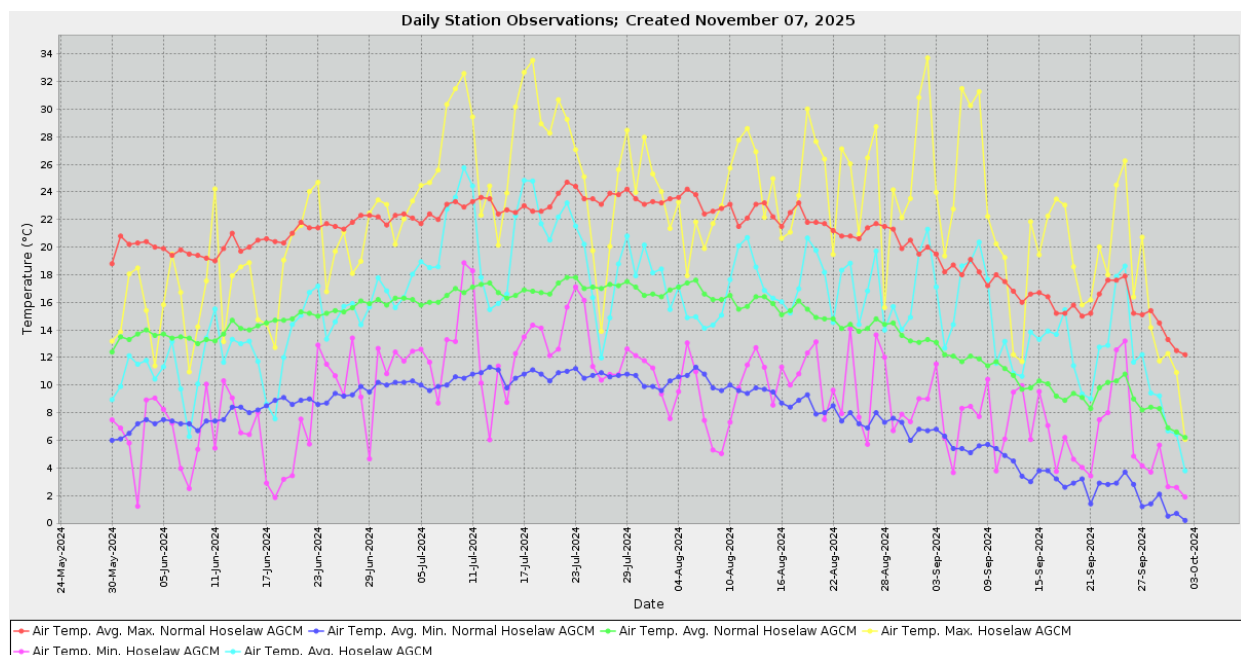
## WEATHER AND LAKE STRATIFICATION

*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.*

In 2024, Minnie Lake experienced a warmer and windier summer compared to normal, with about normal accumulated precipitation (Figure 6). Although it was warmer overall, the beginning of the sampling season was unseasonably cold and wet, with the month of June near breaking the lowest temperatures on record on numerous days. The lowest temperature was recorded on June 2 at 1.2°C. July was the warmest month, with the average temperature being 19.5°C. 2024 also broke numerous heat records, including the hottest day recorded on September 2 at 33.7°C. September was also a warmer than average month, with the average temperature being 13.9°C.

Minnie Lake received less than normal precipitation in the summer of 2024 (206 mm total). Precipitation occurred in short bursts over the summer months, with nearly 20 mm of rain falling on numerous days over the summer (June 12, July 3, and July 26) followed by weeks of no precipitation. Very little precipitation fell in the months of August and September.

Strong winds were also observed throughout the sampling season.



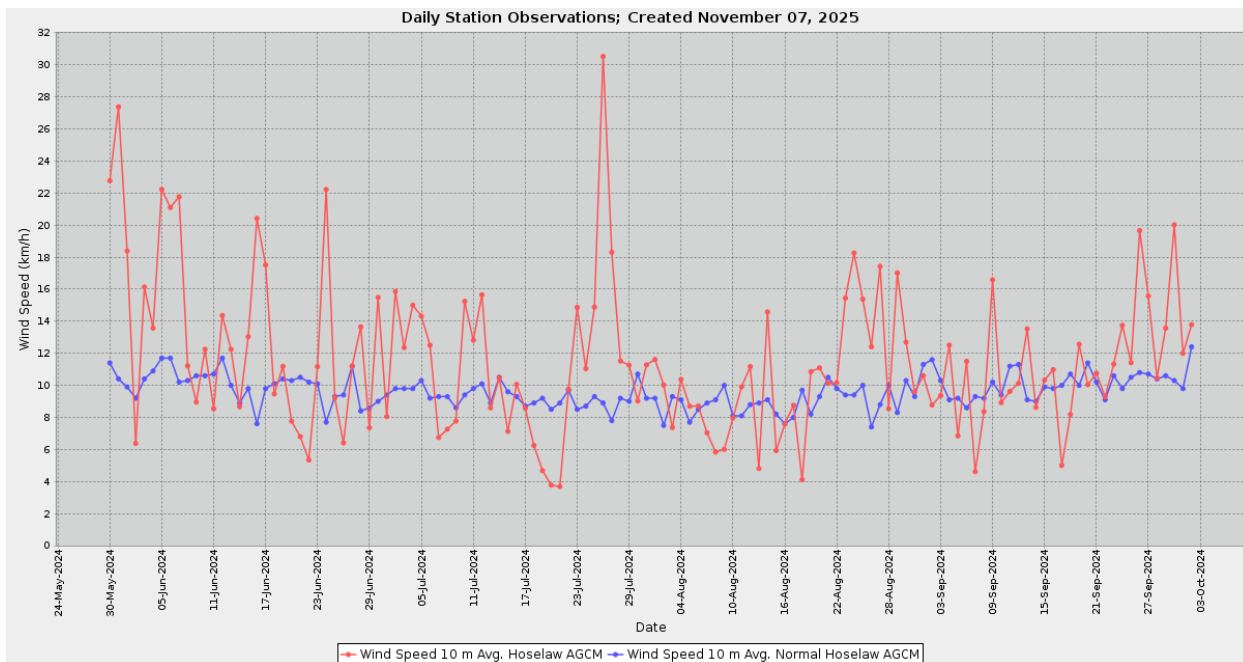
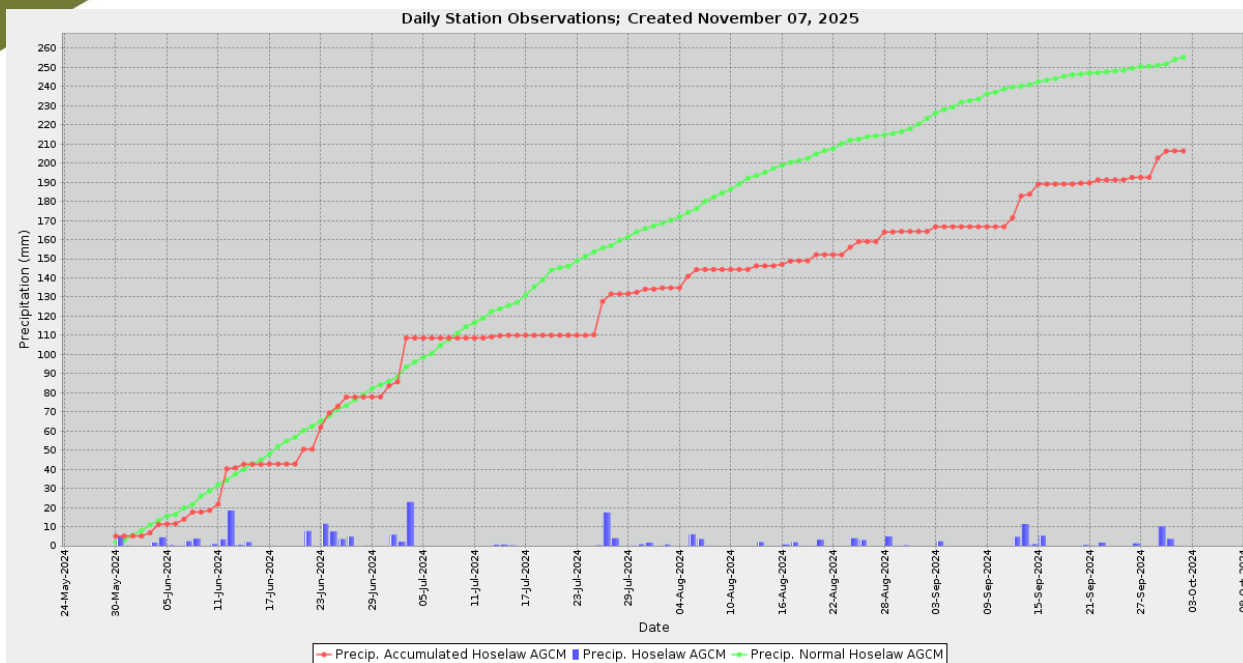


Figure 6. Air temperature ( $^{\circ}\text{C}$ ), wind speed (km/h), and precipitation (cm) measured from Hoselaw weather station southeast of Minnie Lake. Weather data provided by Agriculture, Forestry and Rural Economic Development, Alberta Climate Information Service (ACIS) <https://acis.alberta.ca> (retrieved November, 2025).

## 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.*

Historical records show that water levels have been steadily decreasing at Minnie Lake (Figure 7). Recent readings indicate lake water levels experienced a slight increase from 2016-2024. Despite the recent increase, the lake is still nearly 3 m lower than the historical high recorded at the beginning of the historical record in 1981.

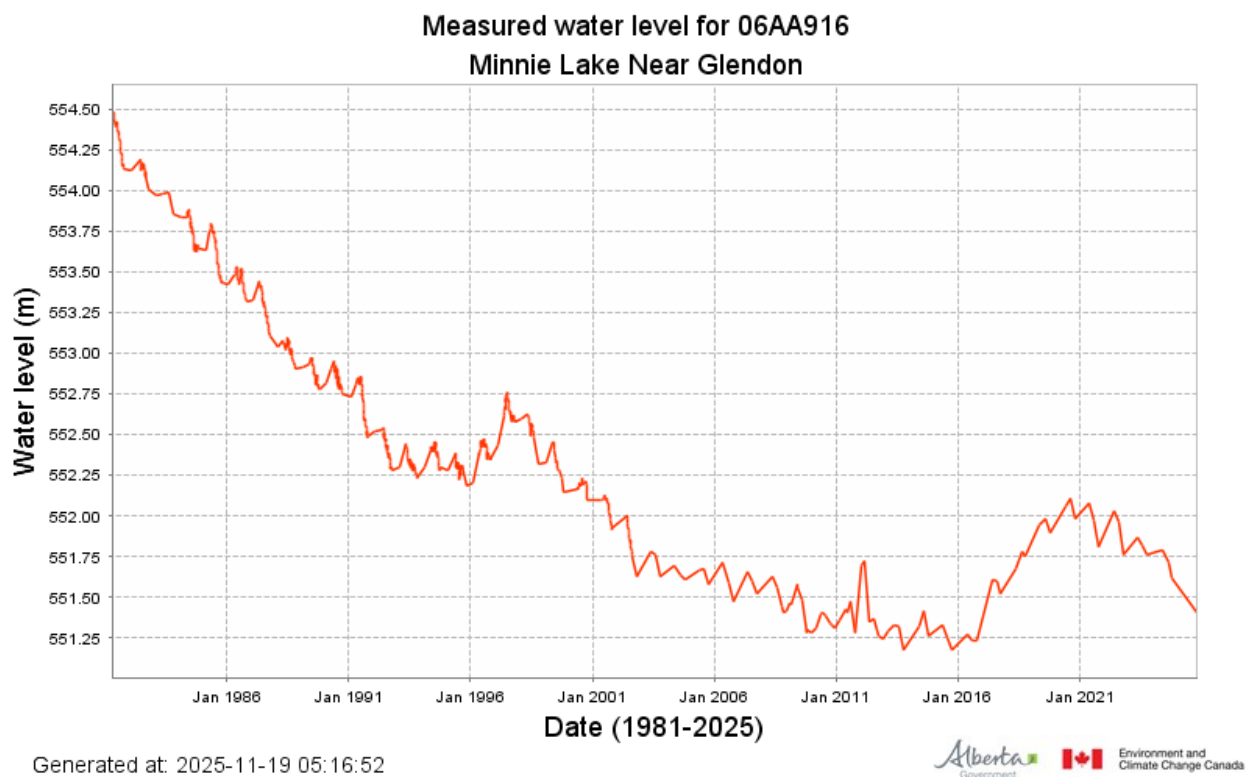


Figure 7. Water levels measured at Minnie Lake in metres above sea level (masl) from 1981-2025. Obtained from Alberta River Basins (<https://rivers.alberta.ca/>).

<sup>3</sup> Decision 2011 ABERCB 019: Canadian Natural Resources Limited Applications for 15 Well and 8 Facility Licences, Sugden Field. 2011. Energy Resources Conservation Board. <https://static.aer.ca/prd/documents/decisions/2011/2011-ABERCB-019.pdf>. Accessed October 22, 2025.

Table 2. Average Secchi depth and water chemistry values for Minnie Lake. Ion data using “extractable” analysis was excluded from this historical record in the years 2008-2015.

<b>Parameter</b>	<b>1985</b>	<b>1986</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>
TP (µg/L)	22	32	40	42	39	52	45	32	391	24
TDP (µg/L)	12	12	24	22	27	26	22	21	427	11
Chlorophyll-a (µg/L)	5.6	6.3	5.3	4.0	3.4	5.2	6.4	3.0	4.1	4.8
Secchi depth (m)	-	4.02	4.5	2.19	4.7	3.85	3.81	3.32	3.67	2.55
TKN (mg/L)	1.2	1.1	1.5	1.5	1.6	1.8	1.7	1.6	1.5	1.5
NO <sub>2</sub> -N and NO <sub>3</sub> -N (µg/L)	7	2	21	8	12	14	11	2	38	-
NH <sub>3</sub> -N (µg/L)	50	24	62	-	99	35	-	24	50	-
DOC (mg/L)	13	14	18	20	20	19	19	22	18	18
Ca <sup>2+</sup> (mg/L)	19	21	-	-	-	-	-	-	-	26
Mg <sup>2+</sup> (mg/L)	91	92	-	-	-	-	-	-	-	144
Na <sup>+</sup> (mg/L)	68	68	94	97	97	96	96	99	103	96
K <sup>+</sup> (mg/L)	13	12	23	19	19	19	20	21	20	20
SO <sub>4</sub> <sup>2-</sup> (mg/L)	197	237	399	421	409	400	451	391	433	440
Cl <sup>-</sup> (mg/L)	4	4	7	7	7	7	8	7	8	8
CO <sub>3</sub> <sup>2-</sup> (mg/L)	-	-	25.7	31.3	23	29	28	44.8	37.9	36.8
HCO <sub>3</sub> <sup>2-</sup> (mg/L)	-	-	408.33	389.67	412	393.4	398	358.6	347.6	376
pH	8.73	8.85	8.63	8.80	8.65	8.77	8.73	8.88	8.78	8.82
Conductivity (µS/cm)	992	1011	1340	1323	1370	1350	1368	1418	1360	1400
Hardness (mg/L)	422	427	562	564	562	605	558	641	591	660
TDS (mg/L)	595	637	897	914	903	902	943	906	948	962
Microcystin (µg/L)	-	-	0.11	0.11	0.08	0.11	0.13	0.09	0.08	0.07
Total Alkalinity (mg/L CaCO <sub>3</sub> )	338	339	378	372	376	371	373	369	348	370

Parameter	2016	2017	2018	2019	2021	2022	2023	2024
TP (µg/L)	19	29	28	41	25	12	26	25
TDP (µg/L)	8	10	9	11	9	5	8	7
Chlorophyll-a (µg/L)	7.0	9.4	8.1	19.4	7.8	4.5	10.6	6.5
Secchi depth (m)	1.9	1.86	2.25	1.58	1.81	2.65	3.05	2.53
TKN (mg/L)	1.5	1.5	1.5	1.6	1.6	1.3	1.6	1.3
NO <sub>2</sub> -N and NO <sub>3</sub> -N (µg/L)	2	2	2	2	6	3	98	4
NH <sub>3</sub> -N (µg/L)	25	22	37	15	22	12	21	11
DOC (mg/L)	19	18	19	20	18	17	16	17
Ca <sup>2+</sup> (mg/L)	23	29	34	36	44	39	33	34
Mg <sup>2+</sup> (mg/L)	142	136	130	130	135	137	142	147
Na <sup>+</sup> (mg/L)	97	93	94	93	96	96	99	103
K <sup>+</sup> (mg/L)	20	20	20	19	20	20	20	21
SO <sub>4</sub> <sup>2-</sup> (mg/L)	428	420	422	467	490	473	498	467
Cl <sup>-</sup> (mg/L)	8	8	8	9	9	9	10	9
CO <sub>3</sub> <sup>2-</sup> (mg/L)	37.8	32.2	26.5	46	34.5	18.7	45	30.3
HCO <sub>3</sub> <sup>2-</sup> (mg/L)	360	354	367.5	346.67	380	390	347.5	363.33
pH	8.86	8.84	8.72	8.85	8.74	8.60	8.78	8.74
Conductivity (µS/cm)	1400	1320	1375	1400	1500	1467	1500	1500
Hardness (mg/L)	634	630	628	640	672	660	678	707
TDS (mg/L)	932	912	918	973	1000	983	1000	987
Microcystin (µg/L)	0.11	0.12	0.26	0.75	0.08	0.64	2.32	0.23
Total Alkalinity (mg/L CaCO <sub>3</sub> )	356	344	348	360	370	350	355	350

Table 3. Concentrations of metals measured in Minnie 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.

Metals	2008	2009	2010	2011	2012	2013	2014	2015	2016	Guidelines
Aluminum (µg/L)	13.75	12.95	14.26	14.84	9.27	22.55	17.4	9.95	7.1	100 <sup>a</sup>
Antimony (µg/L)	0.382	0.375	0.392	0.372	0.37	0.368	0.349	0.398	0.415	/
Arsenic (µg/L)	9.15	9.32	9.56	9.07	9.57	9.83	9.88	10.36	8.34	5
Barium (µg/L)	20.6	18.6	18.5	18.2	15.4	12.7	12.4	14.9	12	/
Beryllium (µg/L)	0.0015	0.0015	0.005	0.0015	0.0057	0.0057	0.004	0.004	0.004	100 <sup>c,d</sup>
Bismuth (µg/L)	0.0072	0.0056	0.0039	5e-04	5e-04	0.008	5e-04	5e-04	5e-04	/
Boron (µg/L)	162	205.5	159.5	204.5	194	186.5	185	185	187	1500
Cadmium (µg/L)	0.012	0.019	0.017	0.014	0.002	0.004	0.002	0.002	0.001	0.36 <sup>b</sup>
Chromium (µg/L)	0.4935	0.3935	0.169	0.2575	0.184	0.3065	0.292	0.125	0.07	/
Cobalt (µg/L)	0.111	0.0923	0.0972	0.07485	0.0697	0.09775	0.0687	0.0875	0.102	500, 1000 <sup>c,d</sup>
Copper (µg/L)	1.02	2.085	0.681	1.082	1.21	1.3	0.903	1.665	1.48	4 <sup>b</sup>
Iron (µg/L)	10.93	43.6	16.1	8.9	5.24	29.3	16.85	13.1	10.7	300
Lead (µg/L)	0.027	0.054	0.085	0.033	0.019	0.062	0.011	0.029	0.03	7 <sup>b</sup>
Lithium (µg/L)	74.05	101.5	84.05	106.5	93.75	93.95	92.95	89.3	101	2500 <sup>d</sup>
Manganese (µg/L)	8.61	6.36	5.9	15.75	13.8	4.52	6.78	7.38	2.94	130 <sup>e</sup>
Molybdenum (µg/L)	0.798	0.726	0.746	0.735	0.668	0.669	0.569	0.619	0.597	73
Nickel (µg/L)	0.27	0.665	0.38	0.151	0.11	0.522	0.348	0.382	0.775	150 <sup>b</sup>
Selenium (µg/L)	0.2	0.292	0.232	0.228	0.05	0.089	0.123	0.085	0.12	1
Silver (µg/L)	0.0012	0.0082	0.0029	3e-04	0.0036	0.0112	0.001	0.001	0.001	0.25
Strontium (µg/L)	74	69.7	55	73.2	58.4	49.7	58.7	76	50.1	/
Thallium (µg/L)	0.0026	0.0015	0.0055	3e-04	4e-04	0.0015	9e-04	4e-04	9e-04	0.8
Thorium (µg/L)	0.063	0.002	0.018	0.01	0	0.032	0.011	0.002	0.009	/
Tin (µg/L)	0.02	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01	/
Titanium (µg/L)	0.666	0.691	1.099	0.686	0.452	1.114	0.685	0.875	0.54	/
Uranium (µg/L)	2.295	2.075	2.16	2.14	2.025	2.1	2.165	2.26	2.31	15
Vanadium (µg/L)	1.305	1.215	1.165	1.06	1	1.035	1.04	1.265	1.36	100 <sup>c,d</sup>
Zinc (µg/L)	1.58	1.34	1.17	1.48	2.04	1.46	1.58	1.55	2.3	30 <sup>f</sup>

Metals	2017	2018	2019	2021	2022	2023	2024	Guidelines
Aluminum (µg/L)	3.9	1.8	6.1	9.4	6	2.7	7.4	100 <sup>a</sup>
Antimony (µg/L)	0.395	0.357	0.344	0.296	0.289	0.277	0.288	/
Arsenic (µg/L)	9.65	7.7	8.91	7.58	6.82	8	7.59	5
Barium (µg/L)	17.4	22.4	15.8	23	15.3	11.6	15.4	/
Beryllium (µg/L)	0.0075	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	100 <sup>c,d</sup>
Bismuth (µg/L)	0.0075	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	/
Boron (µg/L)	194	170	184	179	198	147	175	1500
Cadmium (µg/L)	0.025	0.005	0.005	0.005	0.005	0.005	0.005	0.36 <sup>b</sup>
Chromium (µg/L)	0.25	0.05	0.05	0.05	0.05	0.05	0.05	/
Cobalt (µg/L)	0.124	0.104	0.105	0.087	0.048	0.066	0.067	500, 1000 <sup>c,d</sup>
Copper (µg/L)	2.7	0.17	0.04	0.33	0.19	0.13	0.13	4 <sup>b</sup>
Iron (µg/L)	9	5.8	7.6	15.1	4.7	4.1	6.8	300
Lead (µg/L)	0.01	0.002	0.006	0.017	0.011	0.02	0.009	7 <sup>b</sup>
Lithium (µg/L)	99.8	91.4	94.4	98.4	91.1	75.1	90.2	2500 <sup>d</sup>
Manganese (µg/L)	5.44	3.85	6.97	14.1	5.51	3.56	6.39	130 <sup>e</sup>
Molybdenum (µg/L)	0.484	0.448	0.5	0.361	0.307	0.298	0.226	73
Nickel (µg/L)	1.87	0.4	0.18	0.45	0.37	0.19	0.21	150 <sup>b</sup>
Selenium (µg/L)	0.5	0.7	0.7	0.4	0.1	1	0.5	1
Silver (µg/L)	0.0025	0.001	5e-04	0.001	5e-04	0.002	0.001	0.25
Strontium (µg/L)	84.4	119	93.5	141	97.6	76.7	93.6	/
Thallium (µg/L)	0.011	0.001	0.001	0.001	0.001	0.001	0.001	0.8
Thorium (µg/L)	0.01	0.001	0.004	0.004	0.003	0.02	0.003	/
Tin (µg/L)	0.15	0.03	0.03	0.03	0.03	0.03	0.03	/
Titanium (µg/L)	0.42	0.38	0.41	0.3	0.15	0.49	0.4	/
Uranium (µg/L)	2.02	2.13	2.16	2.04	1.76	1.87	1.71	15
Vanadium (µg/L)	0.957	0.692	0.573	0.531	0.384	0.393	0.381	100 <sup>c,d</sup>
Zinc (µg/L)	3.8	1.9	1	1.8	0.8	2.1	1.4	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 2016 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#\\_aqi\\_fresh\\_concentration](https://ccme.ca/en/chemical/129#_aqi_fresh_concentration)) using 2016 avg. water hardness (as CaCO<sub>3</sub>) and avg. pH

<sup>f</sup> Based on 2016 avg. water hardness (as CaCO<sub>3</sub>), avg. pH, and avg. DOC with CCME equation

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 over time in Minnie Lake. In sum, a decreasing trend was detected in TP and Secchi depth, while an increasing trend was detected in chlorophyll-*a* and TDS. Secchi depth can be subjective and is sensitive to variation in weather; therefore, trend analysis must be interpreted with caution. Detailed methods are available in the [ALMS Guide to Trend Analysis on Alberta Lakes](#).

Table 4. Summary table of trend analysis on Minnie Lake data from 2008 to 2024.

Parameter	Date Range	Direction of Significant Change
Total Phosphorus	2008-2024	Decreasing
Chlorophyll- <i>a</i>	2008-2024	Increasing
Total Dissolved Solids	2008-2024	Increasing
Secchi Depth	2008-2024	Decreasing

## Definitions

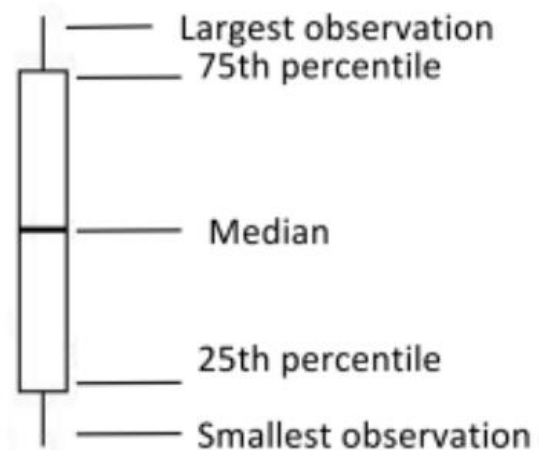
**Median:** the value in a range of ordered numbers that falls in the middle.

**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 75th percentile is the upper quartile of the data, and the 25th percentile is the lower quartile of the data. The top and bottom points are the largest and smallest observations.



## Total Phosphorus (TP)

Trend analysis of TP showed it has significantly decreased in Minnie since 2008 (Tau = -0.5066,  $p < 0.001$ ).

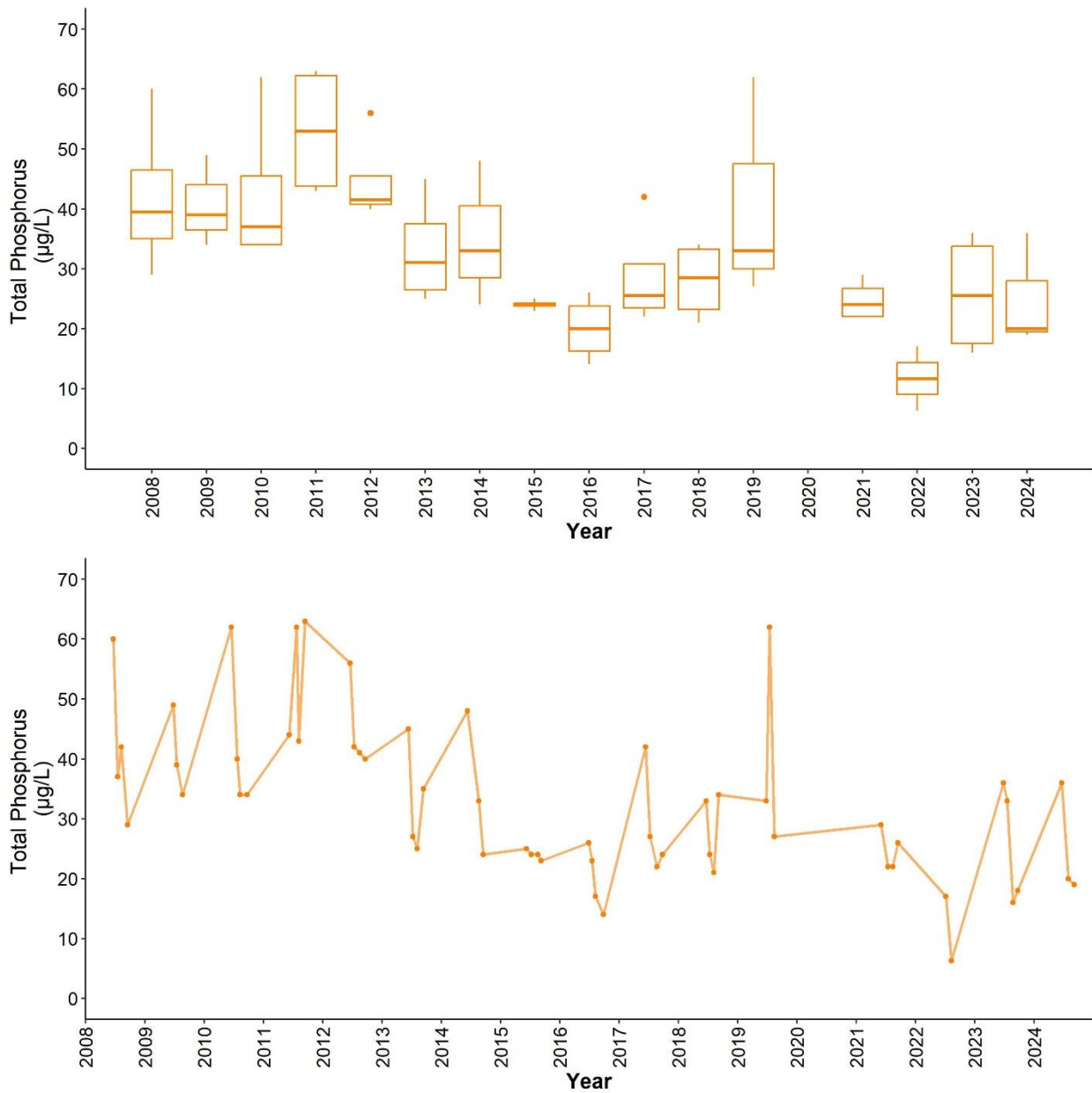


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 2008 and 2024 (n = 58). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

## Chlorophyll-a

Trend analysis of chlorophyll-a showed it has significantly increased over time at Minnie Lake from 2008 to 2024 (Tau = 0.374,  $p < 0.001$ ).

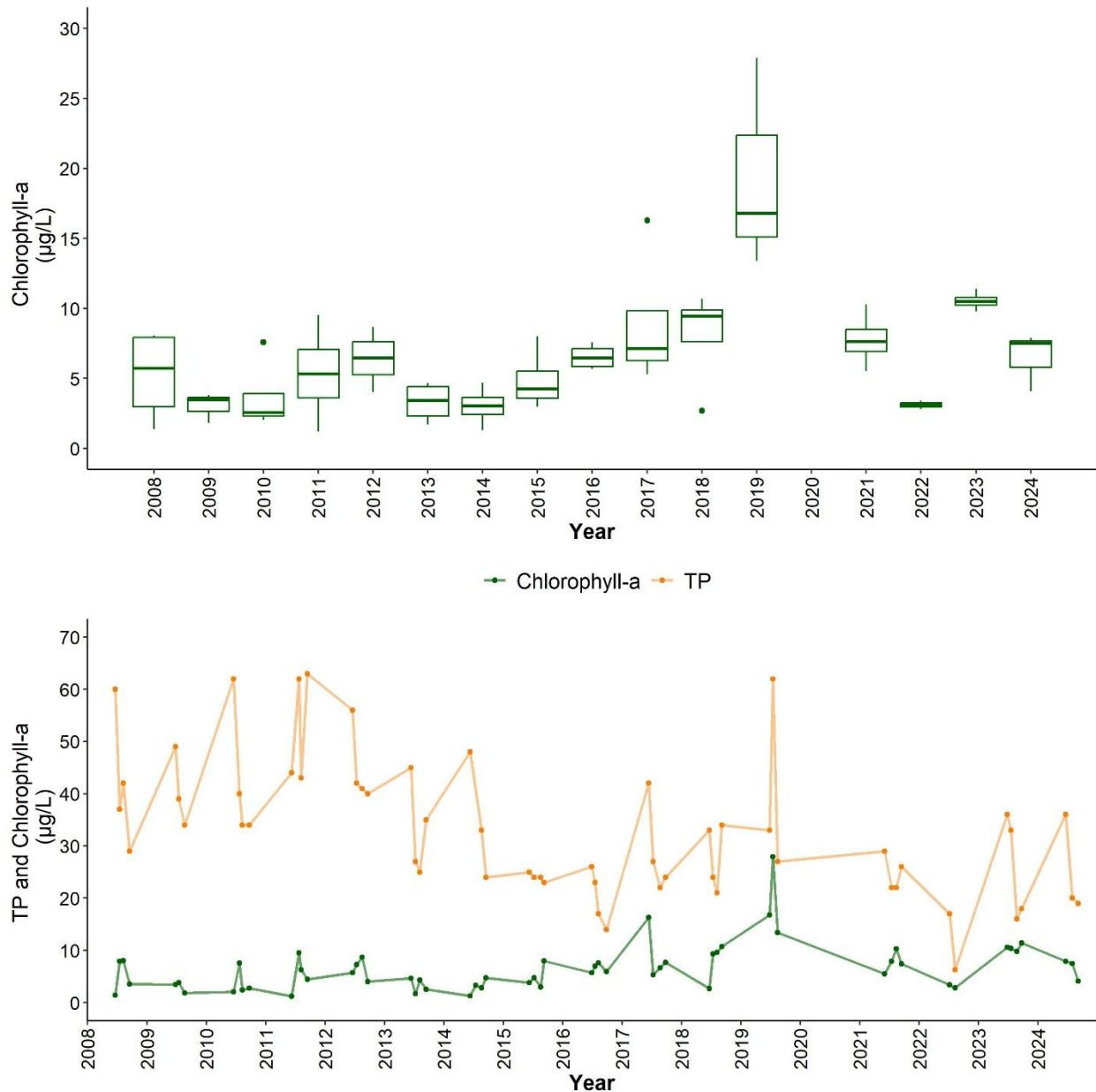


Figure 8. Monthly chlorophyll-a concentrations measured between June and September over the long term sampling dates between 2008 and 2024 ( $n = 59$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

## Total Dissolved Solids (TDS)

Trend analysis showed a significantly increasing trend in TDS in Minnie Lake since 2008 (Tau = 0.4059,  $p < 0.001$ ).

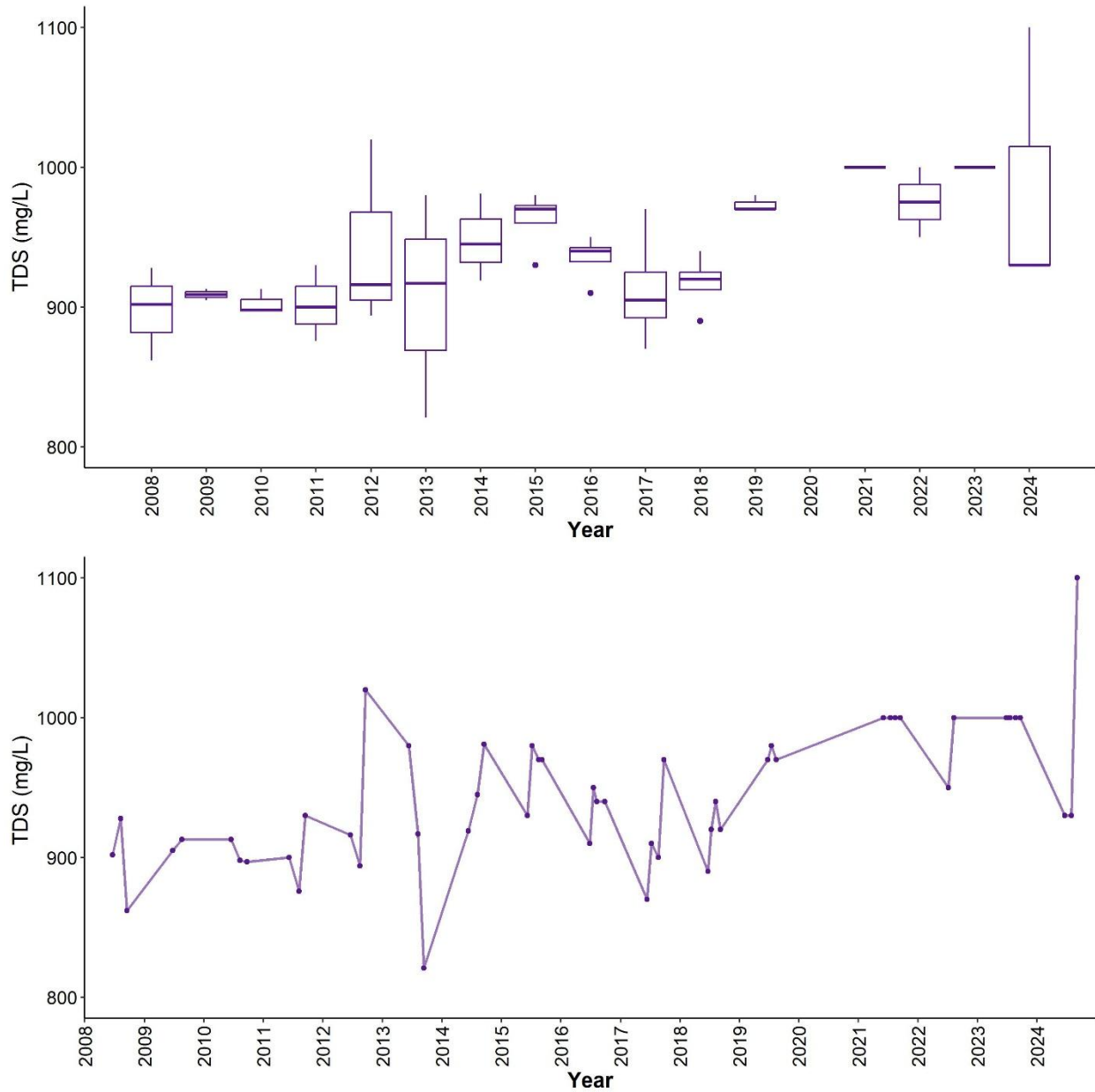
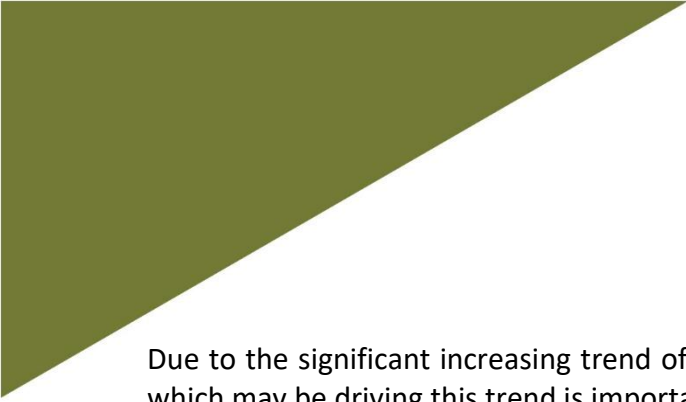


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 2008 and 2024 (n = 52). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.



Due to the significant increasing trend of TDS in Minnie Lake, exploring the specific major ions which may be driving this trend is important to determine.

Trend analysis of major ions at Minnie Lake indicates that potassium, calcium, chloride, and sulphate are significantly increasing (Figure 10). No trends were detected in sodium or alkalinity. Magnesium had insufficient data for calculating a trend. As many ions are moving in the same direction, it is likely that evaporative loss is driving the change in total dissolved solids in Minnie Lake. Interestingly, alkalinity (bicarbonate, carbonate) displays a significant decreasing trend, at appreciably high rate at  $-1.67$  mg/L per year.

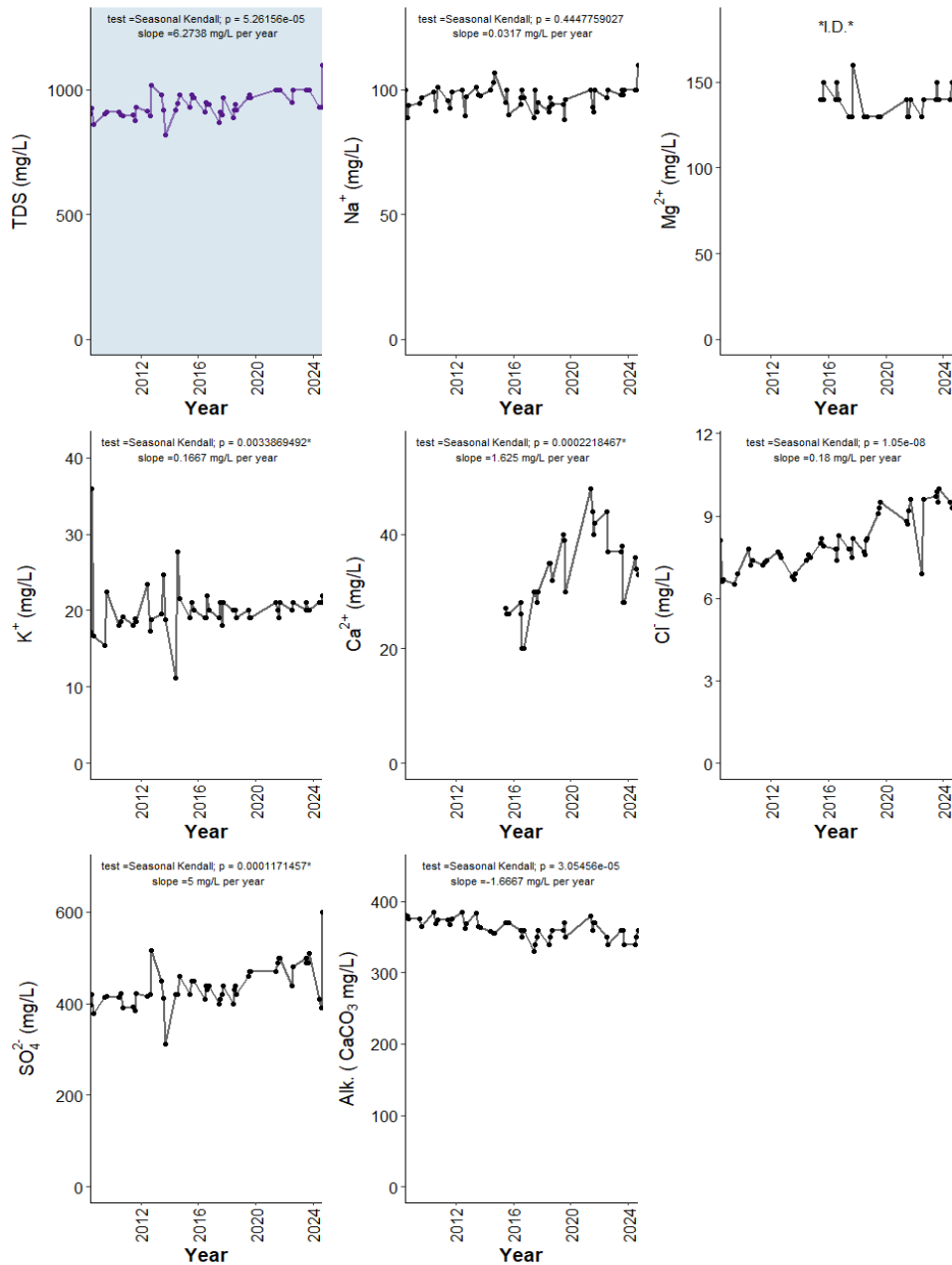


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na<sup>+</sup>, magnesium = Mg<sup>2+</sup>, potassium = K<sup>+</sup>, calcium = Ca<sup>2+</sup>, chloride = Cl<sup>-</sup>, sulphate = SO<sub>4</sub><sup>2-</sup>), and total alkalinity (Alk., as mg/L CaCO<sub>3</sub>) measured monthly between June and September on sampling dates between 2008 and 2024. 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 15th 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 showed that it has significantly decreased (the lake has become less clear) in Minnie Lake since 2008 (Tau = -0.3772,  $p < 0.001$ ).

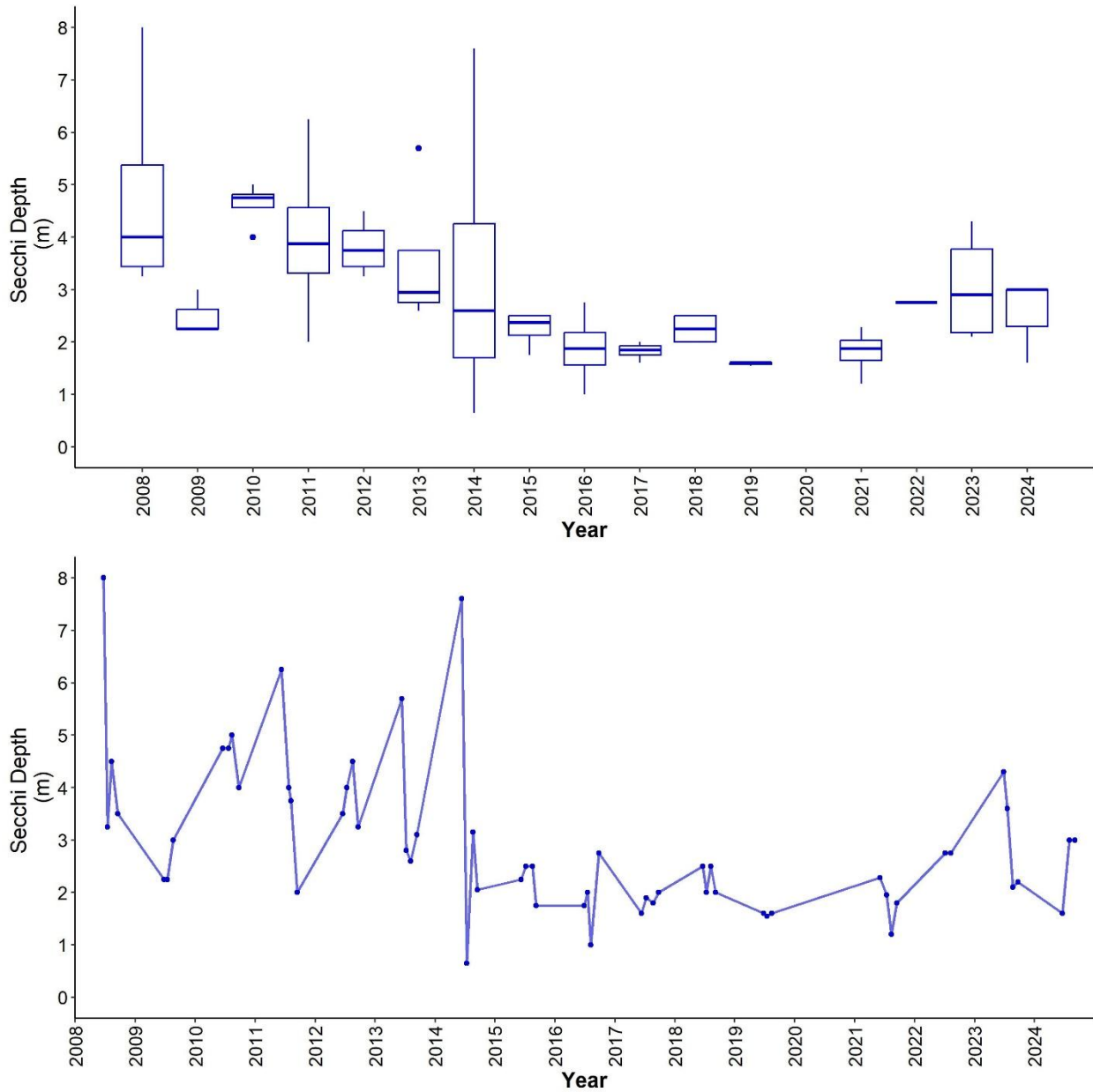


Figure 11. Monthly Secchi depth values measured between June and September over the long term sampling dates between 2008 and 2024 ( $n = 59$ ). The value closest to the 15<sup>th</sup> day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 5. Results of trend tests using total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS), and Secchi depth data from June to September for sampled years from 2008-2024 on Minnie Lake data.

Definition	Unit	Total Phosphorus (TP)	Chlorophyll- <i>a</i>	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	-0.5066	0.374	0.4059	-0.3772
The extent of the trend	Slope (units per Year)	-1.5	0.33	6.2738	-0.1332
The statistic used to find significance of the trend	Z	-5.1906	3.7513	4.0437	-3.8659
Number of samples included	n	58	59	52	59
The significance of the trend	p	*2.096e-07	*0.00018	*5.26156e-05	*0.00011

\*p < 0.05 is significant within 95% ADD "STAR" TO TABLE