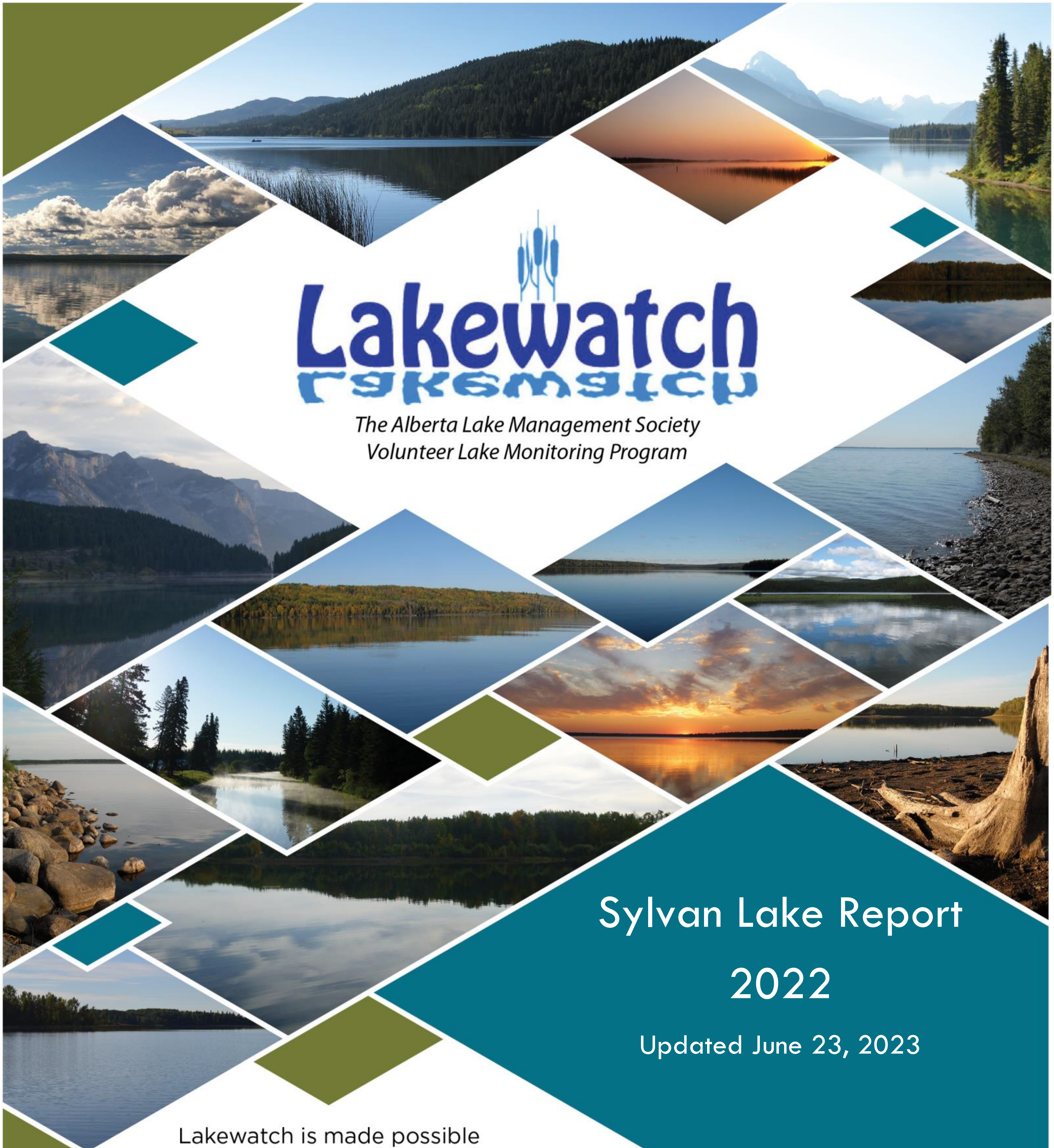

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Sylvan Lake Report 2022

Updated June 23, 2023

Lakewatch is made possible with support from:

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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.

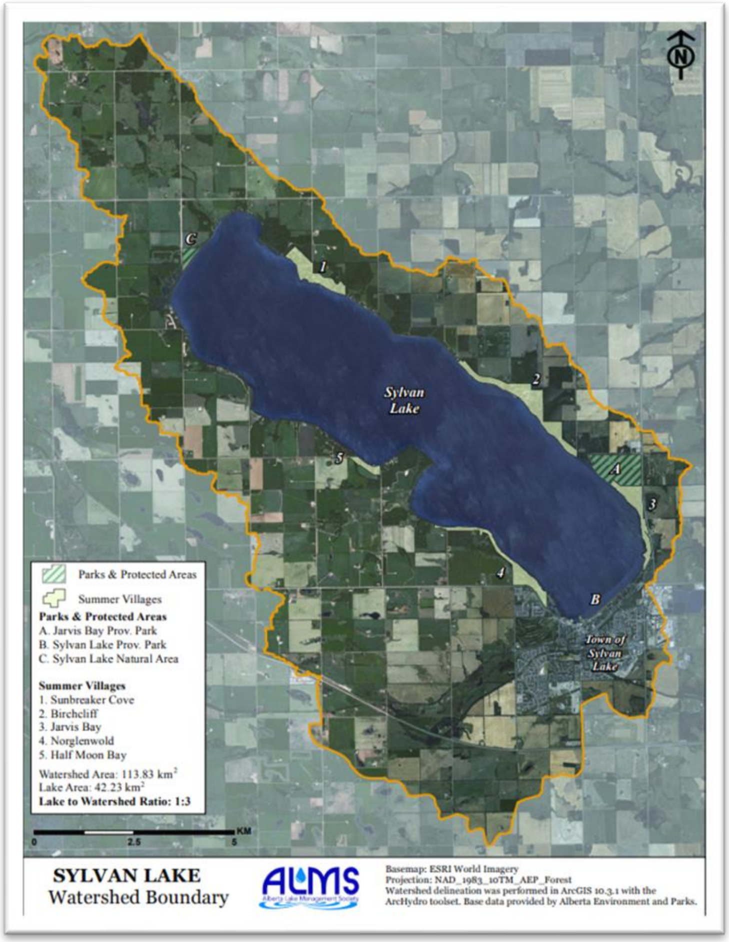
If you require data from this report, please contact ALMS for the raw data files.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. A special thanks to Devon Shouldice, Rick Shouldice, Paul and Brenda Kusch, and Charlie Bredo for their commitment to collecting data at Sylvan Lake. Thank you to Alberta Environment and Protected Areas staff for assisting with sampling in October. 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.

SYLVAN LAKE

Sylvan Lake is a large (42.8 km2), moderately deep (maximum depth =18.3 m) lake located west of the city of Red Deer. The lake was first named "Snake Lake" from the First Nations name Kinabik, which referred to the numerous garter snakes in the area. The name was officially changed to Sylvan Lake in 1903. "Sylvan" is from the Latin sylvanus, which means "of a forest". Most of the surrounding land was originally forested with trembling aspen. However, approximately 90% of the watershed has been converted to agriculture.



Sylvan Lake Watershed Boundary (ALMS, 2016).

Sylvan Lake was first settled by Europeans in 1899 and within 5 years time (by 1904) had become a summer resort area. Its popularity was due to the lake's picturesque shoreline. Since this time, the shore of Sylvan Lake has undergone intensive development with three summer villages, the town of Sylvan Lake, and six subdivisions. Two provincial parks also occupy the lakeshore, namely, Jarvis Bay and Sylvan Lake. Large sandstone banks, reaching up to 20 m above the lake level, are located along the northeast shore. The lake's shoreline is generally composed of sand or a mixture of rock and gravel. Rooted aquatic plants occur in patches in sheltered areas and around the lake and grow densely in the northwest end of the lake. The most common emergent species are bulrush (Scirpus sp.) and common cattail (Typha latifolia). Submergent macrophytes, which can grow up to a lake depth of 3.5 m, include pondweeds (Potamogeton spp.), water buttercup (Ranunculus circinata), Canada waterweed (Elodea Canadensis) and the macroalgae (Chara sp.). In 2014, a macrophyte analysis was conducted on Sylvan Lake and the report can be viewed on the ALMS website. There are at least seven species of fish in Sylvan Lake: northern pike, yellow perch, walleye, burbot, spottail shiners, brook stickleback, and fathead minnows.

The watershed area for Sylvan Lake is 113.83 km^2 and the lake area is 42.23 km^2. The lake to watershed ratio of Sylvan Lake is 1:3. A map of the Sylvan Lake watershed area can be found online at http://alms.ca/wpcontent/uploads/2016/12/Sylvan.pdf.

BEFORE READING THIS REPORT, CHECK OUT A BRIEF INTRODUCTION TO LIMNOLOGY AT ALMS.CA/REPORTS

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 Sylvan Lake was 7 µg/L (Table 2), falling into the oligotrophic, or low productivity trophic classification. This value below all previously observed historical averages going back to 1983 (Table 2). TP ranged from a minimum of 6.3 µg/L on August 24th, to a maximum of 8 µg/L on October 20th (Figure 1).

Average chlorophyll-*a* concentration in 2022 was 3.2 µg/L (Table 2), falling into the oligotrophic, or low productivity trophic classification. Chlorophyll-*a* was highest during the October 20th sampling event at 5.1 µg/L, and lowest at 2.4 µg/L on June 30th and July 19th.

The average TKN concentration was 0.6 mg/L (Table 2), and displayed consistent levels through the season (Figure 1).

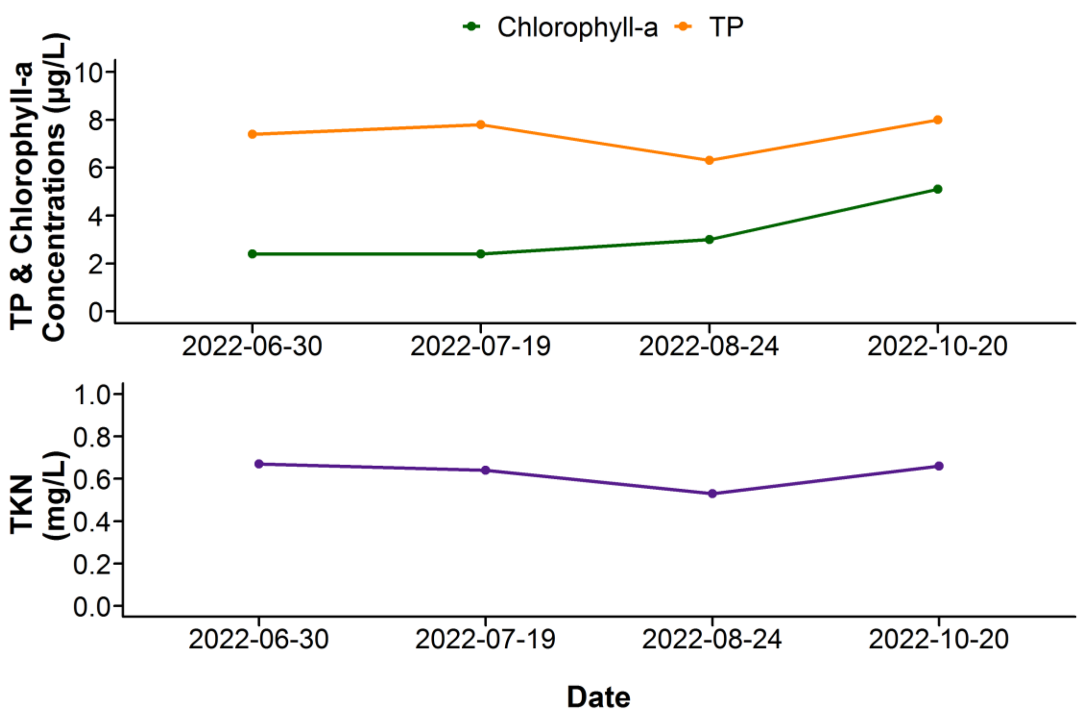


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Sylvan Lake.

Average pH was measured as 8.76 in 2022, buffered by high alkalinity (338 mg/L $CaCO_3$) and bicarbonate (365 mg/L HCO_3). Aside from bicarbonate, sodium and magnesium were in highest abundance, and together contributed to a moderate conductivity of 615 µS/cm (Figure 2, top; Table 2). Sylvan Lake is in the low to moderate range of ion levels, compared to other LakeWatch lakes sampled in 2022. (Figure 2, bottom).

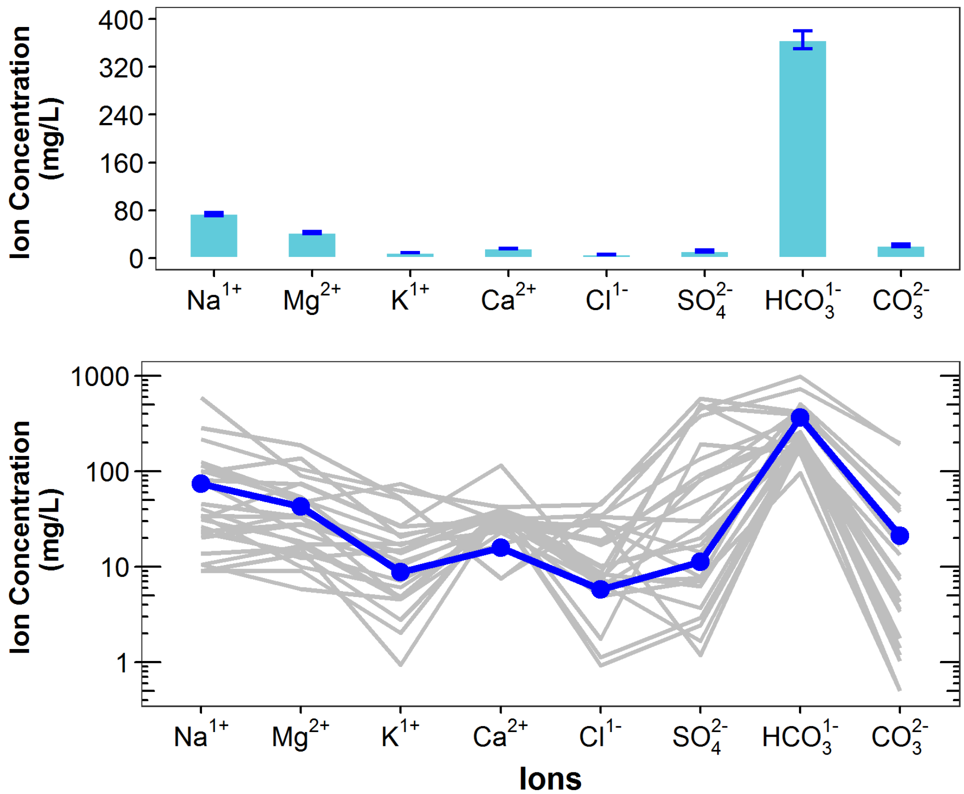


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Sylvan Lake. Top) bars indicate range of values measured, and bottom) Schoeller diagram of average ion levels at Sylvan Lake (blue line) compared to 26 lake basins (gray lines) sampled through the LakeWatch program in 2022 (note $\log_{10}$ 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 Sylvan Lake in 2022, but historical metal data can be found in Table 3.

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 Sylvan Lake in 2022 was 10.64 m, corresponding to an average Secchi depth of 5.32 m (Table 2). Euphotic depth varied over the season, ranging from as deep as 6.65 m on July 19th, to 3.10 m on October 20th (Figure 3). Secchi depth was significantly negatively correlated with chlorophyll-*a* (r = -0.99, p = 0.013).

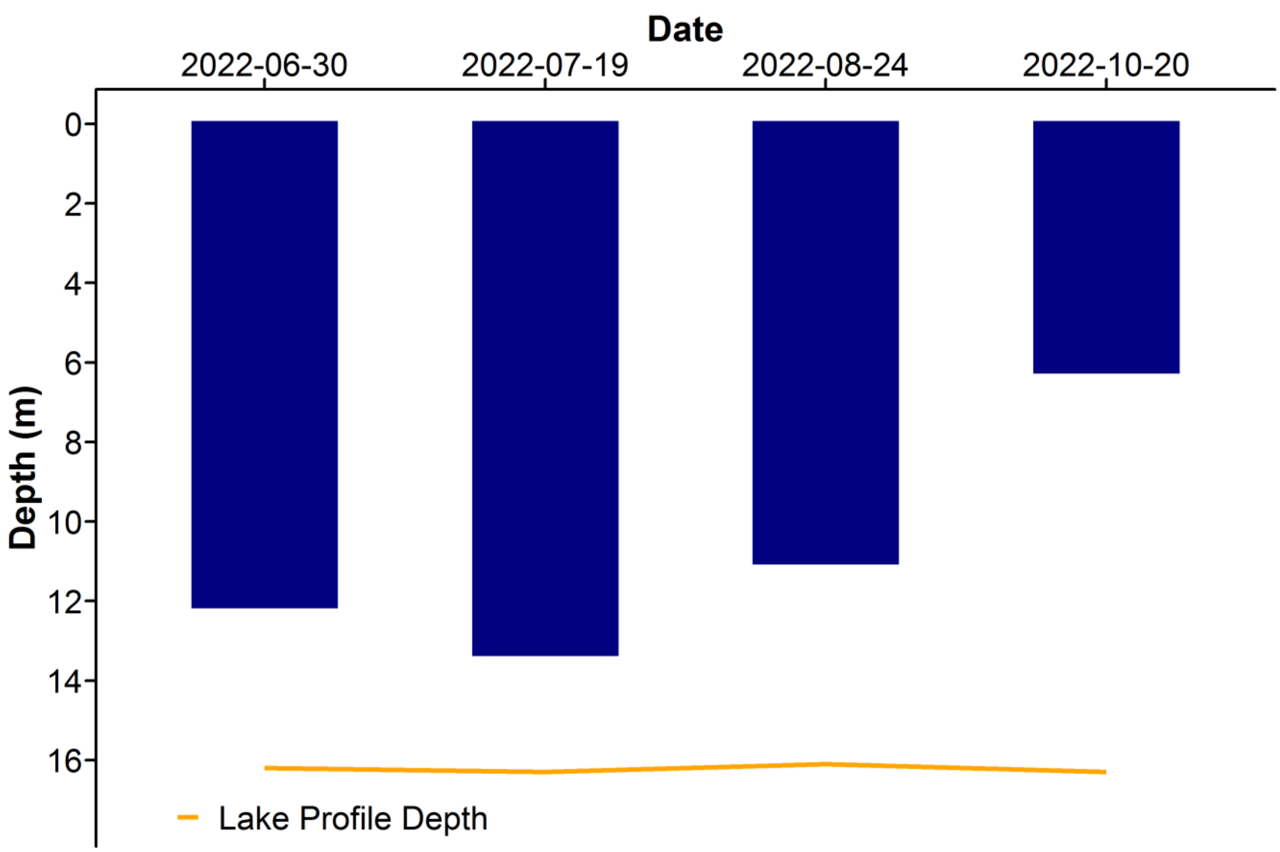


Figure 3. Euphotic depth values measured four times over the course of the summer at Sylvan Lake in 2022.

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 water temperatures of Sylvan Lake varied throughout the summer, with the August 24th sampling date having the warmest temperature of 21.7°C (Figure 4a). The lake was completely mixed during the June and October sampling events, but was weakly stratified during the July and August sampling events.

Sylvan 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). The lake was also well oxygenated throughout deeper areas during the June and October sampling events, but depletion occurred during the July and August sampling events, at about 12 m and 10 m respectively, corresponding to the dates where weak stratification occurred. During the August sampling event, levels proceeded to anoxia (<1.0 mg/L) at 14 m depth and below.

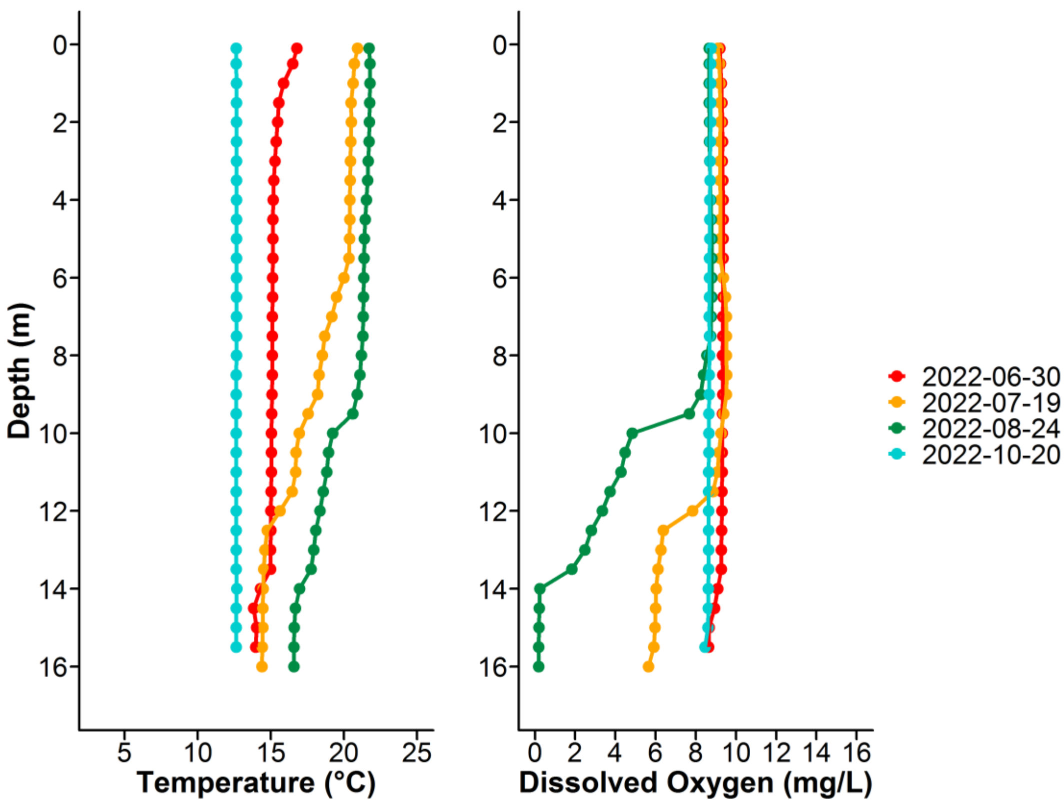


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Sylvan Lake measured four times over the course of the summer of 2022.

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 Sylvan Lake fell below the recreational guideline of 10 μg/L during every sampling event in 2022. In addition, microcystin levels from every sampling event were below the laboratory detection limit of 0.10 μg/L. A value of 0.05 μg/L is assigned when a value is below detection, in order to calculate an average.

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

Date	Microcystin Concentration (μg/L)
30-Jun-22	<0.1
19-Jul-22	<0.1
24-Aug-22	<0.1
20-Oct-22	<0.1
Average	0.05

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 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. In 2022, no mussels or spiny water flea were detected at Sylvan 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.

No watermilfoil specimens were collected from Sylvan Lake in 2022.

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 Sylvan Lake in 2022 were at the historical average (Figure 5). Historical data indicates that since the beginning of the record in 1919, the lake has only varied by about 2m, with the last periods of very low water being in the early 1960s, and in the late 1970s to early 1980s. Levels within the previous 10 years indicate a slight decrease, but relative stability. Significant data gaps exist in the 1930s, 1940s and early 1950s.

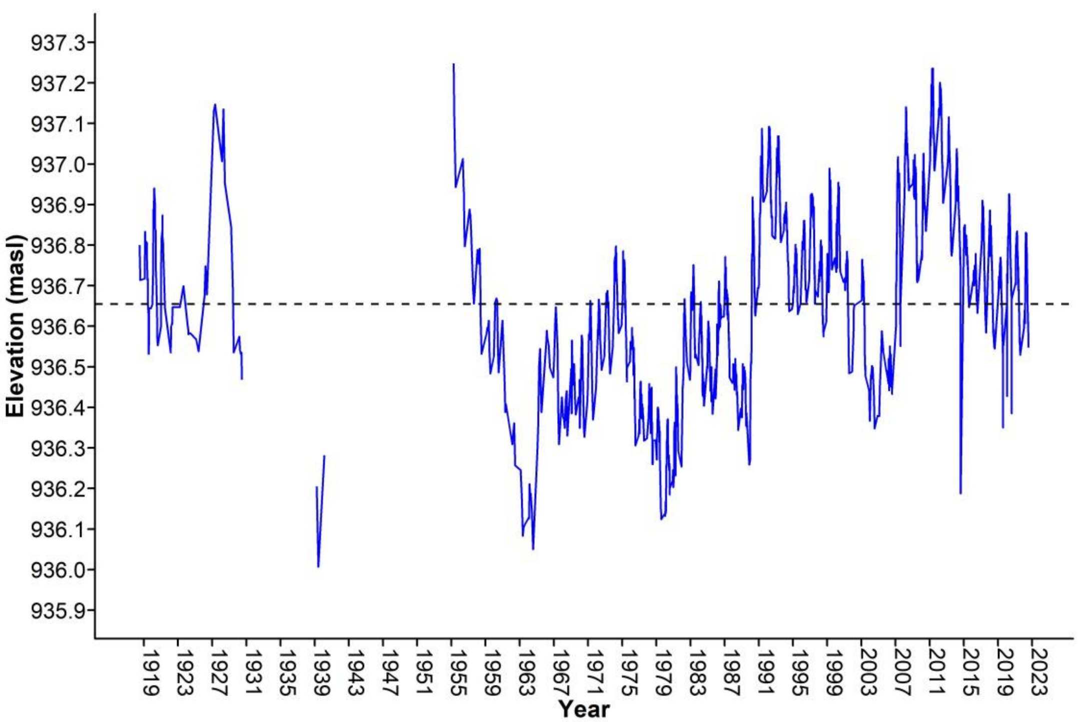


Figure 5. Water levels measured at Sylvan Lake in metres above sea level (masl) from 1919-2022. Data retrieved from Alberta Environment and Parks and/or Environment and Climate Change Canada. Black dashed line represents historical yearly average water level.

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.

Sylvan Lake experienced a warmer, wetter, and windier summer with more solar radiation than normal (Figure 6). A prolonged and calm warm spell leading up to the August 24th sampling event likely led to the high observed surface water temperatures, and stratification.

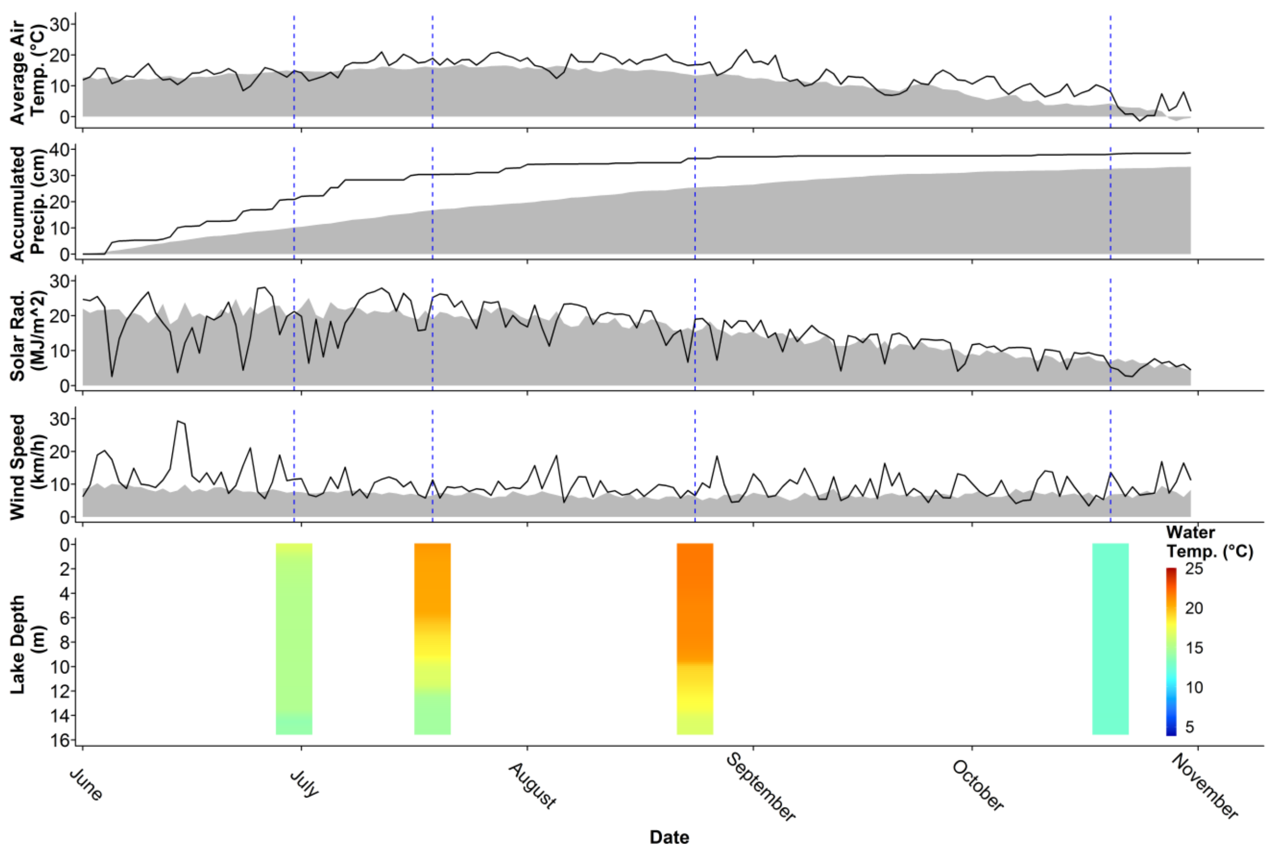


Figure 6. Average air temperature (°C), accumulated precipitation (cm), wind speed (km/h), and solar radiation (MJ/m^2) measured from 'Hespero AGCM' weather station, as well as Sylvan Lake temperature profiles, interpolated (°C). Black lines indicate 2022 levels, gray indicates long-term normals, and blue lines indicate sampling dates for Sylvan 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).

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

Parameter	1983	1984	1985	1986	1987	1988	1989	1990	1992	1993	1994	1995
TP (μg/L)	18	20	14	21	22	25	21	22	30	22	17	19
TDP (μg/L)	/	/	/	/	/	/	/	/	/	/	/	9
Chlorophyll-*a* (μg/L)	2.5	3.8	5.2	3.7	3.9	6.6	3.8	5.7	7	2.4	1.8	4.1
Secchi depth (m)	5.92	5.13	2.68	4.73	3.5	4.62	4.2	4.86	4.82	3.87	6.78	5.36
TKN (mg/L)	/	/	/	/	/	/	/	/	/	/	/	0.7
NO_2-N and NO_3-N (μg/L)	25	25	25	25	10	10	178	10	2	2	8	2
NH_3-N (μg/L)	/	/	/	/	/	/	/	/	/	/	/	7
DOC (mg/L)	/	/	/	/	/	/	/	/	/	/	/	8
Ca (mg/L)	13	16	15	18	18	18	17	17	18	17	18	17
Mg (mg/L)	32	34	35	37	36	38	37	40	38	36	36	37
Na (mg/L)	61	64	67	64	65	68	69	65	65	64	65	64
K (mg/L)	6	7	7	7	7	7	7	7	7	7	7	7
SO_4^{2-} (mg/L)	15	15	12	16	16	14	14	14	12	9	12	9
Cl^- (mg/L)	0	1	2	0	1	2	2	2	2	2	2	2
CO_3 (mg/L)	/	24.2	17	21.3	25.2	25.8	22.3	25.7	22.5	23.3	25	24.7
HCO_3 (mg/L)	/	348	360	354	344	353	360	349	377	376	378	350
pH	8.7	8.85	8.8	8.87	8.85	8.9	8.78	8.89	8.8	8.86	8.93	8.86
Conductivity (μS/cm)	584	580	600	597	596	604	595	589	590	586	574	579
Hardness (mg/L)	/	182	181	198	194	200	195	206	200	190	196	197
TDS (mg/L)	319	334	333	338	339	346	347	342	338	331	338	334
Microcystin (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	318	326	324	325	325	333	333	329	328	328	330	329

Table 2b. Average Secchi depth and water chemistry values for Sylvan Lake. Historical values are given for reference. Number of sample trips are inconsistent between years.*Note that 2014 and 2015 contain suspect TP and TDP data, as per observations from the 2014 Sylvan Lake LakeWatch Report. Suspect data removed from 2014 TP and TDP, but not 2015 TDP.

Parameter	1996	1997	1998	2003	2005	2006	2008	2009	2010	2011	2014	2015
TP (μg/L)	24	24	/	14	22	25	15	20	23	16	13*	18
TDP (μg/L)	11	/	/	5	3	8	6	11	13	5	10*	36*
Chlorophyll-*a* (μg/L)	5.4	5.9	/	3.8	7.3	6.5	3.2	2.6	2.1	2.9	5.0	4.0
Secchi depth (m)	4.75	5.00	4.90	4.82	3.40	4.10	5.40	4.72	7.00	4.97	3.90	3.60
TKN (mg/L)	0.8	/	/	0.6	0.9	0.7	0.6	0.6	0.7	0.6	0.6	0.7
NO_2-N and NO_3-N (μg/L)	12	/	/	3	3	2	4	5	5	3	26	2
NH_3-N (μg/L)	104	/	/	7	2	12	6	10	12	11	26	25
DOC (mg/L)	8	/	/	/	/	7	/	7	8	/	8	7
Ca (mg/L)	18	19	/	/	18	/	18	/	/	/	/	17
Mg (mg/L)	39	38	/	/	39	/	36	/	/	/	/	38
Na (mg/L)	67	67	/	71	69	72	69	70	74	66	75	70
K (mg/L)	8	7	/	8	8	8	7	8	8	/	8	8
SO_4^{2-} (mg/L)	12	13	/	14	15	14	12	16	12	11	9	12
Cl^- (mg/L)	2	2	/	2	3	3	3	3	4	3	4	4
CO_3 (mg/L)	18.6	26	/	26	29	26	27	22	23	34	34	22
HCO_3 (mg/L)	356	360	/	359	351	362	351	366	368	336	339	355
pH	8.66	8.66	/	8.84	8.80	8.86	8.77	8.79	8.81	8.90	8.76	8.83
Conductivity (μS/cm)	586	600	/	/	609	606	617	608	584	599	594	615
Hardness (mg/L)	191	206	/	193	205	191	194	181	196	188	194	202
TDS (mg/L)	324	352	/	350	353	353	345	350	353	340	373	350
Microcystin (μg/L)	/	/	/	/	/	0.04	/	0.11	0.07	/	0.08	/
Total Alkalinity (mg/L $CaCO_3$)	304	339	/	338	336	340	332	337	339	333	335	325

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

Parameter	2016	2018	2022
TP (µg/L)	14	13	7
TDP (µg/L)	4	5	2
Chlorophyll-*a* (µg/L)	5.6	3.2	3.2
Secchi depth (m)	4.03	4.30	5.35
TKN (mg/L)	0.6	0.7	0.6
NO_2-N and NO_3-N (µg/L)	2	3	4
NH_3-N (µg/L)	25	8	11
DOC (mg/L)	8	9	7
Ca (mg/L)	17	17	16
Mg (mg/L)	41	40	42
Na (mg/L)	72	74	74
K (mg/L)	8	9	9
SO_4^{2-} (mg/L)	13	12	11
Cl^- (mg/L)	5	6	6
CO_3 (mg/L)	23	24	21
HCO_3 (mg/L)	370	373	365
pH	8.80	8.76	8.76
Conductivity (µS/cm)	623	623	615
Hardness (mg/L)	213	203	215
TDS (mg/L)	363	370	362
Microcystin (µg/L)	0.12	0.10	0.05
Total Alkalinity (mg/L $CaCO_3$)	337	343	338

Table 3. Concentrations of metals measured in Sylvan 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 (Total Recoverable)	2010	2011	2014	2015	2016	Guidelines
Aluminum µg/L	26.0	13.9	10.8	16.2	6.6	100[a]
Antimony µg/L	0.04	0.03	0.03	0.03	0.03	/
Arsenic µg/L	0.86	0.87	0.77	0.83	0.075	5
Barium µg/L	49.0	50.9	48.5	53.8	50.9	/
Beryllium µg/L	0.006	0.005	0.004	0.004	0.004	100[c,d]
Bismuth µg/L	0.002	0.002	0.002	0.009	0.001	/
Boron µg/L	122.5	105.5	97.05	94.3	103	1500
Cadmium µg/L	0.006	0.001	0.002	0.002	0.001	0.30[b]
Chromium µg/L	0.24	0.08	0.11	0.08	0.02	/
Cobalt µg/L	0.018	0.011	0.007	0.019	0.001	50,1000[c,d]
Copper µg/L	0.16	0.15	0.13	0.18	0.32	4b
Iron µg/L	7.7	3.6	2.9	7.5	3.8	300
Lead µg/L	0.015	0.014	0.014	0.028	0.007	7[b]
Lithium µg/L	31.7	33.0	28.0	28.7	32.7	2500[d]
Manganese µg/L	35.4	43.9	12.55	31.55	26	130[e]
Molybdenum µg/L	0.063	0.053	0.037	0.041	0.026	73
Nickel µg/L	0.003	0.003	0.004	0.004	0.004	150[b]
Selenium µg/L	0.05	0.096	0.03	0.03	0.2	1
Silver µg/L	0.001	0.003	0.001	0.001	0.001	0.25
Strontium µg/L	176	187	180	194.5	193	/
Thallium µg/L	0.0007	0.0006	0.0005	0.0104	0.0005	0.8
Thorium µg/L	0.008	0.0063	0.0012	0.0005	0.0005	/
Tin µg/L	0.015	0.015	0.007	0.026	0.023	/
Titanium µg/L	0.34	0.68	0.20	0.73	0.26	/
Uranium µg/L	0.20	0.20	0.21	0.21	0.20	15
Vanadium µg/L	0.21	0.19	0.19	0.19	0.14	100[c,d]
Zinc µg/L	0.31	0.41	0.55	0.25	0.30	30[f]

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5

[b] Based on 2016 avg. water hardness (as CaCO3) with CCME equation

[c] Based on CCME Guidelines for Agricultural use (Livestock).

[d] Based on CCME Guidelines for Agricultural Use (Irrigation).

[e] Based on CCME Manganese variable calculation (https://ccme.ca/en/chemical/129#_aql_fresh_concentration), using 2016 avg. water hardness (as CaCO3) and avg. pH

[f] Based on 2016 avg. water hardness (as CaCO3), avg. pH, and avg. DOC with CCME equation

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

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 Sylvan Lake. In sum, a significant increasing trend was observed in TDS, a significant decreasing trend was observed for TP, and no significant trends were detected for chlorophyll-*a* or Secchi depth. Secchi depth can be subjective and is sensitive to variation in weather; therefore, trend analysis must be interpreted with caution. Data is presented below as both line and box-and-whisker plots. Detailed methods are available in the *ALMS Guide to Trend Analysis on Alberta Lakes.*

Table 4. Summary table of trend analysis on Sylvan Lake data from 1983 to 2022.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	1983-2022	Decreasing
Chlorophyll-*a*	1983-2022	No Change
Total Dissolved Solids	1983-2022	Increasing
Secchi Depth	1983-2022	No Change

Definitions:

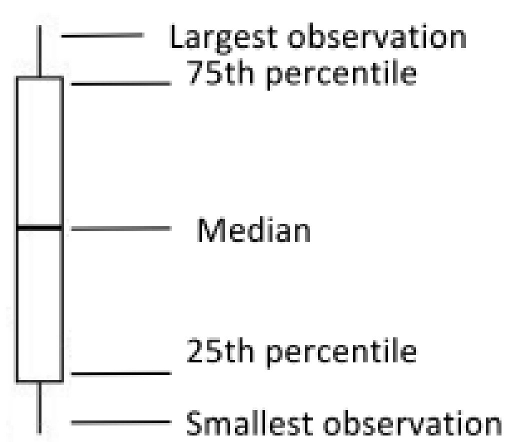
Median: the value in a range of ordered numbers that falls in the middle.

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 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 over time showed that it has significantly decreased in Sylvan Lake since 1983 (Tau = -0.25, p = 0.0016).

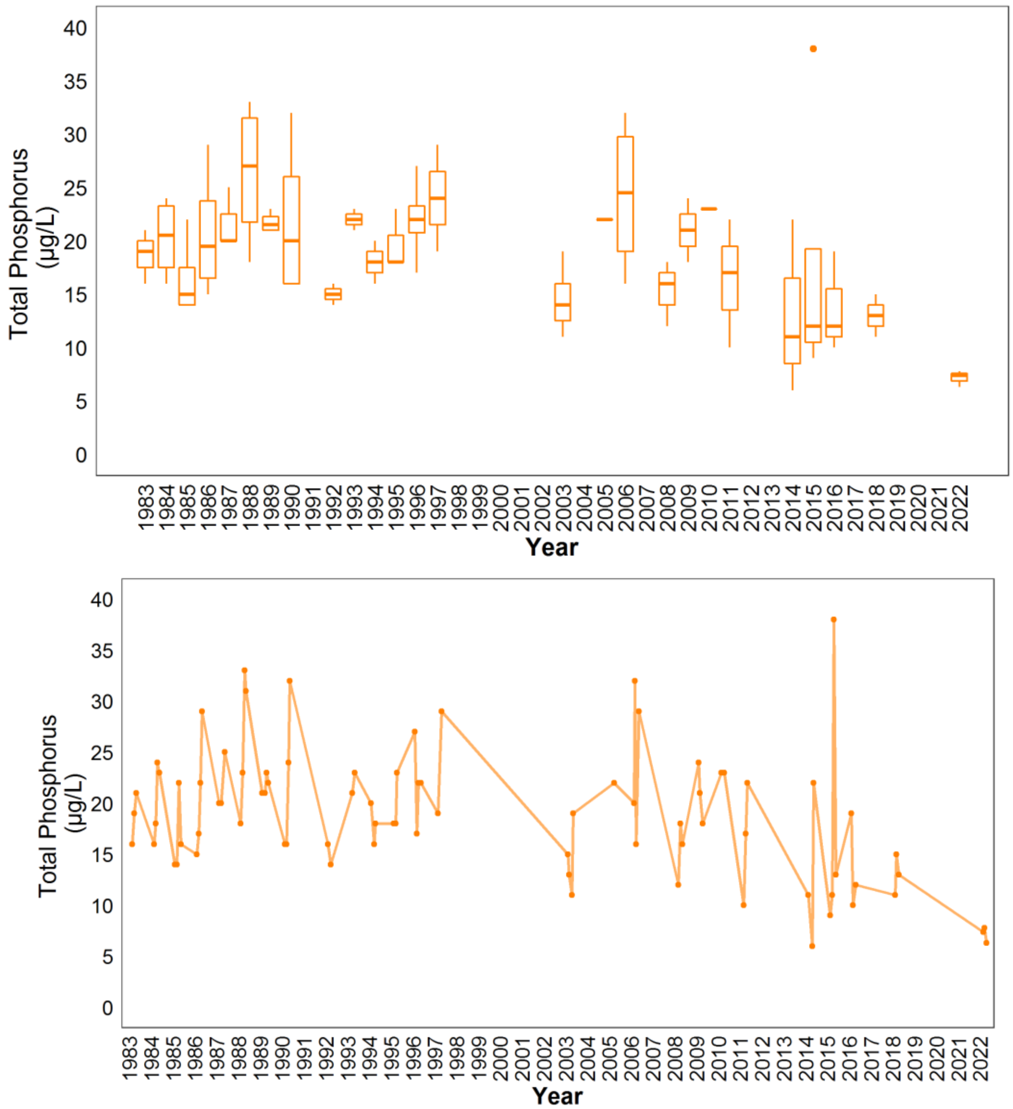
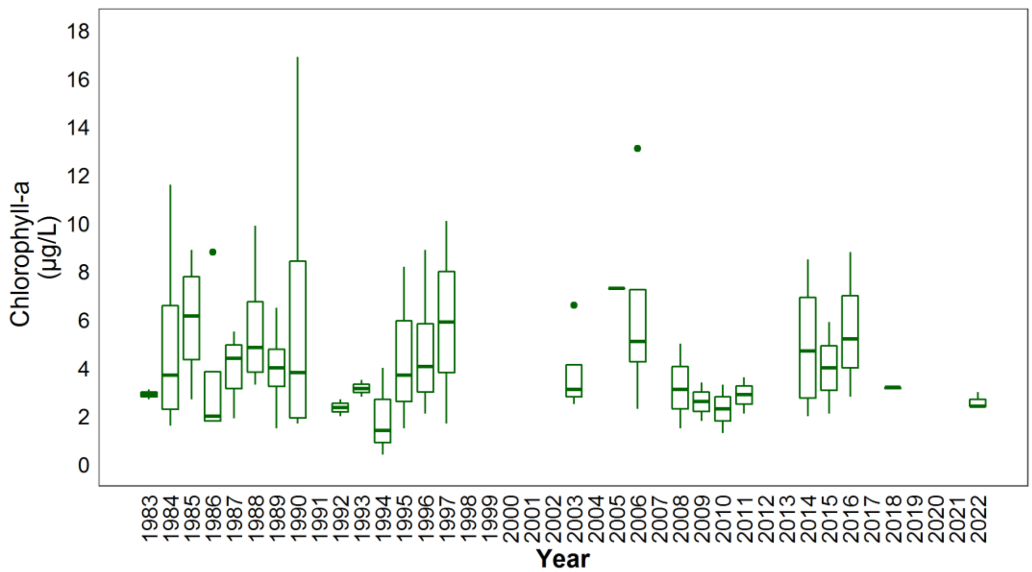


Figure 7. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1983 and 2022 (n = 82). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Trend analysis of chlorophyll-*a* over time showed that it has not significantly changed in Sylvan Lake since 1983 (Tau = -0.04, p = 0.68).



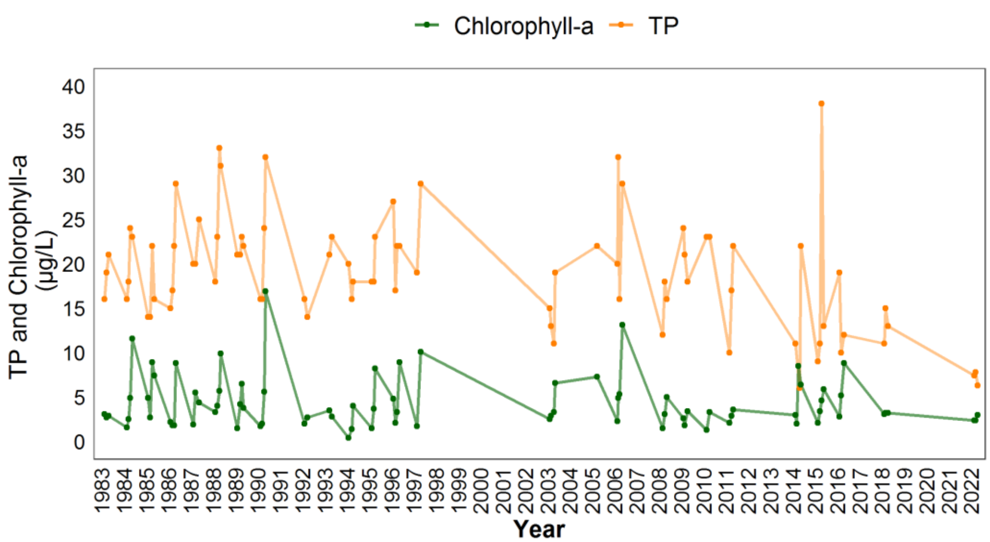


Figure 8. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1983 and 2022 (n = 83). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Trend analysis showed a significant increasing trend in TDS between 1983 and 2022 (Tau = 0.45, p = <0.001) in Sylvan Lake (Figure 9).

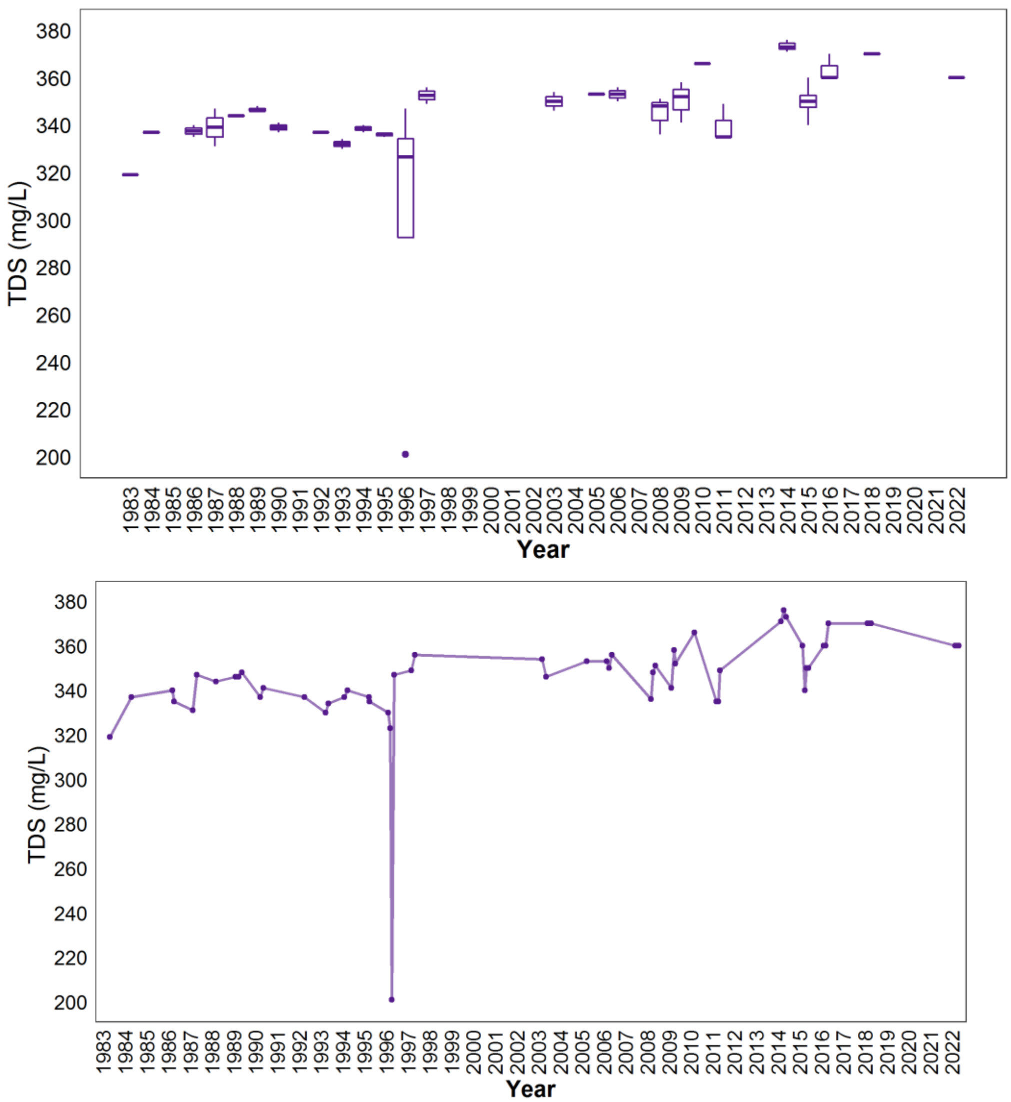


Figure 9. Monthly TDS values measured between June and September over the long term sampling dates between 1983 and 2022 (n = 57). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Due to the significant increasing trend of TDS in Sylvan Lake, exploring the specific major ions which may be driving this trend is important to determine. Trend analysis of major ions at Sylvan Lake indicates that alkalinity (bicarbonate, carbonate) and sodium are likely the key parameters that are driving the increase in TDS (Figure 10). These two parameters display the greatest magnitude of change over time (slopes), but also follow the trajectory of TDS. While the slopes of chloride, magnesium, and potassium are smaller, their increasing trends are also significant, and their trajectories also follow the trajectory of TDS over time.

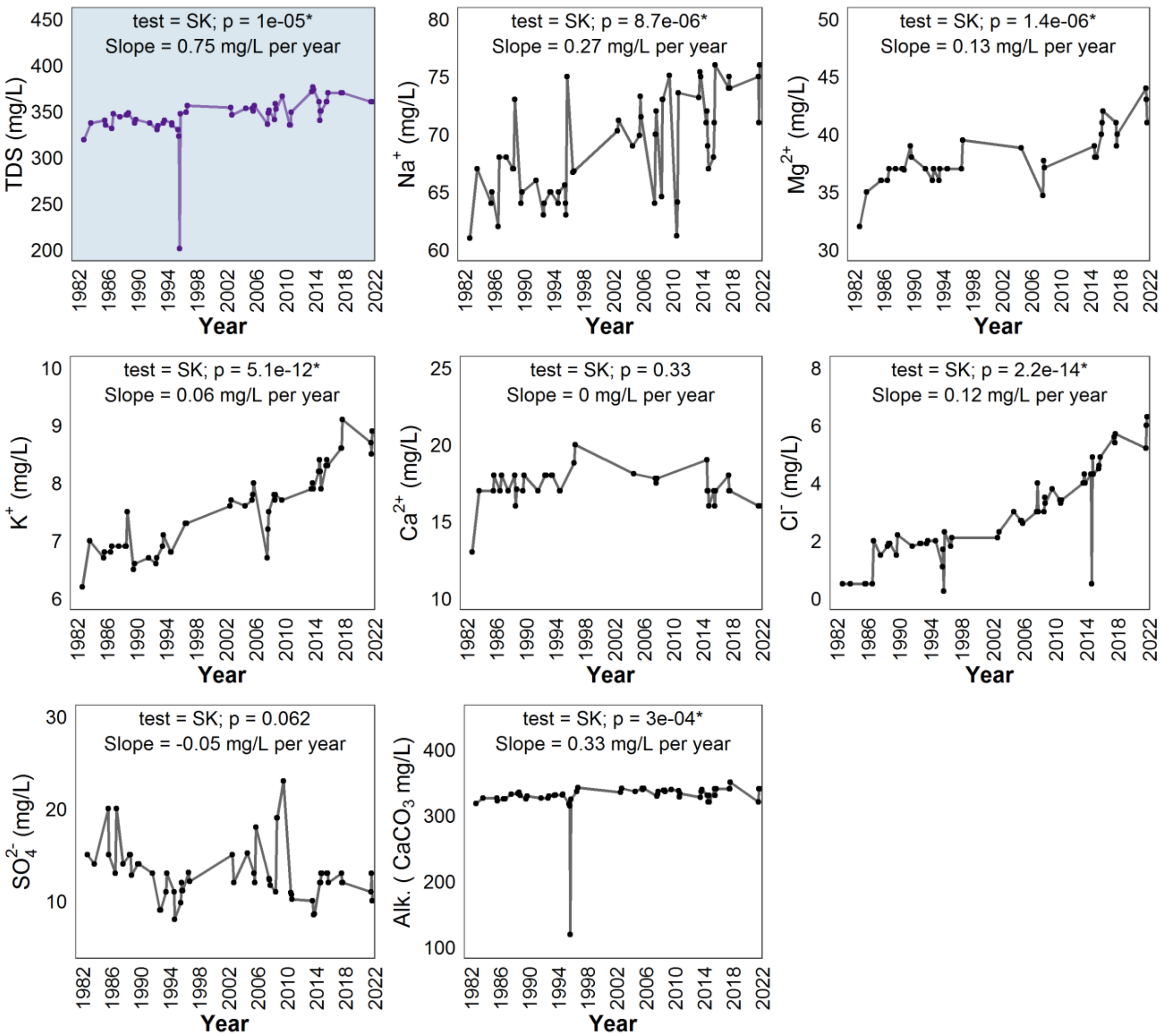
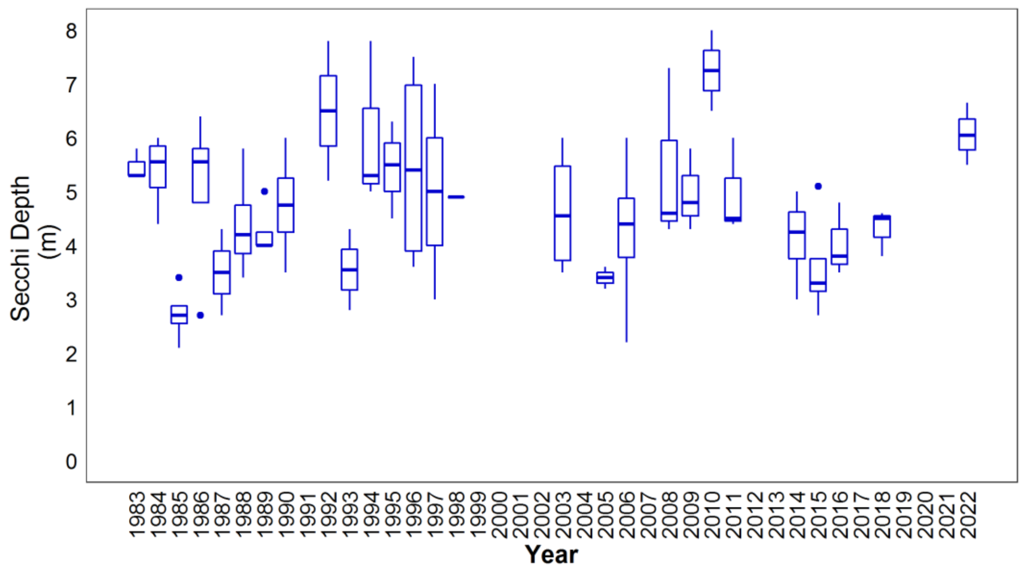


Figure 10. Concentrations of TDS (top left, blue panel), major ions (sodium = Na^+, magnesium = Mg^{2+}, potassium = K^+, calcium = Ca^{2+}, chloride = Cl^-, sulphate = SO_4^{2-}), and total alkalinity (Alk., as mg/L $CaCO_3$) measured monthly between June and September on sampling dates between 1983 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 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 not significantly changed in Sylvan Lake since 1983 (Tau = -0.01, p = 0.98).



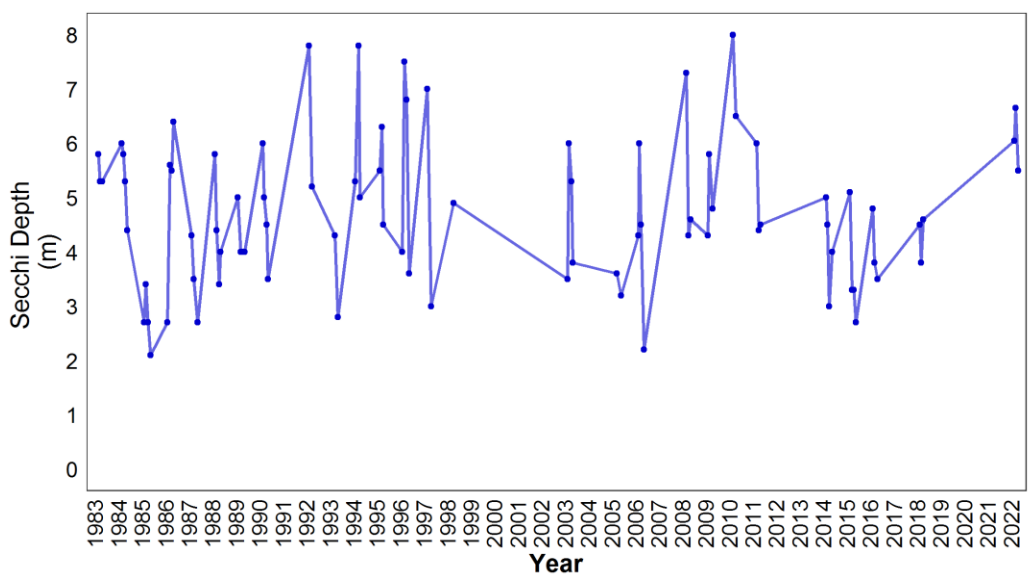


Figure 11. Monthly Secchi depth values measured between June and September on sampling dates between 1983 and 2022 (n = 85). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

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 1983-2022 on Sylvan 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	-0.25	-0.04	0.45	-0.01
The extent of the trend	Slope (units per Year)	-0.21	-0.01	0.75	0.00
The statistic used to find significance of the trend	Z	-3.17	-0.42	4.42	-0.03
Number of samples included	n	82	83	57	85
The significance of the trend	p	1.55×10^{-3}*	0.68	9.97×10^{-6}*	0.98

*$p < 0.05$ is significant within 95%