Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Beauvais Lake Report

2020

Updated April 29, 2021

Lakewatch is made possible with support from:

Alberta Environment and Parks
Pigeon Lake Watershed Association
Moose Lake Watershed Society
Lacombe County
LICA Environmental Stewards

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 Stan McDougall and Klaus Exner for their commitment to collecting data at Beauvais 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, and Klaus Exner prepared the background section of this report.

BEAUVAIS LAKE

Beauvais Lake in Summer – photo by Klaus Exner

Beauvais Lake is situated in a Provincial Park of the same name, 24 km southwest of the town of Pincher Creek. It is named after Remi Beauvais who settled in the area in 1882. Some of the land that is now within the Provincial Park was homesteaded at the beginning of the last century and the first cottages were built at Beauvais Lake in the 1920s. The designation of the first parcel of land as a Provincial Park occurred in 1957. The park grew by increments until the last and largest park expansion in the year 2000 finally encompassed the entire watershed of the lake. Park facilities include an 87 site campground, 2 day use areas and a public dock and boat launch. There are 39 private cottages on lakeshore lots leased from the Province, all of which have full wastewater containment and pump-out. Fishing and hiking are the main recreational pursuits in summer. Ice fishing and cross-country skiing or snowshoeing are popular winter activities. Beauvais Lake is stocked with Rainbow Trout.

Beauvais Lake Provincial Park is in the Montane Ecoregion, a small area in Southern Alberta's abrupt transition zone from prairie grassland to subalpine forests. North-facing slopes are dominated by spruce interspersed with pine (including Limber Pine) Douglas Fir and Trembling Aspen. South-facing slopes are open grasslands with pockets of Trembling Aspen, Balsam Poplar and Douglas Fir. One inlet stream, Beaver Creek, as well as numerous diffuse sources feed the lake and it is drained by a single outlet stream, Chipman Creek. Lake level is stabilized by a weir which was constructed at the Chipman Creek outlet in 1950 and rebuilt in 1986.

Beauvais Lake is 3.1 km long, has a maximum width of 0.6 km and a maximum depth of 10.7 m. It has one main basin and a long, shallow eastern arm. Aquatic plants thrive in shallow areas. Five species of emergent plants and nine species of submergent plants were identified in a 1978 survey[1]. The far eastern end of the lake is closed to all boat use until after July 10 for the protection of nesting habitat for a number of bird species including Trumpeter Swans and Common Loons. The watershed area for Beauvais Lake is 7.09 km^2 and the lake area is 0.89 km^2. The lake to watershed ratio of Beauvais Lake is 1:8.

Water quality data has been collected since 1984. Beauvais Lake is sampled every 4 years as part of the Provincial Parks Lake Monitoring Program. Analysis and reporting of these data was most recently done in 2006[2].

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[1] MacNeill, J. W., 1979. Beauvais Lake: Lake Survey inventory. Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division. Unpublished report, Lethbridge. *In:* Mitchell, P. and E. Prepas, 1990. Atlas of Alberta Lakes, University of Alberta Press.
[2] Swanson, H. and R. Zurawell, 2006. Beauvais Lake Water Quality Monitoring Report - Provincial Parks Lake Monitoring Program, ISBN: 0-7785-5095-8 (Printed Edition).

METHODS

Profiles: Profile data is 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.

Data analysis is done using the program R.[3] Data is reconfigured using packages tidyr [4] and dplyr [5] and figures are produced using the package ggplot2 [6]. Trophic status for each lake is classified based on lake water characteristics using values from Nurnberg (1996)[7]. 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

[3] 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/.

[4] Wickman, H. and Henry, L. (2017). tidyr: Easily Tidy Data with 'spread ( )' and 'gather ( )' Functions. R package version 0.7.2. https://CRAN.R-project.org/package=tidyr.

[5] Wickman, H., Francois, R., Henry, L. and Muller, K. (2017). dplyr: A Grammar of Data Manipulation. R package version 0.7.4. http://CRAN.R-project.org/package=dplyr.

[6] Wickham, H. (2009). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

[7] 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.

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 Beauvais Lake was 9 µg/L (Table 2), falling into the oligotrophic, or minimally productive trophic classification. This value is the lowest in the historical record, and is the first time an average seasonal TP has been low enough at Beauvais for it to be designated oligotrophic. TP was lowest during the June 22nd sampling event at 6 µg/L, and peaked at 10 µg/L on July 23rd, which is the level where it remained for the rest of the season (Figure 1).

Average chlorophyll-*a* concentration in 2020 was 4.8 µg/L (Table 2), falling into the mesotrophic, or moderately productive trophic classification. This value is also on the lower end of the historical record. Chlorophyll-*a* was lowest at the start of the season, with a minimum of 3.1 µg/L on June 22nd, then generally increasing through the season to a maximum of 6.6 µg/L during the September 15th sampling event (Figure 1).

Finally, the average TKN concentration was 0.4 mg/L (Table 2) with concentrations being consistently between 0.4 and 0.5 mg/L on each individual sampling event throughout the 2020 sampling season.

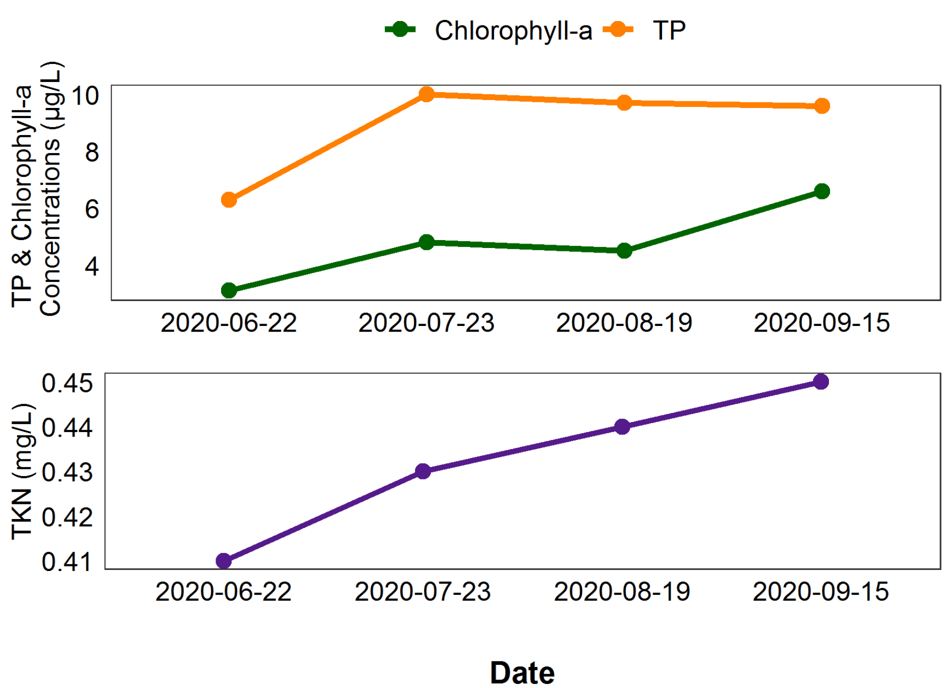


Figure 1. Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured four times over the course of the summer at Beauvais Lake.

Average pH was measured as 8.11 in 2020, buffered by low alkalinity (150 mg/L $CaCO_3$) and bicarbonate (183 mg/L HCO_3). Aside from bicarbonate, the dominant ion was calcium, contributing to a low conductivity of 275 µS/cm (Figure 2, top; Table 2). Beauvais Lake is on the lower end of ion levels compared to other LakeWatch lakes sampled in 2020 (Figure 2, bottom).

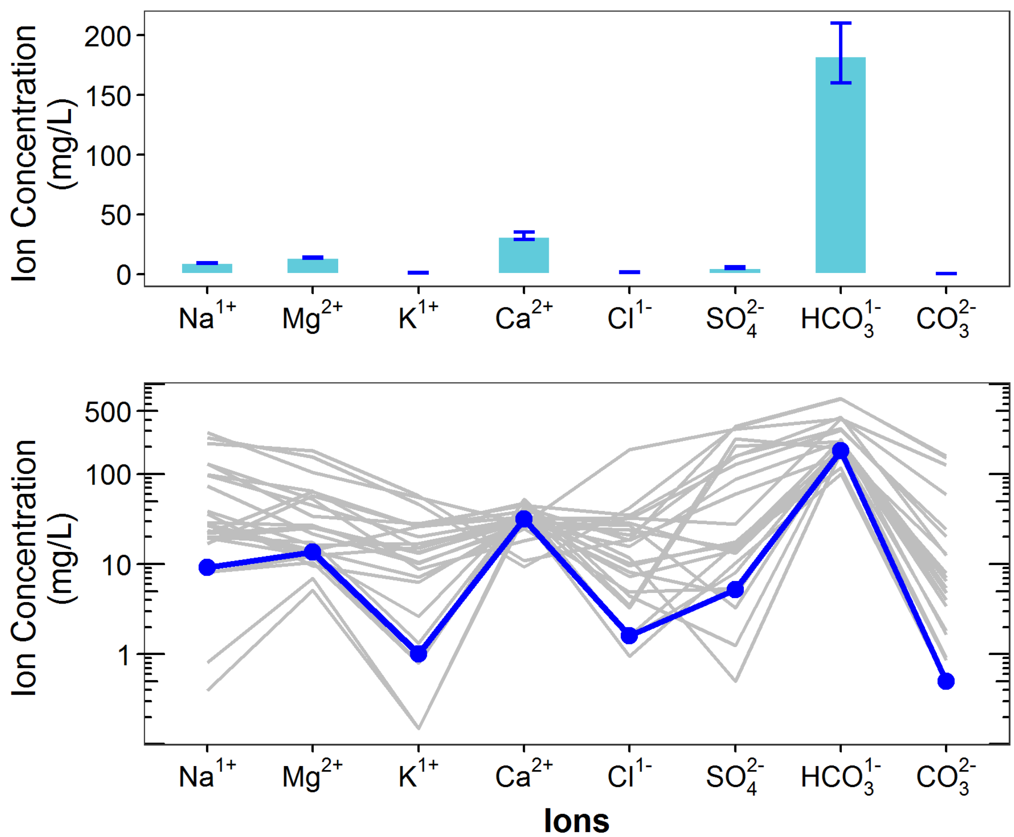


Figure 2. Average levels of cations (sodium = Na^{1+}, magnesium = Mg^{2+}, potassium = K^{1+}, calcium = Ca^{2+}) and anions (chloride = Cl^{1-}, sulphate = SO_4^{2-}, bicarbonate = HCO_3^{1-}, carbonate = CO_3^{2-}) from four measurements over the course of the summer at Beauvais Lake. Top) bars indicate 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_{10} scale on y-axis of bottom figure).

METALS

Samples were analyzed for metals once throughout the summer (Table 3). 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.

Metals were not measured at Beauvais Lake in 2020. Table 3 displays historical metal concentrations.

WATER CLARITY AND EUPHOTIC DEPTH

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

The average euphotic depth of Beauvais Lake in 2020 was 8.83 m corresponding to an average Secchi depth of 4.45 m, which is fairly deep compared to the historical record (Table 2). The euphotic depth is not double the Secchi depth, since June 22nd exhibited a Secchi depth reading equal to lake bottom, meaning the bottom depth was the true euphotic depth on that particular sampling day (Figure 3). Euphotic depth was greatest at the beginning of the summer where it was equal to lake bottom at 9.7 m on June 22nd, and was lowest during the August 18th sample at 7.6 m.

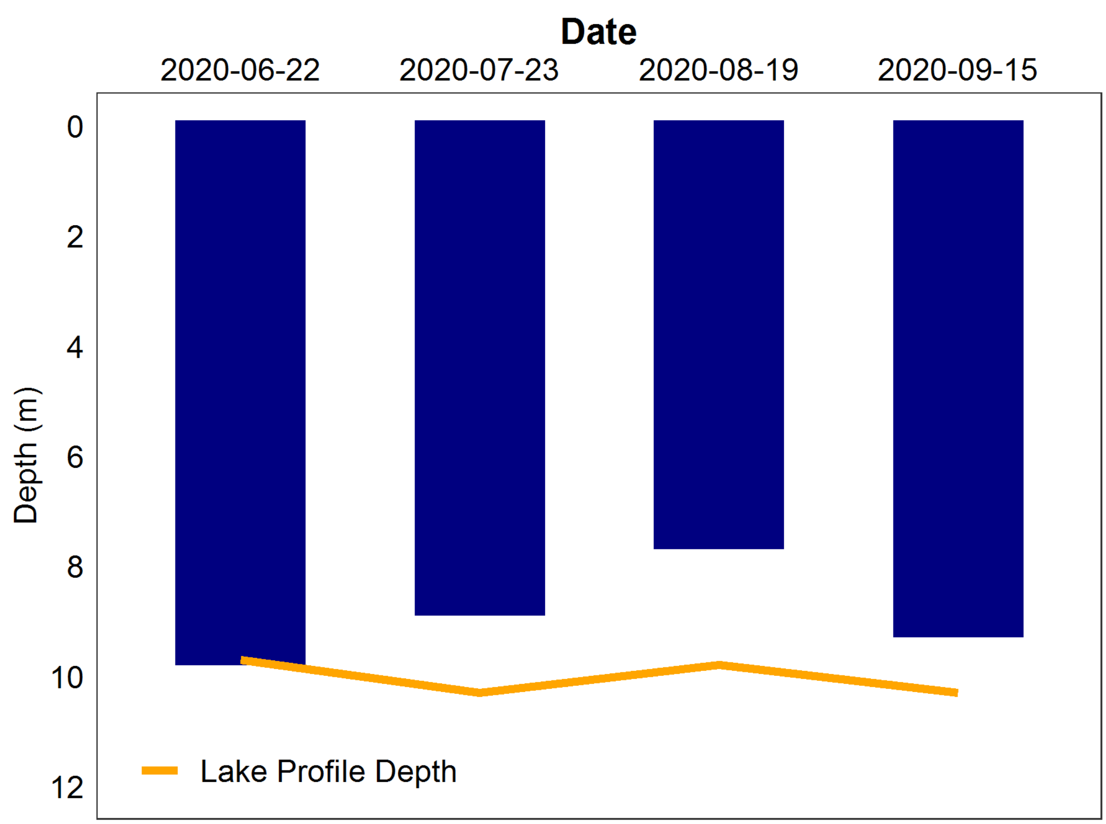


Figure 3. Secchi depth values measured four times over the course of the summer at Beauvais Lake in 2020.

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. Please refer to the end of this report for descriptions of technical terms.

Temperatures of Beauvais Lake varied throughout the summer, with a minimum temperature of 13.3°C at 9.5 m on June 22nd, and a maximum temperature of 19.5°C measured at the surface on July 23rd (Figure 4a). The lake was slightly stratified during every sampling event, but was isothermal (consistent in temperature) during the September 15th sampling event. Beauvais Lake is likely prone to mixing throughout the summer.

Beauvais Lake remained well oxygenated through the upper layer of the water column throughout the summer, measuring above the CCME guidelines of 6.5 mg/L dissolved oxygen (Figure 4b). The oxygen level fell below this level at the very bottom of the lake in every sample event, but the amount of water column below 6.5 mg/L varied depending on the sampling date. Oxygen depletion was more significant In July and August when stratification was higher and stronger.

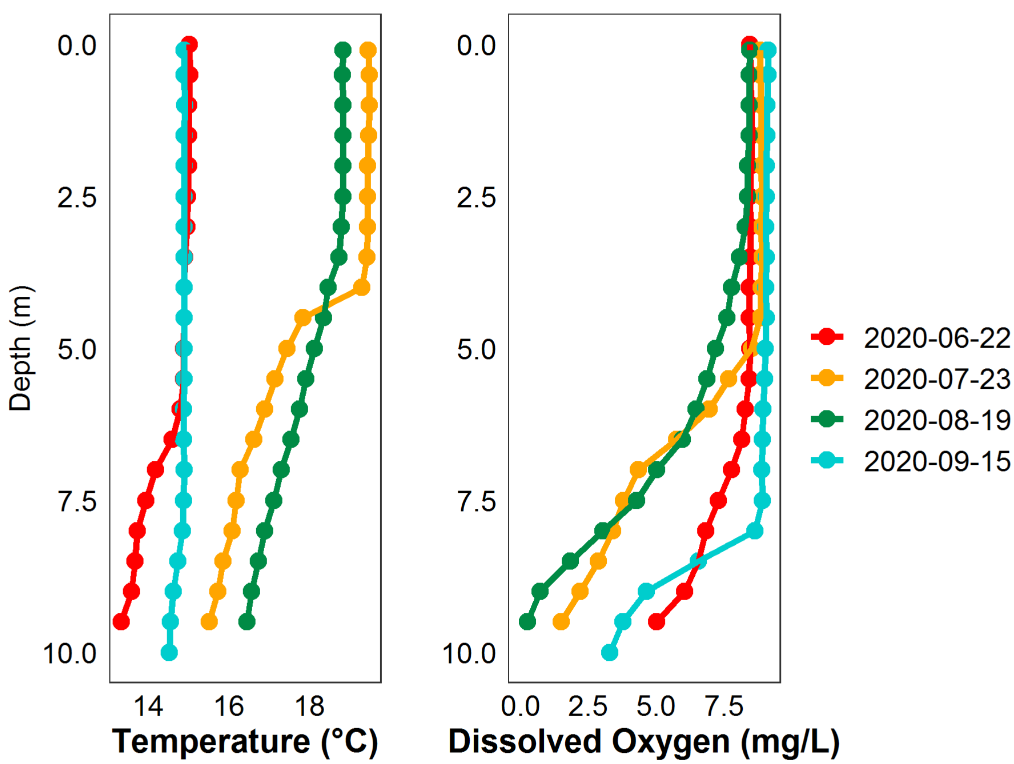


Figure 4. a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Beauvais Lake measured four times over the course of the summer of 2020.

MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, can cause severe liver damage when ingested and skin irritation with prolonged contact. 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 fell below the recreational guideline of 20 μg/L at the locations and times sampled in Beauvais Lake in 2020. Microcystin concentrations were below the detection limit of 0.1 μg/L on all dates sampled. A value of 0.05 μg/L is used for the purpose of calculating average concentration in instances of no detection.

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

Date	Microcystin Concentration (μg/L)
22-Jun-20	<0.10
23-Jul-20	<0.10
19-Aug-20	<0.10
15-Sep-20	<0.10
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 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 Beauvais 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.

No suspect watermilfoil was observed or collected from Beauvais Lake in 2020.

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.

A weir control structure built in 1950 helps to stabilize Beauvais Lake's water levels. Water levels in Beauvais Lake were much more variable in the first two decades since monitoring began in 1973, but have since stabilized (Figure 5). Since 1973, Beauvais Lake water levels have fluctuated within approximately a 2.2m range.

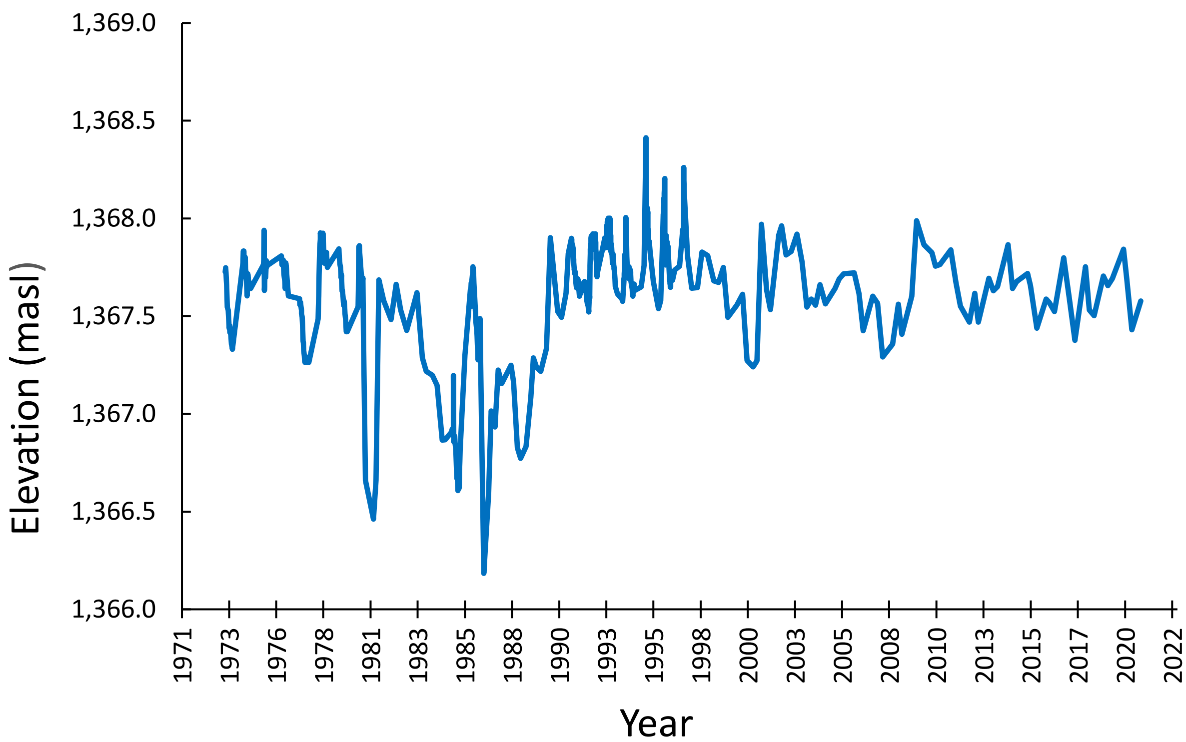


Figure 5. Water levels measured in meters above sea level (masl) from 1973 till April 2021. Data retrieved from Alberta Environment and Parks.

Table 2a. Average Secchi depth and water chemistry values for Beauvais Lake. Historical values are given for reference.

Parameter	1984	1985	1986	1987	1988	1989	1990	1991	1992
TP (µg/L)	34	27	23	24	38	26	25	26	23
TDP (µg/L)	/	/	/	/	/	/	/	/	/
Chlorophyll-*a* (µg/L)	13.5	13.3	8.5	6.6	17.0	5.9	13.0	4.9	7.6
Secchi depth (m)	1.58	1.90	2.33	2.78	2.30	2.66	2.62	4.70	4.02
TKN (mg/L)	/	0.8	/	/	/	/	/	/	/
NO_2-N and NO_3-N (µg/L)	25	25	25	10	9	5	10	3	3
NH_3-N (µg/L)	/	/	/	/	/	/	/	/	/
DOC (mg/L)	/	/	/	/	/	/	/	/	/
Ca (mg/L)	26	28	33	34	29	31	34	37	34
Mg (mg/L)	13	15	12	14	16	16	16	16	15
Na (mg/L)	11	11	10	9	11	11	9	10	11
K (mg/L)	2	2	1	1	1	1	1	1	1
SO_4^{2-} (mg/L)	6	3	10	7	7	9	7	6	4
Cl^- (mg/L)	1	1	1	2	1	1	1	1	1
CO_3 (mg/L)	4	6	3	6	3	4	4	/	2
HCO_3 (mg/L)	171	176	186	188	189	185	198	209	203
pH	8.48	8.40	8.43	8.55	8.35	8.32	8.28	8.17	8.36
Conductivity (µS/cm)	279	286	306	319	302	303	315	326	320
Hardness (mg/L)	120	131	132	141	137	142	150	157	148
TDS (mg/L)	148	151	161	165	160	165	166	173	168
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	148	148	157	165	158	158	165	171	168

Table 2b. Average Secchi depth and water chemistry values for Beauvais Lake. Historical values are given for reference.

Parameter	1993	1994	1995	1996	1997	1999	2000	2004	2005	2006
TP (μg/L)	24	27	25	22	26	24	21	23	17	19
TDP (μg/L)	/	/	8	/	/	/	/	/	/	/
Chlorophyll-*a* (μg/L)	6.6	4.0	5.4	4.7	4.2	6.2	4.5	7.0	6.4	4.5
Secchi depth (m)	3.05	3.93	2.58	3.12	2.95	3.27	2.65	3.65	2.60	2.90
TKN (mg/L)	/	/	0.3	/	/	/	/	/	0.5	/
NO_2-N and NO_3-N (μg/L)	6	4	9	/	/	2	50	/	14	/
NH_3-N (μg/L)	/	/	6	/	/	/	/	/	/	/
DOC (mg/L)	/	/	6	/	/	/	/	/	/	/
Ca (mg/L)	39	36	34	37	37	29	32	/	/	/
Mg (mg/L)	15	15	13	12	12	12	13	/	/	/
Na (mg/L)	10	10	8	7	7	11	8	/	/	/
K (mg/L)	1	1	1	1	1	1	1	/	/	/
SO_4^{2-} (mg/L)	5	3	5	7	7	7	9	/	/	/
Cl^- (mg/L)	1	1	0.5	0.4	0.3	0.4	1	/	/	/
CO_3 (mg/L)	5	4	2	3	0.3	2	3	/	3	/
HCO_3 (mg/L)	204	198	175	178	181	172	174	/	163	/
pH	8.50	8.34	8.13	8.24	8.11	8.25	8.40	/	8.44	/
Conductivity (μS/cm)	320	310	273	292	289	264	289	/	258	/
Hardness (mg/L)	158	149	136	142	140	125	135	/	/	/
TDS (mg/L)	172	163	147	158	154	147	151	/	/	/
Microcystin (μg/L)	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	172	164	145	150	149	144	146	/	139	/

Table 2c. Average historical Secchi depth and water chemistry values for Beauvais Lake. Historical values are given for reference.

Parameter	**2007**	**2008**	**2012**	**2016**	**2020**
TP (µg/L)	30	23	21	13	9
TDP (µg/L)	/	8	9	4	3
Chlorophyll-*a* (µg/L)	7.4	4.8	5.6	7.0	4.8
Secchi depth (m)	2.82	2.82	4.22	2.88	4.45
TKN (mg/L)	/	0.5	0.5	0.5	0.4
NO_2-N and NO_3-N (µg/L)	/	5	3	3	2
NH_3-N (µg/L)	/	10	15	25	13
DOC (mg/L)	/	7	7	6	6
Ca (mg/L)	/	/	/	27	32
Mg (mg/L)	/	/	/	14	14
Na (mg/L)	/	11	6	9	9
K (mg/L)	/	1	1	1	1
SO_4^{2-} (mg/L)	/	12	7	5	5
Cl^- (mg/L)	/	1	1	1	2
CO_3 (mg/L)	/	4	1	0.3	0.5
HCO_3 (mg/L)	/	174	155	158	183
pH	/	8.26	7.95	8.15	8.11
Conductivity (µS/cm)	/	274	250	250	275
Hardness (mg/L)	/	130	115	123	135
TDS (mg/L)	/	156	130	135	153
Microcystin (µg/L)	/	/	/	/	0.05
Total Alkalinity (mg/L $CaCO_3$)	/	144	127	128	150

Table 3. Concentrations of metals measured in Beauvais Lake in each sampling year since 2012. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference. Values exceeding these guidelines are presented in red.

Metals (Total Recoverable)	**2012***	**2016**	**Guidelines**
Aluminum µg/L	-	-	100[a]
Antimony µg/L	0.06	0.06	/
Arsenic µg/L	0.48	0.69	5
Barium µg/L	112	109	/
Beryllium µg/L	<0.003	0.021	100[c,d]
Bismuth µg/L	0.0062	0.0100	/
Boron µg/L	28.0	13.7	1500
Cadmium µg/L	0.005	0.028	0.26[b]
Chromium µg/L	0.11	0.08	/
Cobalt µg/L	0.02	0.04	1000[d]
Copper µg/L	0.40	0.39	4[b]
Iron µg/L	59.4	61.9	300
Lead µg/L	0.037	0.074	7[b]
Lithium µg/L	2.35	3.24	2500[e]
Manganese µg/L	44.6	23.6	200[e]
Molybdenum µg/L	0.53	0.49	73[c]
Nickel µg/L	<0.005	0.422	150[b]
Selenium µg/L	<0.1	0.18	1
Silver µg/L	-	-	0.25
Strontium µg/L	177	187	/
Thallium µg/L	0.0003	0.1540	0.8
Thorium µg/L	0.014	0.021	/
Tin µg/L	0.043	0.045	/
Titanium µg/L	0.40	0.34	/
Uranium µg/L	0.18	0.18	15
Vanadium µg/L	0.17	0.22	100[d,e]
Zinc µg/L	0.47	0.70	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5
[b] Based on water hardness > 180mg/L (as CaCO3)
[c] CCME interim value.
[d] Based on CCME Guidelines for Agricultural use (Livestock Watering).
[e] 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 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 Beauvais Lake. In sum, significant decreases were observed in TP, chlorophyll-*a,* and TDS, and a significant increasing trend was observed in Secchi depth. Secchi depth can be subjective and is sensitive to variation in weather - 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 Beauvais Lake data from 1984 to 2020.

Parameter	Date Range	Direction of Significant Trend
Total Phosphorus	1984-2020	Decreasing
Chlorophyll-*a*	1984-2020	Decreasing
Total Dissolved Solids	1984-2020	Decreasing
Secchi Depth	1984-2020	Increasing

Definitions:

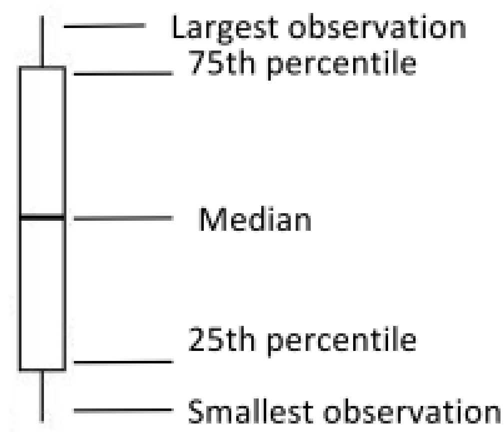
Median: the value in a range of ordered numbers that falls in the middle.

Trend: a general direction in which something is changing.

Monotonic trend: a gradual change in a single direction.

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

Box and Whisker Plot: a box-and-whisker plot, or boxplot, is a way of displaying all of our annual data. The median splits the data in half. The 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)

Total phosphorus (TP) has decreased significantly over the course of data collection at Beauvais Lake (Tau = -0.37, *p* < 0.001).

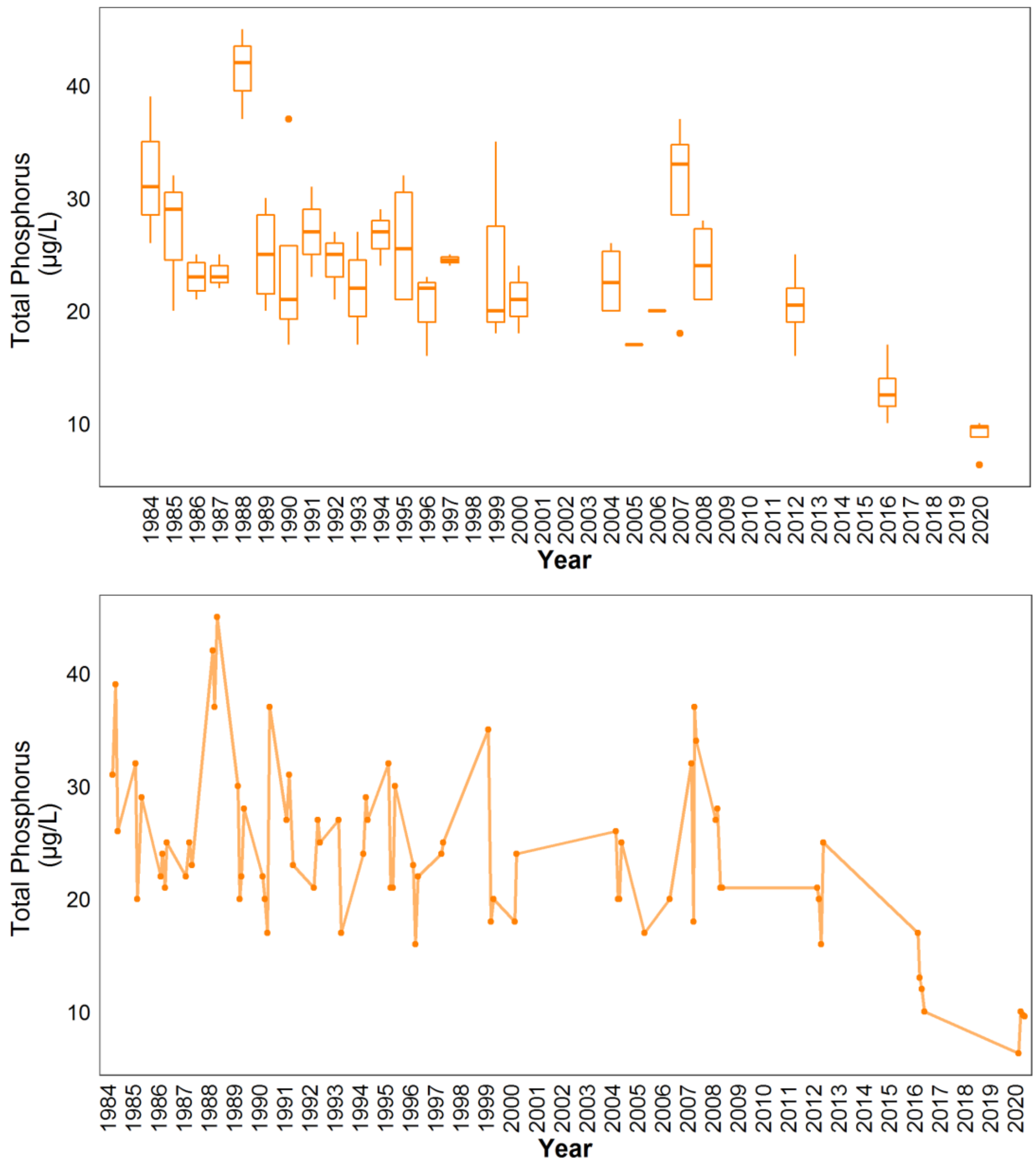


Figure 6. Monthly total phosphorus (TP) concentrations measured between June and September over the long term sampling dates between 1984 and 2020 (n = 75). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Chlorophyll-*a*

Chlorophyll-*a* has decreased significantly since sampling began at Beauvais Lake (Tau = -0.19, p = 0.04, Table 2). TP and Chlorophyll-*a* did significantly correlate throughout the historical record (r = 0.48, p = 2.08×10^{-6}).

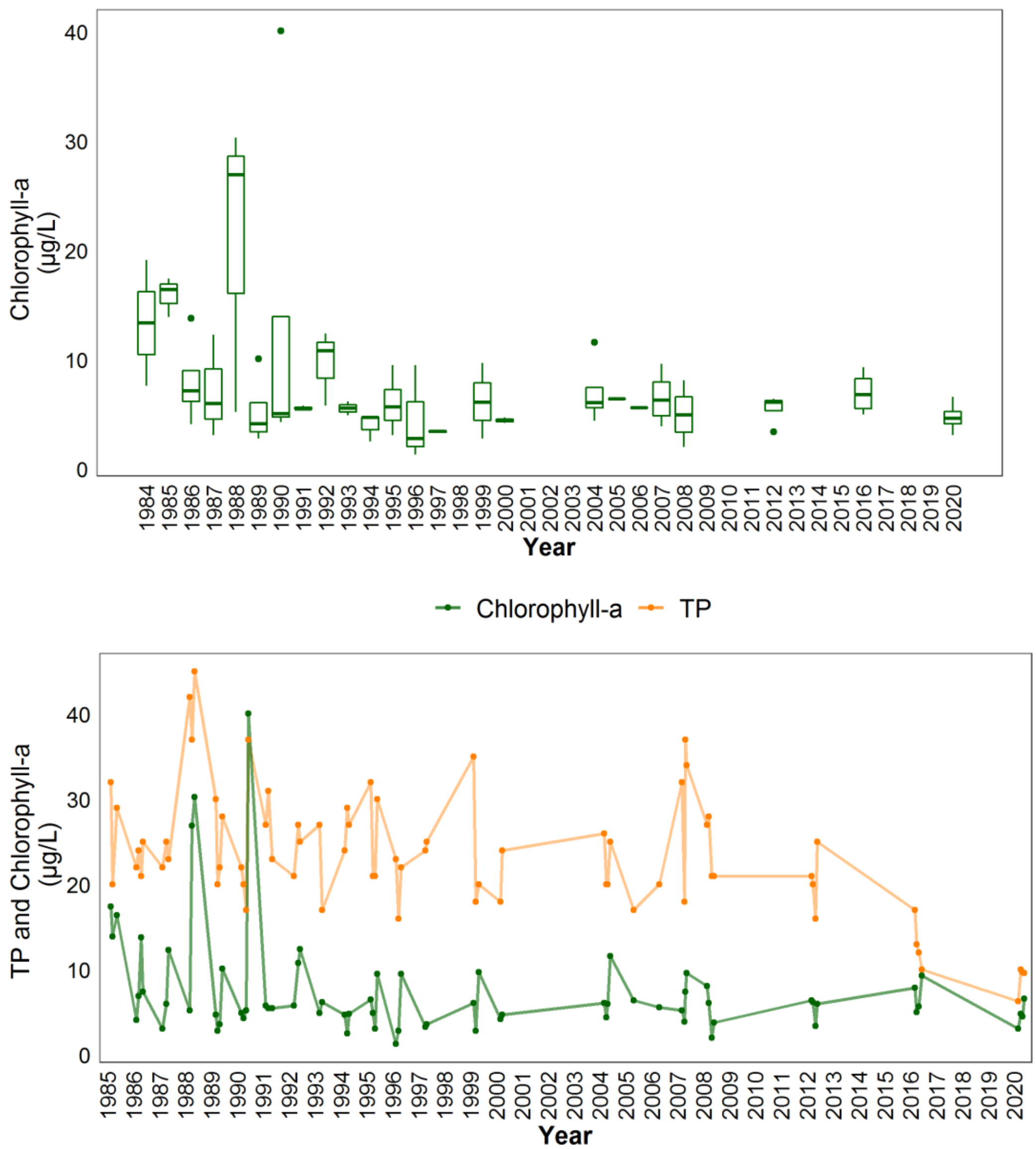


Figure 7. Monthly chlorophyll-*a* concentrations measured between June and September over the long term sampling dates between 1984 and 2020 (n = 74). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples. Line graph is overlain by TP concentrations.

Total Dissolved Solids (TDS)

Total dissolved solids have decreased significantly since sampling began in 1984 (Tau = -0.33, $p < 0.01$). Unlike chlorophyll-*a*, TP and Secchi depth, TDS was not determined during every sampling event at Beauvais Lake, particularly in sampling events prior to 2016.

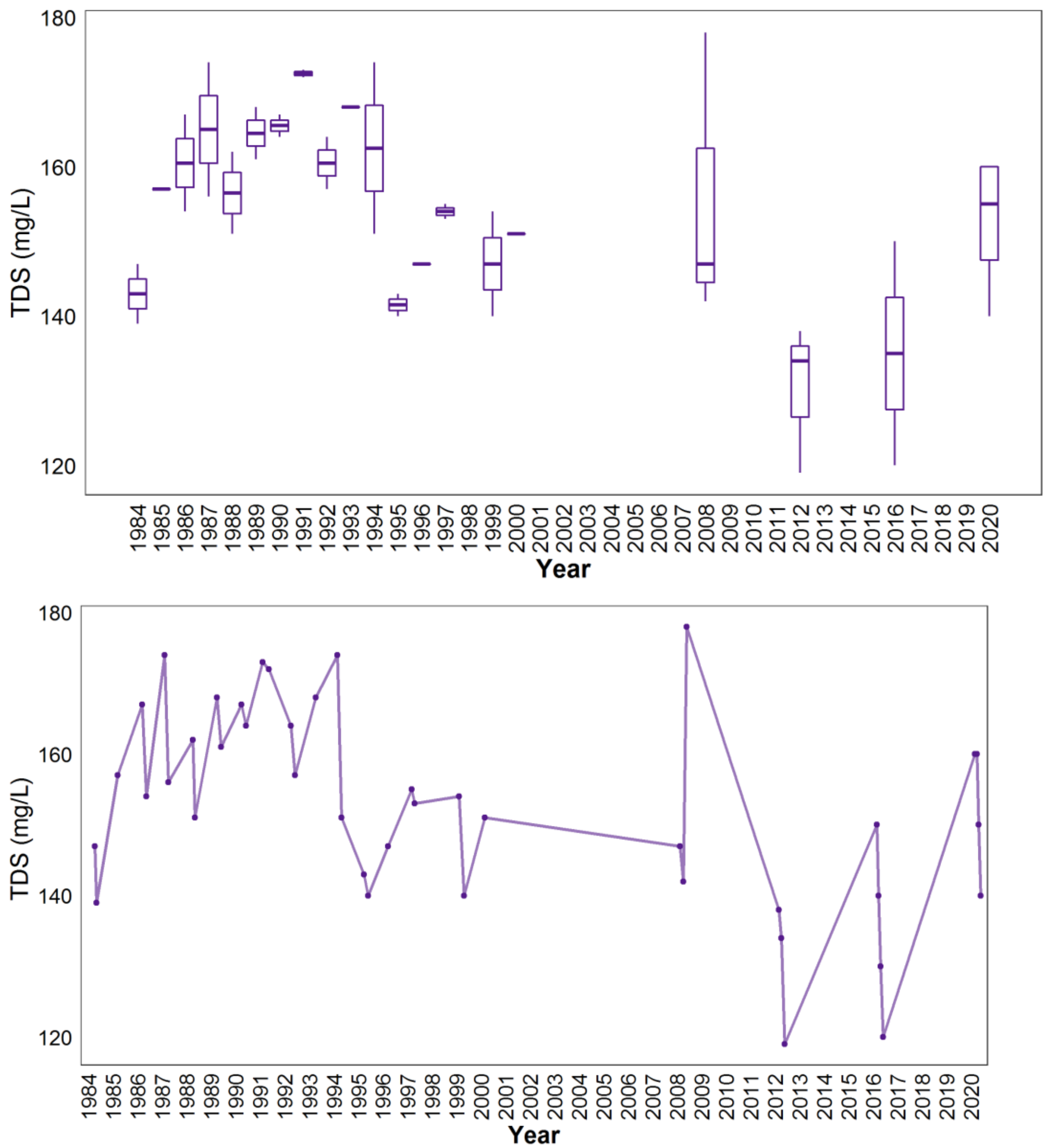
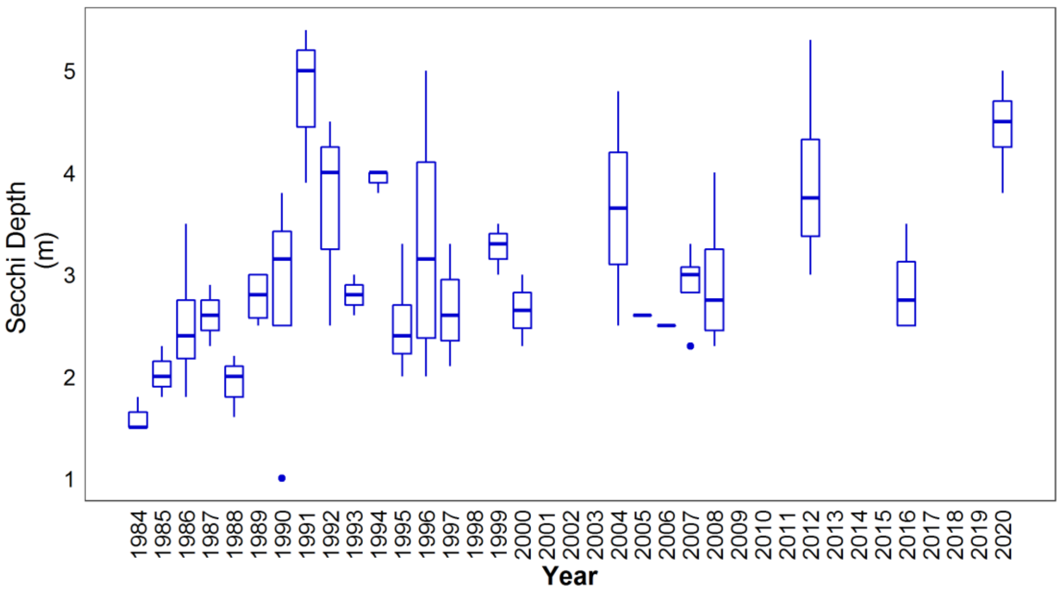


Figure 8. Monthly TDS values measured between June and September over the long term sampling dates between 1984 and 2020 (n = 42). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Secchi Depth

Trend analysis found that water clarity measured as Secchi depth has increased (become more clear) over the sampling period (Tau = 0.31, $p > 0.001$).



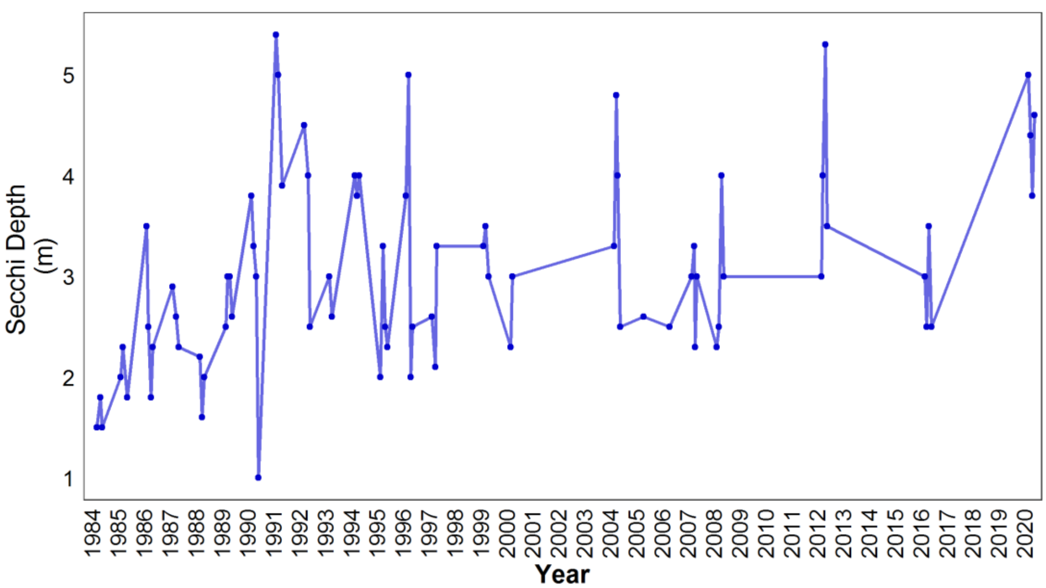


Figure 9. Monthly Secchi depth values measured between June and September over the long term sampling dates between 1984 and 2020 (n = 77). The value closest to the 15th day of the month was chosen to represent the monthly value in cases with multiple monthly samples.

Table 6. Results of Seasonal Kendall Trend test using monthly total phosphorus (TP), chlorophyll-*a*, total dissolved solids (TDS), and Secchi depth data from June to September on Beauvais 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	-0.37	-0.19	-0.33	0.31
The extent (slope) of the trend	Slope	-0.33	-0.078	-0.57	0.041
The statistic used to find significance of the trend	Z	-4.39	-2.05	-2.71	3.63
Number of samples included	n	75	74	42	77
The significance of the trend	*p*	1.11×10^{-5}*	0.040*	6.70×10^{-3}*	2.80×10^{-4}*

*$p < 0.05$ is significant within 95%