



*THE ALBERTA LAKE MANAGEMENT SOCIETY  
VOLUNTEER LAKE MONITORING PROGRAM*

## **2015 Moose Lake Report**

*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 on Alberta Lakes. Equally important is educating lake users about their aquatic environment, 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 a lay 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 people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

This report has been published before the completion of the data validation process.

### **Acknowledgements**

The LakeWatch program is made possible through the dedication of its volunteers. We would like to thank Grant Ferbey for his assistance with sampling Moose Lake in 2015. We would also like to thank Laticia McDonald, Ageleky Bouzetos, and Mohamad Youssef who were summer technicians with ALMS in 2015. Executive Director Bradley Peter was instrumental in planning and organizing the field program. Mike Bilyk was involved in the training aspects of the program. Lisa Reinbolt was responsible for data management. This report was prepared by Bradley Peter and Alicia Kennedy. The Beaver River Watershed Alliance (BRWA), the Lakeland Industry and Community Association (LICA), the Alberta Environmental Monitoring Evaluation and Reporting Agency (AEMERA), and Environment Canada, were major sponsors of the program.

## MOOSE LAKE:

Moose Lake (Figure 1) is located 240 km northeast of Edmonton and 3.5 km west of the Town of Bonnyville. Moose Lake has over 64 km of irregular shoreline within a 40 km<sup>2</sup> lake surface area. The lake is comprised of four main bays with a maximum depth of 19 m and a mean depth of 5.6 m. A sounding (depth measurement) was last conducted in 1962.



Figure 1 – Bathymetric map of Moose Lake.<sup>1</sup>

The lake was once known by its French name Lac d'Original, which was inspired by the abundance of moose.<sup>1</sup> In 1789, Angus Shaw established a trading post for the North West Company on the northwest shore of Moose Lake, one of the earliest European settlements known to Alberta. Later, in the early 1900's, French Canadian settlers began arriving in the area. In 1928, the railway was extended from St. Paul to Bonnyville.<sup>1</sup>

Moose Lake's abundance of natural resources was in high demand to supply a rapidly expanding population. Mink farming, agriculture, and three commercial fish-packing plants were in operation by 1936.<sup>1</sup> Commercial, domestic, and recreational fisheries are currently managed in Moose Lake. Walleye, northern pike, and yellow perch are the most popular sport fish; however, the lake also contains cisco, lake whitefish, burbot, suckers, and forage fish.

Moose Lake is still heavily used, particularly on summer weekends. Shoreline development is intense and includes cottage subdivisions, campgrounds, and summer villages. Aquatic reeds fringe the shoreline, which is predominantly sheltered. Dominant emergent plants include bulrush (*Scirpus validus*) and cattail (*Typha latifolia*). Common submergent plants are pondweeds (*Potamogeton* spp.) and northern watermilfoil (*Myriophyllum sibiricum*).

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<sup>1</sup> Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from <http://sunsite.ualberta.ca/projects/alberta-lakes/>

## WATER QUANTITY:

*There are many factors influencing water quantity. Some of these factors include the size of the lakes drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake.*

Water levels in Moose Lake have been monitored since 1950, at a time when water levels were 533.2 meters above sea level. Concern over lowering water levels resulted in the construction of a weir in 1951. Water levels then rose steadily to 534.1 m asl by 1966. After 1966, the weir deteriorated, and water levels dropped to 532.6 m asl in 1968. Water levels showed a step fluctuation for the next 20 years. A new weir with a target elevation of 533.2 m asl was installed in 1986 to ensure habitat for fish and waterfowl, recreational enjoyment, and drinking water. The new weir was, however, ineffective, and water levels continued to drop to the lowest recorded level of 531.9 m asl in October 1993. In 1996 and 1997, water levels were restored to 533.2 m asl (the weir crest); unfortunately, water levels again declined to 1994 levels. The lowest average monthly water level on record was reached in October 2002 at 531.0 m asl. The most recent available data for Moose Lake suggests the lake reached 532.801 m asl in 2014.

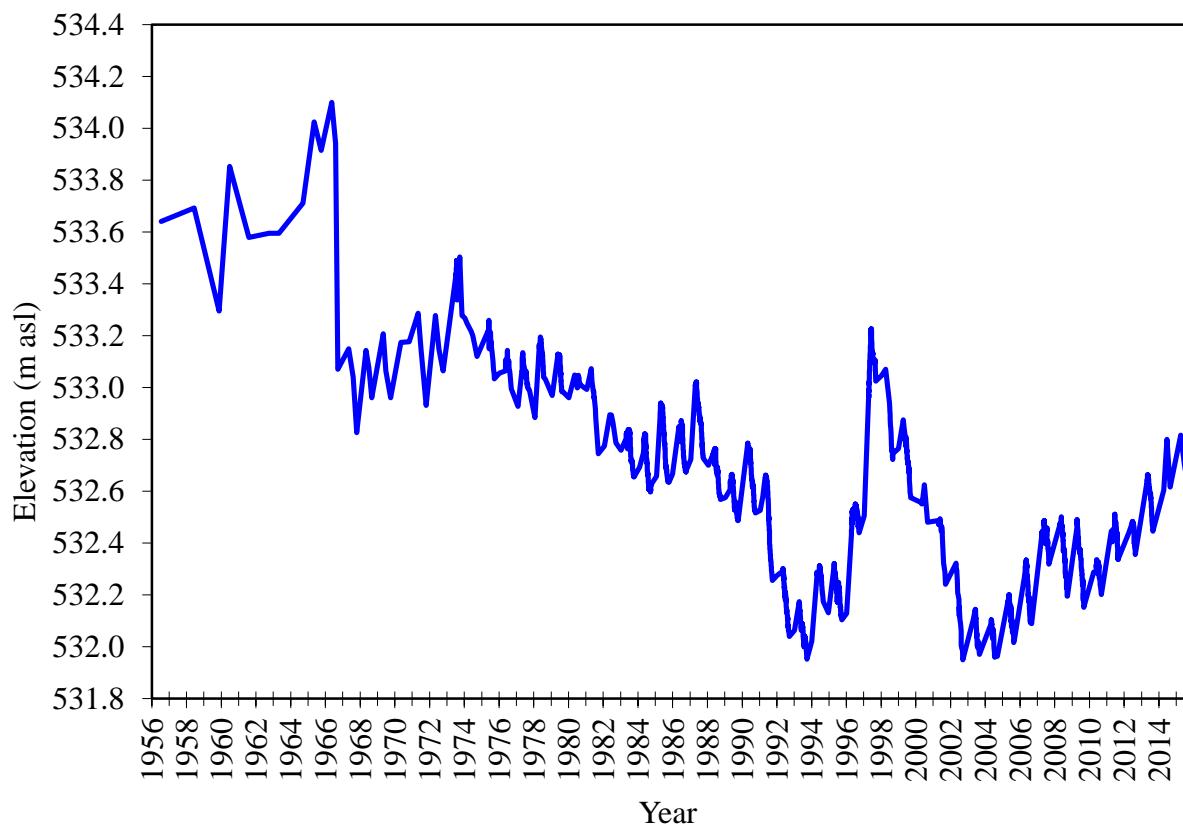


Figure 2 – Historical monthly water levels measured as water quantity in meters above sea level (m asl) for Moose Lake from 1956-2014. Data retrieved from Alberta Environment and Parks.

## WATER CLARITY AND SECCHI 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 disk depth.

Secchi disk depth fluctuated greatly throughout the summer at Moose Lake. On June 23<sup>rd</sup>, Secchi disk depth measured a seasonal maximum of 4.50 m – by September 2<sup>nd</sup>, however, Secchi disk depth had decreased to 1.25 m (Figure 3). Water clarity closely followed changes in chlorophyll-*a* concentration, suggesting phytoplankton populations are the primary factor decreasing water clarity in Moose Lake. In 2015, Secchi disk depth averaged 2.60 m – this average falls well within the historical variation previously observed at Moose Lake (Table 2).

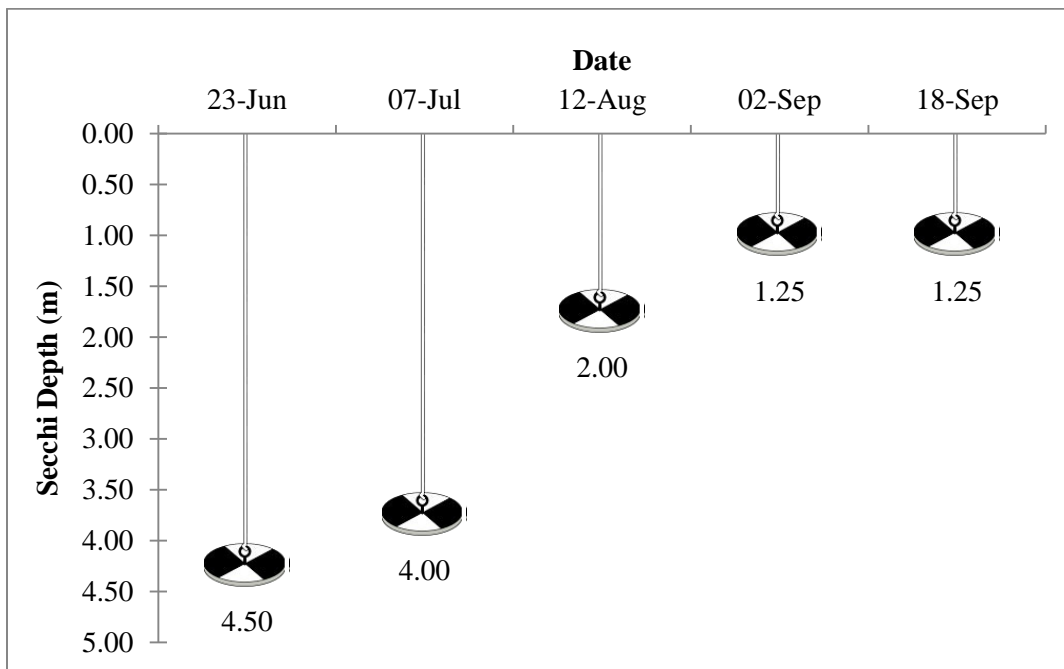


Figure 3 – Secchi depth values measured five times over the course of the summer at Moose Lake in 2015.

## WATER TEMPERATURE AND DISSOLVED OXYGEN:

Water temperature and dissolved oxygen 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.

Temperature in Moose Lake changed greatly throughout the summer of 2015 (Figure 4a). Thermal stratification was present on both June 23<sup>rd</sup> and July 7<sup>th</sup>, and not observed for the rest of the summer. At the surface, water temperatures were warm, measuring a maximum of 23.20 °C on August 12<sup>th</sup>. Temperatures were also warm at the lakebed, measuring a maximum of 18.24 °C on September 2<sup>nd</sup>. By September 18<sup>th</sup>, the entire water column measured ~14 °C. The presence of thermal stratification early in the summer in Moose Lake had obvious impacts on the lake's dissolved oxygen profile.

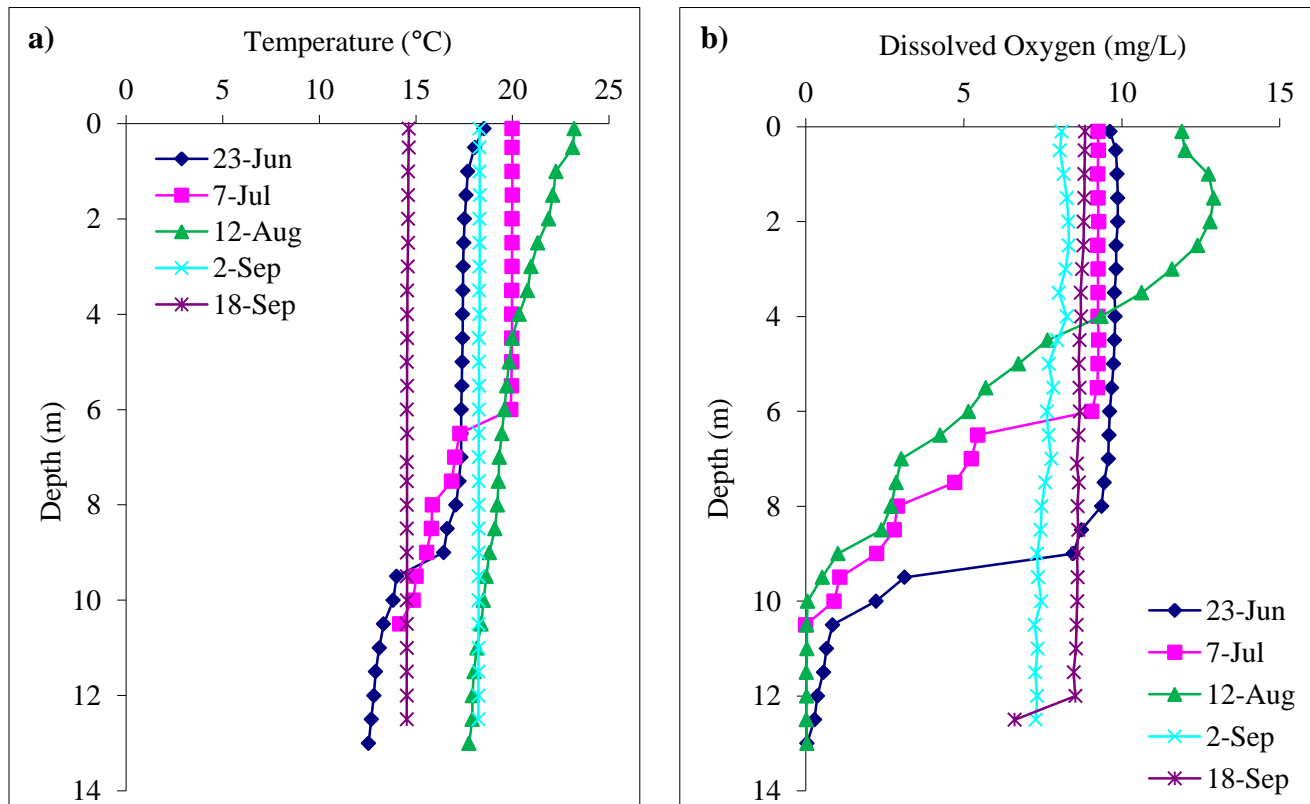


Figure 4 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Moose Lake measured five times over the course of the summer of 2015.

At its surface, Moose Lake remained well oxygenated, consistently measuring above the Canadian Council for Ministers of the Environment guidelines of 6.5 mg/L for the Protection of Aquatic Life (Figure 4b). Anoxic conditions were in Moose Lake's deeper waters on June 23<sup>rd</sup>, July 7<sup>th</sup>, and August 12<sup>th</sup>. Anoxic conditions are more likely to develop when thermal stratification is present as this isolates the oxygen rich surface waters from oxygen-poor bottom waters. Further contributing to the oxygen decline in deeper waters is the process of decomposition, which is an oxygen process, and occurs at the lakebed. On both September 2<sup>nd</sup> and September 18<sup>th</sup>, when temperatures cooled and thermal stratification was not present, Moose Lake was well oxygenated from the surface to the lakebed.

## 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 1 for a complete list of parameters.

Average total phosphorus (TP) concentration measured 33  $\mu\text{g/L}$  in 2015 (Table 2). This value falls just into the eutrophic, or productive, trophic classification and falls on the low end of the historical variation previously observed in Moose Lake. TP concentration increased throughout the summer, measuring a seasonal minimum of 20  $\mu\text{g/L}$  on July 7<sup>th</sup> and a seasonal maximum of 48  $\mu\text{g/L}$  on September 18<sup>th</sup> (Figure 5).

Chlorophyll-*a* concentration measured an average of 14.6  $\mu\text{g/L}$  in 2015 (Table 2). This average falls into the eutrophic, or productive, trophic classification. An average of 14.6 falls on the low end of the historical variation previously observed at Moose Lake. Throughout the summer, chlorophyll-*a* concentration increased steadily, measuring a minimum of 5.9  $\mu\text{g/L}$  on June 23<sup>rd</sup> and a maximum of 23.1  $\mu\text{g/L}$  on September 2<sup>nd</sup> (Figure 5).

Finally, total Kjeldahl nitrogen (TKN) concentration measured an average of 1.6 mg/L in 2015 (Table 2). Similar to TP and chlorophyll-*a* concentration, TKN increased throughout much of the summer, measuring a minimum of 1.4 mg/L on June 23<sup>rd</sup> and a maximum of 1.8 mg/L on September 2<sup>nd</sup> (Figure 5).

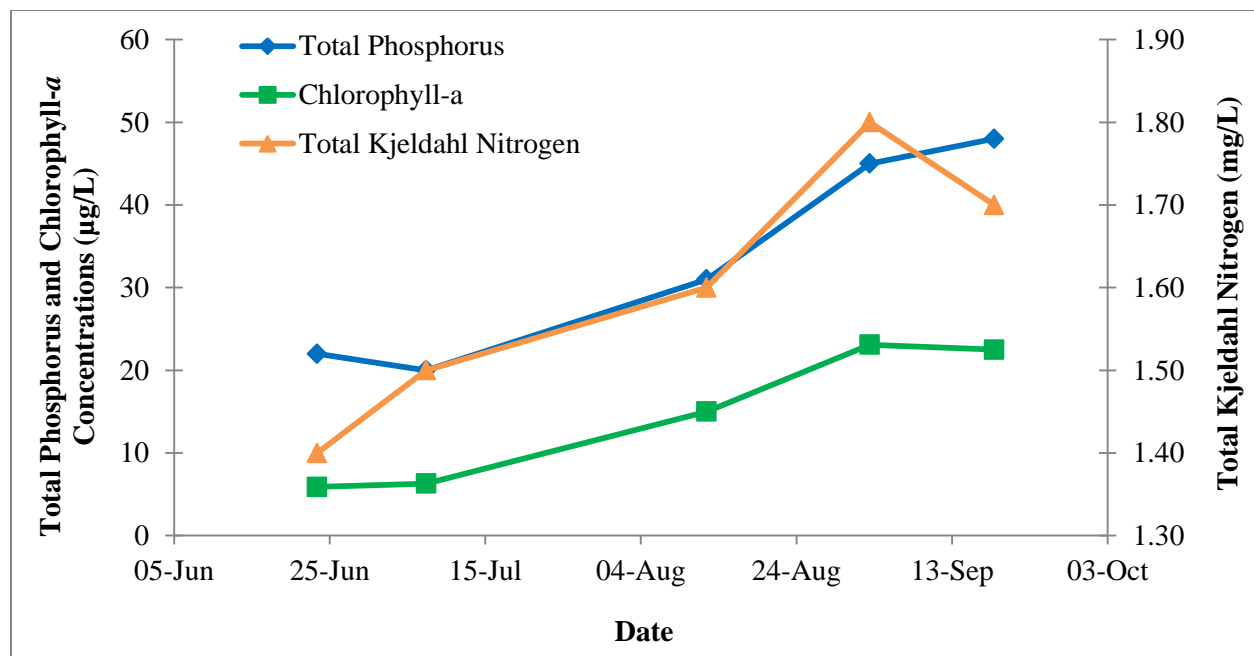


Figure 5 – Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentration measured five times over the course of the summer at Gull Lake.

Average pH measured 8.80 in 2015 – Moose Lake is well buffered against changes to pH due to its alkalinity (344 mg/L CaCO<sub>3</sub>) and bicarbonate (366 mg/L HCO<sub>3</sub>). Conductivity in Moose lake is high, measuring 990 uS/cm. Dominant ions contributing to conductance in Moose Lake include magnesium (52 mg/L), sodium (110 mg/L), and sulphate (168 mg/L).

Metals were measured twice at Moose Lake and all values fell within their respective guidelines (Table 3).

#### **MICROCYSTIN:**

*Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 µg/L.*

In 2015, low concentrations of microcystin were detected in the Moose Lake composite samples (Table 1). While concentrations of microcystin were low, this is only one of many cyanobacterial toxins, therefore all cyanobacterial blooms should be treated with caution. In addition, ALMS data represents composite samples collected across the lake, whereas single grab samples from areas where individuals recreate may have higher concentrations of microcystin.

Table 1 – Microcystin concentrations measured five times at Moose Lake in 2015.

Date	Microcystin Concentration (µg/L)
June 23	0.17
July 7	0.16
August 12	0.37
September 2	0.84
September 18	1.16
<b>Average</b>	<b>0.54</b>

#### **INVASIVE SPECIES:**

*Quagga and Zebra mussels are invasive species which, if introduced to our lakes, will have significant negative ecological, economical, and recreational impacts. ALMS collects water samples which are analyzed for mussel veligers (juveniles) and monitors substrates for adult mussels. In order to prevent the spread of invasive mussels, always clean, drain, and dry your boat between lakes. To report mussel sightings or mussel-fouled boats, call the confidential Alberta hotline at 1-855-336-BOAT.*

In 2015, no zebra or quagga mussels were detected in Moose Lake.



Table 2 - Average Secchi disk depth and water chemistry values for Moose Lake. Previous years averages are provided for comparison.

<b>Parameter</b>	<b>1983</b>	<b>1984</b>	<b>1985</b>	<b>1986</b>	<b>1987</b>	<b>1988</b>	<b>1989</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>
TP (µg/L)	36.5	46.1	25.4	40.2	50.0	41.5	50.5	54.3	44.3	39.6	40.8	42.9
TDP (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Chlorophyll- <i>a</i> (µg/L)	13.67	16.19	12.54	17.55	21.53	15.98	22.32	31.10	15.70	20.95	22.72	14.60
Secchi depth (m)	2.25	1.92	3.75	2.53	2.48	2.48	2.18	3.35	2.69	3.00	2.11	2.28
TKN (mg/L)	/	/	1.3	/	/	/	/	/	/	/	/	/
NO <sub>2</sub> and NO <sub>3</sub> (µg/L)	25	25	25	25	25	25	25	25	25	20.3	22.1	17.3
NH <sub>3</sub> (µg/L)	/	/	190	/	/	/	/	/	/	/	17	23
DOC (mg/L)	/	/	/	/	/	/	/	/	/	/	18	/
Ca (mg/L)	24.0	23.5	26.6	27.3	27.5	27.3	21.0	23.0	22.5	25.5	23.5	22.0
Mg (mg/L)	32.5	34.0	35.0	36.0	36.0	40.3	39.8	41.5	43.5	44.0	44.5	44.7
Na (mg/L)	62.0	64.5	63.5	66.0	62.5	73.7	77.5	73.5	76.0	82.5	84.3	85.0
K (mg/L)	11.5	11.5	12.5	11.8	11.5	12.1	12.5	11.9	12.9	13.1	13.8	13.9
SO <sub>4</sub> <sup>2-</sup> (mg/L)	81.5	83.8	87.5	92.3	94.0	102.0	107.5	105.5	112.5	117.0	115.0	116.7
Cl <sup>-</sup> (mg/L)	11.50	12.50	12.80	12.67	14.00	12.83	13.90	15.30	13.60	15.95	16.45	16.97
CO <sub>3</sub> (mg/L)	/	16.8	9.0	11.6	14.4	11.5	12.1	25.5	16.0	21.5	29.5	26.3
HCO <sub>3</sub> (mg/L)	/	273.3	289.6	288.9	283.4	302.7	294.7	275.0	300.0	329.5	329.5	328.7
pH	8.40	8.68	8.63	8.63	8.65	8.58	8.70	8.94	8.70	8.85	8.99	8.99
Conductivity (µS/cm)	656.5	641.3	666.8	678.0	681.0	715.0	708.5	705.5	736.0	780.0	786.8	790.3
Hardness (mg/L)	/	198.3	213.5	216.0	216.5	234.0	218.0	228.5	235.0	245.0	241.8	238.0
TDS (mg/L)	369.5	381.2	389.6	400.4	399.4	428.8	435.0	431.5	444.0	471.5	474.5	473.7
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L CaCO <sub>3</sub> )	243.5	252.2	252.6	257.0	256.5	267.3	262.0	268.0	272.5	289.0	295.0	291.7

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO<sub>2+3</sub> = nitrate+nitrite, NH<sub>3</sub> = ammonia, DOC = dissolved organic carbon, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO<sub>4</sub> = sulphate, Cl = chloride, CO<sub>3</sub> = carbonate, HCO<sub>3</sub> = bicarbonate, TDS = total dissolved solids, TSS = total suspended solids. A forward slash (/) indicates an absence of data. Historical data may not reflect an entire summer sample set (May, June, July, August, September).

Table 2 Continued... Average Secchi disk depth and water chemistry values for Moose Lake. Previous years averages are provided for comparison.

<b>Parameter</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</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)	42.7	30.9	47.9	52.5	38.0	50.5	59.2	42.8	46.5	49.0	53.3	109.3	74.0	33
TDP (µg/L)	/	/	/	14.5	15	13	17	20	16.75	17.8	17.8	41.3	31.2	10
Chlorophyll- <i>a</i> (µg/L)	17.56	5.15	16.80	39.48	22.60	27.30	35.46	15.71	19.03	46.14	26.76	50	14.26	14.56
Secchi depth (m)	1.98	3.45	2.75	2.25	2.69	2.15	1.30	3.06	1.56	2.88	1.84	0.96	3.66	2.60
TKN (mg/L)	1.6	/	/	1.7	1.5	1.6	1.8	1.6	1.7	1.6	1.7	2	1.6	1.6
NO <sub>2</sub> and NO <sub>3</sub> (µg/L)	22.3	25	25	21.8	20.3	25	25	13.8	7.8	3.63	2.5	2.5	36	6.6
NH <sub>3</sub> (µg/L)	/	/	/	33.25	37.5	15.5	23.2	43	23.5	30.8	19.75	18.5	87.4	36.4
DOC (mg/L)	18	/	/	/	17.5	18.1	18	17.6	18.45	16.87	17.9	23.9	17.25	16
Ca (mg/L)	22.8	30.8	27.8	25.4	24.5	24.6	25.4	24.3	20.6	23.6	25.4	25.7	25.8	25
Mg (mg/L)	45.0	43.5	43.2	53.5	49.9	47.0	48.1	48.4	50.6	56.0	48.5	53	47.9	52
Na (mg/L)	87.0	83.9	83.8	110.7	112.0	113.5	114.7	117.3	129.0	114.0	107.0	116.3	129.0	110
K (mg/L)	14.6	14.5	14.6	12.2	16.7	19.5	17.4	19.7	18.6	20.3	21.3	24.1	21.3	18
SO <sub>4</sub> <sup>2-</sup> (mg/L)	125.0	123.5	113.0	149.3	155.5	151.0	154.7	165.0	164.0	156.0	161.0	150.7	150.0	168
Cl <sup>-</sup> (mg/L)	17.55	17.20	19.20	23.40	24.55	24.90	25.40	27.67	28.60	27.40	27.70	27.60	33.70	33
CO <sub>3</sub> (mg/L)	19.0	13.0	15.0	29.3	28.5	35.0	31.7	30.3	27.5	18.0	28.8	36.3	29.2	27
HCO <sub>3</sub> (mg/L)	321.0	322.0	313.5	342.7	350.0	334.5	345.7	348.0	357.5	371.5	358.5	341.8	413.0	366
pH	8.76	8.56	8.64	8.87	8.86	8.99	8.81	8.90	8.85	8.70	8.87	8.90	8.71	8.80
Conductivity (µS/cm)	792.8	808.0	776.0	/	934.5	867.5	947.3	953.7	964.5	974.0	993.0	989.3	996.0	990
Hardness (mg/L)	240.8	268.0	245.5	283.7	266.5	255.0	261.3	259.7	260.0	290.0	263.0	282.3	261.5	280
TDS (mg/L)	489.0	/	/	573.0	583.5	580.0	587.0	604.0	610.0	599.0	596.7	602	639	618
Microcystin (µg/L)	/	/	/	/	/	0.418	0.080	0.593	0.113	1.178	1.002	0.2265	0.6	0.54
Total Alkalinity (mg/L CaCO <sub>3</sub> )	295.3	288.0	284.0	330.3	334.0	333.0	336.0	336.0	338.5	334.0	342.3	370.5	338.6	344

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO<sub>2+3</sub> = nitrate+nitrite, NH<sub>3</sub> = ammonia, DOC = dissolved organic carbon, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO<sub>4</sub> = sulphate, Cl = chloride, CO<sub>3</sub> = carbonate, HCO<sub>3</sub> = bicarbonate, TDS = total dissolved solids, TSS = total suspended solids. A forward slash (/) indicates an absence of data. Historical data may not reflect an entire summer sample set (May, June, July, August, September).

Table 3 - Average concentrations of metals measured in Moose Lake on August 14<sup>th</sup> and September 21<sup>st</sup>. Values shown for 2015 are an average of those dates. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	2003	2004	2005	2009	2010	2011	2012	2013	2014	2015	Guidelines
Aluminum µg/L	14.75	4.95	3.34	16.05	10.7	4.08	5.175	19.15	7.215	4	100 <sup>a</sup>
Antimony µg/L	0.075	0.065	0.065	0.058	0.0531	0.05605	0.05795	0.2195	0.0469	0.052	6 <sup>e</sup>
Arsenic µg/L	1.99	2.03	2.19	2.12	2.16	2.085	2.21	6.055	2.06	1.93	5
Barium µg/L	46.1	50.2	47.8	45.4	44.9	46	46.95	30.15	48.9	45.85	1000 <sup>e</sup>
Beryllium µg/L	0.06	0.0015	0.0015	0.0038	0.0015	0.00385	0.00375	0.00565	0.004	0.004	100 <sup>d,f</sup>
Bismuth µg/L	0.00575	0.0011	0.0061	0.0061	0.0012	0.0005	0.0005	0.00795	0.0005	0.00325	/
Boron µg/L	169.5	172	176	197	185	202	191	184.5	189	187.5	5000 <sup>ef</sup>
Cadmium µg/L	0.03	0.007	0.00465	0.005	0.0048	0.0043	0.01	0.0028	0.002	0.001	0.085 <sup>b</sup>
Chromium µg/L	0.325	0.87	0.606	0.298	0.22	0.2175	0.351	0.3355	0.817	0.34	/
Cobalt µg/L	0.01	0.014	0.0205	0.0107	0.0067	0.03045	0.0027	0.0559	0.007285	0.012	1000 <sup>f</sup>
Copper µg/L	0.56	0.75	0.607	0.492	0.263	0.4985	0.6635	0.9385	0.5545	0.46	4 <sup>c</sup>
Iron µg/L	3.25	1	37	8.05	7.65	22.8	1	25.95	9.03	8.15	300
Lead µg/L	0.079	0.0472	0.08015	0.216	0.0114	0.0134	0.04765	0.0555	0.06535	0.0145	7 <sup>c</sup>
Lithium µg/L	40.05	53.4	57.3	61.2	53.1	70.75	55.05	75.15	52.85	53.45	2500 <sup>g</sup>
Manganese µg/L	9.28	8.14	7.26	7.55	7.2	5.615	7.99	6.315	8.51	5.35	200 <sup>g</sup>
Molybdenum µg/L	0.59	0.846	0.7045	0.598	0.556	0.6275	0.6245	0.6305	0.523	0.517	73 <sup>d</sup>
Nickel µg/L	0.03	0.0025	0.11	<0.005	0.0025	0.16275	0.0025	0.3131	0.03485	0.004	150 <sup>e</sup>
Selenium µg/L	0.525	0.27	0.2755	0.3955	0.375	0.3575	0.2535	0.2115	0.528	0.045	1
Silver µg/L	0.0025	0.0025	0.0013	0.0016	0.0018	0.007675	0.004025	0.01155	0.001	0.001	0.1
Strontium µg/L	282.5	309	307.5	303	281	287.5	242	169.6	297	275.5	/
Thallium µg/L	0.0925	0.0019	0.02925	0.0042	0.0021	0.00045	0.00015	0.001	0.001375	0.001925	0.8
Thorium µg/L	0.00425	0.009	0.01925	0.00245	0.0083	0.0118	0.00015	0.0298	0.00045	0.004375	/
Tin µg/L	0.08	0.015	0.015	0.037	0.015	0.0318	0.0387	0.015	0.005725	0.02	/
Titanium µg/L	0.65	0.67	0.862	1.129	0.756	0.4875	0.6475	1.285	1.025	0.81	/
Uranium µg/L	0.43	0.437	0.5905	0.454	0.433	0.463	0.445	1.3055	0.4455	0.494	100 <sup>e</sup>
Vanadium µg/L	0.445	0.388	0.3845	0.29	0.244	0.2605	0.3	0.672	0.3855	0.16	100 <sup>f,g</sup>
Zinc µg/L	2.98	7.9	4.335	0.722	0.498	0.68	1.054	1.0815	0.8145	0.35	30

Values represent means of total recoverable metal concentrations.

<sup>a</sup> Based on pH ≥ 6.5; calcium ion concentrations [Ca<sup>+2</sup>] ≥ 4 mg/L; and dissolved organic carbon concentration [DOC] ≥ 2 mg/L.

<sup>b</sup> Based on water Hardness of 300 mg/L (as CaCO<sub>3</sub>)

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

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

<sup>e</sup> Based on Canadian Drinking Water Quality guideline values.

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

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

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

# A BRIEF INTRODUCTION TO LIMNOLOGY

## INDICATORS OF WATER QUALITY:

Water samples are collected in LakeWatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in LakeWatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

## TEMPERATURE AND MIXING:

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of the lake.

As the difference in temperature between warm surface and cold deeper water increases, two distinct layers are formed. Limnologists call these layers of water the **epilimnion** at the surface and the **hypolimnion** at the bottom. The layers are separated by a transition layer known as the **metalimnion** which contains the effective wall separating top and bottom waters called a **thermocline**. A thermocline typically occurs when water temperature changes by more than one degree within one meter depth. The hypolimnion and epilimnion do not mix, nor do elements such as oxygen supplied at the surface move downward into the hypolimnion. In the fall, surface waters begin to cool and eventually reach the same temperature as hypolimnetic water. At this point the water mixes from top to bottom in what is often called a **turnover** event. Surface water cools further as ice forms and again a thermocline develops this time with 4° C water at the bottom and near 0° C water on the top.

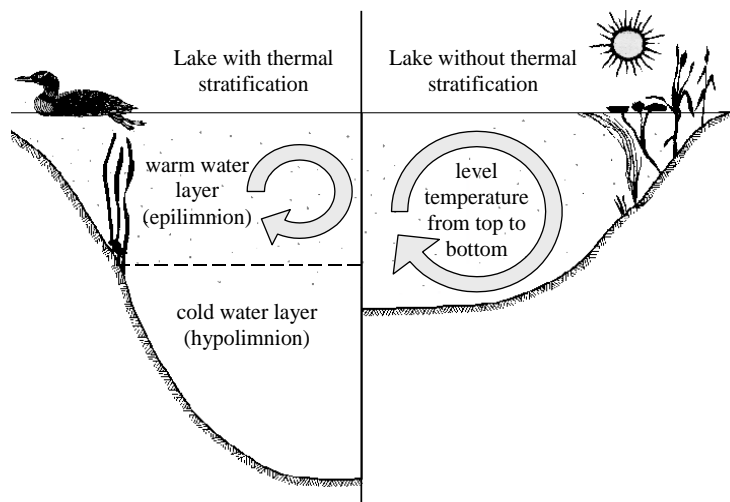


Figure A: Difference in the circulation of the water column depending on thermal stratification.

In spring another turnover event occurs when surface waters warm to 4° C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are **termed polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice free season the lake is polymictic.**

#### **DISSOLVED OXYGEN:**

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 mg•L<sup>-1</sup> and should not average less than 6.5 mg•L<sup>-1</sup> over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg•L<sup>-1</sup> in areas where early life stages of aquatic biota, particularly fish, are present.

#### **GENERAL WATER CHEMISTRY:**

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

#### **PHOSPHORUS AND NITROGEN:**

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote

algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

#### **CHLOROPHYLL-A:**

Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the amount of algae in the water. Some highly productive lakes are dominated by larger aquatic plants rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

#### **SECCHI DISK TRANSPARENCY :**

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and insects, depend on aquatic plants for food and shelter.

**TROPHIC STATE:**

Trophic state is classification of lakes into four categories of fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are; **oligotrophic, mesotrophic, eutrophic** and **hypereutrophic (Table 2)**.

A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

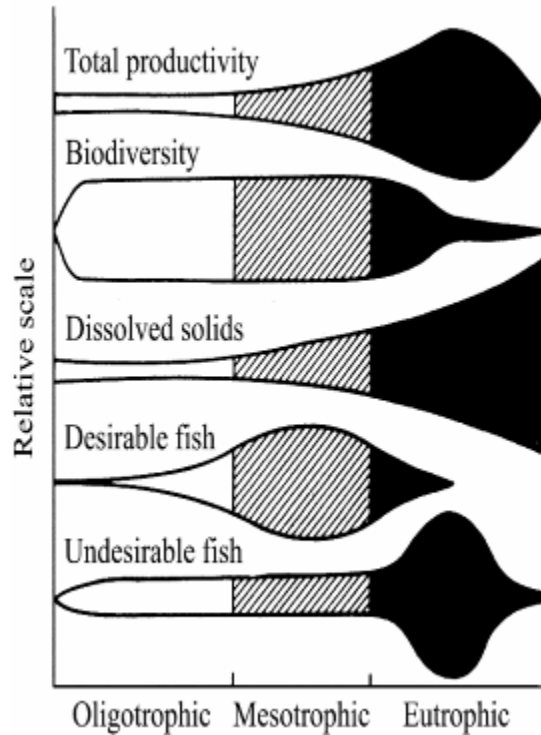


Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

Table A - Trophic status classification based on lake water characteristics.

Trophic state	Total Phosphorus (µg•L <sup>-1</sup> )	Total Nitrogen (µg•L <sup>-1</sup> )	Chlorophyll a (µg•L <sup>-1</sup> )	Secchi Depth (m)
Oligotrophic	< 10	< 350	< 3.5	> 4
Mesotrophic	10 – 30	350 - 650	3.5 - 9	4 - 2
Eutrophic	30 – 100	650 - 1200	9 - 25	2 - 1
Hypereutrophic	> 100	> 1200	> 25	< 1