



*THE ALBERTA LAKE MANAGEMENT SOCIETY  
VOLUNTEER LAKE MONITORING PROGRAM*

## **2014 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.

### **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 2014. We would also like to thank Jackson Woren, Brittany Kereliuk, and Kara MacAulay who were summer technicians with ALMS in 2014. Program Coordinator 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 Jackson Woren and Bradley Peter. Alberta Environment, the Beaver River Watershed Alliance (BRWA), the Lakeland Industry and Community Association (LICA), and Environment Canada, were major sponsors of the program.

If you are interested in becoming a volunteer with the LakeWatch program or having your lake monitored, please e-mail us at [info@alms.ca](mailto:info@alms.ca) or call us at 780-415-9785.

## 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*).

<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 (m asl; Figure 2). 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 water level on record was reached in October 2002 at 531.0 m asl. In 2014, water levels measured a maximum of 532.665 m asl.

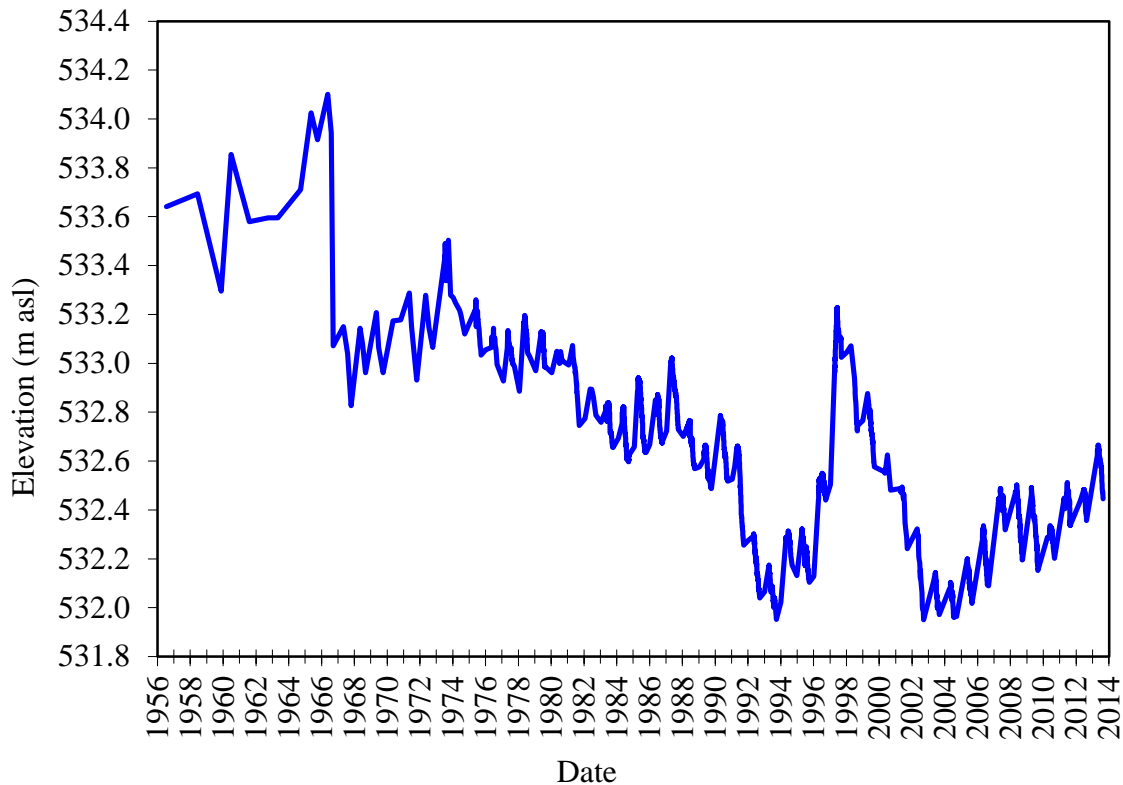
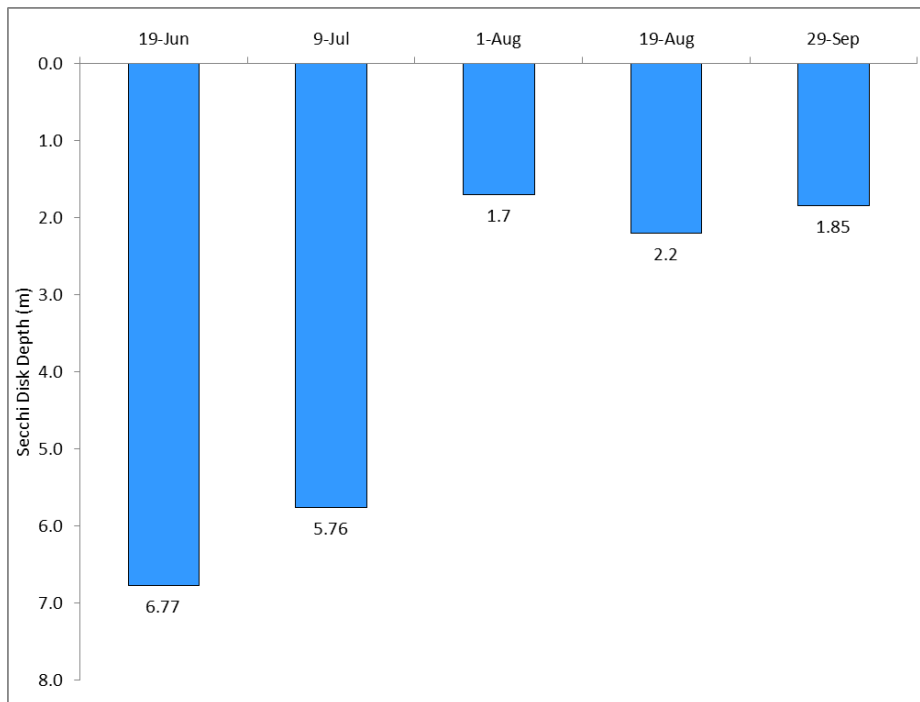


Figure 2 – Historical water levels for Moose Lake in meters above sea level (m asl) retrieved from Alberta Environment and Sustainable Resource Development.

## 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*

Average Secchi disk depth at Moose Lake in 2014 measured 3.67 m. This is the second highest Secchi disk average measured at Moose Lake – 3.75 m being the highest recorded in 1985. Secchi disk depth fluctuated greatly throughout the summer, ranging between a minimum of 1.7 m on August 1<sup>st</sup> to a maximum of 6.77 m on June 19<sup>th</sup>. As a eutrophic lake, cyanobacteria is often the greatest impediment to water clarity at Moose Lake. Compared to 2013, average concentration of chlorophyll-*a* fell around the historical average.



## 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.*

In 2014, weak and deep thermal stratification was observed on the first four of the five sampling trips (Figure 3a). While this stratification occurred over only a small depth,

there were clear declines in oxygen concentrations at these depths, suggesting thermal stratification plays an important role in oxygen dynamics. Surface temperatures varied throughout the summer ranging from a minimum of 12.74°C on September 29<sup>th</sup> to a maximum of 23.18°C on August 1<sup>st</sup>. Moose Lake had become isothermal by September 29<sup>th</sup>, measuring ~12 °C for the entire depth of the water column.

Dissolved oxygen concentrations were elevated in the top portions of Moose Lake on August 1<sup>st</sup> likely due to photosynthesis by algae/cyanobacteria (Figure 3b). All five trips showed that surface dissolved oxygen concentrations were above the Canadian Council for Ministers of the Environment (CCME) recommended guidelines of 6.5 mg/L for the Protection of Aquatic Life. However, in deeper depths oxygen was reduced, often falling below the CCME guidelines – oxygen rapidly declined to anoxia after 4.0 m on August 1<sup>st</sup> and after 6.0 m all other dates with the exception of September 29<sup>th</sup>. Near the lake sediments and below the thermoclines, oxygen levels proceeded towards anoxia. The presence of anoxia at the lakebed may contribute to the release of phosphorus from the sediments. By September 29<sup>th</sup>, as with temperature, dissolved oxygen concentrations were uniformly mixed throughout the water column at Moose Lake. The decomposition of organic matter, such as algae/cyanobacteria, likely plays a large role in driving down dissolved oxygen concentrations near the lakebed.

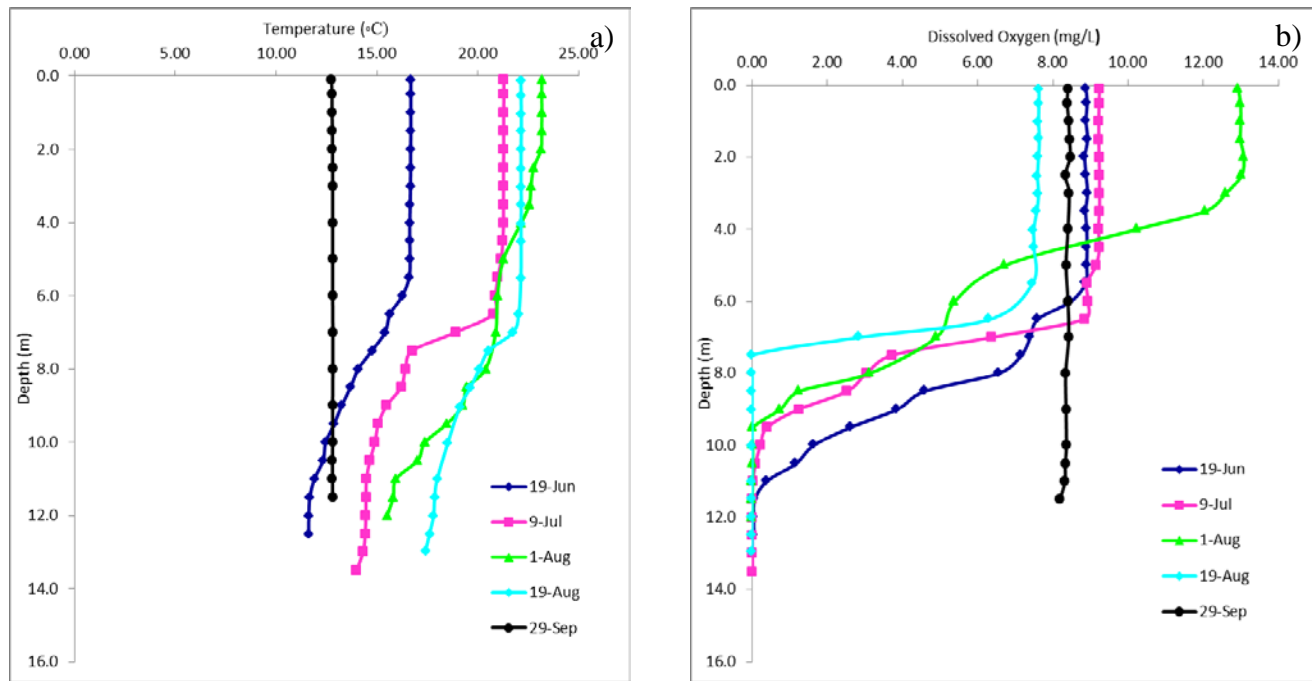


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles measured five times throughout the summer at Moose Lake.

**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) measured 74 µg/L during the summer of 2014 (Figure 4, Table 1). This average falls into the eutrophic, or biologically productive, classification – in addition, this is the second highest average concentration measured to date next to 2013 with an average of 109.3 µg/L. The maximum TP concentration recorded throughout the summer was a spike of 148 µg/L on September 29<sup>th</sup>. In addition, two other spikes of 70 µg/L and 83 µg/L were observed on June 19<sup>th</sup> and August 1<sup>st</sup> respectively. The lowest concentration was recorded on August 19<sup>th</sup> with a concentration of 30 µg/L. Field observations report that a rain event may have led to the increase in TP in June, however, it is unclear what led to the spikes in TP in Moose Lake in 2014. TP is the primary nutrient responsible for determining how much algae/cyanobacteria can potentially grow in a lake.

Average chlorophyll-*a* concentration, an indicator of algal/cyanobacterial biomass, measured 14.26 µg/L (Figure 4, Table 1). This average falls into the hypereutrophic, or extremely productive, category. Chlorophyll-*a* concentrations ranged throughout the summer, measuring a minimum of 1.80 µg/L on June 19<sup>th</sup> and a maximum of 28.0 µg/L on August 1<sup>st</sup>. Chlorophyll-*a* concentration is a product of a combination of factors including light, temperature, and nutrient availability.

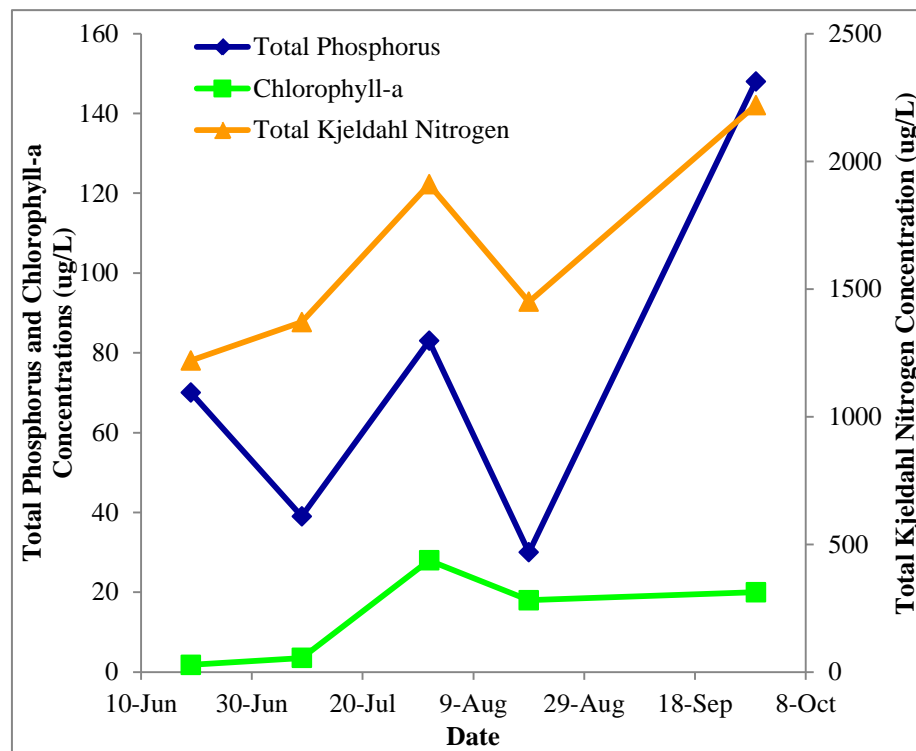


Figure 4 – Average total phosphorus (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (µg/L) concentrations measured five times over the course of the summer at Moose Lake.

Finally, average total Kjeldahl nitrogen measured 1634  $\mu\text{g/L}$  in 2014 (Figure 4, Table 1). Similar to chlorophyll-*a* concentrations, average TKN concentrations fall into the hypereutrophic category. TKN ranges from a minimum of 1220  $\mu\text{g/L}$  on June 19<sup>th</sup> to a maximum of 2220  $\mu\text{g/L}$  on September 29<sup>th</sup>.

Average pH at Moose Lake during the summer of 2014 measured 8.708, well above neutral; the lake water is likely buffered against changes to pH due to high alkalinity (338.6 mg/L  $\text{CaCO}_3$ ) and high bicarbonate concentration (413 mg/L  $\text{HCO}_3$ ; Table 1). Moose Lake has a high conductivity (996  $\mu\text{S/cm}$ ), with dominant ions being sulphate (150 mg/L), sodium (129 mg/L) and magnesium (47.9 mg/L).

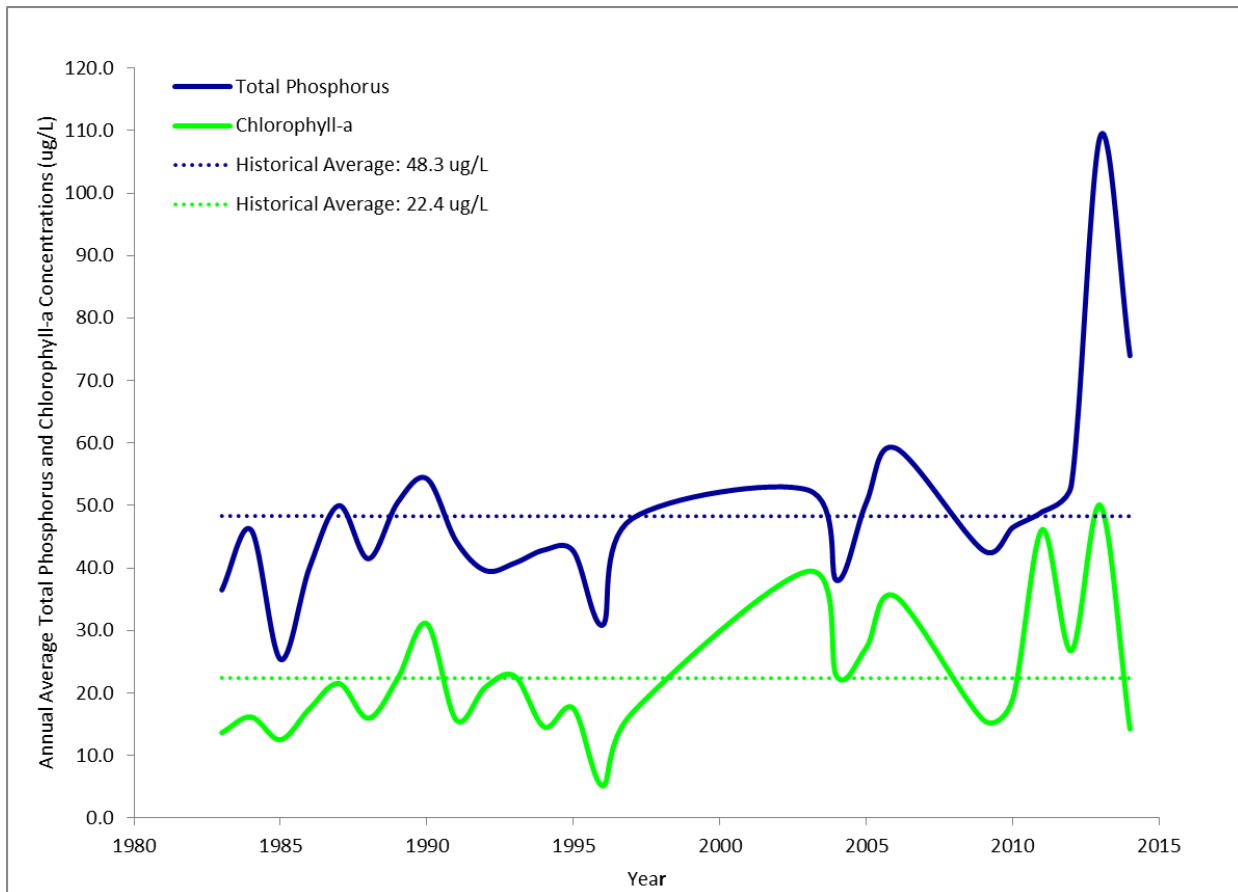


Figure 7 - Historical trends for total phosphorus and chlorophyll-*a* concentrations. Dotted lines mark historical averages.

Metals were monitored for twice throughout the summer of 2014 at Moose Lake. Unlike 2013, the average concentration of arsenic did not exceed the Canadian Council for Ministers of the Environment Guidelines for the Protection of Aquatic Life (Table 2). Arsenic levels have historically been high in the Beaver River Watershed due to the areas natural geology; however, high arsenic levels have only been observed by LakeWatch in



Moose Lake during 2013. All other metals sampled for in 2014 fell within their respective guidelines.

#### **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.*

Microcystin, a toxin produced by cyanobacteria, measured an average concentration of 0.6 µg/L. Concentrations ranged from a minimum of 0.08 on June 19<sup>th</sup> to a maximum of 1.43 on September 29<sup>th</sup>. Though chlorophyll-*a* concentrations were high, the dominant species of cyanobacteria in the lake was likely not a microcystin producing species. However, species of cyanobacteria which do not produce microcystins may produce other toxins and caution should be observed when recreating around all cyanobacterial blooms.

#### **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 2014, no zebra or quagga mussels were detected in Moose Lake.

Table 1 – Average Secchi disk depth and water chemistry values for Moose Lake. Previous years averages are provided for comparison.

Parameter	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	2003	2004	2005	2006	2009	2010	2011	2012	2013	2014
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	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
TDP (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	14.5	15	13	17	20	16.75	17.8	17.8	41.3	31.2
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	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
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	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
TKN (µg/L)	/	/	1280	/	/	/	/	/	/	/	/	/	1590	/	/	1660	1515	1598	1820	1588	1700	1615	1697	2035	1634
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	22.3	25	25	21.8	20.3	25	25	13.8	7.8	3.63	2.5	2.5	36
NH <sub>3</sub> (µg/L)	/	/	190	/	/	/	/	/	/	/	17	23	/	/	/	33.25	37.5	15.5	23.2	43	23.5	30.8	19.75	18.5	87.4
DOC (mg/L)	/	/	/	/	/	/	/	/	/	/	18	/	18	/	/	/	17.5	18.1	18	17.6	18.45	16.87	17.9	23.9	17.25
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	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
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	792.8	808.0	776.0	/	934.5	867.5	947.3	953.7	964.5	974.0	993.0	989.3	996.0
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	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
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	489.0	/	/	573.0	583.5	580.0	587.0	604.0	610.0	599.0	596.7	602	639
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	0.418	0.080	0.593	0.113	1.178	1.002	0.2265	0.6
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	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

Note: TP = total phosphorus, TDP = total dissolved phosphorus, 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. A forward slash (/) indicates an absence of data.

Table 2 - Concentrations of metals measured in Moose Lake on August 1<sup>st</sup> and September 29<sup>th</sup> 2014. Values shown for 2014 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.

<b>Metals (Total Recoverable)</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>Guidelines</b>
Aluminum µg/L	14.75	4.95	3.34	16.05	10.7	4.08	5.175	19.15	7.215	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	6 <sup>c</sup>
Arsenic µg/L	1.99	2.03	2.19	2.12	2.16	2.085	2.21	6.055	2.06	5
Barium µg/L	46.1	50.2	47.8	45.4	44.9	46	46.95	30.15	48.9	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	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	/
Boron µg/L	169.5	172	176	197	185	202	191	184.5	189	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	0.085 <sup>b</sup>
Chromium µg/L	0.325	0.87	0.606	0.298	0.22	0.2175	0.351	0.3355	0.817	/
Cobalt µg/L	0.01	0.014	0.0205	0.0107	0.0067	0.03045	0.0027	0.0559	0.007285	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	4 <sup>c</sup>
Iron µg/L	3.25	1	37	8.05	7.65	22.8	1	25.95	9.03	300
Lead µg/L	0.079	0.0472	0.08015	0.216	0.0114	0.0134	0.04765	0.0555	0.06535	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	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	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	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	150 <sup>c</sup>
Selenium µg/L	0.525	0.27	0.2755	0.3955	0.375	0.3575	0.2535	0.2115	0.528	1
Silver µg/L	0.0025	0.0025	0.0013	0.0016	0.0018	0.007675	0.004025	0.01155	0.001	0.1
Strontium µg/L	282.5	309	307.5	303	281	287.5	242	169.6	297	/
Thallium µg/L	0.0925	0.0019	0.02925	0.0042	0.0021	0.00045	0.00015	0.001	0.001375	0.8
Thorium µg/L	0.00425	0.009	0.01925	0.00245	0.0083	0.0118	0.00015	0.0298	0.00045	/
Tin µg/L	0.08	0.015	0.015	0.037	0.015	0.0318	0.0387	0.015	0.005725	/
Titanium µg/L	0.65	0.67	0.862	1.129	0.756	0.4875	0.6475	1.285	1.025	/
Uranium µg/L	0.43	0.437	0.5905	0.454	0.433	0.463	0.445	1.3055	0.4455	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	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	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.

Values in red exceed their 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

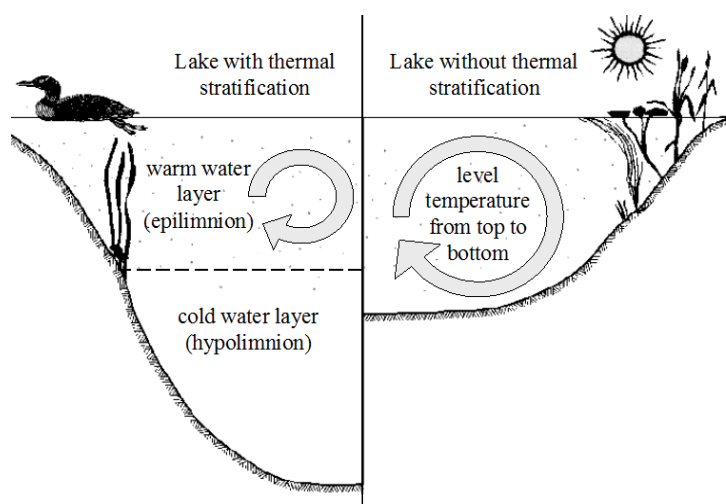


Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

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.

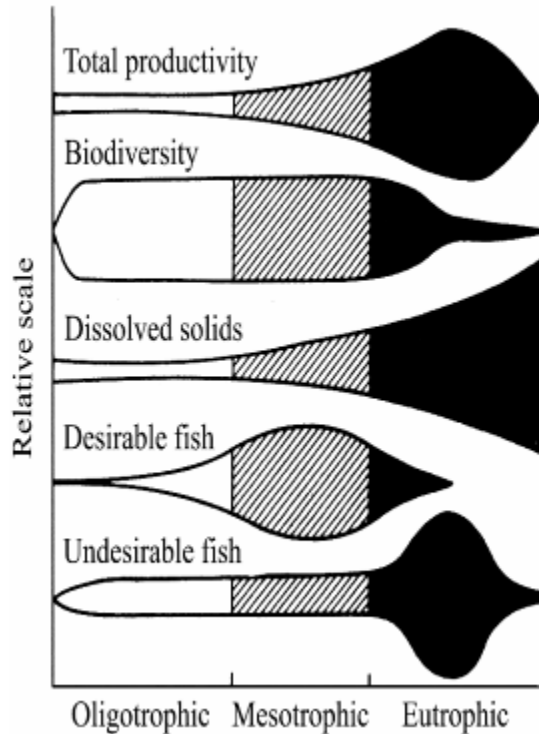


Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

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