



*THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM*

2011 Moose Lake Report

COMPLETED WITH SUPPORT FROM:





Alberta Lake Management Society's LakeWatch Program

LakeWatch has several important objectives, one of which is to collect and interpret water quality data 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 and LakeWatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Sean and Carmen Verrier for their efforts in collecting data in 2011, and Kay Lee Kinch for coordinating the program this summer. We would also like to thank Jessica Davis and Pauline Pozsonyi who were summer interns with ALMS in 2011. Program Coordinator Bradley Peter was instrumental in planning and organizing the field program. Technologists Shelley Manchur and Brian Jackson were involved in the training aspects of the program. Doreen LeClair, Chris Rickard, and Lisa Reinbolt were responsible for data management. Théo Charette, Ron Zurawell, Lori Neufeld, and Sarah Lord prepared the original report, which was updated for 2011 by Bradley Peter and Arin Dyer. Alberta Environment, the Beaver River Watershed Alliance (BRWA), and the Municipal District of Wainwright were major sponsors of the LakeWatch 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 km² 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.

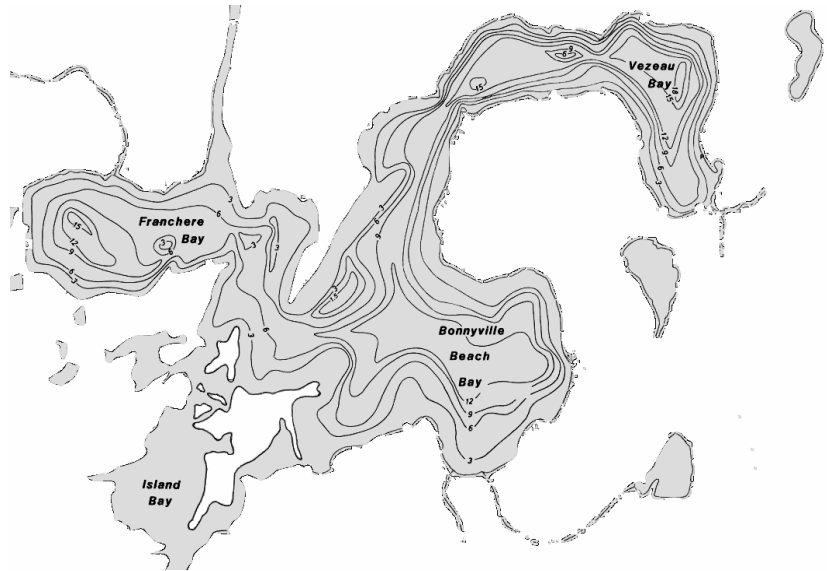


Figure 1 – Bathymetric map of Moose Lake.¹

The lake was once known by its French name Lac d'Original, which was inspired by the abundance of moose.¹ In 1789, Angus Shaw established a trading post for the North West Company on the northwest shore of Moose Lake, the earliest white settlement 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.¹

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 1936.¹ 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 exalbescens*).

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

WATER LEVELS:

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.

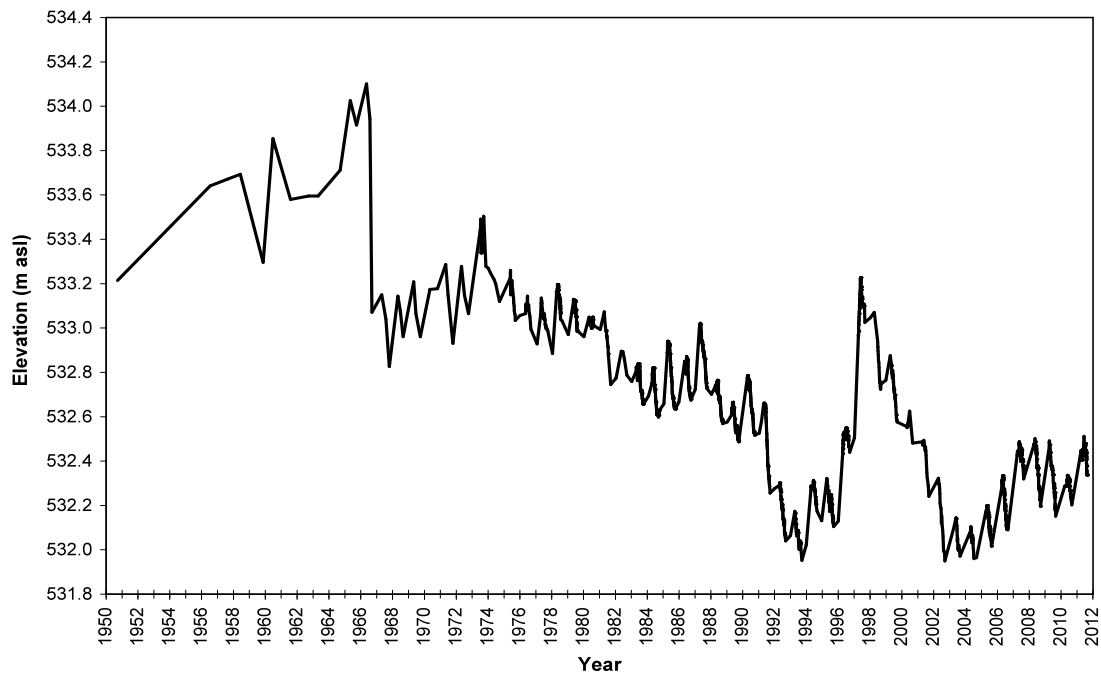


Figure 2 – Historical water levels for Moose Lake in meters above sea level (m asl) retrieved from Alberta Environment

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 recent years, water levels have fluctuated between 532.2 m asl and 532.4 m asl.

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 measured at Moose Lake during the summer of 2011 was 2.88 m. This value is slightly more transparent than the recorded historical average (Table 1). Multiplying the average by two provides the euphotic depth, which suggests that enough light is available for photosynthesis for the first 5.76 m, or 50% of the water column. Throughout the summer, Secchi disk depth changed greatly, measuring a seasonal maximum of 5.25 m on June 28th, and 1.50 m on both August 14th and August 23rd. Because of the sharp decline in transparency during August, it is likely that algae/cyanobacteria play a large role in reducing the water transparency at Moose Lake.

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.

Throughout the summer, surface water temperature at Moose Lake changed by 6.63 °C (Figure 3a). On August 14th, surface water temperature was at a maximum of 21.21°C, while on September 23rd, surface water temperature had decreased to 14.58 °C. Weak stratification was observed only on June 28th, where a thermocline was present between 8.5-9.5 m. The presence of a thermocline contributes to the depletion of dissolved oxygen in deeper waters.

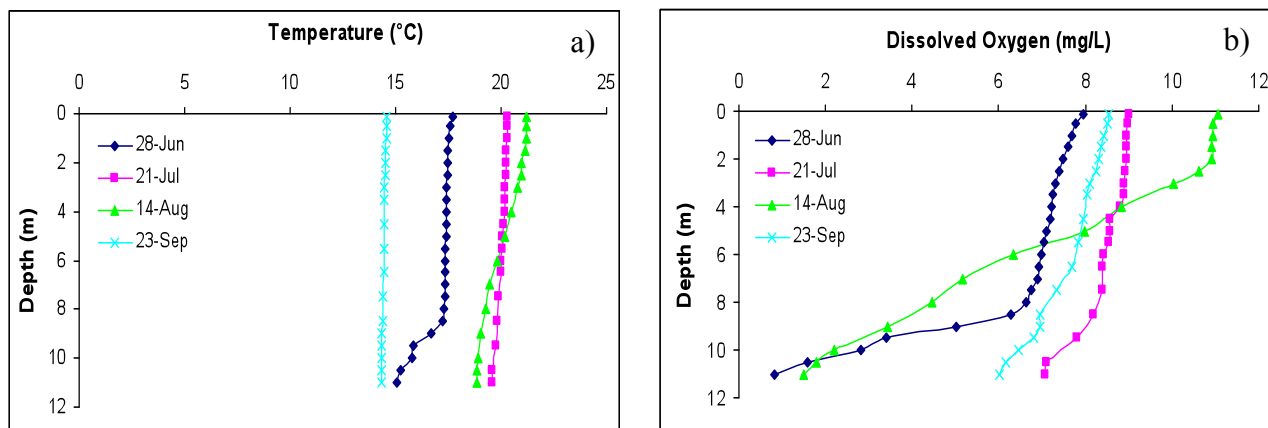


Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Moose Lake measured four times during the summer of 2011.

Surface dissolved oxygen at Moose Lake varied between a seasonal minimum of 7.95 mg/L on June 28th, to a maximum of 11.07 mg/L on August 14th (Figure 3b). On June 28th and August 14th, dissolved oxygen concentration proceeded towards anoxia near the

lakebed. Anoxia is often the result of decaying organic matter (mainly algae/cyanobacteria) in lower depths which is an oxygen consuming process. Moose Lake was well oxygenated for most of its depth, measuring above the Canadian Council for Ministers of the Environment guideline of 6.5 mg/L for the Protection of Aquatic Life for more than half of the water column.

WATER CHEMISTRY:

*ALMS measures a suite of water chemistry parameters. Phosphorous, 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 Phosphorous (TP) measured at Moose Lake during 2011 was 49 µg/L, which falls into the eutrophic, or nutrient rich, classification. This falls well within the range of natural variation measured at Moose Lake in the past. TP increased steadily from June to August, ranging from 31 µg/L to 70 µg/L, and began to decline in September, to 50 µg/L (Figure 4).

Average Total Kjeldahl Nitrogen (TKN) measured 1615 µg/L, which falls into the hypereutrophic, or extremely nutrient rich, classification. Similar to TP, TKN increased steadily throughout the summer, and began to decline in September.

Finally, chlorophyll-*a* concentration, an indirect measure of algae/cyanobacterial biomass, measured an average of 46.14 µg/L. This value falls into the hypereutrophic classification, and is the highest average recorded since monitoring began in 1986. Chlorophyll-*a* concentration changed dramatically throughout the summer, measuring a minimum of 2.67 µg/L on June 28th, and maximum of 119 µg/L on July 21st.

Average pH measured at Moose Lake was 8.7, well above neutral. High bicarbonate concentrations (371.5 mg/L HCO₃) and high alkalinity (334 CaCO₃) help to buffer the lake against changes to pH. Other dominant ions include sodium (114 mg/L) and sulphate (156 mg/L). Concentrations of microcystin, a toxin produced by cyanobacteria, were high during the summer of 2011 (1.18 µg/L). Metals were also measured during the summer at 2011, and all values fell within their respective guidelines.

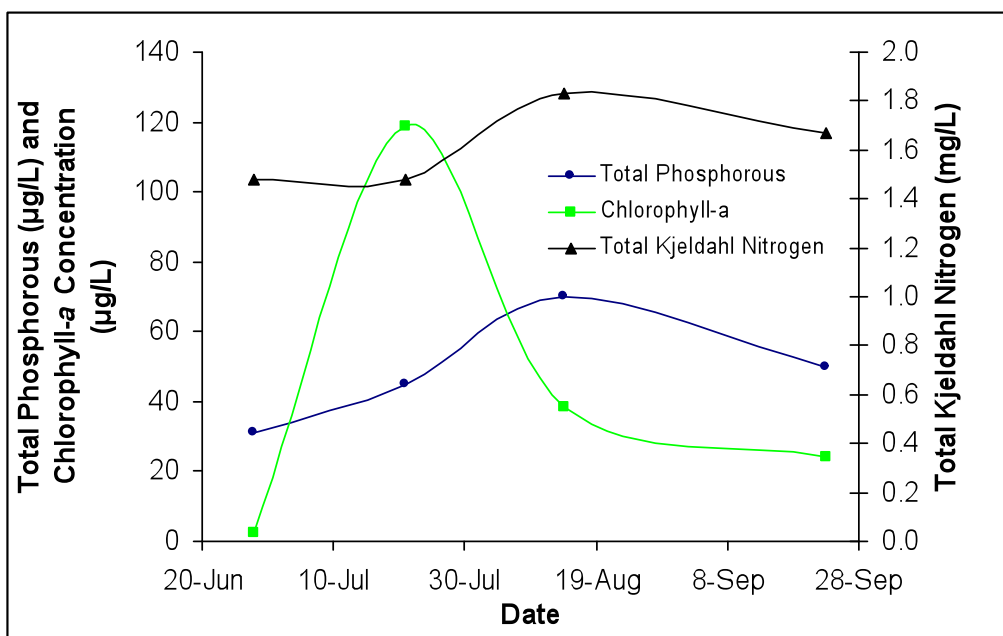


Figure 4 - Total phosphorous (µg/L), chlorophyll-a concentration (µg/L), and total Kjeldahl nitrogen (mg/L), measured five times over the course of the summer at Moose Lake.

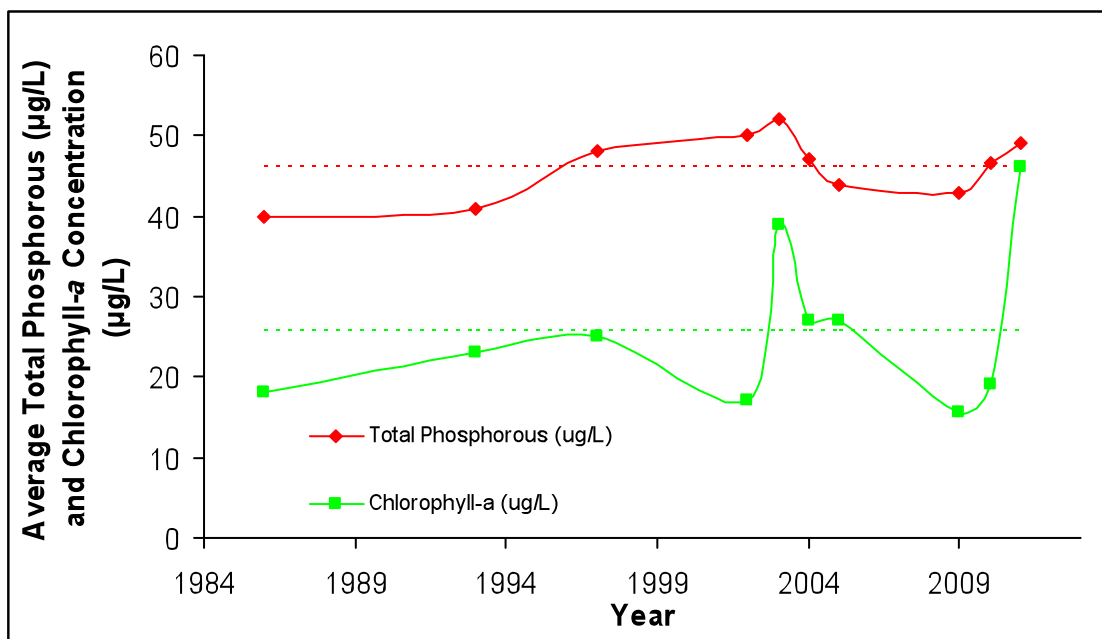


Figure 5 – Historical total phosphorous (µg/L) and chlorophyll-a (µg/L) concentrations measured at Moose Lake from 1986-2011.

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

Parameter	1986	1993	1997	2002	2003	2004	2005	2009	2010	2011
TP (µg/L)	40	41	48	50	52	47	44	43	46.5	49
TDP (µg/L)	/	/	/	13	15	15	13	20.00	16.8	17.8
Chlorophyll-a (µg/L)	18	23	25	17	39	27	27	16	19.03	46.14
Secchi depth (m)	2.5	2	2.8	1.6	2.2	2.7	2.2	3.1	1.56	2.88
TKN (µg/L)	/	/	/	/	/	/	/	1589	1700	1615
NO ₂ and NO ₃ (µg/L)		3		1.5	16	5.3	<5	8.75	7.75	3.63
NH ₃ (µg/L)	/	/	/	6.1	33	44	13	43	23.5	30.8
DOC (mg/L)	/	/	/	/	/	/	/	17.6	18.50	16.87
Ca (mg/L)	27	24	28	27	25	24	25	24	21	23.57
Mg (mg/L)	36	44	42	50	54	51	47	48	51	56
Na (mg/L)	66	84	84	97	111	113	114	117	124	114
K (mg/L)	12	14	15	18	17	17	20	20	18.6	20.3
SO ₄ ²⁻ (mg/L)	92	115	118	144	149	156	151	165	164.0	156
Cl ⁻ (mg/L)	13	16	19	22	23	24	25	28	28.6	27.4
CO ₃ (mg/L)	16	30	16	26	29	29	35	30	27.5	18
HCO ₃ (mg/L)	289	330	314	336	343	349	334	348	358	371.5
pH	8.6	9	8.6	8.8	8.9	8.9	9.0	8.9	8.9	8.7
Conductivity (µS/cm)	678	787	776	922	954	932	867	954	965	974
Hardness (mg/L)	/	/	131	/	122	128	/	260	260	290
TDS (mg/L)	400	474	480	590	573	/	580	604	610	599
Microcystin (µg/L)	/	/	/	/	/	/	0.42	0.59	0.11	1.177551
Total Alkalinity (mg/L CaCO ₃)	257	295	284	319	330	334	333	336	339	334

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO₂₊₃ = nitrate+nitrite, NH₃ = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO₄ = sulphate, Cl = chloride, CO₃ = carbonate, HCO₃ = bicarbonate. A forward slash (/) indicates an absence of data.

Table 2 - Concentrations of metals measured at Moose Lake on July 7th and September 10th 2010. Values shown for 2010 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	Guidelines
Aluminum µg/L	14.75	4.95	3.34	16.05	10.7	4.08	100 ^a
Antimony µg/L	0.075	0.065	0.065	0.058	0.0531	0.05605	6 ^e
Arsenic µg/L	1.99	2.03	2.19	2.12	2.16	2.085	5
Barium µg/L	46.1	50.2	47.8	45.4	44.9	46	1000 ^e
Beryllium µg/L	0.06	0.0015	0.0015	0.0038	0.0015	0.00385	100 ^{d,f}
Bismuth µg/L	0.00575	0.0011	0.0061	0.0061	0.0012	0.0005	/
Boron µg/L	169.5	172	176	197	185	202	5000 ^{ef}
Cadmium µg/L	0.03	0.007	0.00465	0.005	0.0048	0.0043	0.085 ^b
Chromium µg/L	0.325	0.87	0.606	0.298	0.22	0.2175	/
Cobalt µg/L	0.01	0.014	0.0205	0.0107	0.0067	0.03045	1000 ^f
Copper µg/L	0.56	0.75	0.607	0.492	0.263	0.4985	4 ^c
Iron µg/L	3.25	1	37	8.05	7.65	22.8	300
Lead µg/L	0.079	0.0472	0.08015	0.216	0.0114	0.0134	7 ^c
Lithium µg/L	40.05	53.4	57.3	61.2	53.1	70.75	2500 ^g
Manganese µg/L	9.28	8.14	7.26	7.55	7.2	5.615	200 ^g
Molybdenum µg/L	0.59	0.846	0.7045	0.598	0.556	0.6275	73 ^d
Nickel µg/L	0.03	0.0025	0.11	<0.005	0.0025	0.16275	150 ^c
Selenium µg/L	0.525	0.27	0.2755	0.3955	0.375	0.3575	1
Silver µg/L	0.0025	0.0025	0.0013	0.0016	0.0018	0.007675	0.1
Strontium µg/L	282.5	309	307.5	303	281	287.5	/
Thallium µg/L	0.0925	0.0019	0.02925	0.0042	0.0021	0.00045	0.8
Thorium µg/L	0.00425	0.009	0.01925	0.00245	0.0083	0.0118	/
Tin µg/L	0.08	0.015	0.015	0.037	0.015	0.0318	/
Titanium µg/L	0.65	0.67	0.862	1.129	0.756	0.4875	/
Uranium µg/L	0.43	0.437	0.5905	0.454	0.433	0.463	100 ^e
Vanadium µg/L	0.445	0.388	0.3845	0.29	0.244	0.2605	100 ^{f,g}
Zinc µg/L	2.98	7.9	4.335	0.722	0.498	0.68	30

Values represent means of total recoverable metal concentrations.

^a Based on pH \geq 6.5; calcium ion concentrations $[\text{Ca}^{+2}] \geq 4$ mg/L; and dissolved organic carbon concentration $[\text{DOC}] \geq 2$ mg/L.

^b Based on water Hardness of 300 mg/L (as CaCO_3)

^c Based on water hardness > 180 mg/L (as CaCO_3)

^d CCME interim value.

^e Based on Canadian Drinking Water Quality guideline values.

^f Based on CCME Guidelines for Agricultural use (Livestock Watering).

^g 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

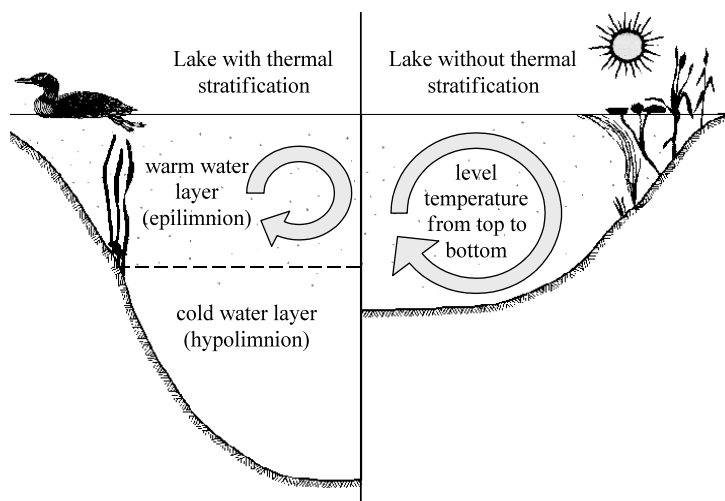


Figure A: Difference in the circulation of the water column depending on thermal stratification.

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⁻¹ and should not average less than 6.5 mg•L⁻¹ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg•L⁻¹ 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.

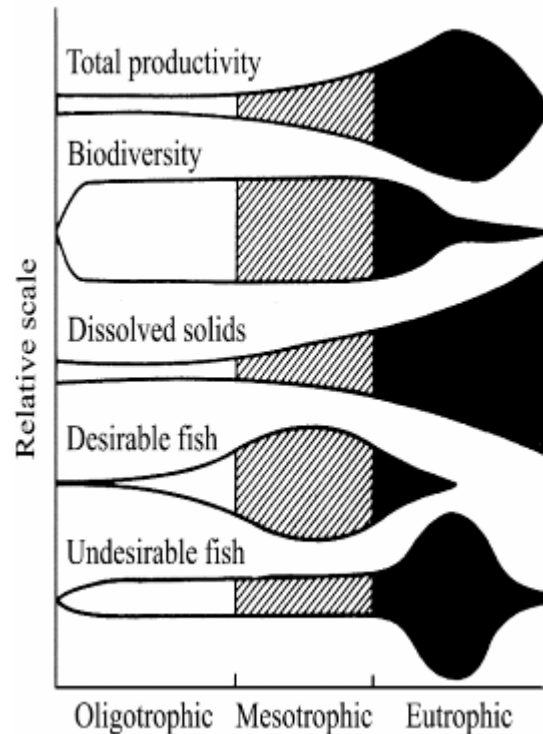


Figure B: Suggested changes in various lake characteristics with eutrophication.

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

Trophic state	Total Phosphorus (µg•L ⁻¹)	Total Nitrogen (µg•L ⁻¹)	Chlorophyll a (µg•L ⁻¹)	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