



*The Alberta Lake Management Society
Volunteer Lake Monitoring Program*

Moose Lake

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2009 Report

Completed with support from:



Alberta Lake Management Society

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Water is integral to supporting and maintaining life on this planet as it moderates the climate, creates growth and shapes the living substance of all of Earth's creatures. It is the tide of life itself, the sacred source.

David Suzuki (1997) The Sacred Balance

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 these 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 Kay Lee Kinch and Virginia Brietzke for their efforts in collecting data in 2009. We would also like to thank Noemie Jenni and Cristen Symes who were summer interns with ALMS in 2009. Project Technical Coordinator, Jill Anderson was instrumental in planning and organizing the field program. Technologists, Shelley Manchur, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Théo Charette (ALMS President) and Jill Anderson (Program Manager) were responsible for program administration and planning. Théo Charette and Lori Neufeld prepared the original report, which was updated by Sarah Lord for 2009. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Moose Lake

Moose Lake (**Figure 1**) is located 240 km NE 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.

The lake was once known by its French name Lac d'Orignal, which was inspired by the abundance of moose (Mitchell and Prepas 1990). 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 1900s, French Canadian settlers began arriving in the area. In 1928, the railway was extended from St. Paul to Bonnyville.



Figure 1. Bathymetric map of Moose Lake. Contours represent 3 m intervals.

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. 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 submerging plants are pondweeds (*Potamogeton spp.*) and northern watermilfoil (*Myriophyllum exalbescens*).

Results

Water Level

Water levels in Moose Lake have been monitored since 1950, at a time when water levels were measured at 533.2 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. Then weir deteriorated, and water levels dropped to a low of 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.

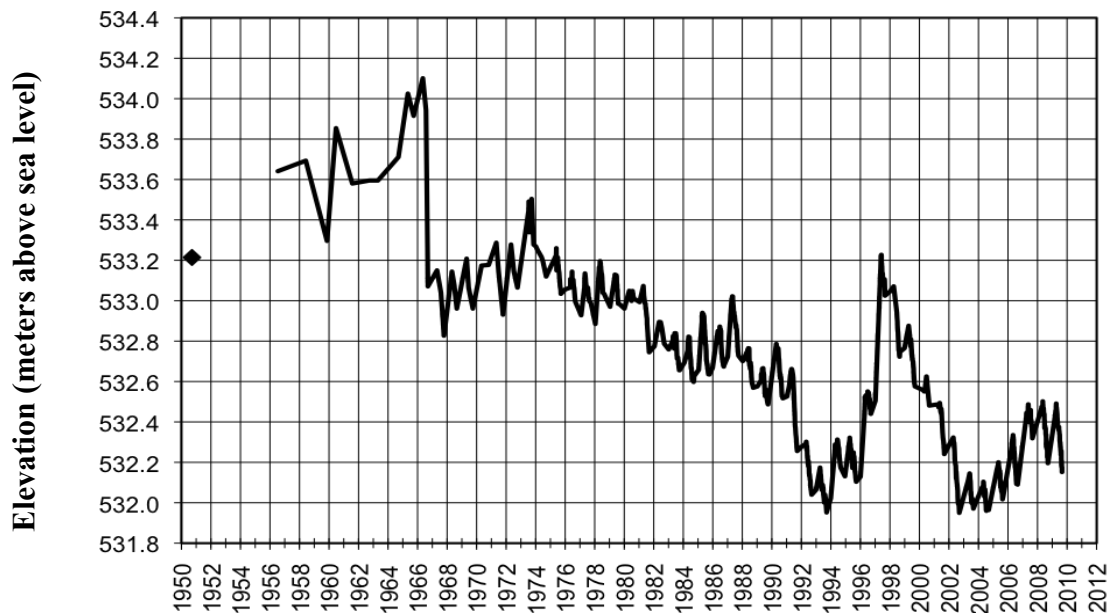


Figure 2. Historical water levels (m asl) in Moose Lake, Alberta 1951 – 2009.

The new weir was 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 531.9 m asl. In 2003, the average water level increased to 532.1 m asl, which is 0.62 m below the long-term

average. The withdraw limit for the Town of Bonnyville is 3 million m³/year. This would account for approximately 0.8 m of depth if the maximum limit was extracted, and there were no runoff from the watershed (Mitchell and Prepas 1990).

Water Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. Please refer to the end of this report for descriptions of technical terms.

Thermal stratification in Moose Lake was not observed during the summer of 2009 (**Figure 3**). On 30 June, surface water temperature was 17.9°C and declined to 14.5°C at the lakebed. On 21 July, surface water temperature warmed to 18.9°C, and increased to a seasonal recorded maximum of 19.9°C on 6 August. Surface water temperature declined slightly to 19.5°C on 31 August.

Dissolved oxygen (DO) concentrations in upper layers of surface waters of Moose Lake were ≥ 7 mg/L on all sampling dates through the summer, well within the acceptable range for surface water quality (DO ≥ 5.0 mg/L) (**Figure 3**). DO concentrations declined gradually with depth, reaching near zero (e.g. anoxic) below 10 m depth on 30 June and 31 August. On 21 July and 6 August, deep waters remained well-oxygenated with DO concentrations above 5.0 mg/L. Deep-water anoxia is common in summer, as bacterial decomposition of organic matter at the lakebed consumes oxygen.

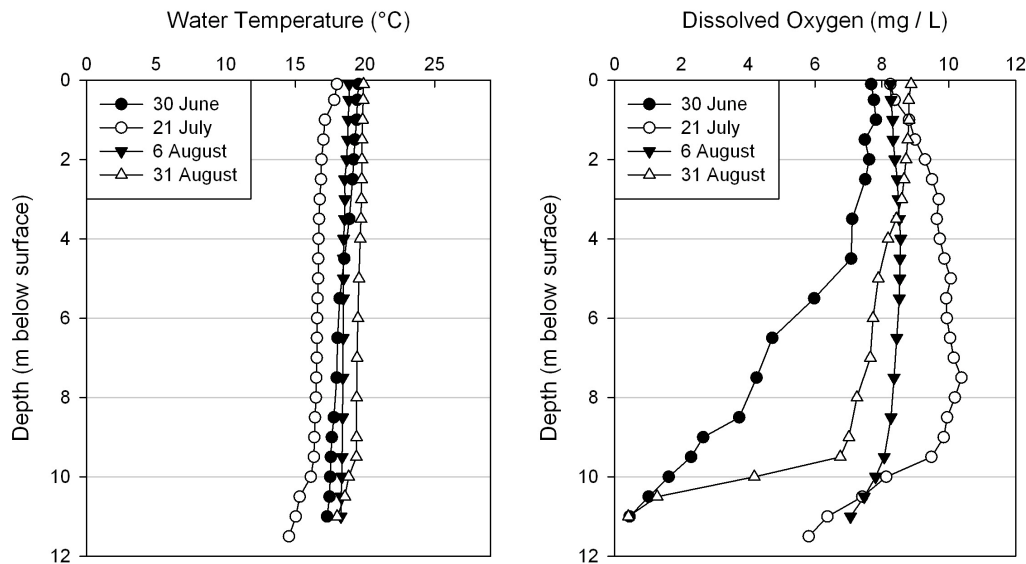


Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Moose Lake during the summer of 2009.

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.

Water clarity on Moose Lake was measured four times during the summer of 2009. Moose Lake was relatively clear compared to other lakes in Alberta, with average Secchi depth of 3.06 m (**Table 1**). On 30 June, light penetrated 6.25 m or ~57% of the total lake depth, which allowed for algal growth in the entire water column of the lake. By 21 July, Secchi depth had decreased to 2.75 m, and dropped further to 2.0 m by 6 August. Water clarity reached a seasonal recorded minimum of 1.25 m Secchi depth on 31 August. This pattern of water clarity dynamics is typical of highly productive Alberta lakes, when algal growth during July and August causes reduced water clarity. Water clarity typically recovers in September as lower temperatures limit growth, and dying algae fall out of the water column and settle on the lakebed where they are decomposed by anaerobic bacteria.

Water Chemistry

Based on lake water characteristics, Moose Lake is considered eutrophic (see *A Brief Introduction to Limnology* at the end of this report). In 2009, Moose Lake had high concentrations of total phosphorus (average TP = 42.8 µg/L), total nitrogen (average TN = 1596 µg/L), and algal biomass (average chlorophyll *a* = 15.7 µg/L) in 2009 (**Table 1**). Total phosphorous increased over the summer, from 41 µg/L on 30 June to a seasonal recorded maximum of 56 µg/L on 31 August (**Figure 4**). Total nitrogen also increased, from 1.397 mg/L to 1.799 mg/L between June and August. Chlorophyll *a* (a measure of algal biomass) increased steadily 3.94 µg/L on 30 June to 27.6 µg/L on 31 August.

During the summer 2009, Moose Lake was well buffered from acidification with an average pH = 8.9, which is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, sodium, and magnesium (**Table 1**). Ion concentrations have increased since first reported in 1986, but are still well below levels that would impair water quality.

The average concentrations of various metals (as total recoverable concentrations) in Moose Lake were measured twice in the summer of 2009. All concentrations were within CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

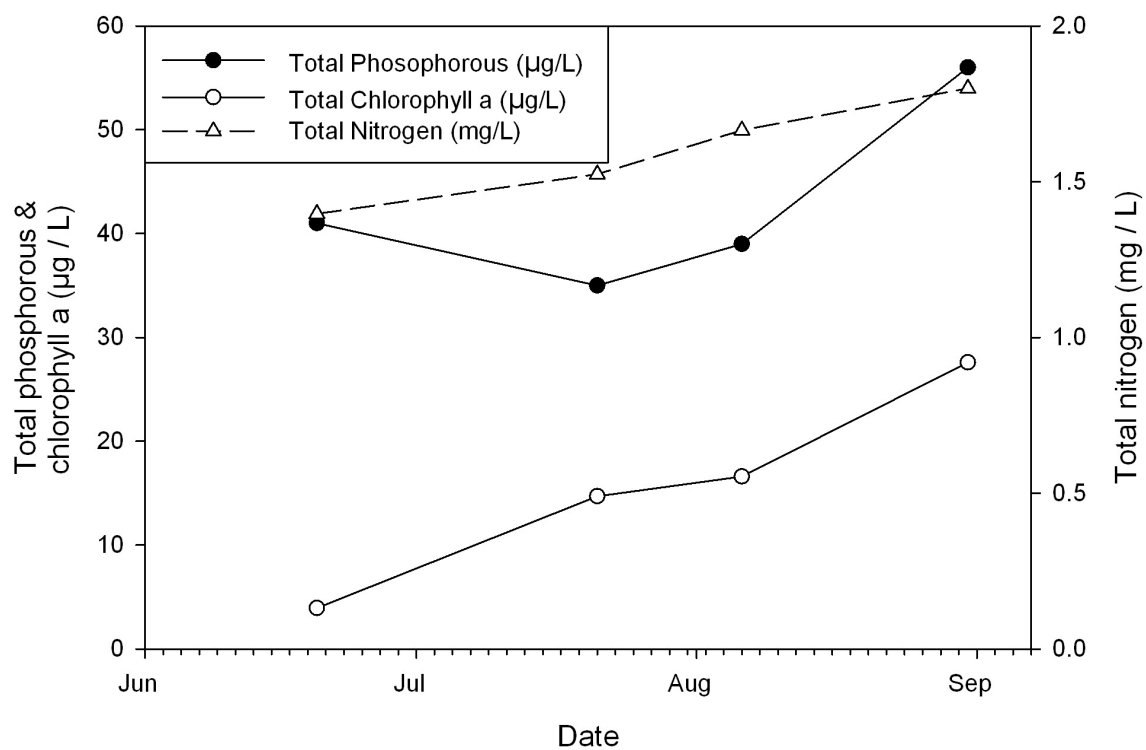


Figure 4. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Moose Lake during the summer of 2009.

Table 1. Mean water chemistry and Secchi depth values for Moose Lake, summer 2009 compared to previous years.

Parameter	1986	1993	1997	2002	2003	2004	2005	2009
TP (µg/L)	40	41	48	50	52	47	44	42.8
TDP (µg/L)	-	-	-	13	15	15	13	20.0
Chlorophyll- <i>a</i> (µg/L)	18	23	25	17	39	27	27	15.7
Secchi depth (m)	2.5	2.0	2.8	1.6	2.2	2.7	2.2	3.06
TKN (µg/L)								1589
NO _{2,3} (µg/L)	-	3.0	-	1.5	16	5.3	<5	8.75
NH ₄ (µg/L)	-	-	-	6.1	33	44	13	43.0
Dissolved organic C (mg/L)	-	-	-	-	-	-	-	17.6
Ca (mg/L)	27	24	28	27	25	24	25	24.3
Mg (mg/L)	36	44	42	50	54	51	47	48.4
Na (mg/L)	66	84	84	97	111	113	114	117.3
K (mg/L)	12	14	15	18	17	17	20	19.7
SO ₄ ²⁻ (mg/L)	92	115	118	144	149	156	151	165
Cl ⁻ (mg/L)	13	16	19	22	23	24	25	27.6
TDS (mg/L)	400	474	480	590	573	-	580	604
pH	8.6	9.0	8.6	8.8	8.9	8.9	9.0	8.9
Conductivity (µS/cm)	678	787	76	922	954	932	867	954
Hardness (mg/L)	-	-	-	-	-	-	-	260
HCO ₃ (mg/L)	289	330	314	336	343	349	334	348
CO ₃ (mg/L)	16	30	16	26	29	29	35	30.3
Total Alkalinity (mg/L CaCO ₃)	257	295	284	319	330	334	333	336

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl_a = chlorophyll *a*, TKN = total Kjeldahl nitrogen, NO₂₊₃ = nitrate+nitrite, NH₄ = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO₄ = sulphate, Cl = chloride, CO₃ = carbonate, HCO₃ = bicarbonate.

*Atlas of Alberta Lakes (Mitchell and Prepas, 1990).

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Appendix 1

Mean concentrations of metals in Moose Lake, summer 2009, compared to previous years and to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals (total)	2003	2004	2005	2009	Guidelines
ALUMINUM µg/L	14.75	4.95	3.34	16.05	100 ^a
ANTIMONY µg/L	0.075	0.065	0.065	0.058	6 ^e
ARSENIC µg/L	1.99	2.03	2.19	2.12	5
BARIUM µg/L	46.1	50.2	47.8	45.4	1000 ^e
BERYLLIUM µg/L	0.06	0.0015	0.0015	0.0038	100 ^{d,f}
BISMUTH µg/L	0.00575	0.0011	0.0061	0.0061	
BORON µg/L	169.5	172	176	197	5000 ^{e,f}
CADMIUM µg/L	0.03	0.007	0.00465	0.005	0.085 ^b
CHROMIUM µg/L	0.325	0.87	0.606	0.298	
COBALT µg/L	0.01	0.014	0.0205	0.0107	1000 ^f
COPPER µg/L	0.56	0.75	0.607	0.492	4 ^c
IRON µg/L	3.25	1.0	37	8.05	300
LEAD µg/L	0.079	0.0472	0.08015	0.216	7 ^c
LITHIUM µg/L	40.05	53.4	57.3	61.2	2500 ^g
MANGANESE µg/L	9.28	8.14	7.26	7.55	200 ^g
MOLYBDENUM µg/L	0.59	0.846	0.7045	0.598	73 ^d
NICKEL µg/L	0.03	0.0025	0.11	<0.005	150 ^c
SELENIUM µg/L	0.525	0.27	0.2755	0.3955	1
SILVER µg/L	0.0025	0.0025	0.0013	0.0016	
STRONTIUM µg/L	282.5	309	307.5	303	
THALLIUM µg/L	0.0925	0.0019	0.02925	0.0042	0.8
THORIUM µg/L	0.00425	0.009	0.01925	0.00245	
TIN µg/L	0.08	0.015	0.015	0.037	
TITANIUM µg/L	0.65	0.67	0.862	1.129	
URANIUM µg/L	0.43	0.437	0.5905	0.454	100 ^e
VANADIUM µg/L	0.445	0.388	0.3845	0.29	100 ^{f,g}
ZINC µg/L	2.98	7.9	4.335	0.722	30
FLUORIDE mg/L	-	0.24	0.0273	-	1.5

With the exception of fluoride (which reflects the mean concentration of dissolved fluoride only), values represent means of total recoverable metal concentrations.

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

^b Based on water Hardness of 300 mg/L (as CaCO₃).

^c Based on water Hardness > 180 mg/L (as CaCO₃).

^d CCME interim value.

^e Based of Canadian Drinking Water Quality guideline values.

^f Based of CCME Guidelines for Agricultural Use (Livestock Watering).

^g Based of CCME Guidelines for Agricultural Use (Irrigation).

A Brief Introduction to Limnology

Indicators of water quality

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to 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 affected (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 fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 6). 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 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 0° C water on the top.

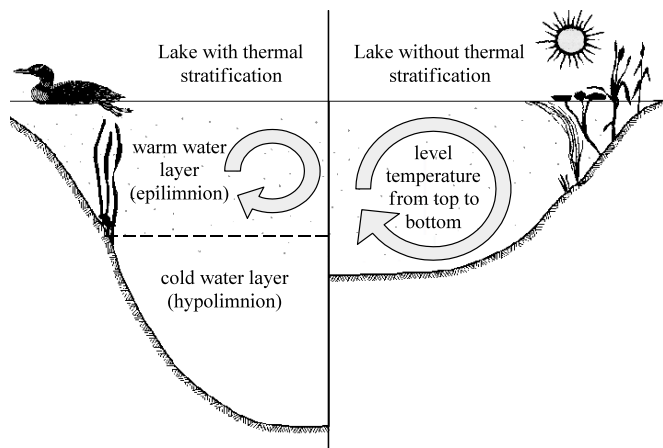


Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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 and should not average less than 6.5 mg/L over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg/L 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. Larger aquatic plants, known as macrophytes, rather than algae, dominate some highly productive lakes. In these lakes, chlorophyll-*a* and nutrient values taken from water samples do not include productivity from large aquatic plants. As a result, lakes like Chestermere, which are dominated by macrophytes, can exist at 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 Depth

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. Secchi disk depth is the oldest, simplest, and quickest quantitative measure of water clarity. A Secchi disk is a black and white disk that is lowered down through

the water column until it can no longer be seen. Secchi disk depth is the midpoint between the depth at which it disappears when lowered and reappears when it is pulled up again. The Secchi disk depth in lakes with high algal biomass will generally be shallow. However, Secchi disk depth is not only affected by algae. 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 shallow Secchi disk depths despite low algal growth and nutrient concentrations.

The euphotic zone, calculated as twice the Secchi disk depth, is the portion of the water column that has sufficient light for aquatic plants to grow. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Aquatic plants are important because they ensure clear lake water by reducing shoreline erosion and stabilizing lake bottom sediments. Many lakes in Alberta are shallow and have bottom sediments with 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 fish, depend on aquatic plants for food and shelter.

Trophic state

Trophic state is a classification system for lakes that depends on fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll-*a*) concentrations, the trophic states are: **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. The nutrient and algal biomass concentrations that define these categories are shown in table 2 and a graph of Alberta lakes compared by trophic state can be found on the ALMS website. A majority of lakes in Alberta are meso- to eutrophic because they naturally contain high nutrient concentrations due to our deep fertile soils. Thus, lakes in Alberta are susceptible to human impacts because they are already nutrient-rich; any further nutrient increases can bring about undesirable conditions illustrated in Figure. 7.

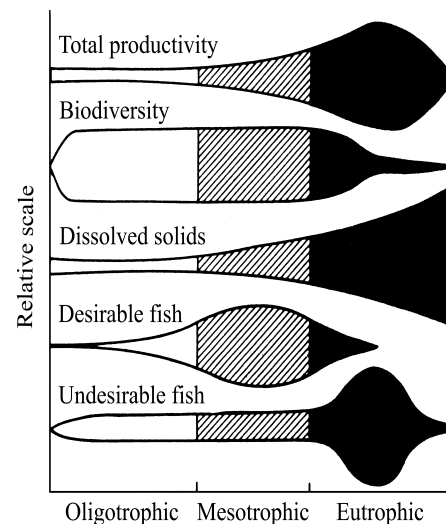


Figure 7: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

Table 2: Trophic status based on lake water characteristics

Trophic state	Total Phosphorus (µg/L)	Total Nitrogen (µg/L)	Chlorophyll a (µg/L)	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

Note: These values are from a detailed study of global lakes reported in Nurnberg 1996. Alberta Environment uses slightly different values for TP and CHL based on those of the OECD reported by Vollenweider (1982). The AENV and OECD cutoffs for TP are 10, 35 and 100; for CHL are 3, 8 and 25. AENV does not have TN or Secchi depth criteria. The corresponding OECD exists for Secchi depth and the cutoffs are 6, 3 and 1.5 m.