Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Moose Lake

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2004 Report

Completed with support from:

Alberta Lake Management Society
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University of Alberta,
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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 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

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Moose Lake

Moose Lake is located 240 km NE of Edmonton and 3.5 km west of the Town of Bonnyville. 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 (Mitchell and Prepas 1990), the earliest white settlement known to Alberta (Alberta Recreation, Parks and Wildlife Foundation 1992). Later in the early 1900's, French Canadian settlers began arriving in the area. Soon after, in 1928, the railway was extended from St. Paul to Bonnyville (Mitchell and Prepas 1990). Moose Lake was in high demand for its abundance of natural resources for a rapidly expanding population. Mink farming, agriculture, and three commercial fish-packing plants were in operation by 1936 (Mitchell and Prepas 1990). Commercial, domestic and recreational fisheries are currently managed in Moose Lake (Bodden 2002). Walleye (*Stizostrdion vitreum*), northern pike (*Esox lucius*) and yellow perch (*Perch flavescens*) are the most popular sport fish however; the lake also contains cisco (*Coregenus artidii*), lake whitefish (*Corehonus clupeaformis*), burbot (*Lota lota*), suckers and forage fish. Shoreline developement is intense with cottage subdivisions, campgrounds, and summer villages. Moose Lake receives heavy use during summer, particularly on weekends. (Mitchell and Prepas 1990). 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*).

Moose Lake has over 64 km of irregular shoreline within a 40 km^2 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 (**Figure 1**). A sounding (depth measurement) was last conducted in 1962. Moose Lake is eutrophic, and murky periodically throughout the summer. Dense blue-green algal (*Anabaena sp*.) blooms occur during the late summer or fall (Mitchell and Prepas 1990), while May and June tend to have better water clarity (Mitchell 1999). Phosphorus concentrations are received normally from run-off and bottom sediments (Mitchell and Prepas 1990), which have accumulated since the lake formed about 10,000 years ago (AENV 1989). Nutrient concentrations increase throughout the summer and may peak as late as September with an associated peak biomass for chlorophyll *a* (measured algal biomass). More than 100 species of blue-green algae have been recorded in Alberta. A typical lake water sample usually contains 20 or more blue-green algae species. However, the most troublesome blooms in central Alberta lakes are caused by three species of blue-green algae: *Aphanizomenon flos-aquae, Microcystis aeruginosa, and Anabaena flos-aquae*.

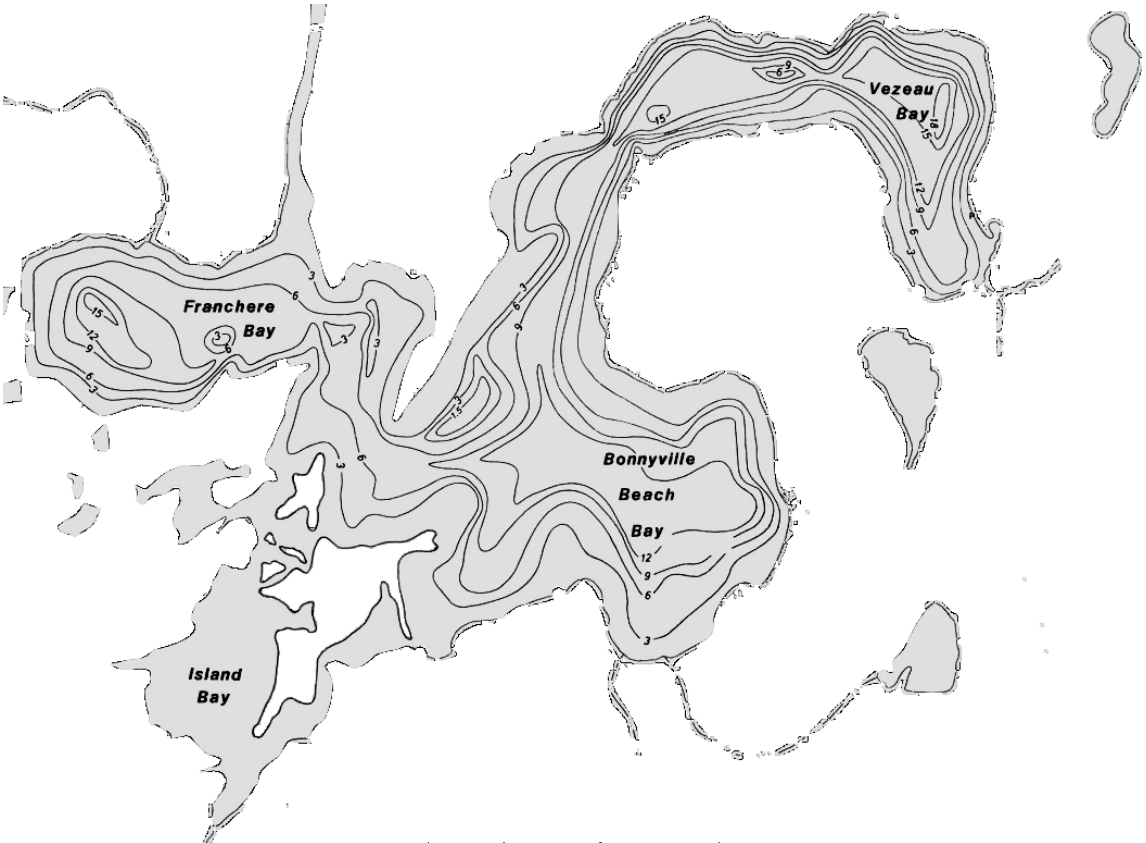


Figure 1. Bathymetric map of Moose Lake. Contours represent 3 m.

Water levels

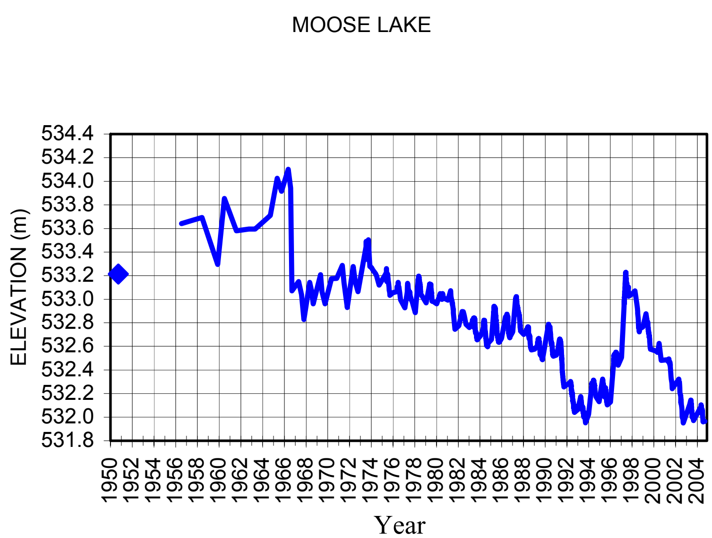


Figure 2. Historic water levels for Moose Lake, 1950 to 2004.

Water levels in Moose Lake have been monitored since 1950, at that time water levels were measured at 533.2 m above sea level (**Figure 2**). Concern over lowering water levels resulted in the construction of a weir in 1951. Water levels then rose steadily to 534.10 m by 1966 (**Figure 2**). The weir deteriorated, and water levels dropped to a low of 532.60 m in 1968. Water levels showed a step fluctuation for the next 20 years. A new weir with a target elevation of

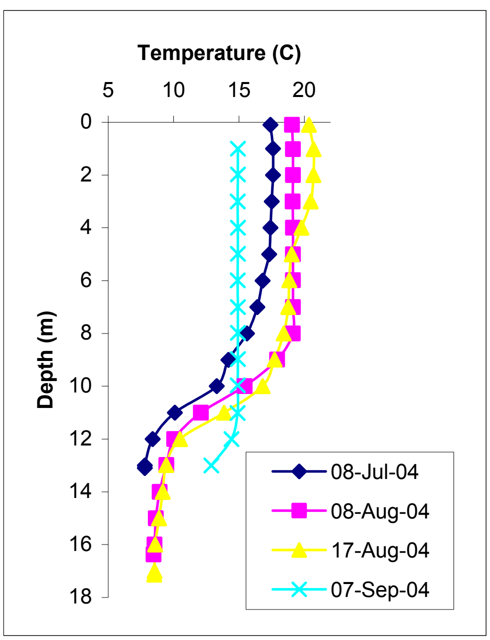
533.23 m was installed in 1986 to ensure habitat for fish and waterfowl, recreational enjoyment and drinking water (Mitchell and Prepas, 1990). The new weir was ineffective as water levels continued to drop to the lowest recorded level of 531.95 m in Oct. 1993. In 1996, and 1997 water levels were restored to 533.23 m by July 1997 (the weir crest). Unfortunately, due to recent droughts, water levels again declined to 1994 levels. The lowest water level on record was matched in October 2002 at 531.9 m (**Figure 2**). In 2003, the average water level increased to 532.05 m, this is however, 0.62 m below the long-term average. Water levels in 2004 remained consistent with the 2003 levels. The withdraw limit for the Town of Bonnyville is 3 million m^3/year, this would account for approximately 0.8 m of depth if the maximum limit were extracted, and there were no runoff from the watershed (Mitchell and Prepas 1990).

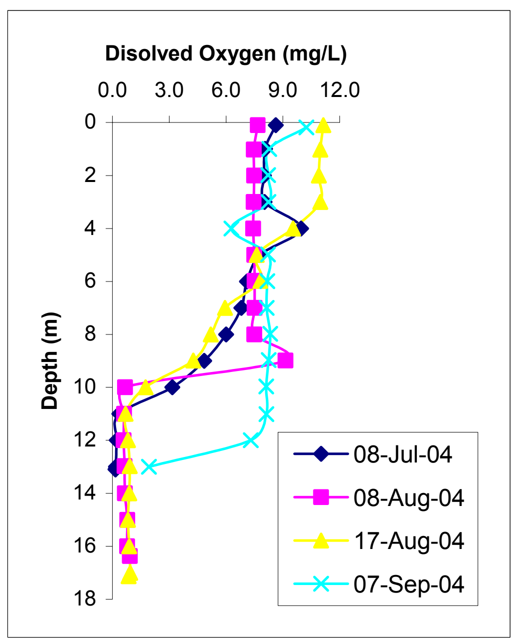
Results

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.

A very weak thermal stratification was apparent at 10 m in Moose Lake, during the summer of 2004 (**Figure 3**). Consequently, the entire water column was well aerated and dissolved oxygen concentrations were above 5 mg/L, to this depth (**Figure 4**).





Figures 3 & 4. Temperature and Dissolved Oxygen profiles of Moose Lake summer 2004.

This meets the provincial guidelines for the protection of aquatic life, for oxygen concentration, except at the very bottom near the sediments. This is common since the lake bottom is where most of the oxygen-consuming decomposition of organic
This meets the provincial guidelines for the protection of aquatic life, for oxygen concentration, except at the very bottom near the sediments. This is common since the lake bottom is where most of the oxygen-consuming decomposition of organic
matter occurs. In general, the water column of Moose Lake was well aerated.

Water clarity and Secchi Depth

Suspended materials, both living and dead, influence water clarity, as well as some coloured dissolved compounds in the water column. During the melting of snow and ice in spring, lake water can become cloudy from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

In 2004, Moose Lake's water was fairly clear with a mean Secchi disk depth of 2.69 m. Average water clarity in 2004 was .49 m clearer than in 2003 (**Table 1**). Water clarity was greatest in early July at 5.5 m, clarity declined to 3 m in late August and then gradually increased to 3.5 m by late September. The water clarity of Moose Lake followed patterns in algal biomass, or water greenness (**Figure 5**).

Water chemistry

Moose Lake had high nutrient concentrations and algal biomass compared to lakes throughout Canada, and therefore is considered eutrophic (*see details on trophic status classification at end of this report*). In the Alberta context, Moose Lake is perhaps a bit above average in these characteristics. In 2004, total phosphorus, total nitrogen, and consequently, algal biomass, all increased throughout the summer (**Figure 5**). Algal biomass increased 3 fold from early August to early September indicating a hypereutrophic condition in the lake during early fall (**Figure 5**).

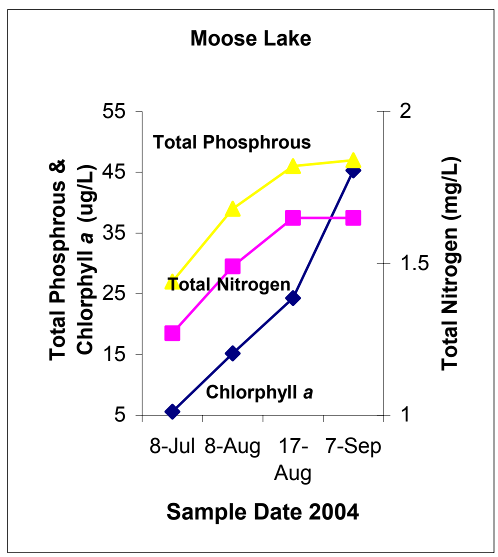


Figure 5. Total phosphorous, total nitrogen and chlorphyll *a* (i.e. water greenness) concentrations, summer 2004.

Algal biomass (as measured by chlorophyll *a* concentrations (**Figure 5**)) in Moose Lake were highest in the early fall of 2004. Moose Lake follows the typical pattern in Alberta lakes of an increase in nutrient and algae over the summer due to nutrient loading from sediment.

Moose Lake is well protected from acidification; its pH of 8.9 (**Table 1**) is well above that of pure water (i.e., pH 7). This is typical for most of northern Alberta lakes, on account of the parent material of the soils. Bicarbonate, sulphate, sodium, and magnesium are the dominant ions in Moose Lake. The concentration of most ions increased over the last two decades (**Table 1**), indicating that Moose Lake is not in hydrologic equilibrium. Since runoff has been quite low in the Cold Lake area over the same time, evaporative concentration is likely responsible for the change in ion concentration. As a result of the drought conditions experienced in the watershed of Moose Lake groundwater has become a significant contributor to the water budget of the Lake. The increase of groundwater inflow may explain the change in ion concentration. Groundwater is generally dominated by magnesium and sodium sulfate or chloride. Atmospheric deposition of acidifying pollutants is another possibility for the increasing sulfate concentrations. Increased sodium concentrations from sewage effluent or road salt application are typically associated with increasing chloride concentrations as well. However, since other ions not generated by petroleum burning or road salt also doubled during this time, these activities are not likely solely responsible for the differences. Despite these increases in ion concentrations, nutrients and algae have not changed much over the last two decades, which indicates that Moose Lake does not seem to be impacted by eutrophication.

Table 1. Average chemical characteristics of Moose Lake.

Parameter	1986	1993	1997	2002	2003	2004
Total P (µg/L)	40	41	48	50	52	47
TDP (µg/L)				13	15	15
Chla (µg/L)	18	23	25	17	39	27.02
Secchi (m)	2.5	2.0	2.8	1.6	2.2	2.69
Total N (mg/L)				1.4	1.7	1.57
NO_{2+3} (µg/L)		3.0		1.5	16	5.3
NH_4 (µg/L)				6.1	33	44
Ca (mg/L)	27	24	28	27	25	24.4
Mg (mg/L)	36	44	42	50	54	50.7
Na (mg/L)	66	84	84	97	111	113
K (mg/L)	12	14	15	18	17	17
SO_4 (mg/L)	92	115	118	144	149	156
Cl (mg/L)	13	16	19	22	23	24.4
CO_3 (mg/L)	16	30	16	26	29	29
HCO_3 (mg/L)	289	330	314	336	343	349
TDS (mg/L)	400	474	480	590	573	_
Conductivity ug/cm	678	787	776	922	954	932
pH	8.6	9.0	8.6	8.8	8.9	8.9
Total Alkalinity (mg/L $CaCO_3$)	257	295	284	319	330	334

Note: TDP = total dissolved phosphorus, Chla = chlorophyll a, TKN = total kjehldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = carbonate, Cond = conductivity, TDS = total dissolved solids.

The average concentrations of

various heavy metals (as total recoverable concentrations) were below CCME guidelines for the Protection of Freshwater Aquatic Life. Results of the metal analyses, compared to guideline values, are listed in Appendix 1.

Appendix 1

Mean concentrations of total metals, Moose Lake, 2004 compared to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals (total)	2003	2004	Guidelines
ALUMINUM ug/L	14.75	4.95	100[a]
ANTIMONY ug/L	0.075	0.065	6[e]
ARSENIC ug/L	1.99	2.03	5
BARIUM ug/L	46.1	50.2	1000[e]
BERYLLIUM ug/L	0.06	0.0015	100[d,f]
BISMUTH ug/L	0.00575	0.0011	
BORON ug/L	169.5	172	5000[e,f]
CADMIUM ug/L	0.03	0.007	0.085[b]
CHROMIUM ug/L	0.325	0.87	
COBALT ug/L	0.01	0.014	1000[f]
COPPER ug/L	0.56	0.75	4[c]
IRON ug/L	3.25	1.0	300
LEAD ug/L	0.079	0.0472	7[c]
LITHIUM ug/L	40.05	53.4	2500[g]
MANGANESE ug/L	9.28	8.14	200[g]
MOLYBDENUM ug/L	0.59	0.846	73[d]
NICKEL ug/L	0.03	0.0025	150[c]
SELENIUM ug/L	0.525	0.27	1
SILVER ug/L	0.0025	0.0025	0.1
STRONTIUM ug/L	282.5	309	
THALLIUM ug/L	0.0925	0.0019	0.8
THORIUM ug/L	0.00425	0.009	
TIN ug/L	0.08	0.015	
TITANIUM ug/L	0.65	0.67	
URANIUM ug/L	0.43	0.437	100[e]
VANADIUM ug/L	0.445	0.388	100[f,g]
ZINC ug/L	2.98	7.9	30
FLUORIDE mg/L		0.24	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 $CaCO_3$).

[c] Based on water Hardness > 180 mg/L (as $CaCO_3$).

[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

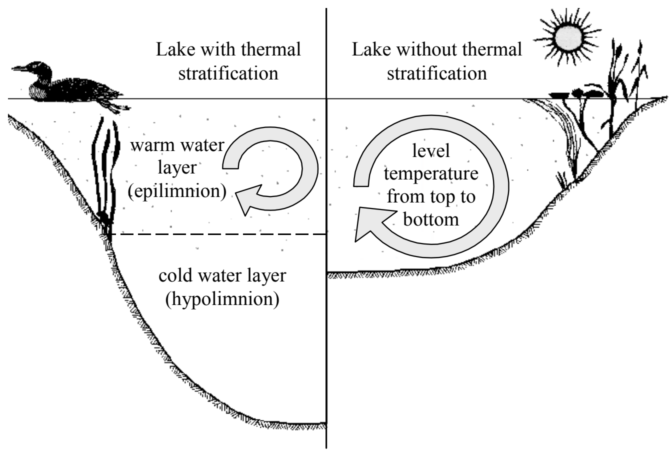


Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

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.

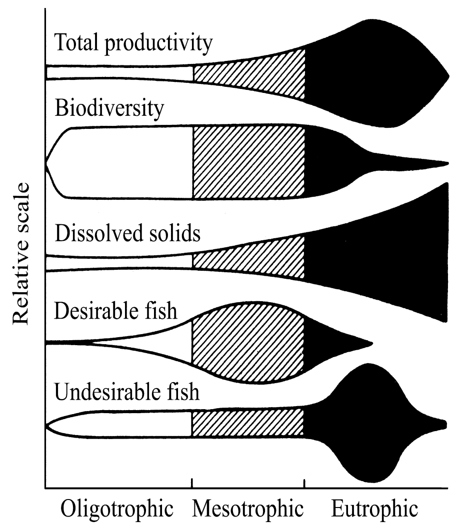


Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.

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