The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Crane (Moore) Lake

2008 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, Théo Charette and Ron Zurawell. We would like to thank Gord Coulman and Dave Legault for their efforts in collecting data in 2008. We would also like to thank Lisa Brodziak and Sophie Damlencour who were summer interns with ALMS in 2008. 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, Ron Zurawell (Limnologist, AENV), and Lori Nuefeld prepared the original report, which was updated by Sarah Lord for the 2008 report. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Crane Lake

Introduction

Crane Lake was originally named Moore Lake, after Dr. Bromley Moore, a former President of the College of Physicians and Surgeons and a friend of the surveyor Marshall Hopkins (Alta. Cult. Multicult. N.d.). Moore Lake is locally referred to as Crane Lake and Lakewatch adopts the name as well.

Figure 1. Photo of Crane Lake, Alberta, 31 July 2005.

Crane Lake is a medium sized (surface area 9.28 km^2) and deep (max. depth 26m, mean depth 8.3m) water body located in the Beaver River Basin (**Figure 1**, **2**). Crane Lake is located in Alberta's Lakeland Region, and is valued for its clear water and lovely natural shoreline. The lake is situated about 280 km northeast of Edmonton in the Municipal District of Bonnyville. The town of Bonnyville, south of the lake, and the City of Cold Lake are the principal urban centres in the area.

Most of Crane Lake's shoreline is Crown Land. Two provincial recreation areas are located on the south shore of Crane Lake. Both are operated by Alberta Recreation and Parks and are open year-round. Crane Lake East Provincial Recreation Area has 26 un-serviced campsites while Crane Lake West Provincial Recreation Area has 24 campsites, 18 of which are serviced. Both parks provide picnic tables and shelters, firepits, pump water, boat launches, beaches and swimming areas.

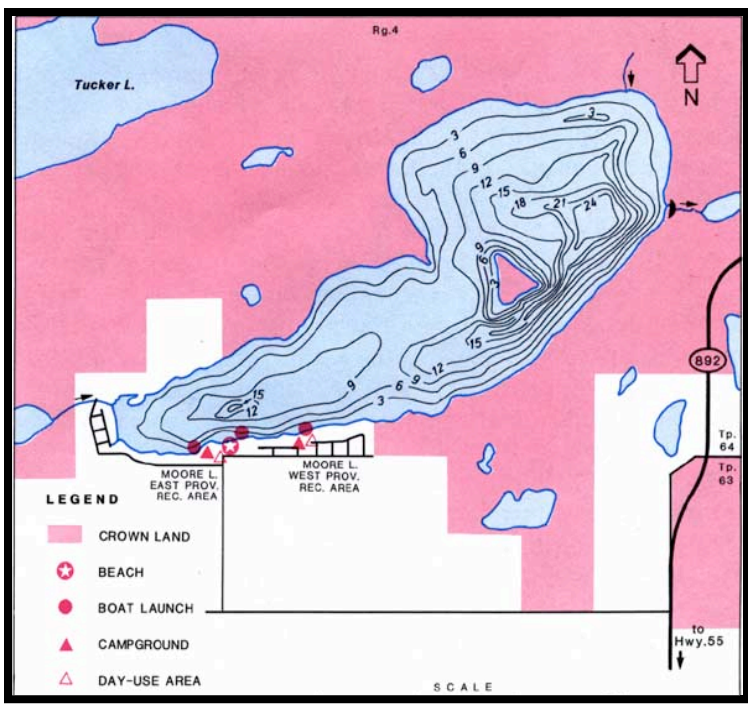

Figure 2. Bathymetry map of Crane Lake, AB. Contour intervals are 3 m.

Crane Lake is a headwater lake with a small drainage basin that is only four times the size of the lake. The only inlets are two minor streams, one each on the northeast and west shores. The outlet flows from the east shore into nearby Hilda and Ethel lakes and eventually into the Beaver River. The eastern basin slopes quite steeply to a maximum depth of 26 m northeast of the island. The western basin, with a maximum depth of 15 m, is relatively shallow. Its deepest locations are south of the island and north of the recreation areas. The lake basin drops off very steeply southeast of Doris Island. Sport fish species in the lake are walleye, northern pike, yellow perch and lake whitefish. Significant growth of aquatic vegetation is limited to only a few areas, such as in the west basin; the lack of extensive vegetation limits fish spawning and feeding habitat in the lake.

Crane Lake is situated on a rolling morainal plain in the Dry-mixedwood subregion of the Boreal-mixedwood ecoregion (Kocaoglu 1975; Strong and Leggat 1981). The main tree species in the watershed include jack pine on well-drained soils, trembling aspen on moderately drained soils, and black spruce and willows on poorly drained soils. Large wetlands are located along the two inflows and at the south end of the lake. Agricultural activity in the drainage basin is limited by undesirable soil structure and a relatively short growing season (Alta. Mun. Aff. 1987). Most of the cultivated land is located south of the lake. The main agricultural activity is cattle grazing and a limited number of grazing permits and leases have been issued for Crown land in the drainage basin (Alta. Mun. Aff. 1987).

Results

Water Levels

Water levels in Crane Lake have been monitored since 1980 by Environment Canada under the joint federal-provincial hydrometric agreement. Water levels are measured as the elevation in meters above sea level (m asl) of the surface of the lake. Since the 1980's the water level of Crane Lake has fluctuated around 549.5 m asl (**Figure 3**). In 1992, Crane Lake reached its lowest recorded level at 549.1 m asl, but has since recovered. In 2006, water levels reached a recorded high at 549.8 m asl.

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.

Crane Lake was thermally stratified throughout most of the summer 2008 (**Figure 4**). Maximum surface water temperature was 21.7º C and occurred on 3 July, declining to 19.85º C on 9 August and 16.28º C on 6 September. The upper, warm layer of water (e.g. epilimnion) extended to 6 m in July, and ~10 m in August and September. Water temperature was < 10º C below 13 m depth on all sample dates.

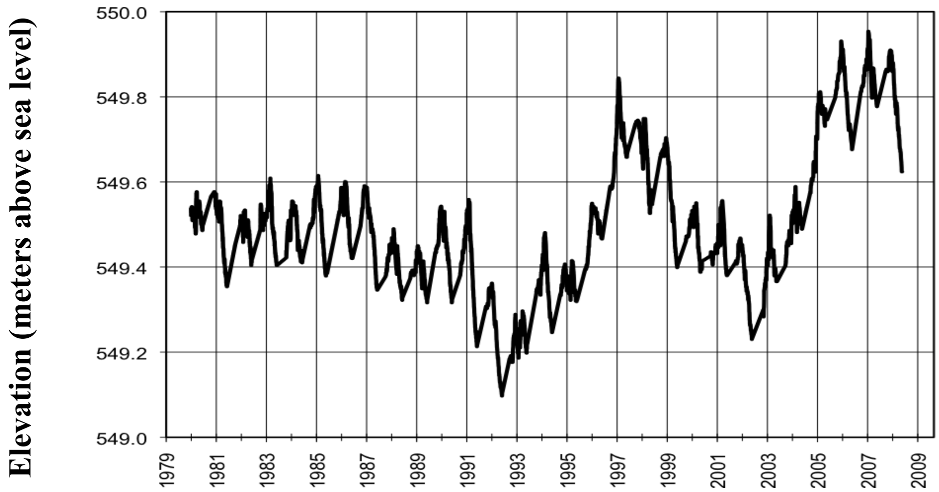

Figure 3. Historical water levels (meters above sea level (asl)) in Crane Lake, Alberta 1980 – 2009.

Dissolved oxygen (DO) concentrations peaked on 3 July, with a slight increase in DO at 3 – 7m depth, which indicated a phytoplankton layer was concentrated at the thermocline (**Figure 4**). A distinct chemocline was present on all sample dates, as DO concentrations declined sharply at 11 m in July, August and September. Below 15 m depth in July and 12 m depth in August and September, DO declined to near zero (e.g. anoxic). The pattern of DO concentrations in the hypolimnion (deep waters of the lake) is a sign of microbial decomposition, which consumes oxygen at the lakebed. Despite anoxic conditions in the hypolimnion, the oxygen levels in surface layers of Crane Lake were within the acceptable range for surface water quality in 2008, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L).

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.

Crane Lake is a moderately deep lake compared to many lakes in Alberta. Compared to shallower lakes, Crane Lake appears relatively clear, with an average Secchi depth = 4.0 meters. In 2008, light penetrated to an average 15% of the total lake depth (**Table 1**), thus algal growth was limited to the top layers of the lake. As algae grew throughout the summer, water clarity declined by 2.0 m over the late summer, decreasing from a maximum of 5.0m on 3 July to a minimum of 3.0m on 6 September. Water clarity in Crane Lake has remained relatively constant over the past 16 years.

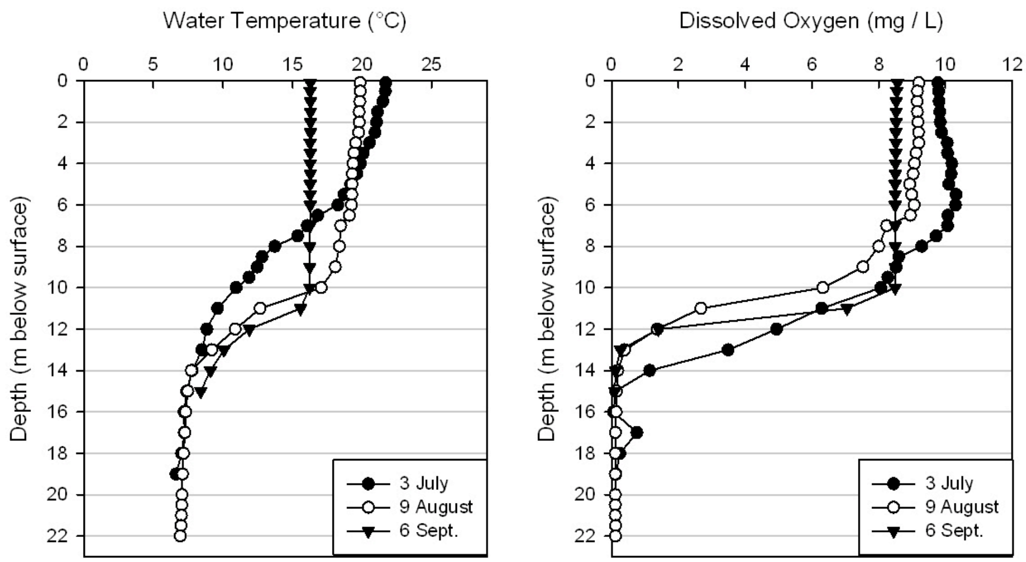

Figure 4. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Crane Lake during the summer of 2008.

Water chemistry

Based on lake water characteristics, Crane Lake is considered mesotrophic (see *A Brief Introductory to Limnology* at the end of this report). This was evidenced by moderate concentrations of total phosphorus (average TP = 22.5 µg/L) in the mesotrophic range, and algal biomass (average chl *a* = 2.45 µg/L) (**Figure 5**) in the oligotrophic range in 2008. Total Kjeldahl nitrogen (average TN = 0.93 mg/L or 930 µg/L) values were within the eutrophic range, which suggests that algae were phosphorous limited in Crane Lake (**Figure 5**). Indeed, algal biomass increased when TP increased. TN and TP concentrations have remained relatively unchanged over the past 17 years.

Crane Lake is well-protected from acidification. In 2008, lake pH = 8.9 was well above that of pure water (i.e., pH 7). Crane is a hardwater lake and ion concentrations are moderate-high (**Table 1**). Dominant ions include bicarbonate, sodium, magnesium, and carbonate. Atmospheric deposition of acidifying pollutants from petroleum activities can often increase sulphate and nitrate/nitrite concentrations. Sulphate, sodium, and chloride concentrations increased slightly from 1980's levels. The changes in ion concentration may be due, in part to changes in weathering and from groundwater inputs to the lake. Increased sulphate concentration indicates a potential increase in groundwater discharge relative to surface runoff. Ions may also become more concentrated with reduced water level. Due to a 20-year drought, these two scenarios are likely.

Heavy metal concentrations (total recoverable concentrations) in Crane Lake were measured once on 6 September 2008. Arsenic and thorium increased from 2005 to 2008 (**Appendix 1**). Heavy metal concentrations in 2008 did not exceed CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

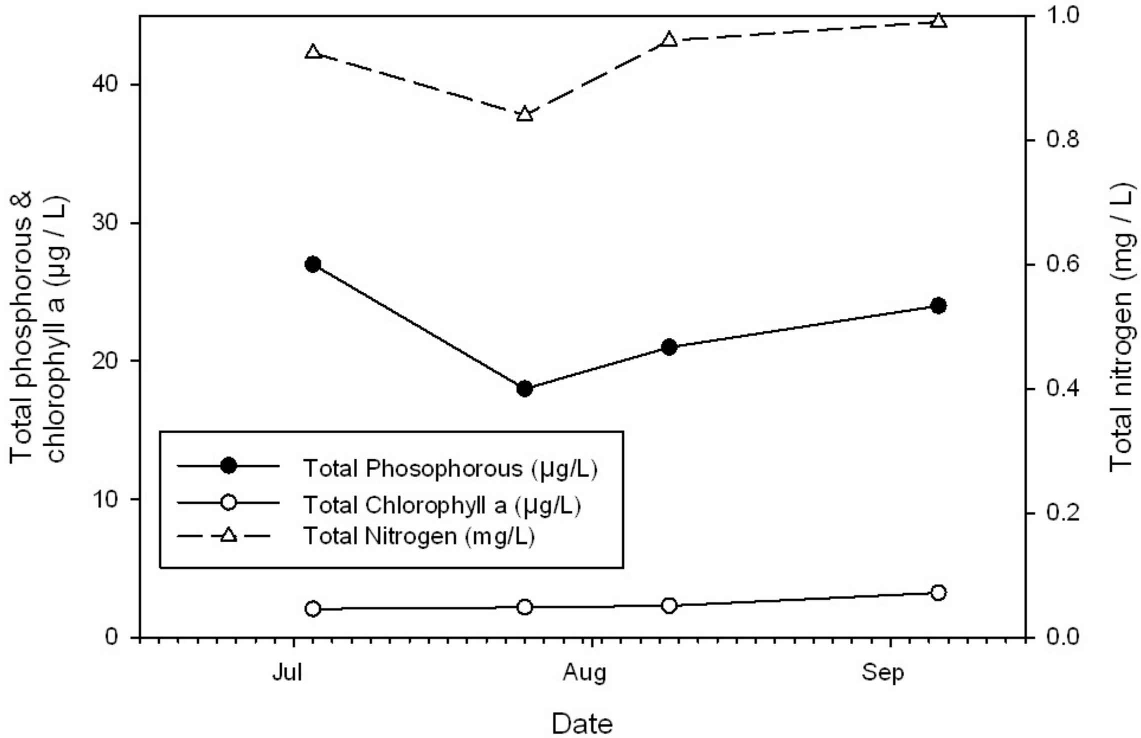

Figure 5. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Crane Lake during the summer of 2008.

Table 1. Mean water chemistry values for Crane Lake, Alberta, summer 2008 compared to previous years.

Parameter	1980	1981	1997	2005	2006	2007	2008
TP (μg/L)	-	26.8	23	20	23.2	22.8	22.5
Total dissolved P (μg/L)	-	11	10	10	10.8	10.8	12.3
Chlorophyll-*a* (μg/L)	7.9	8.2	7.0	7.0	4.77	3.9	2.45
Secchi disk depth (m)	2.7	3.3	3.5	3.2	2.9	2.8	4.0
TN (mg/L)	1.24	0.94	0.97	0.99	0.98	0.85	0.93
NO_{2+3} (μg/L)	5	3	8	6	7.8	<0.005	<0.005
NH_4 (μg/L)	29	22	7	10	14	13.5	9.75
Dissolved organic C (mg/L)	14.5	13.8	-	13.7	13.7	13.9	13.4
Ca (mg/L)	16.6	16.7	15.7	13.7	15.2	15.4	15.4
Mg (mg/L)	41	39.8	48.0	41.8	47.7	49.3	50.4
Na (mg/L)	89	81	116	125	112.2	123.7	124.3
K (mg/L)	6.6	7.7	7.8	8.1	8.2	8.4	8.13
SO_4 (mg/L)	18	20.5	27.9	24	28	25.7	29.7
Cl (mg/L)	20.7	21.0	26.2	29.3	29.7	30.4	30.3
CO_3 (mg/L)	-	-	39	41	40.5	43.3	42.7
HCO_3 (mg/L)	-	-	415	457	459	461	469
pH	8.7	8.5	8.9	8.9	8.9	8.9	8.9
Conductivity (μS/cm)	724	704	822	842	873	862	868
Total dissolved solids (mg/L)	405	-	482	509	507	523	532
Total suspended solids (mg/L)	1.9	2.3	-	3	-	-	-
Total Alkalinity (mg/L $CaCO_3$)	354	356	400	443	444	450	455

Note: TP = total phosphorus, Chla = chlorophyll *a*, TN = total Kjeldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate.
***Atlas of Alberta Lakes (Mitchell and Prepas, 1990).**

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Appendix 1

Concentration of metals in Crane Lake, measured on 6 September 2008, compared to mean metal concentrations during summer 2005 – 2007. CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are provided as a reference.

Metals (total)	2005	2006	2007	2008	Guidelines
ALUMINUM µg/L	2.1	9.07	5.36	8.86	100[a]
ANTIMONY µg/L	0.03	0.03	0.029	0.0423	6[e]
ARSENIC µg/L	4.27	3.02	3.66	4.48	5
BARIUM µg/L	13.4	14.4	14.4	13.8	1000[e]
BERYLLIUM µg/L	0.003	0.003	<0.003	<0.003	100[d,f]
BISMUTH µg/L	0.0005	0.001	0.002	0.004	-
BORON µg/L	255	327	276	289	5000[e,f]
CADMIUM µg/L	0.01	0.005	0.010	0.0131	0.085[b]
CHROMIUM µg/L	0.24	0.359	0.217	0.405	-
COBALT µg/L	0.01	0.025	0.013	0.015	1000[f]
COPPER µg/L	0.25	0.38	0.238	1.31	4[c]
IRON µg/L	6.5	6	6.81	8.8	300
LEAD µg/L	0.05	0.066	0.100	0.0345	7[c]
LITHIUM µg/L	65.7	72.5	61.8	62.1	2500[g]
MANGANESE µg/L	1.8	1.7	2.45	1.87	200[g]
MOLYBDENUM µg/L	3.19	3.59	3.15	3.23	73[d]
NICKEL µg/L	0.01	0.092	0.064	<0.005	150[c]
SELENIUM µg/L	0.19	0.52	0.416	0.721	1
SILVER µg/L	0.001	0.001	<0.0005	0.0014	0.1
STRONTIUM µg/L	68	75.2	73.8	69	-
THALLIUM µg/L	0	0.01	0.002	0.0018	0.8
THORIUM µg/L	0.004	0.006	0.018	0.0197	-
TIN µg/L	0.02	0.03	<0.03	<0.03	-
TITANIUM µg/L	0.61	0.79	0.07	0.744	-
URANIUM µg/L	0.19	0.21	0.206	0.208	100[e]
VANADIUM µg/L	0.15	0.25	0.21	0.235	100[f,g]
ZINC µg/L	2.08	2.5	0.751	0.362	30
FLUORIDE mg/L	0.22	-	-	-	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

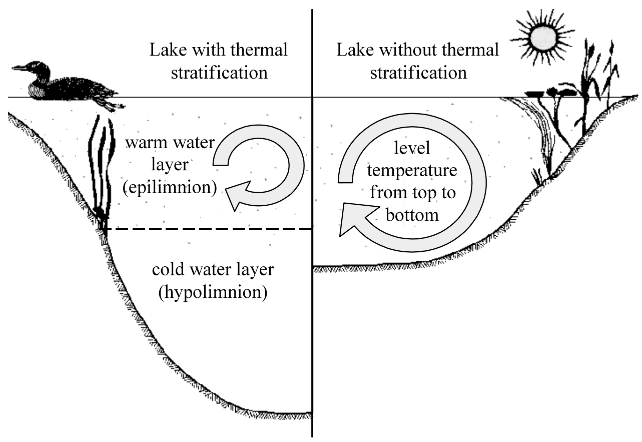

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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. A third layer, known as the metalimnion, provides an effective barrier between the epi- and hypolimnion. The metalimnion reflects a rapid transition in water temperature known as the **thermocline**. A thermocline typically occurs when water temperature changes by several degrees within one-meter of depth. The thermocline acts as an effective physico-chemical barrier to mixing between the hypolimnion and epilimnion, restricts downward movement of elements, such as oxygen, from the surface 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 state 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 terrestrial plants and plants and algae of tropical lakes, phosphorus is usually in shortest supply in temperate 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, reflect lower-nutrient trophic states than would otherwise result if macrophyte-based chlorophyll were 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 low. Secchi disk depth, however, is not only affected by algae, high concentrations of suspended sediments, particularly fine clays or glacial till common in plains or mountain reservoirs of Alberta, also impact water clarity. 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.

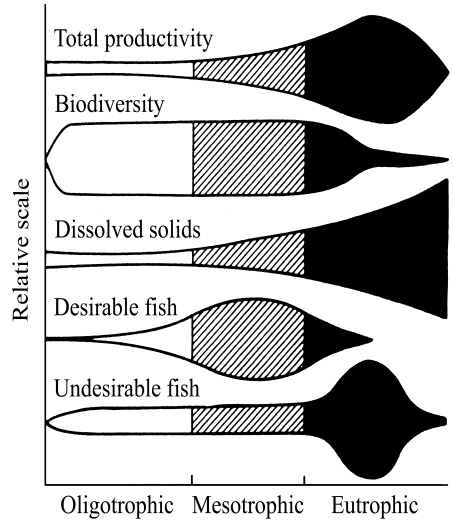

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.

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.