ALMS
Alberta Lake Management Society

Lakewatch

The Alberta Lake Management Society Volunteer Lake monitoring report

Lac Santé

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2008 Report

Completed with support from:

Alberta Environment

Alberta Lake Management Society

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> *And you really live by the river? What a jolly life!"*
> *"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing."* *Kenneth Grahame The Wind in the Willows*
>
> *"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water."*
> *BBC World Water Crisis Homepage*

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

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Lac Santé

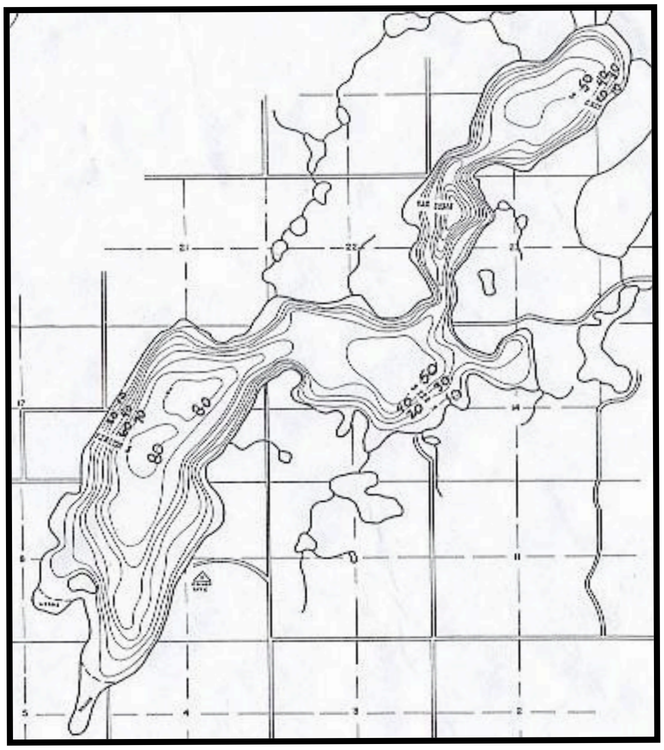

Figure 1. Bathymetry map of Lac Santé, Alberta. Courtesy of the Government of Alberta, Department of Agriculture - Water Resources Division, 1968.

Lac Santé is a relatively large lake located northeast of the Town of Two Hills. It is a multi-basin lake, and the maximum depth of deepest basin is ~ 25 m. Lac Santé's catchment is largely devoted to agricultural practices, and its shoreline is well-developed. The southern-most basin is the largest and deepest of four basins. The three other basins (to the northeast) are smaller and all of similar depth (15 – 19 m) (**Figure 1**). Lac Santé is a dimictic lake, undergoing thermal stratification during the open water season.

The lake is located approximately 140 km northeast of Edmonton. To get to this lake, take Hwy 16 east for 86 km, turn left onto Hwy 631 for 29 km, followed by a left on Hwy ~ 46 (past the town of Two Hills), crossing the North Saskatchewan River. Turn east on the first paved road north of the river, and continue for 13 km to the lake. The boat launch is situated among a cluster of private lots. All campgrounds along the shores of this lake are privately owned; however boats may be launched at the County boat launch. Lac Santé is known for its great fish stocks.

Water Level

Water levels have been recorded at Lac Santé since 1968. The lake has encountered a tremendous decline in water level over the past 38 years, roughly equal to 4 m (**Figure 2**). Between 1968 and 1974 a slight increase in water level was recorded, followed by relatively constant decline until January 1996. From January 1996 to October 1998, Lac Santé experienced a brief period of increased water level, after which the pattern of decline continued and has since steepened. The lowest water level was 603.6 m above sea level (asl) in October 2008, showing that the decline in water level is continuing. The highest recorded water level was 608.0 m asl in July 1971.

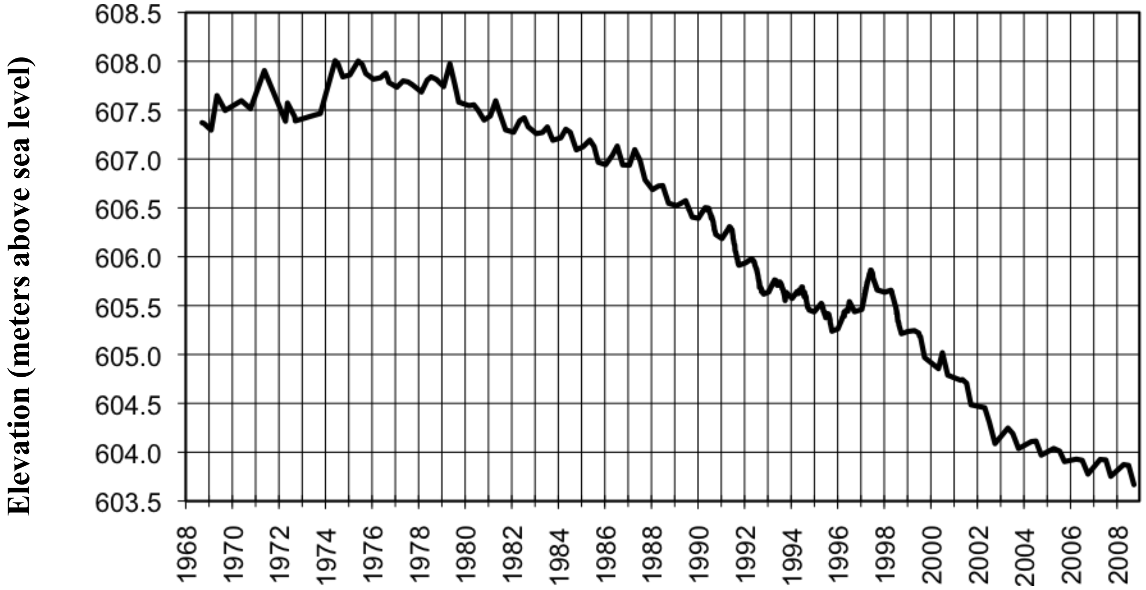

Figure 2. Historical water levels (meters above sea level (asl)) in Lac Santé, Alberta 1968 – 2009.

Results

Water temperature and dissolved oxygen

Thermal stratification in Lac Santé was observed during the summer 2008 (**Figure 3**). In July, the thermocline occurred at 7 m depth. In mid-August, the depth at which the thermocline occurred was 10 m. By 12 September the thermocline had dropped to 11 m depth. During the sampling period, the lake did not overturn.

Dissolved oxygen (DO) concentration in surface waters in Lac Santé was ≥ 8 mg/L throughout the open water season (**Figure 3**). DO concentrations declined at a depth of 8 m in July and at 8 m in August, but in September the chemocline dropped to 10 m depth. In July and August, DO was near zero (e.g. anoxic) from 10 m depth down to the lake bed, and in September the anoxic zone extended from 12 m depth to the lake bed. The oxygen levels in surface layers of Lac Santé were within the acceptable range for surface water quality, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L).

Although the lake did not mix within the sample period, Lac Santé is a dimictic lake. Anoxic conditions near the lake bed have been observed in other years. Deep-water anoxia is common in summer, and the decomposition of organic matter produced during the open water season continues on into the winter months, which in turn, leads to low winter oxygen concentrations (as decomposition requires oxygen).

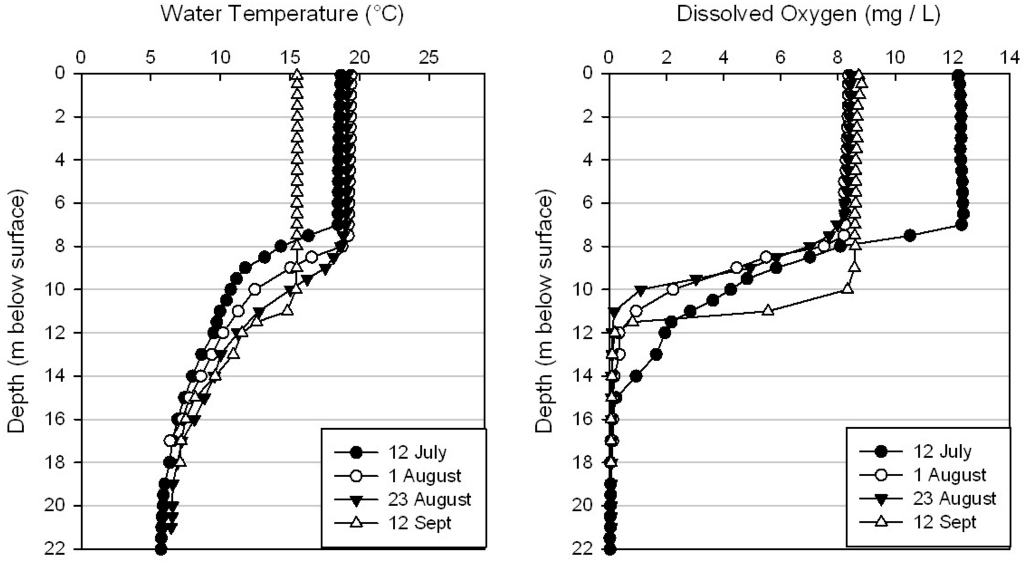

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Lac Santé during the summer of 2008.

Water clarity and Secchi Disk Depth

Water clarity is influenced by suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is the Secchi disk depth. Following the period of ice and snowmelt, a lake can have low clarity due to spring runoff and the inflow of suspended sediments into the lake. Lake water usually clears in the spring but then becomes more turbid due to algal growth taking place throughout the summer open water season.

Water clarity data for Lac Santé was measured four times during the summer of 2008. Lac Santé was clear, relative to other lakes in Alberta, with average Secchi disk depth = 4.8 m (**Table 1**). On 12 July, light penetrated 5.75 m or ~25% of the total lake depth, which allowed for algal growth in the top 11.5 m of the lake. Thus, based on light penetration, Lac Santé has the potential to very productive. By 1 August, Secchi disk depth had decreased to 4.5 m, but increased slightly to 5.0 m on 23 August. 12 September had the lowest Secchi disk depth of 4.0 m.

Water chemistry

Based on lake water characteristics measured in July, Lac Santé is considered eutrophic to slightly mesotrophic (see *A Brief Introduction to Limnology* at the end of this report). Total phosphorus (TP = 51.7 µg/L) and total Kjeldahl nitrogen (TN = 2.24 mg/L) concentrations were within the eutrophic range (**Table 1**). Chlorophyll *a* (chl *a* = 3.51 µg/L) was within the mesotrophic range. Alberta Environment classifies Lac Santé as eutrophic (AE 2007).

Total phosphorous declined slightly through the summer from 0.056 mg/L on 12 July to 0.050 mg/L on 12 September, but total nitrogen increased from 2.13 to 2.34 mg/L during the same period (**Figure 4**). Chlorophyll a (a measure of algal biomass) increased steadily from 2.59 ug/L on 12 July to 4.75 ug/L on 12 September. Because the algal growth was not accompanied by significant declines in nutrient concentrations, this indicates that consumption of nitrogen and phosphorous by algae in the lake were balanced by input from landscape runoff and nutrient release from lake sediments.

During the summer 2008, Lac Santé was well buffered from acidification with an average pH = 9.0, which is well above that of pure water (i.e., pH 7). While mean ionic concentrations were not measured in 2008, sodium and potassium concentrations were high in 2006 (**Table 1**). This indicated high evaporative loss from both the watershed and catchment, which is an unavoidable consequence of a dry climate and extensive agricultural practices. The reduction in water levels observed in Lac Santé lead to the higher concentration of ions. High sodium and potassium concentrations were also observed in 2007 and 2008.

The average concentrations of various heavy metals (as total recoverable concentrations) in Lac Santé were not available for the summer of 2008, except for iron, which was within CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

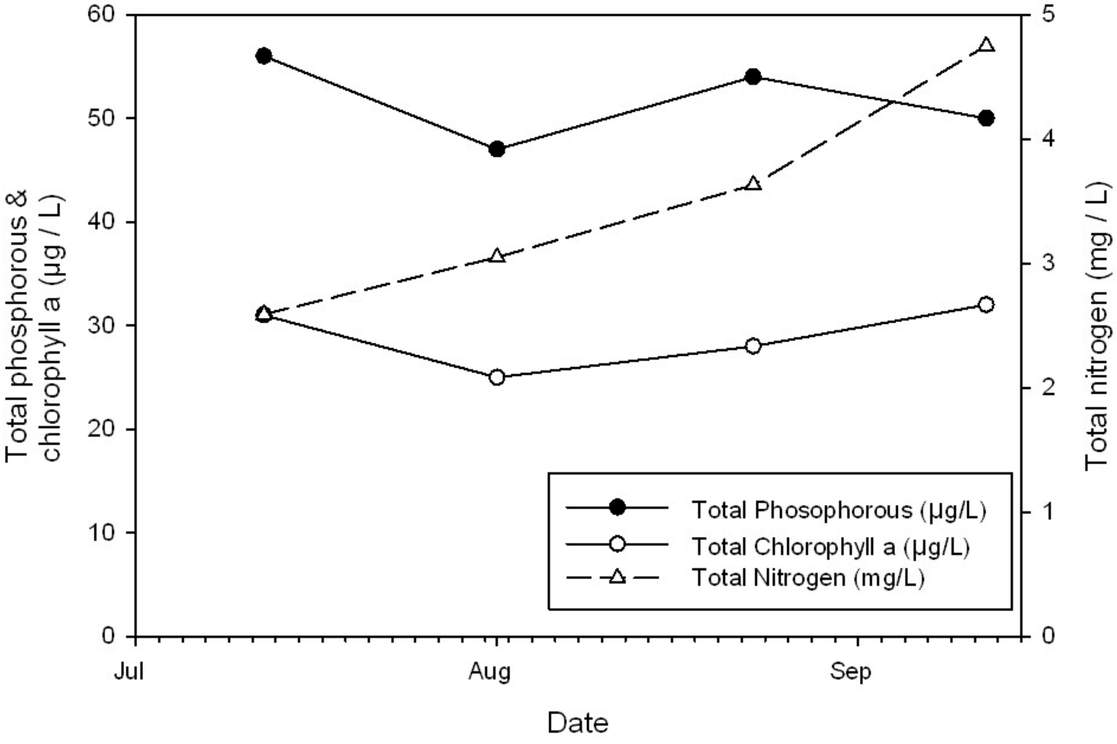

Figure 4. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Lac Santé during the summer of 2008.

Table 1. Water chemistry values for Lac Santé, summer 2006 - 2008.

Parameter	2006	2007	2008
TP (μg/L)	61	52	51.7
TDP (μg/L)	-	37	29
Chl *a* (μg/L)	7.33	5.41	3.51
Secchi (m)	4.75	5	4.8
TKN (μg/L)	2298	2030	2243
$NO_{2,3}$ (μg/L)	6.5	402	10.5
NH_4 (μg/L)	151.2	43	33.5
Dissolved organic C (mg/L)	-	29.3	26.5
Ca (mg/L)	8.14	8.6	7.8
Mg (mg/L)	178.67	181	152.7
Na (mg/L)	209.67	212	207
K (mg/L)	48.97	51.8	49.5
SO_4^{2-} (mg/L)	295	279	282.7
Cl^- (mg/L)	16.3	16.2	16.4
TDS (mg/L)	1293	1280	1253
pH	9.15	9.1	9.0
Conductivity (μS/cm)	1873	1871	1887
Hardness (mg/L)	756	-	648
HCO_3 (mg/L)	791	797	808.3
CO_3 (mg/L)	148	138	140.3
Total Alkalinity (mg/L $CaCO_3$)	895	883	897.3

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TKN = 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).

Appendix 1

The concentrations of metals were not measured in Lake Santé except for iron, measured once on 1 July 2007. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (total)	**2007**	**2008**	**Guidelines**
ALUMINUM μg/L	-	-	100[a]
ANTIMONY μg/L	-	-	6[e]
ARSENIC μg/L	-	-	5
BARIUM μg/L	-	-	1000[e]
BERYLLIUM μg/L	-	-	100[d,f]
BISMUTH μg/L	-	-	
BORON μg/L	-	-	5000[e,f]
CADMIUM μg/L	-	-	0.085[b]
CHROMIUM μg/L	-	-	
COBALT μg/L	-	-	1000[f]
COPPER μg/L	-	-	4[c]
IRON μg/L	38.4	35.2	300
LEAD μg/L	-	-	7[c]
LITHIUM μg/L	-	-	2500[g]
MANGANESE μg/L	-	-	200[g]
MOLYBDENUM μg/L	-	-	73[d]
NICKEL μg/L	-	-	150[c]
SELENIUM μg/L	-	-	1
STRONTIUM μg/L	-	-	
SILVER μg/L	-	-	
THALLIUM μg/L	-	-	0.8
THORIUM μg/L	-	-	
TIN μg/L	-	-	
TITANIUM μg/L	-	-	
URANIUM μg/L	-	-	100[e]
VANADIUM μg/L	-	-	100[f,g]
ZINC μg/L	-	-	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentration $[Ca^{+2}] \geq 4$ 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).

References

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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 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 $mg{\bullet}L^{-1}$ and should not average less than 6.5 $mg{\bullet}L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg{\bullet}L^{-1}$ 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**. 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.

Trophic status classification based on lake water characteristics.

Trophic state	Total Phosphorus ($\mu g \cdot L^{-1}$)	Total Nitrogen ($\mu g \cdot L^{-1}$)	Chlorophyll a ($\mu g \cdot L^{-1}$)	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

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.