The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Lac Santé

2009 Report

Completed with support from:

Alberta Environment

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 Terry Noble for his efforts in collecting data in 2009. We would also like to thank Noemie Jennie 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, Ron Zurawell (Limnologist, AENV), and Lori Nuefeld 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.

Lac Santé

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.

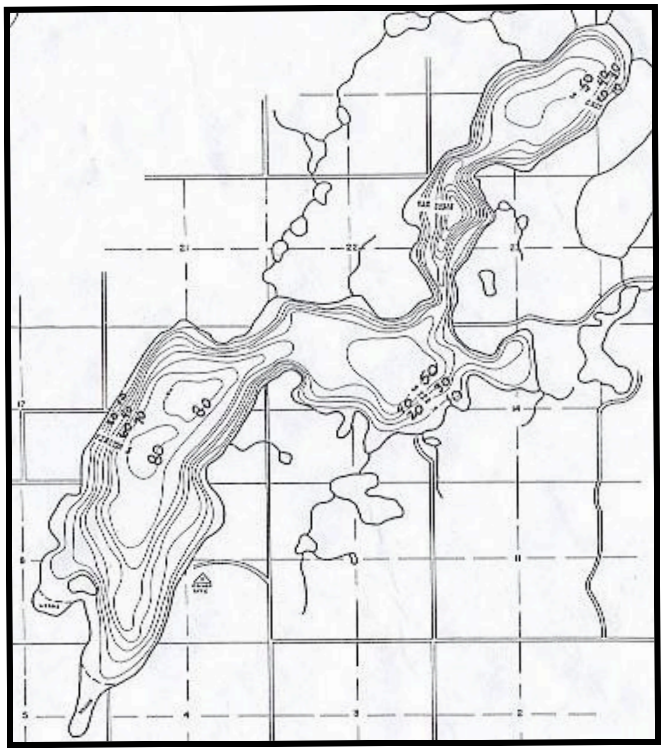

Figure 1. Bathymetric map of Lac Santé, Alberta. Contour intervals represent 10 feet.

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.

Results

Water Level

Water levels have been recorded at Lac Santé since 1968. The lake has experienced 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 resumed. The lowest water level was 603.6 m above sea level (m asl) in October 2009, showing that the decline in water level is continuing. The highest recorded water level was 608.0 m asl in July 1971.

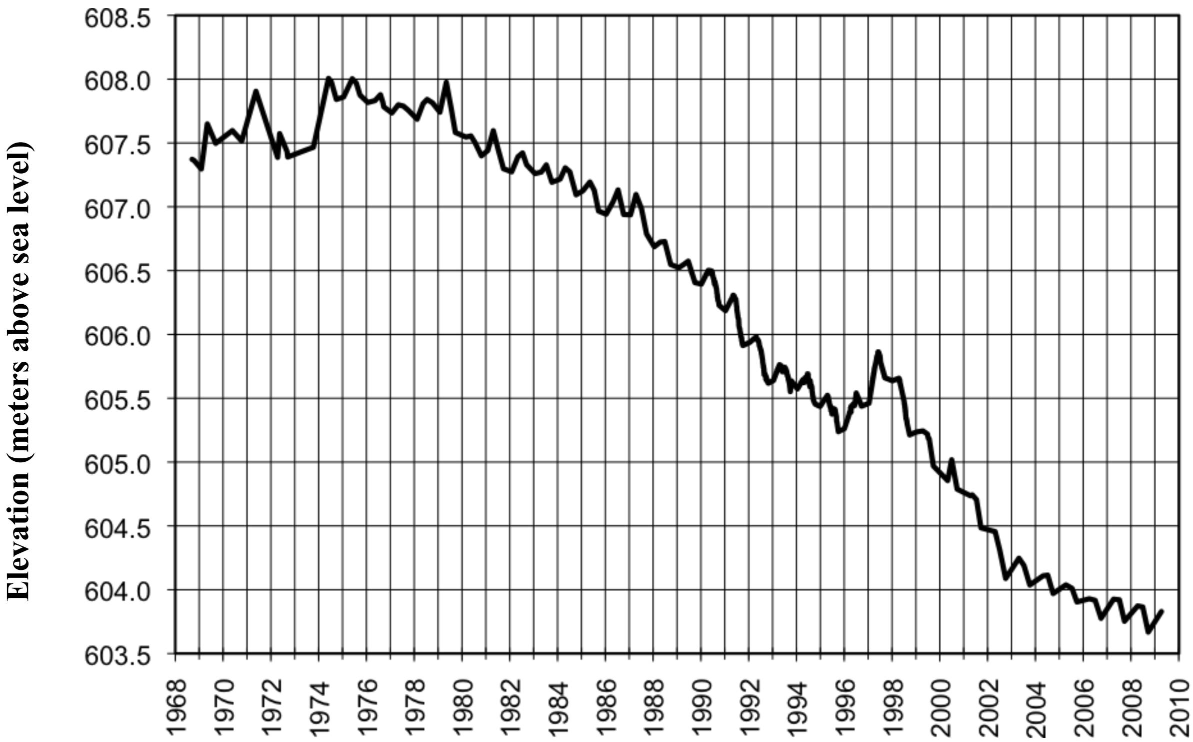

Figure 2. Historical water levels (m asl) in Lac Santé, Alberta 1968 – 2009.

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 Lac Santé was observed during the summer 2009 (**Figure 3**). On 7 June, surface water temperature was 12.2ºC and declined to 5.0ºC at the lakebed, and the thermocline occurred at 8 m depth. By July 12, surface waters had warmed to 16.5ºC but deep waters (e.g. hypolimnion) remained cool at 6.3ºC, and the thermocline dropped to 9 m depth. On 27 July, surface waters reached a seasonal maximum temperature of 20.8ºC and the thermocline dropped further to 9.5 m depth. In mid-August, surface waters cooled to 18.2ºC and the thermocline returned to 8 m depth. During the sampling period, the lake did not overturn.

Dissolved oxygen (DO) concentrations in surface waters in Lac Santé were ≥ 9 mg/L throughout the open water season, well within the acceptable range for surface water quality, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L) (**Figure 3**). DO concentrations declined gradually to near zero at the lakebed on 7 June. In July and August, DO declined rapidly at 8 m depth, and DO was near zero (e.g. anoxic) from 17 m, 15 m, and 11 m depth down to the lakebed on 12 July, 27 July, and 16 August respectively. Deep-water anoxia is common during summer as bacterial decomposition of organic matter in lake sediments consumes oxygen. Although the lake did not mix within the sample period, Lac Santé is a dimictic lake and anoxic conditions near the lakebed have been observed in other years.

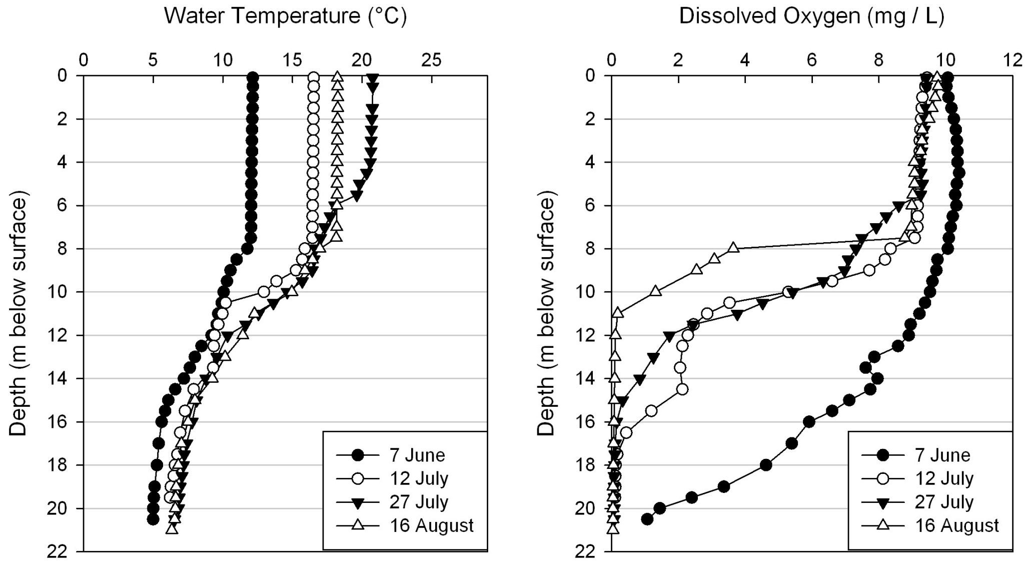

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Lac Santé during the summer of 2009.

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 data in Lac Santé was measured four times during the summer of 2009. Lac Santé is very clear relative to other lakes in Alberta, with an average Secchi depth of 5.75 m (**Table 1**) in 2009. On 7 June, light penetrated 8.0 m or ~37% of the total lake depth, which allowed for algal growth in the top 16.0 m of the lake. In July, Secchi depth decreased to 6.0 m, and by 16 August, Secchi depth reached a seasonal minimum of 3.0 m depth. The decline in water clarity closely followed the increase in algal biomass through the summer.

Water Chemistry

Based on lake water characteristics measured in July, Lac Santé is considered eutrophic (see *A Brief Introduction to Limnology* at the end of this report). In 2009, Lac Santé had high concentrations of total phosphorus (average TP = 61.0 µg/L) and total nitrogen (average TN = 2.347 mg/L), and moderate algal biomass (average chlorophyll *a* = 7.67

μg/L) (**Table 1**). Total phosphorous declined from 77.0 μg/L on 7 June to 48 μg/L on 12 July, and then recovered to 60 μg/L by 27 July. Total nitrogen also decreased from early June to early July, and then recovered to a seasonal maximum of 2.645 mg/L by 16 August (**Figure 4**). Chlorophyll *a* (a measure of algal biomass) increased over the summer, from a minimum of 0.6 μg/L on 7 June to a maximum of 19.9 μg/L on 16 August, although it was not measured on the 27 July sampling date.

During the summer 2009, Lac Santé was well buffered from acidification with an average pH = 9.1, which is well above that of pure water (i.e., pH 7). The reduction in water levels observed in Lac Santé is the likely cause of increasing concentrations of most ions in the lake (**Table 1**). Dominant ions include bicarbonate, sulfate, sodium, and magnesium. The concentrations of various metals in Lac Santé were not measured in 2009.

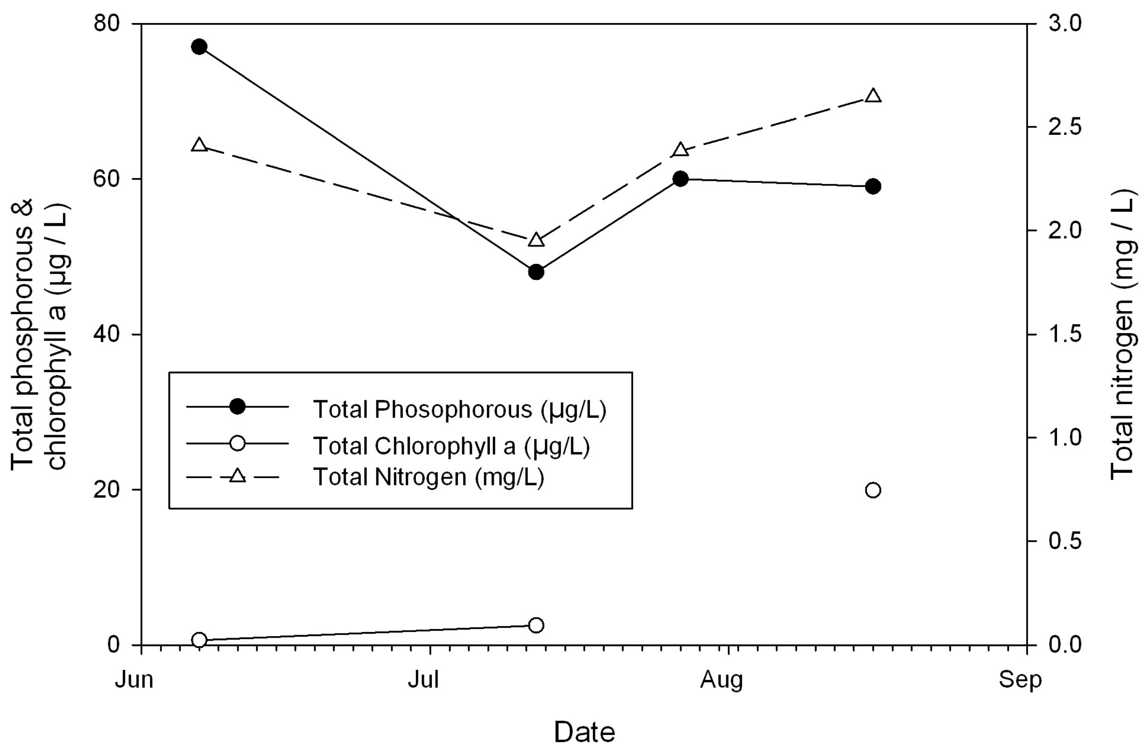

Figure 4. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Lac Santé during the summer of 2009.

Table 1. Mean water chemistry and Secchi depth values for Lac Santé, Alberta, summer 2009 compared to previous years.

Parameter	2006	2007	2008	2009
TP (μg/L)	61	52	51.7	61.0
TDP (μg/L)	-	37	29	38.5
Chl *a* (μg/L)	7.33	5.41	3.51	7.67
Secchi depth (m)	4.75	5	4.8	5.75
TKN (μg/L)	2298	2030	2243	2335
$NO_{2,3}$ (μg/L)	6.5	402	10.5	11.5
NH_4 (μg/L)	151.2	43	33.5	39.5
Dissolved organic C (mg/L)	-	29.3	26.5	29.8
Ca (mg/L)	8.14	8.6	7.8	8.73
Mg (mg/L)	178.67	181	152.7	159.3
Na (mg/L)	209.67	212	207	217.5
K (mg/L)	48.97	51.8	49.5	55.1
SO_4^{2-} (mg/L)	295	279	282.7	319.8
Cl^- (mg/L)	16.3	16.2	16.4	17.4
TDS (mg/L)	1293	1280	1253	1325
pH	9.15	9.1	9.0	9.1
Conductivity (μS/cm)	1873	1871	1887	1918
Hardness (mg/L)	756	-	648	677
HCO_3 (mg/L)	791	797	808.3	820.8
CO_3 (mg/L)	148	138	140.3	143.8
Total Alkalinity (mg/L $CaCO_3$)	895	883	897.3	912.5

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).

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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 transferred to a lake at its surface and slowly mc downward depending on water circulation in the with a large surface area or a small volume tend t due to wind. In deeper lakes, circulation is no water to depths typically greater than 4 or 5 m remains at the bottom of the lake. As the di surface and cold deeper water increases, two dis

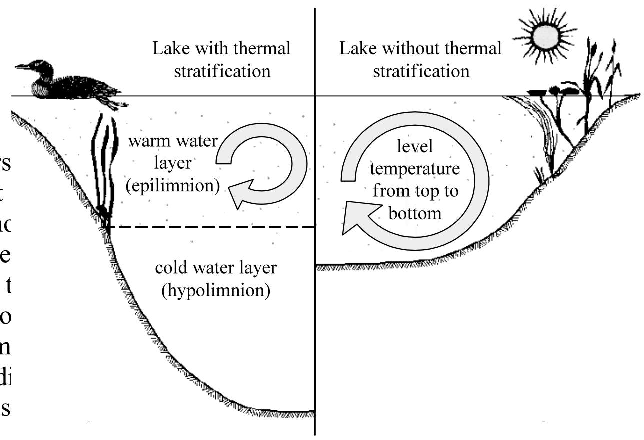

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

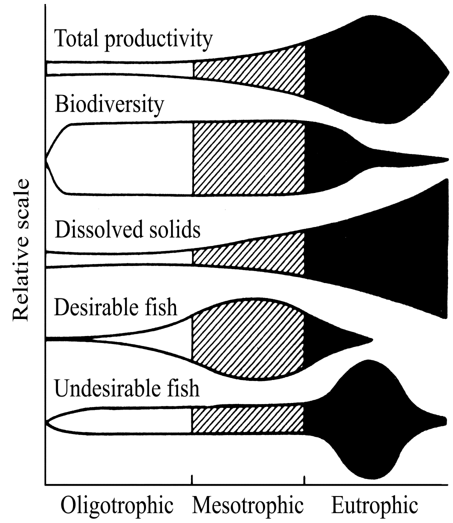

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.