THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2012 Lac Santé Lake Report

COMPLETED WITH SUPPORT FROM:

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 those 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.

Historical data has been re-queried and summarized for the 2012 report.

Acknowledgements

The LakeWatch program is made possible through the dedication of its volunteers. We would like to thank Terry Noble for his assistance with sampling Lac Santé in 2012. We would also like to thank Randi Newton and Erin Rodger who were summer technicians with ALMS in 2012. Program Coordinator Bradley Peter was instrumental in planning and organizing the field program. Technologists Trina Ball and Brian Jackson were involved in the training aspects of the program. Lisa Reinbolt was responsible for data management. This report was prepared by Bradley Peter and Arin Dyer. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the program.

If you are interested in becoming a volunteer with the LakeWatch program or having your lake monitored, please e-mail us at info@alms.ca or call us at 780-415-9785.

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 the 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 2). Lac Santé is a dimictic lake, undergoing thermal stratification during the open water season.

Figure 1 – A view of the shoreline at Lac Santé. Photo by Pauline Pozsonyi.

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 63 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 amongst 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.

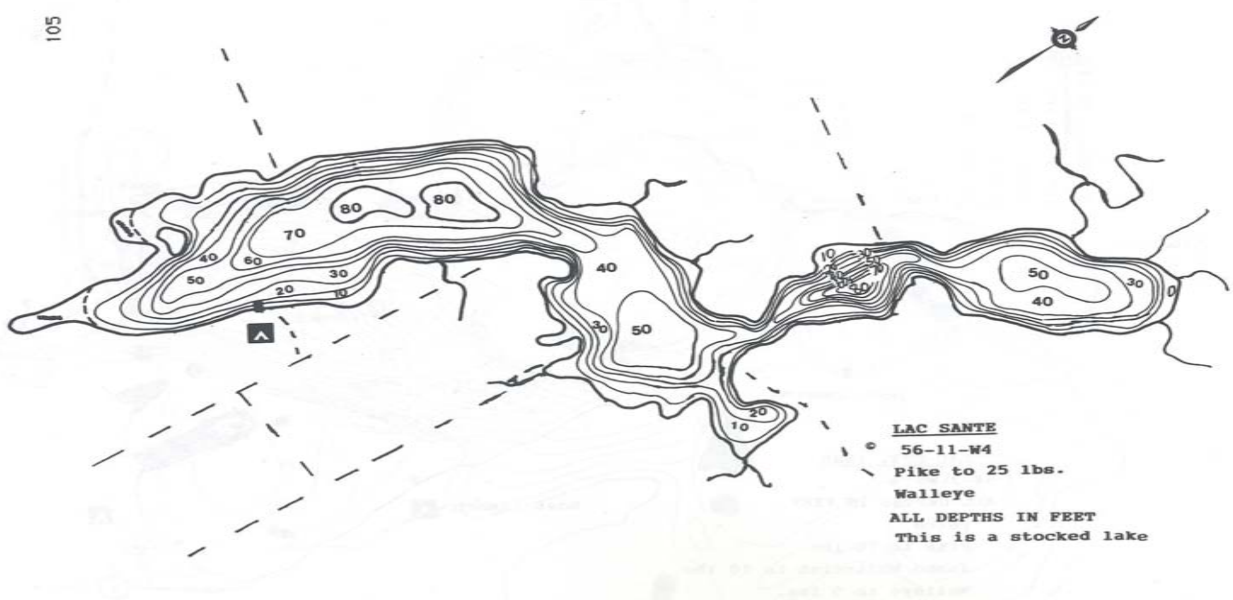

Figure 2 – Bathymetric chart of Lac Santé. Contour intervals are measured in feet.

WATER LEVELS:

There are many factors influencing water quantity. Some of these factors include the size of the lakes drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake.

Water levels at Lac Santé have shown a general trend towards decline since 1981 (Figure 3). A historical maximum of 608.006 meters above sea level (m asl) was measured in 1974, and a historical minimum of 603.448 m asl was measured in 2010. Since the historical maximum, water levels have dropped approximately 4.0 m.

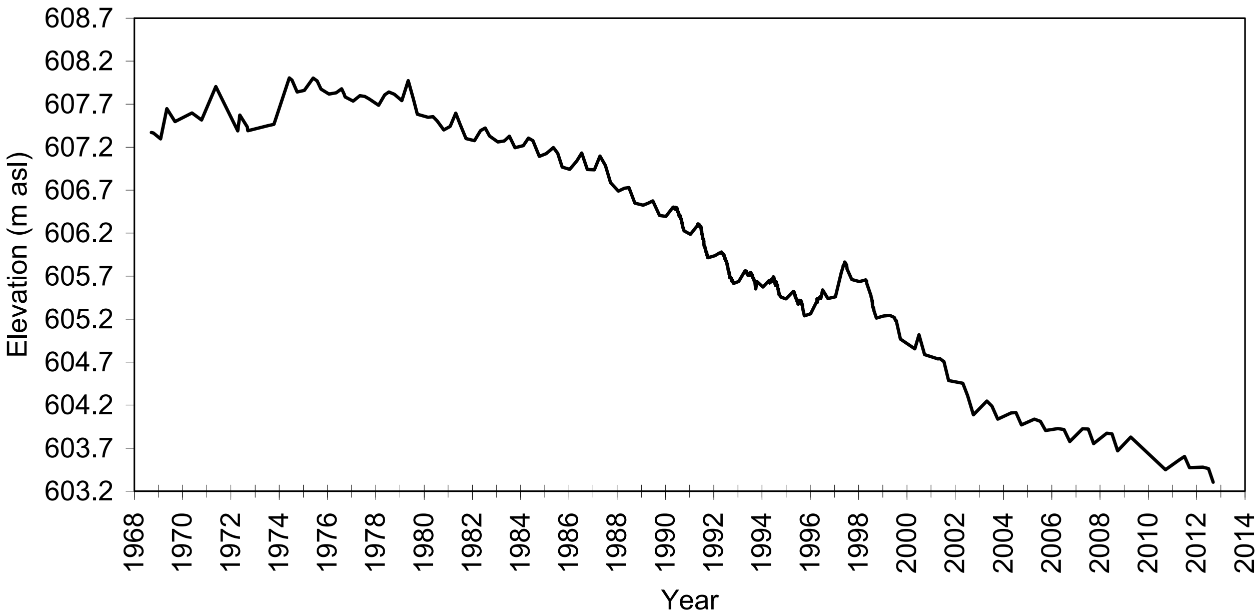

Figure 3– Water levels from 1968-2012 for Lac Santé measured in meters above sea level (m asl). Data obtained from Alberta Environment.

WATER CLARITY & 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.

Average Secchi disk depth at Lac Santé during the summer of 2012 measured 6.81 m; this is the greatest Secchi depth measured at Lac Santé since 2006 (Table 1). Secchi depth was measured four times throughout the summer and changed relatively little, measuring a maximum of 8.50 m on June 13th and a minimum of 6.00 m on August 21st. Low concentrations of algae/cyanobacteria and low concentrations of total suspended solids (1.7 mg/L) both contribute to the deep water clarity measured at Lac Santé (Table 1).

WATER TEMPERATURE AND DISSOLVED OXYGEN:

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Surface water temperature at Lac Santé ranged from 17.04 °C on June 13th to 22.55 °C on August 7th (Figure 4a). Thermal stratification was observed on each sampling trip, beginning as early as 3.50 m on July 10th and as late as 10.00 m on June 13th. It is possible that Lac Santé never completely mixes – in 2011, thermal stratification was still present as late as September 19th. The presence of thermal stratification has important implications for nutrient dynamics and dissolved oxygen concentrations.

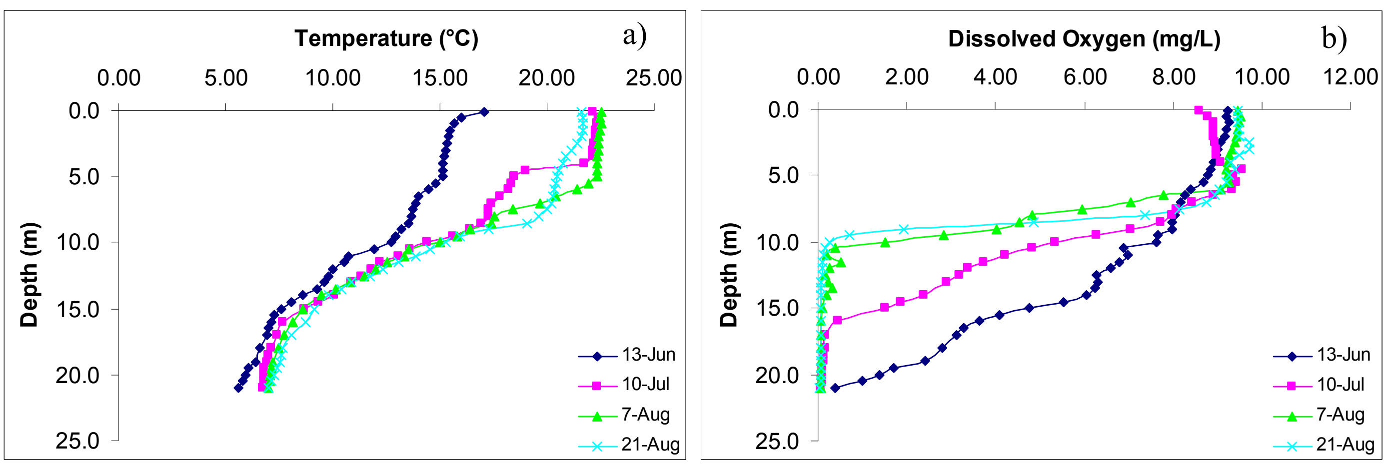

Figure 4 – a) temperature (°C) and b) dissolved oxygen (mg/L) profiles measured four times during the summer of 2012 at Lac Santé.

Dissolved oxygen levels remained healthy above the thermocline at Lac Santé, consistently measuring above the Canadian Council for Ministers of the Environment (CCME) guidelines of 6.5 mg/L for the Protection of Aquatic Life (PAL) (Figure 4b). Below the thermocline, however, dissolved oxygen concentrations decreased dramatically, reaching anoxia as early as 10.0 m. Separation by the thermocline from atmospheric oxygen, and isolation of the oxygen-consuming decomposition that occurs on the lakebed, both contribute to the decline in dissolved oxygen concentrations observed at Lac Santé. This type of dissolved oxygen profile is typical of deep lakes in Alberta.

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 1 for a complete list of parameters.

Average Total Phosphorus (TP) in 2012 measured 47.0 µg/L (Table 1) This value falls into the eutrophic, or nutrient rich, classification. This value is less than that measured in previous years, though Lac Santé has consistently fallen into the eutrophic classification. TP is the primary nutrient responsible for determining algae/cyanobacteria growth in a lake.

Despite high levels of TP in Lac Santé, chlorophyll-*a* concentration, a measure of algal/cyanobacterial biomass, were very low, measuring only 2.92 µg/L in 2012 (Figure 5). Throughout the summer, chlorophyll-*a* concentration changed very little, measuring a minimum of 1.63 µg/L on June 13th and a maximum of 3.80 µg/L on August 21st. The 2012 average is much lower than that measured in previous years at Lac Santé. It is likely that the high conductivity and high sulphate concentrations of Lac Santé help to keep the algae/cyanobacteria levels in check. While nutrients have a strong influence on algae/cyanobacteria growth, other factors such as light availability and temperatures play important roles as well.

Total Kjeldahl Nitrogen (TKN) measured an average of 2160 µg/L in 2012 (Table 1). This value falls into the hypereutrophic, or extremely productive, classification. The 2012 value falls well within the historical variation measured at Lac Santé.

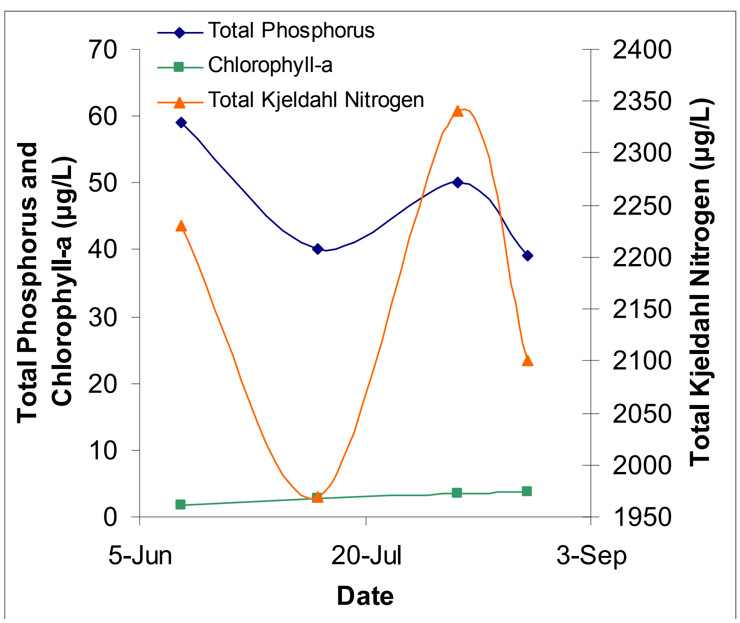

Figure 5 – Total phosphorus (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (µg/L) measured at Lac Santé four times over the course of 2012.

Average pH in 2012 measured 9.13, which is well above neutral (Table 1). Lac Santé has high concentrations of alkalinity (930.75 mg/L $CaCO_3$) and bicarbonate (829.8 mg/L HCO_3) which act as buffers against changes to pH. Lac Santé has a high conductivity (1985 uS/cm) with the dominant contributing ions being magnesium (153.5 mg/L) and sulphate (318 mg/L). Microcystin, a toxin produced by cyanobacteria, averaged to 0.19 µg/L, well below the recreational guidelines of 20 µg/L.

Metals were measured once at Lac Santé; arsenic was the only metal to exceed the CCME PAL guidelines. Arsenic also exceeded these guidelines in 2011 (Table 2). Naturally high levels of arsenic are not uncommon in surface waters of the Beaver River Watershed.

Table 1 – Average Secchi disk depth and water chemistry values for Lac Santé. Previous years averages are provided for comparison.

Parameter	2006	2007	2008	2009	2012
TP (µg/L)	61	48.5	51.75	61	47
TDP (µg/L)	45.6	31.5	29	38.5	35.5
Chlorophyll-*a* (µg/L)	7.338	7.105	3.505	7.67	2.92
Secchi depth (m)	4.75	3.25	4.83	5.75	6.81
TKN (µg/L)	2298	2010	2243	2335	2160
NO_2 and NO_3 (µg/L)	4.1	202	6.5	10.9	3.63
NH_3 (µg/L)	151.2	32	33.5	39.5	33.25
DOC (mg/L)	31.37	30.9	26.53	29.83	28.9
Ca (mg/L)	8.14	7.68	7.8	8.74	7.67
Mg (mg/L)	178.7	175	152.7	159.3	153.5
Na (mg/L)	209.7	215	207	217.5	216.5
K (mg/L)	49.9	50.75	49.2	55.13	56.75
SO_4^{2-} (mg/L)	295.3	273	282.7	319.8	318
Cl^- (mg/L)	48.97	50.8	49.5	55.13	17.4
CO_3 (mg/L)	148	146.5	140.3	143.75	150
HCO_3 (mg/L)	790.7	789.5	808.3	820.75	829.8
pH	9.18	9.12	9	9.1	9.13
Conductivity (µS/cm)	1873.3	1880	1886.7	1917.5	1985
Hardness (mg/L)	756	740	648	677.3	651.5
TDS (mg/L)	178.7	175	152.7	159.3	1330
TSS	16.3	16.4	16.4	17.4	1.7
Microcystin (µg/L)	0.66	0.68	0.17	0.13	0.19
Total Alkalinity (mg/L $CaCO_3$)	1293	1275	1253	1325	930.75

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO_{2+3} = nitrate+nitrite, NH_3 = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. A forward slash (/) indicates an absence of data.

Table 2 - Concentrations of metals measured in Lac Santé on August 7th. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	**2011**	**2012**	**Guidelines**
Aluminum µg/L	20.1	22	100[a]
Antimony µg/L	0.1525	0.159	6[e]
Arsenic µg/L	5.43	5.62	5
Barium µg/L	4.36	4.69	1000[e]
Beryllium µg/L	0.00435	0.016	100[d,f]
Bismuth µg/L	0.0018	0.0005	/
Boron µg/L	434	378	5000[ef]
Cadmium µg/L	0.00425	0.0189	0.085[b]
Chromium µg/L	0.3045	0.362	/
Cobalt µg/L	0.09975	0.119	1000[f]
Copper µg/L	1.2235	1.03	4[c]
Iron µg/L	14.425	18.1	300
Lead µg/L	0.02425	0.0202	7[c]
Lithium µg/L	261.5	205	2500[g]
Manganese µg/L	5.625	3.68	200[g]
Molybdenum µg/L	1.14	1.26	73[d]
Nickel µg/L	0.2125	0.506	150[c]
Selenium µg/L	0.349	0.239	1
Silver µg/L	0.015725	0.0167	0.1
Strontium µg/L	22.3	23.1	/
Thallium µg/L	0.000425	0.0004	0.8
Thorium µg/L	0.02115	0.00015	/
Tin µg/L	0.015	0.0375	/
Titanium µg/L	1.42	1.35	/
Uranium µg/L	4.575	4.55	100[e]
Vanadium µg/L	1.365	1.62	100[f,g]
Zinc µg/L	1.345	1.39	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5; calcium ion concentrations $[Ca^{+2}]$ ≥ 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 > 180mg/L (as $CaCO_3$)
[d] CCME interim value.
[e] Based on Canadian Drinking Water Quality guideline values.
[f] Based on CCME Guidelines for Agricultural use (Livestock Watering).
[g] Based on CCME Guidelines for Agricultural Use (Irrigation).
A forward slash (/) indicates an absence of data or guidelines.

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

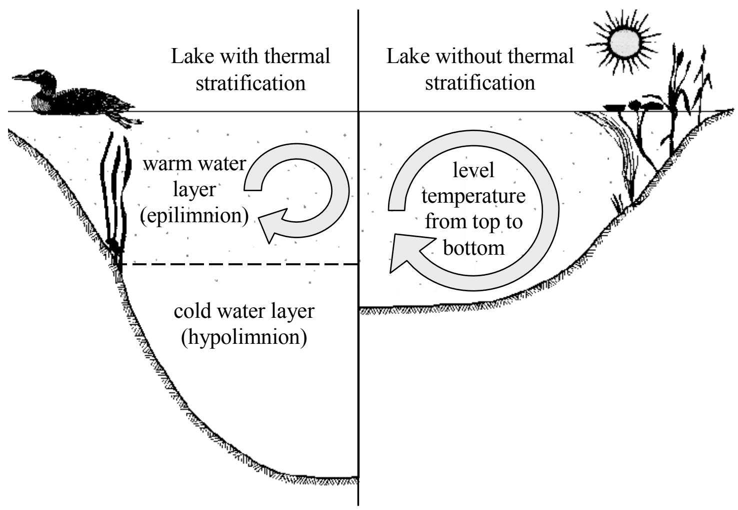

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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 $mg•L^{-1}$ and should not average less than 6.5 $mg•L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg•L^{-1}$ 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 (Table 2)**.

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.

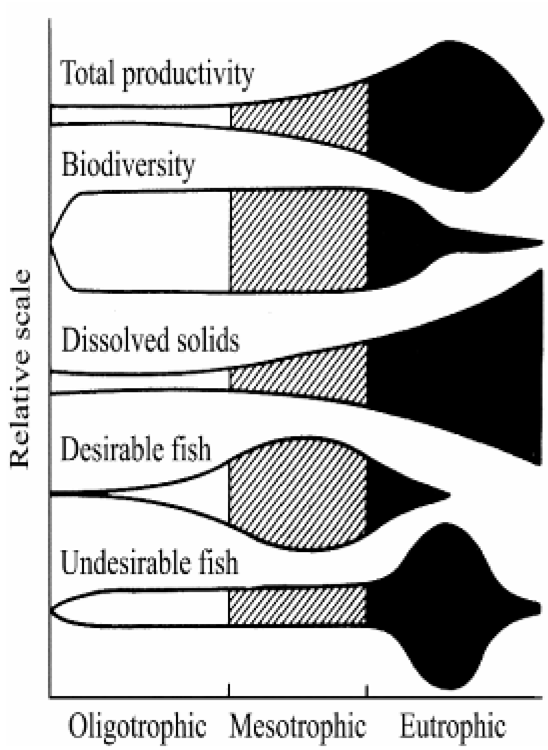

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

Table A - Trophic status classification based on lake water characteristics.

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