The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Clear Lake

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2008 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

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Clear Lake

Introduction

Clear Lake is located in the North Saskatchewan River drainage basin in east-central Alberta, near the Battle River valley. The lake sits at an elevation of 663 m above sea level and has a length of approximately 1.2 km and a width of 0.9 km. A bathymetric map of the lake is shown in **Figure 1**. The maximum depth of this lake is 18.59m (61 ft); mean depth data are unavailable.

The town of Wainwright, with a population of 5,400, and the Canadian Forces Base Wainwright are located approximately 20 km northwest of Clear Lake. Clear Lake, along with its larger neighbour Arm Lake, together make up a popular recreation area for the region. Clear Lake has roughly 104 residences on its shores, and also hosts a public beach and picnic area. Popular activities on the lake include swimming, boating, and fishing. During the ALMS sampling in the summer of 2006, resident lake users reported that large aquatic plants (known as macrophytes) have been increasing in the lake over the years. Because there are no long-term records it is difficult to say for certain if macrophyte cover has increased in the lake, but increasing nutrients and water clarity in some lakes can cause an increase in aquatic plant cover.

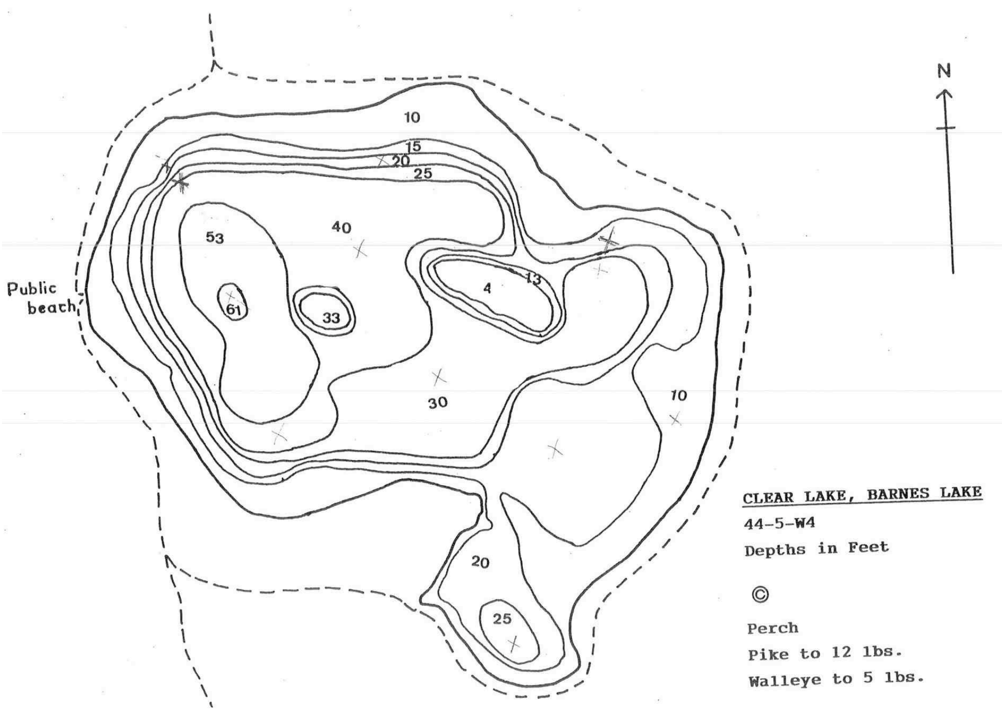

Figure 1. Bathymetric map of Clear Lake, AB.

Results

Water Levels

Water level in Clear Lake is not monitored. Unfortunately, previous Lakewatch reports used water level data that was for a different Clear Lake; corrections have been listed on the ALMS website.

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.

Clear Lake was thermally stratified throughout most of the summer of 2008 (**Figure 3**). A thermocline at 7 m depth had already formed by the first sampling date of 26 June, when surface water temperature was 19° C and declined to 5.8° C at the lake bottom. The thermocline increased in intensity by 29 July but remained at 7 m depth. Surface water temperature was highest on 19 August at 21.4° C, and the thermocline depth decreased to 4.5 m below the surface. On 8 September, surface waters had cooled to 15.5° C and thermocline depth increased to 11 m.

The surface waters (top 7 m) in Clear Lake were well-oxygenated and complied with surface water quality guidelines throughout the summer. In water depths deeper than 7 m, the amount of dissolved oxygen (DO) and water temperature declined rapidly. Despite near-anoxic conditions at the lake bed, the oxygen level in surface layers of Clear Lake was within the acceptable range for surface water quality, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L). The deeper waters of the lake were anoxic (DO = 0 mg/L) from 12 – 18m on 26 June, 19 August, and 8 September. On 29 July the anoxic zone was larger, extending from 8 – 18m.

There is a noticeable change in water temperature and dissolved oxygen in the upper layers of Clear Lake between 29 July and 8 September. Upper layers cooled between July and September, although hypolimnetic (bottom) layers remained isolated. The change in thermocline depth corresponded to a change in chemocline depth from 7m to 11m (i.e. the depth at which DO changes rapidly).

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.

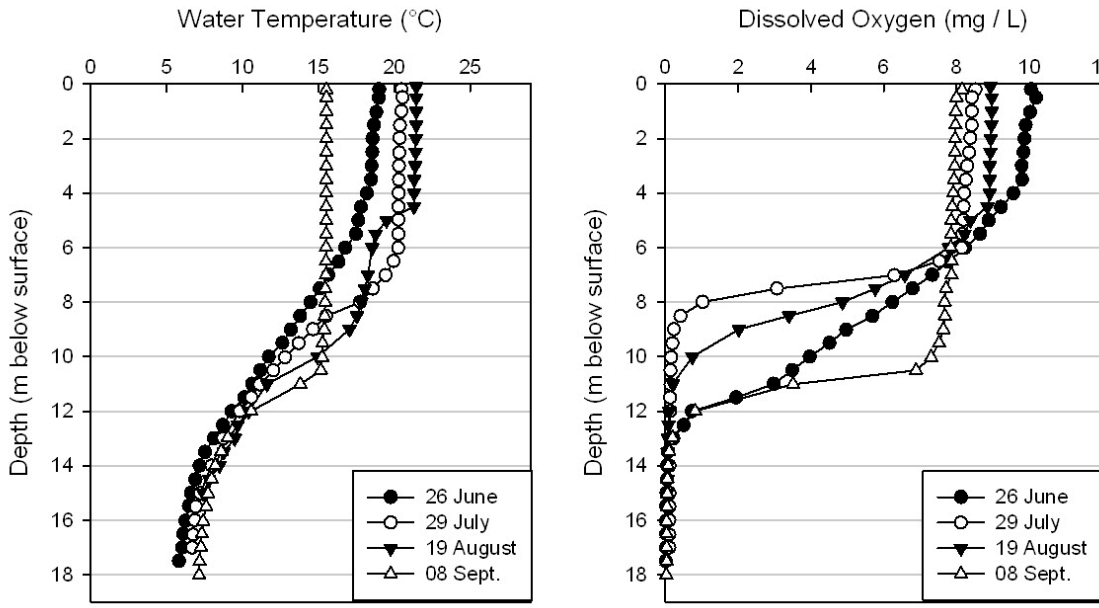

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Clear Lake during the summer of 2008.

As suggested by the name, Clear Lake's water was relatively clear during the summer of 2008 (average Secchi disk depth of 5.7 m or 31% of total lake depth; **Table 1**). Measured water clarity was greatest on 26 June, with a Secchi disk depth of 9 m. Water clarity began to decline by 29 July (Secchi depth = 5.8 m) and then steeply by 19 August (Secchi depth = 3.0 m), which corresponds to an increase in suspended particles. Water clarity increased in September (5 m) and was similar to late July conditions. This pattern is typical of productive lakes, in which suspended particles decrease water clarity (early summer), algae grow and consume suspended particles (late summer) and water becomes clear again. Fall over-turn may alter water clarity, especially if bottom sediments are re-suspended. As water clarity was good in September in Clear Lake, it suggests that fall over-turn either had not occurred yet or was incomplete, and bottom sediments were not re-suspended.

Water chemistry

Based on lake water characteristics, Clear Lake is oligotrophic to mesotrophic (see *A Brief Introduction to Limnology* at the end of this report). Nitrogen concentrations are within the eutrophic range (average TN = 0.88 mg / L), but phosphorous concentrations (average TP = 27 µg/L) fall within the mesotrophic range and algal biomass (chll *a* = 2.6 µg/L) is within the oligotrophic range (**Table 1**). Given that lakes in Alberta are naturally productive, Clear Lake is below average in nutrient concentrations and algae biomass. Total phosphorous and nitrogen concentrations, and algal biomass were relatively stable during the summer of 2008 (**Figure 4)**, although the data were limited to four sample dates.

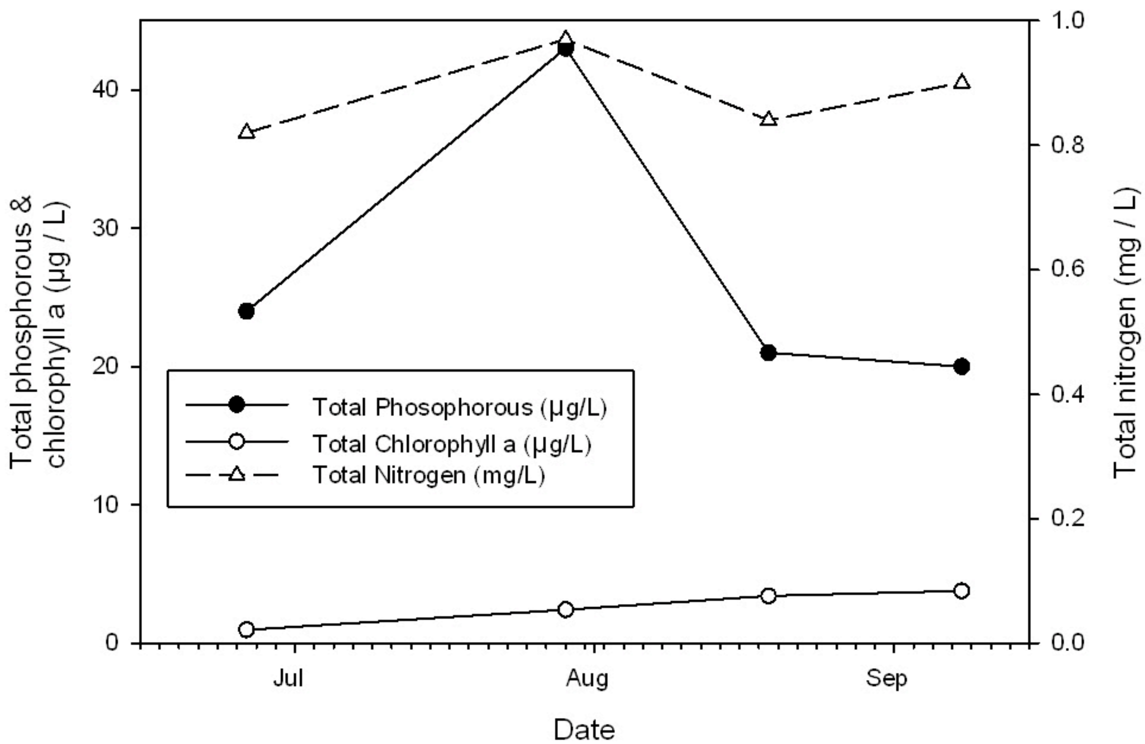

Figure 4. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Clear Lake during the summer of 2008.

Given that this is the third year that ALMS has monitored Clear Lake it is difficult to determine if phosphorus, nitrogen, and algae concentrations have undergone a recent change or if they have remained relatively constant; no obvious trends are present.

Clear Lake is a hardwater lake (**Table 1**) that is well-protected from acidification. The lake pH = 8.7 is well above that of pure water (= pH 7). While ion concentrations are fairly high compared to lakes globally, concentrations are low compared to other Alberta lakes sampled by ALMS. Dominant ions include bicarbonate, carbonate, sodium, and magnesium (**Table 1**). Because there are no long-term records of ion concentrations from Clear Lake it is not possible to assess possible changes in ion concentrations over time. Metal concentrations were not measured in Clear Lake in 2008.

Table 1. Mean water chemistry values for Clear Lake, summer 2006 - 2008.

Parameter	2006	2007	2008
TP (µg/L)	24	22	27
TDP (µg/L)	9.4	10	13.8
Chlorophyll-*a* (µg/L)	5.4	1.8	2.6
Secchi disk depth (m)	3.2	5.5	5.7
TN (mg/L)	0.94	0.87	0.88
NO_{2+3} (µg/L)	< 5	8	< 5
NH_4 (µg/L)	29	37.3	36.8
Dissolved organic C (mg/L)	9.8	10.9	9.6
Ca (mg/L)	18	19.6	20.5
Mg (mg/L)	43	43.5	43.7
Na (mg/L)	21	21.1	21
K (mg/L)	6.2	6.5	6.1
SO_4 (mg/L)	10.7	-	7.7
Cl (mg/L)	1.7	1.9	2.0
CO_3 (mg/L)	18	26.5	18
HCO_3 (mg/L)	292	300	294
pH	8.7	8.7	8.7
Conductivity (µS/cm)	479	470	479
Total dissolved solids (mg/L)	261	259	264
Total Alkalinity (mg/L $CaCO_3$)	268	274	271

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TN = total Kjeldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. SO_4 = sulphate (not measured in 2007).

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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 5). 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.

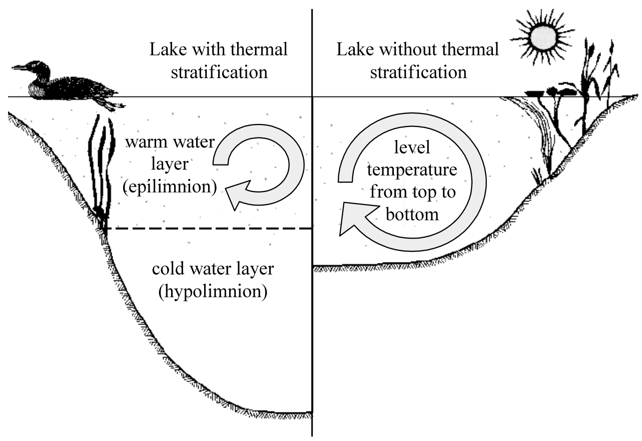

Figure 5: Difference in the circulation of the water column depending on thermal stratification.

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.

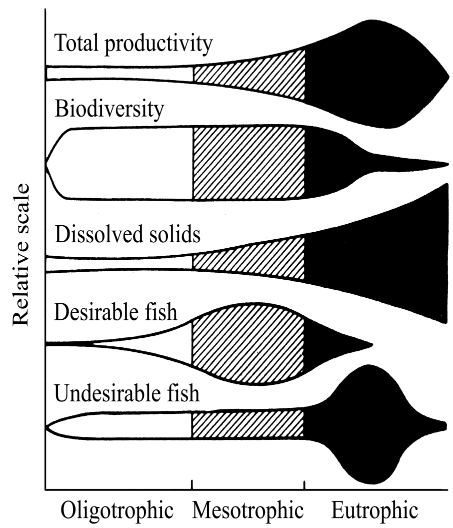

Figure 6: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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. 6.

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.