Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Lac La Biche Lake

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2004 Report

Completed with support from:

Alberta Lake Management Society

LICA
Lakeland Industry & Community Association

Lakeland County

Alberta Environment

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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 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 by the dedication of the Lakewatch Chairs, Théo Charette, Preston McEachern and Ron Zurawell, and the volunteers. Wendee Herrick and Megan Rawles of the Lakeland County Office were our volunteers at Lac La Biche Lake and made sampling possible through the dedication of time and of course watercraft. Our summer field technician and volunteer coordinator, Heather Jones, was a valuable addition and contributor to this year's program. Numerous Alberta Environment staff also contributed to successful completion of the 2004 program. Project Technical Coordinator, Shelley Manchur was instrumental in planning and organizing the field program. Technologists, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair was responsible for data management. Théo Charette and Preston McEachern (ALMS Directors) were responsible for program administration and planning. Heather Jones and Ron Zurawell (Limnologist, AENV) prepared this report. Alberta Environment and Lakeland County financially supported sampling of Lac LaBiche.

Lac La Biche (East and West Basins)

Introduction

The historical name of Lac La Biche comes from the Cree people of the area, who called the lake *Waskesiu Sakhahegan,* which translates to Elk Lake. The name "Lac La Biche" comes from the French word "biche" which translates to "hind", a term used to describe the female of the European Red Deer. The same designation was used to describe the North American Elk by the French Fur Traders (Mitchell and Prepas, 1990). This term was carried west with the French Fur Traders; henceforth the name of the lake became "Lac La Biche "or in coarse English translation "Red Deer Lake"-first appearing on a 1793 Mackenzie map (Chipeniuk, 1975).

Figure 1. Watershed of Lac La Biche.

Lac La Biche is located 54° 52" N & 112° 05"W; in the Athabasca River Basin. The Lac LaBiche watershed, or the surface area of land from where the lake receives its water, is approximately 4,040 km² in area (**Figure 1**). The watershed is approximately 17 times the size of the lake (234 km²), and is located east and north of Lac la Biche Lake. As precipitation collects in the form of snow, ice or rain it picks up nutrients, soil particles and other materials and carries them to the lake. Large watersheds, compared to the lake volume, export more nutrients than relatively small watersheds. Thus, lakes with relatively large watersheds tend to be more concentrated in nutrients and algae (Prepas et al. 2001).

The main inflow to Lac La Biche is the Owl River and its tributaries, which are the Clyde, Logan, and Piché Rivers, along with Gull Creek, all entering the East Basin from the northern area of the watershed. At the south of the East Basin, two small creeks of which only one is named (Red Deer Brook) enter the lake. Plamondon Creek is the main inflow into the West Basin. There are several small-unnamed creeks and streams located around the lake that flow into both the East and West Basins of Lac La Biche. The only outflow of the lake is Lac La Biche River located on the northwest shore of the West Basin (**Figure1**). Lac La Biche River outflows into the Athabasca River.

As a very scenic lake (**Figure 2**), Lac La Biche is highly valued for its sandy beaches, forested parks, and lakeshores. Lac la Biche is situated in Lakeland County aptly named for the abundance of lakes found in this region. The lake is home to two communities, the Town of Lac La Biche, which is located on the East basin, and the Hamlet of Plamondon, which is located on the West basin. Private homes, sub divisions, and cottages are scattered along the shoreline of both east and west basins of the lake. Development around the lake is relatively low compared to the total lakeshore area. However, a large percentage of the total shoreline is used for agriculture purposes (Mitchell and Prepas, 1990). Primary industries in the area are forestry, oil and gas production, commercial and recreational fisheries, tourism and agriculture. In 1925 all the islands on the lake were designated as bird sanctuaries (Lakeland County, 2002). The lake is a stop over for migratory birds and home to large populations of cormorants. Forest and wetlands cover the majority of the drainage basin of Lac La Biche (Mitchell and Prepas, 1990). A gradual demise of the forests of the southern and western parts of the lake drainage basin has taken place in the last 20^{th} Century, largely for agriculture use (Schindler et al, 2003).

Figure 2. Lac La Biche East Basin, near the town of Lac La Biche. Photo courtesy of Heather Jones, 2004 ALMS Field Tech.

This area topography is described as knob and kettle. In the poorly drained soils of this zone, Organic and Gleysolic soils are prevalent.The dominant soil order within the Lac La Biche watershed is Luvisols. Areas of Regosol, Organic and Brunisolic soils are also found within the Lac La Biche watershed (Mitchell & Prepas, 1990). South and west of Lac la Biche are numerous bogs and fens in these areas organic soils are found (Mitchell & Prepas, 1990). The areas south and west of the lake are in poorly drained regions and, are saturated with water for long periods.

The surface area of Lac La Biche is 234 km² with a maximum depth of 21.3 m, and a mean depth of 8.4 m. The lake is comprised of two basins East and West separated by a peninsula and two large islands (**Figure 3**). The East basin is more complex compared to the West basin, with several smaller sub basins, numerous islands, sand and gravel spits, and a causeway connecting Big Island (Sir Winston Churchill Provincial Park) to the mainland. The maximum depth of the East basin is 12 m. The west basin is less complex in shape and has a gradual bottom slope with a maximum depth of 21.3 m

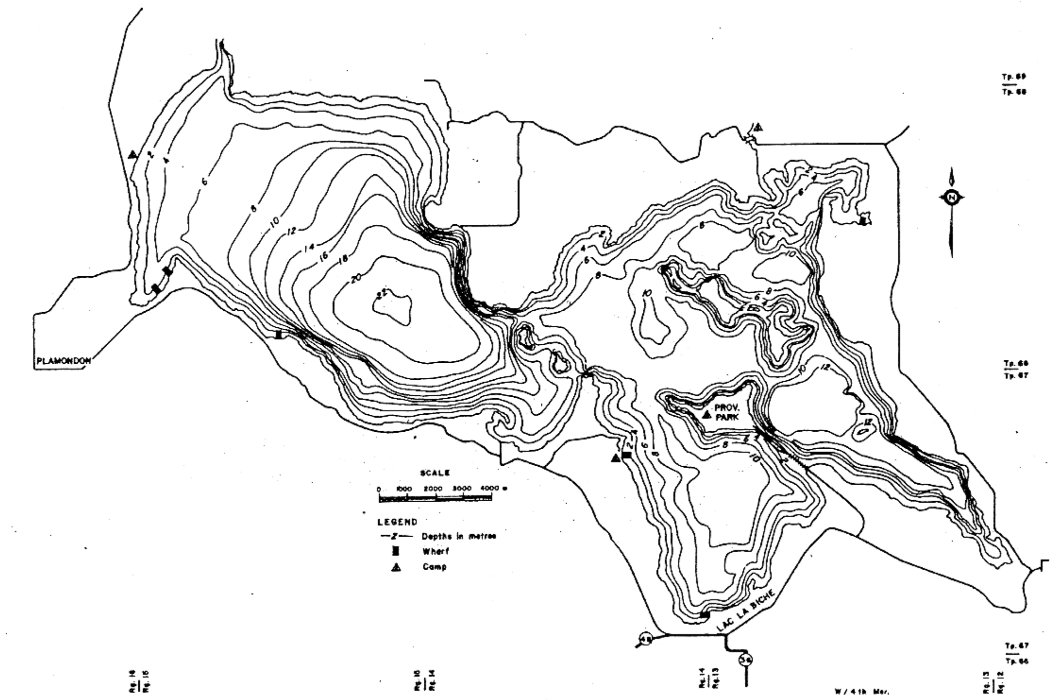


Figure 3. Bathemetry of Lac La Biche. Each contour line represents 2 m.

Results

Water Levels

Water levels in Lac La Biche have been recorded since monitoring began in 1929 (**Figure 4**). Maximum water levels occurred in 1961, when they reached 557.4 m. Minimum levels were in 1993, when they dropped to 542.6 m. Water levels in Lac La Biche seem to display a step pattern: levels dropped in the late 1980s and have remained about 0.3 m lower than pre-1972 mean.

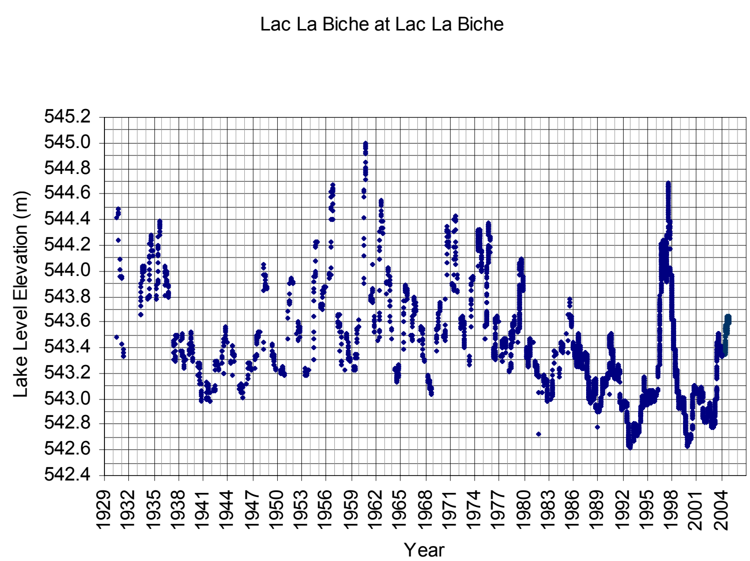


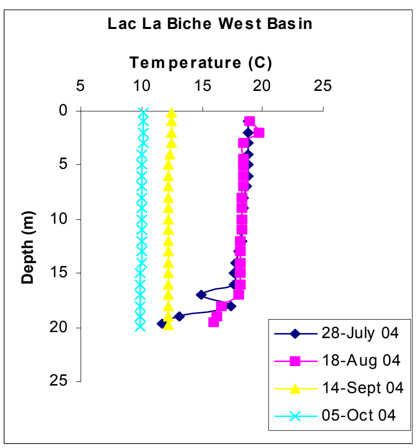
Figure 4. Historical Water Levels of Lac La Biche.

A decline in precipitation during the 1980s and 1990s in the Lac La Biche County, resulted in a decrease to mean annual inflow from 315 million m³ to 195 million m³ (Bothe, 1989; Tagggert, 1995). The reduction to annual inflow caused a gradual decrease in lake levels. This resulted in an increase to the lake water resident time from 7 years to 13 years (Mitchell, 1993, 2000). In 1998, Lac La Biche showed a spike in water levels then a dramatic decrease to 542.6 m. The water levels in the lake appear to be recovering due to the increase in precipitation in 2004.

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.

Temperature in the western basin of Lac La Biche was fairly constant with depth during the summer of 2004, indicating well-mixed and oxygenated waters (Figure 6), with few signs of themal stratification. Low oxygen concentrations at the bottom of the western basin (Figure 6) are the result of decomposition of organic matter at the lake bottom but, for the most part, did not extend to the rest of the water column because of fairly good water circulation. Consequently, dissolved oxygen



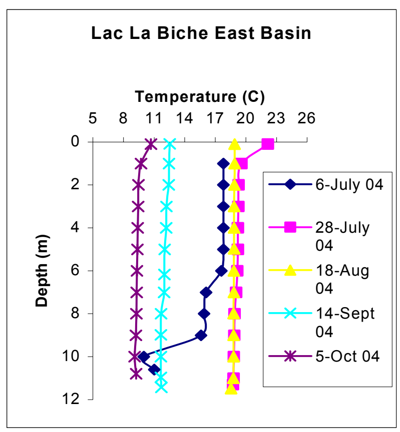
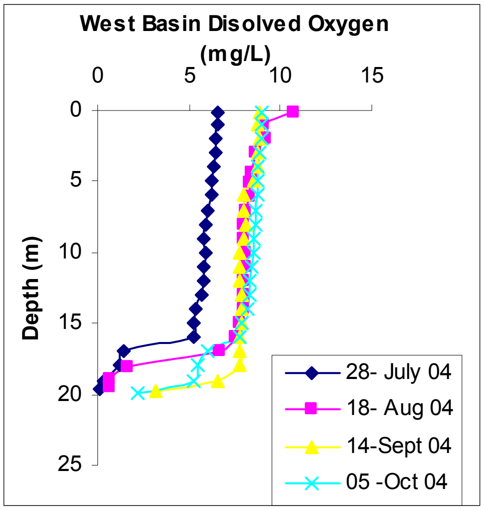


Figure 4 & 5: Temperature profiles for Lac La Biche East and West Basins, summer 2004.

concentrations in the western basin met the Provincial Guidelines for the Protection of Aquatic Life (5 mg/L dissolved oxygen) throughout most of the water column, except at the bottom 3 meters of the basin.

The eastern basin's water column thermally stratified during July: the temperature changed at near a depth of 6 meters on July 6 and near the surface on July 28th (Figure 5). Oxygen concentrations mimicked temperature concentrations, with oxygen concentrations dropping rapidly below the thermocline (Figure 7). These results indicate oxygen-consuming decomposition of organic matter at the lake bottom and a lack of circulation of oxygen-rich waters from the lake surface. The pattern of oxygen levels decreasing with depth displays a clinograde oxygen profile, which suggests that the lake is eutrophic. For the remainder of the sampling season water temperature was constant with depth.



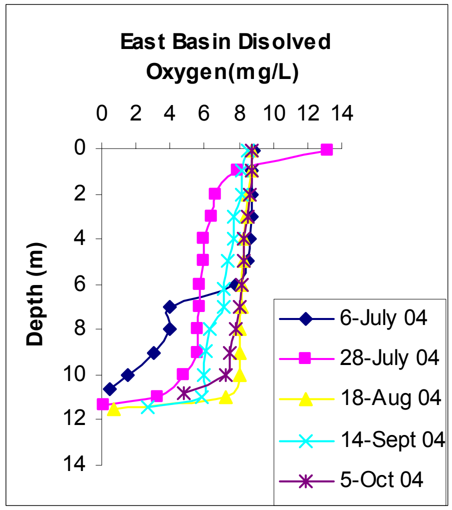


Figure 6 & 7. Dissolved Oxygen Profiles of the East & West Basins of Lac La Biche, summer 2004.

Water Clarity and Secchi Depth

Water clarity is influenced by suspended materials, both living and dead, as well as some coloured dissolved compounds in the water column. During the melting of snow and ice in spring, lake water can become cloudy from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

Lac La Biche water averaged a fair clarity during the sample season of 2004: Secchi disk depth averaged better than two meters in both basins (**Table 1**). However, water clarity got very low at the end of July in the East basin at 0.25 m, and 1.5 m in the West basin. Clarity was highest in early October in the East basin at 4.2 m, and 3.25 m in the West basin.

Water Chemistry

Both basins of Lac La Biche are hypereutrophic, which means that they have very high productivity and have average summer concentrations of total P above 100 µg/L (Table 1; **see a Brief Introduction to Limnology at the end of this report**). In general, the eastern basin has higher concentrations of nutrients and three times the amount of algae (as determined by chlorophyll *a* concentration). In both basins, nutrient concentrations and algal biomass increased throughout the summer up to mid-august, and then declined again in the fall. This is a classic Alberta example of release of nutrients from the sediments enabled by low oxygen concentrations. This usually occurs in late summer, when thermal stratification is strongest. The highest concentration of nutrients in the East basin occurred on July 28 as a result of internal loading that coincided with strong thermal stratification and low oxygen concentration in the water column (Figure 7). When these conditions occur phosphorus is released from the sediment, and with wind action can be transported to the photic zone of the water column where it is actively taken up by algae.

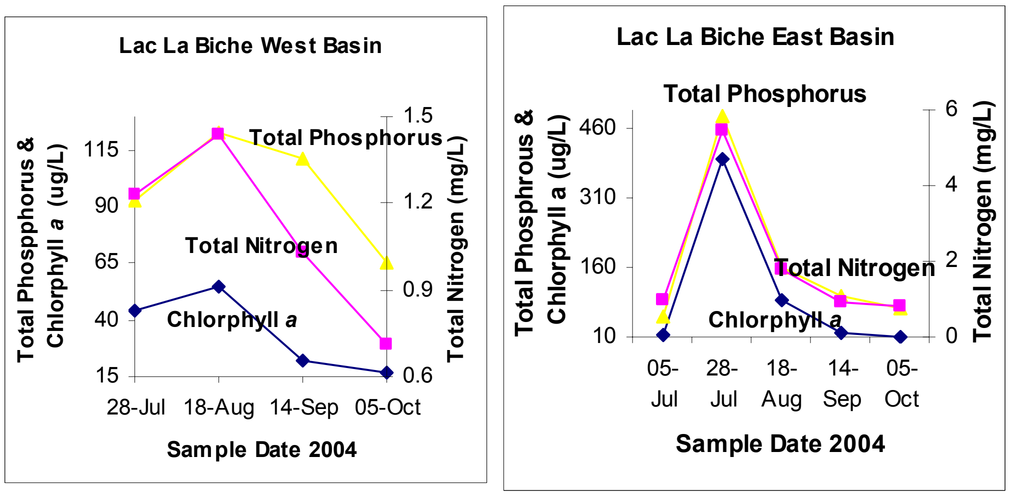


Figure 8. West and East Basins of Lac La Biche Total Nitrogen and Total Phosphorus (2004).

Lac La Biche has a long history of algal blooms dating back to the 1920's (Chipeniuk, 1975). Both the East and West basins of Lac La Biche exhibit the necessary factors that promote algae growth. These factors include; a stable water column, warm water temperatures, high epilimnetic nutrient concentrations, low nitrogen

Figure 9. High algal biomass in the East Basin, late July 2004. Photo courtesy of Heather Jones, 2004 ALMS Field Tech.

to phosphorus ratios, high pH, low available CO_2 concentrations, and reduced grazing by large zooplankton.

The algal biomass, measured as chlorophyll *a* peaked higher in the East basin in late July (**Figure 9**) than in the West basin, although an increase was seen in the West basin compared to other sample dates (**Figure 8**). It was suggested in a study by Mitchell, 1993, that the east basin's average higher algal biomass (**Table 1**) is a result of prevailing winds that blow algae eastward where they accumulate in the sub basins against the causeway and along the shoreline.

Calcium and bicarbonate are the dominant ions of the lake, which reflects the calcium carbonate parent material of the drainage basin; the water in both basins is hard and well buffered. The East and West basins are very similar in chemical make up (**Table 1**). This similarity reflects the relative shallowness of each basin, and the typical wind activity of the area, which keeps the water well mixed during the open water seasons. The pH, salinity and related variables are well within the range required for aquatic organisms, and drinking water (Guidelines for Canadian Drinking Water, 2004). There is not enough historical data collected on the chemistry of Lac La Biche to conclude if any major changes have occurred. Continued testing of the lake is encouraged to build an extended database.

Table 1: Mean chemical characteristics of Lac La Biche East and West Basins.

Parameter	East 2004	West 2004
Total P (µg/L)	0.146	0.103
TDP (µg/L)	0.055	0.062
Chlorophyll *a* (µg/L)	91.48	32.2
Secchi disk depth (m)	2.06	2.25
Total N (µg/L)	1.81	1.07
NO_{2+3} (µg/L)	0.0905	0.1236
NH_4 (µg/L)	0.026	0.376
Ca (mg/L)	31.7	32.9
Mg (mg/L)	10.24	10.31
Na (mg/L)	13	14
K (mg/L)	3	3
SO_4 (mg/L)	9	9
Cl (mg/L)	3.5	3.5
CO_3 (mg/L)	180	176
HCO_3 (mg/L)	3	4
Total Alkalinity (mg/L $CaCO_3$)	149	150
pH	8.13	8.32

lote. TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = otassium, SO_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = arbonate.

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

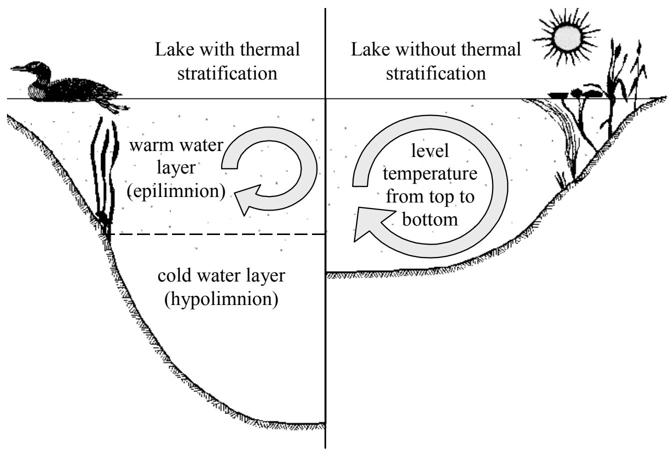


Figure 10: Difference in the circulation of the water column depending on thermal stratification.

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. 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 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 suggest 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 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. 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, can exist at 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 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 shallow. However, Secchi disk depth is not only affected by algae. 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 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.

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.

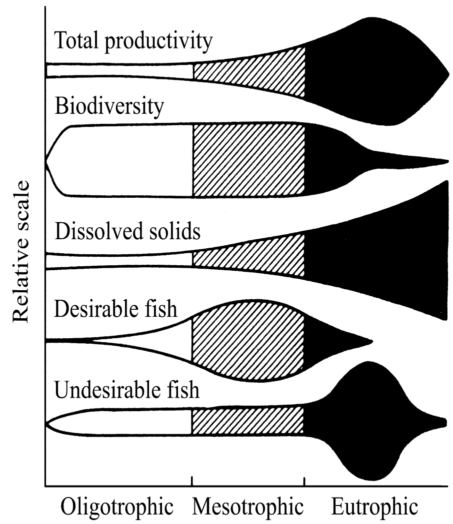


Figure 11: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.