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Lakewatch

Buck Lake

The Alberta Lake Management Society
Volunteer Lake monitoring report

And you really live by the river? What a jolly life!"

"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." *Kenneth Grahame The Wind in the Willows*

"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water." *BBC World Water Crisis Homepage*

A note from the Lakewatch Coordinator Preston McEachern

Lakewatch has several important objectives, one of which is to document and interpret water quality in Alberta Lakes. Equally important are the objectives of educating lake users about their aquatic environment; enhancing public involvement in lake management; and facilitating a link between aquatic scientists and lake users. The 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. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these sources.

The 2002 Lakewatch Report has undergone a substantial change in format from previous years. I am no longer the author as much as an editor including text and figures from others who have done an excellent job describing lakes throughout Alberta. I have attempted to give due credit to these outstanding people and apologize for blatant plagiarism where it occurs. As editor, feel free to castigate me for errors. I have included easily accessible information that is likely to have been updated in recent years and readers are encouraged to help update these reports by sending new information to me.

I would like to thank all people who share my love for aquatic environments and particularly those who have helped in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that water will not be the limiting factor in the health of our planet.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Alberta Environment employees. Mike Bilyk, John Willis, Doreen LeClair and Dave Trew from Alberta Environment were instrumental in funding, training people and organizing with Lakewatch data. Comments on this report by Dave Trew were appreciated. Alberta Lake Management Society members and the board of directors helped in many facets of water collection and management. Susan Cassidy was our summer field coordinator and was an excellent addition to the program. Her hard work made it possible for Lakewatch to expand to 17 lakes, more than triple the number in any previous year! Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred.

Buck Lake

Buck Lake, in the county of Wetaskiwin, resides in an area originally known as *Minnehik* or "Place of the Pines" by local Cree. Buck Lake, itself, was known for having "large whitefish of unusually fine flavor" that were harvested for the fur traders at Rocky Mountain House. Local forestry operations removed most of the larger trees in the early part of this century. Subsequent industrial activity was dominated by intensive drilling for oil and gas and agriculture (Mitchell and Prepas 1990). The lake is important for recreation with Calhoun's Bay Provincial Recreation area and the popular town of Buck Lake which hosts the annual Buck Lake Stampede. Sport fish include lake whitefish, walleye, northern pike and yellow perch. Buck Lake has supported active commercial and domestic fisheries in the past.

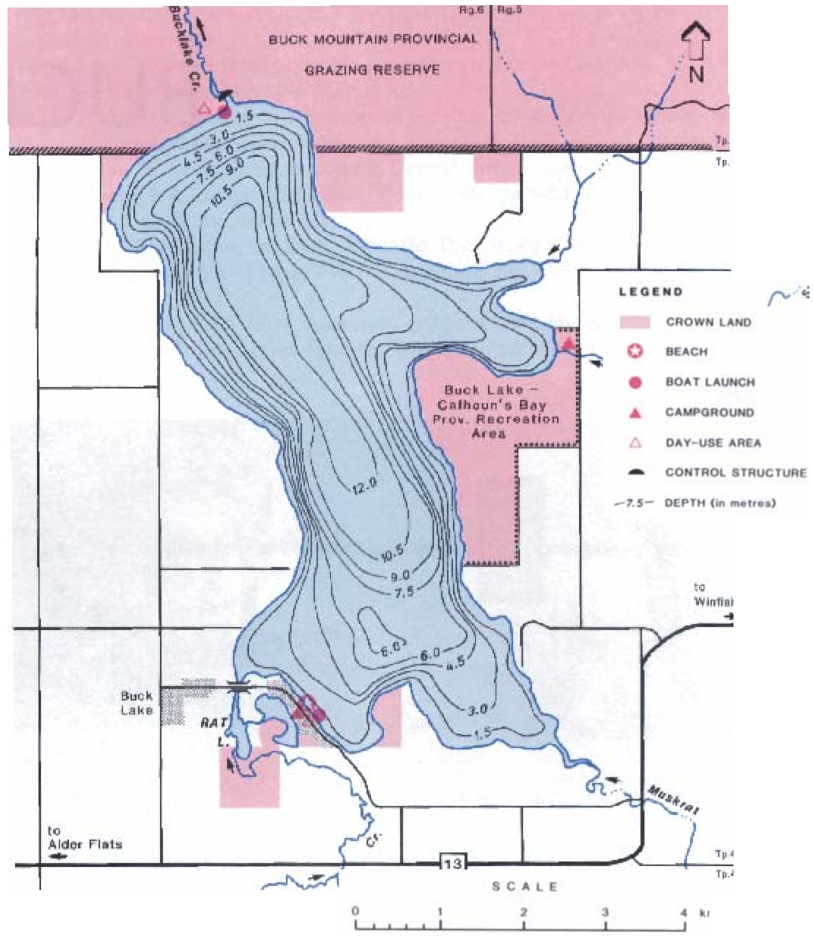


Fig. 1: Bathymetry of Buck Lake. From Mitchell and Prepas 1990.

Buck Lake is over 12 m deep (Fig. 1) and is dimictic. However, dense algal blooms are known to occur during summer months due to the lakes natural fertility. Detailed studies have been done on plant and fish ecology in Buck Lake. Nutrient concentrations, particularly phosphorus, increases through the summer and may peak as late as September with an associated peak biomass for phytoplankton. Phytoplankton are dominated by Cryptophyta in early summer followed by Cyanophyta and Bacillariophyta (Diatoms) in mid summer and finally Cyanophyta in the Fall (Mitchell and Prepas 1990). Green algae comprise a small percentage of phytoplankton community. Aquatic reeds fringe much of the lake with *Scirpus validus* being a dominant plant. These reed beds support the healthy fishery of Buck Lake. For example whitefish spawning is concentrated in reed and submerged aquatic plant beds at gravel substrates along the south end and Calhoun's Bay shorelines.

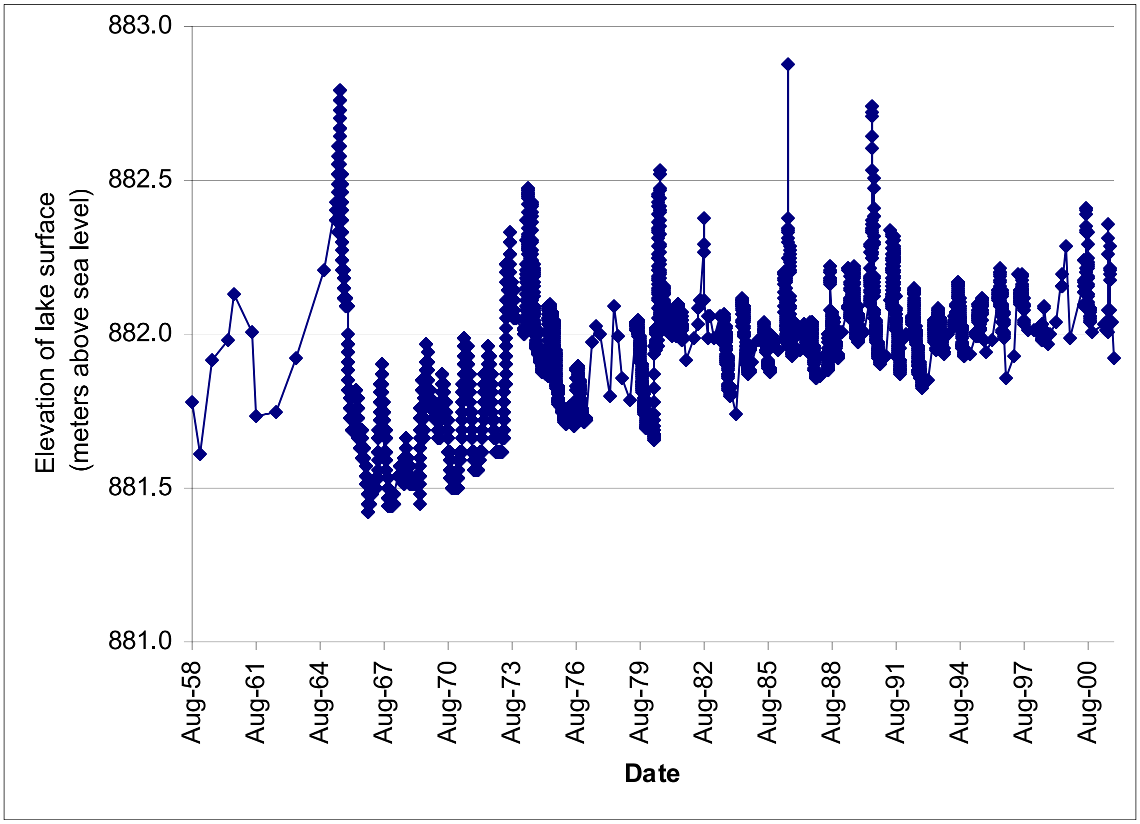
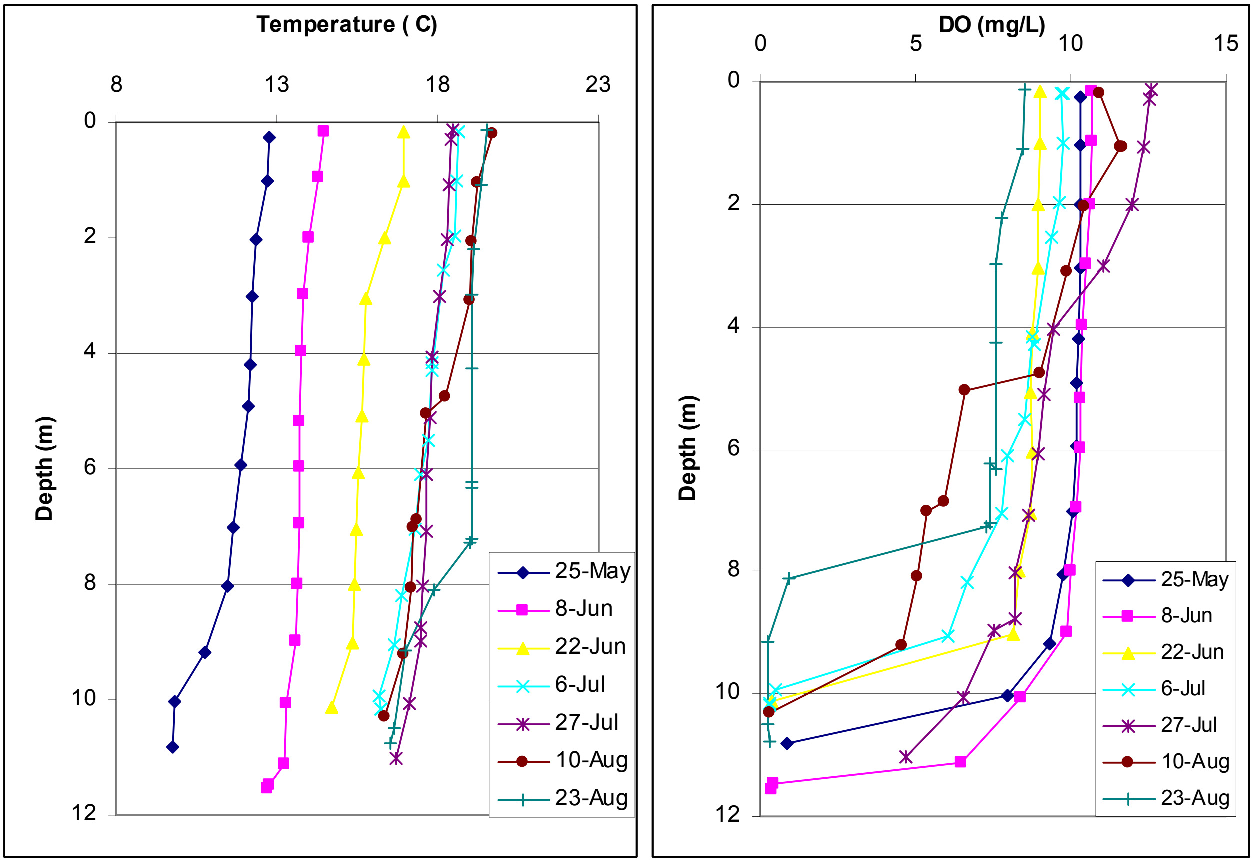


Fig. 2: Water levels of Buck Lake, 1958-2001.

Water levels in Buck Lake have been monitored since 1958. Water levels rose to one of the highest values in 1965 but dropped 1.4 m to a minimum in 1966 (Fig. 2). A weir was installed at the outflow of Buck Lake to stabilize water levels in 1966 and water levels slowly rose through the next 20 years to an average elevation close to 882.1 m above sea level which has been maintained through to October 2001. Unlike other lakes in Alberta, decreasing water level is not a problem in Buck Lake.



Figs 3 & 4: Temperature and dissolved oxygen profiles for Jackfish Lake in 2001

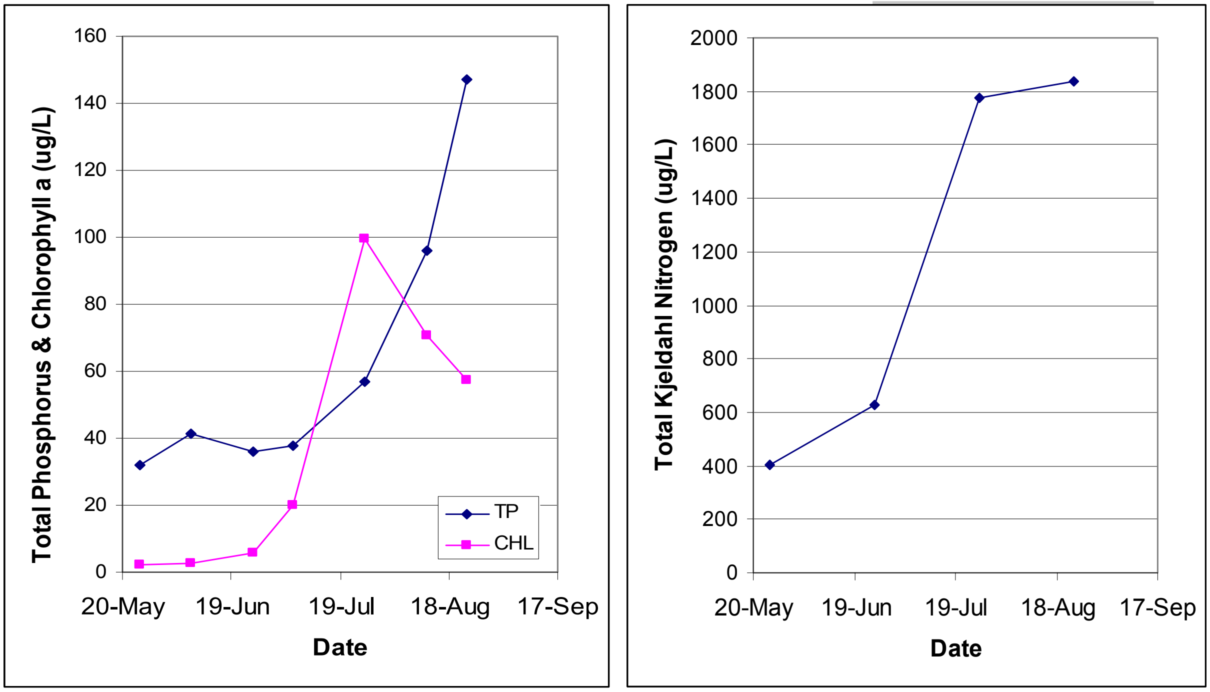
Results

Water temperature and dissolved oxygen

Weak thermal stratification formed at 5m depth in early August. Stratification became stronger through August and moved down to 7 m depth. Dissolved oxygen concentrations were above 9 mg•L^{-1} through the summer until August and relatively uniform with depth until close to the lake bottom. As a result of stratification in August, dissolved oxygen concentrations declined below the thermocline at 5 m then 7 m to near anoxic conditions.

Water clarity and Secchi Depth

Water clarity is influenced by the suspended material, both living and dead, as well as some coloured dissolved compounds in the water column. The most widely used measure of lake water clarity is the Secchi depth. After ice and snowmelt a lake can have low clarity due to spring runoff and suspended sediments in the lake. Lake water usually clears in the spring but then becomes less clear as algae grow through the summer. In Buck Lake, the Secchi depth was 3.3 m in May, rose to its maximum clarity in June (4.05 m) and slowly declined to 1.8 m in mid-August. Water colour averaged 25 mg•L^{-1} Pt but was only measured in late July and August.



Figures 5 & 6: Total phosphorus, chlorophyll *a* and Kjeldahl nitrogen for Buck Lake, summer 2001.

Table1: Mean values from summer 2001 samples compared to values from those reported in the Atlas of Alberta Lakes.

Parameter	1983	1984	1991	2001
TP (μg•L^{-1})	38	42	62	64
Chl (μg•L^{-1})	15.4	20.8	33.2	37
Secchi (m)	3.4	2.9	1.6	2.6
TKN (μg•L^{-1})	750	770	-	1160
TN (μg•L^{-1})	770	772	-	1181
$NO_{2+3}N$ (μg•L^{-1})	20	2	-	21
NH_4^+ N (μg•L^{-1})	29	7	-	2
Ca (mg•L^{-1})	23	-	23	25
Mg (mg•L^{-1})	5	-	6	6
Na (mg•L^{-1})	12	-	10	13
K (mg•L^{-1})	4	-	4	5
SO_4^{2-} (mg•L^{-1})	< 7	-	5	4
Cl^- (mg•L^{-1})	4	-	2	2
Total Alkalinity (mg•L^{-1} $CaCO_3$)	111	-	83	112

Water chemistry

Ion concentrations have remained virtually unchanged in Buck Lake since data were collected in 1983. Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The stable ion concentrations suggest Buck Lake has remained in equilibrium with its hydrology over the period of data records. Atmospheric deposition of acidifying pollutants from petroleum activities can often be seen in increasing sulfate concentrations. Excessive evaporation or changes in surface runoff that favor groundwater contributions or even problems with well injections of wastewater all result in changes inn base cation concentrations. Such changes were not observed in Buck Lake indicating that it has not been impacted by these types of development.

Buck Lake is eutrophic with what is considered high nutrient concentration and algal biomass compared to lakes throughout Canada. In the Alberta context, Buck Lake is about average in these characteristics. Nutrient concentrations seem to have increased from 1983 to 1991. However, this may be due in part to climate and wind conditions in each year. Buck Lake stratified in 1984, 1991 and in 2001. This stratification led to the formation of an anoxic hypolimnion with high concentrations of phosphorus which were included in the summer mean value. For example, in 1991, total phosphorus concentrations were over 120 $\mu g \bullet L^{-1}$ below 7 m depth from late July through early September. In 2001, a similar pattern developed with hypolimnetic TP reaching over 200 $\mu g \bullet L^{-1}$. Over 80% of phosphorus supply to Buck Lake is estimated to derive from lake sediments as internal load (Mitchell 1992). Willowhaven Creek is the only inflow with significant total phosphorus concentrations (148 $\mu g \bullet L^{-1}$) but its low flow likely limits the impacts on Buck Lake.

Chlorophyll *a* (CHL) concentrations in Buck Lake were relatively low in 1983 (<30 $\mu g \bullet L^{-1}$) compared to 1984, 1991 and 2001 when they typically exceeded 50 $\mu g \bullet L^{-1}$ during late summer. In 2001, peak chlorophyll *a* concentrations were 100 $\mu g \bullet L^{-1}$ in late July and remained above 50 for the remainder of the summer (Fig. 5). Late July algal biomass, as indicated by CHL, indicated bloom conditions as CHL exceeded TP concentration. August samples demonstrated that the algal community had declined to a more equilibrium condition with the rising TP concentration. Bloom conditions similarly occurred in 1991 but were not to the extent seen in 2001.

While Buck Lake does not appear to be impacted by the problems common to other lakes in Alberta such as loss of water and changes in ion chemistry, the 2001 data do indicate that one common problem, eutrophication my be occurring in Buck Lake. Monitoring of nutrient concentrations should continue in Buck Lake to determine if they are elevated and if excessive algal blooms continue to occur. Algal community composition should be determined as a follow up to data collected in 1983 to determine if the algal blooms contain potentially toxin producing cyanobacteria. Additional analyses of water samples for the cyanotoxin microcystin may be warranted during bloom periods in August.

A brief introduction to Limnology

Indicators of water quality

Water samples are collected in Lakewatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in Lakewatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

Temperature and mixing

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of the lake. As the difference in temperature between warm surface and cold deeper water increases, two distinct layers are formed. Limnologists call these layers of water the **epilimnion** at the surface and the **hypolimnion** at the bottom. The layers are separated by a transition layer known as the **metalimnion** which contains the effective wall separating top and bottom waters called a **thermocline**. A thermocline typically occurs when water temperature changes by more than one degree within one meter depth. The hypolimnion and epilimnion do not mix, nor do elements such as oxygen supplied at the surface move downward into the hypolimnion. In the fall, surface waters begin to cool and eventually reach the same temperature as hypolimnetic water. At this point the water mixes from top to bottom in what is often called a **turnover** event. Surface water cools further as ice forms and again a thermocline develops this time with 4° C water at the bottom and near 0° C water on the top.

In spring another turnover event occurs when surface waters warm to 4° C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are termed **polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic** meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice free season the lake is polymictic.

Dissolved Oxygen

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 mg•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**. A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

Trophic status classification based on lake water characteristics.

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

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.