Preston McEachern
9637 – 81 Ave.
Edmonton, AB, T6C 0X6
(780) 427-1197
prestonm@telusplanet.net

Lakewatch

Sandy 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.

Sandy Lake

Sandy Lake is a shallow, extensively developed recreational lake northwest of Edmonton. At one time it was known for having a good yellow perch fishery with some northern pike. The name derives from the sand that dominates surface geology throughout the region. Likely important to nomadic Plains Cree, Treaty No. 6 established the Alexander Indian Reserve east of Sandy Lake in 1876. Agriculture developed around Sandy Lake throughout the 1800s as European settlers arrived. However, recreation became the primary use for Sandy Lake in the 1900s and by 1988 there were over 1000 lots within 1.5 km of the shoreline. In addition to permanent and summer inhabitants, there are two commercial campgrounds, a day use area, two public boat launches and a Girl Guides camp at Sandy Lake. .

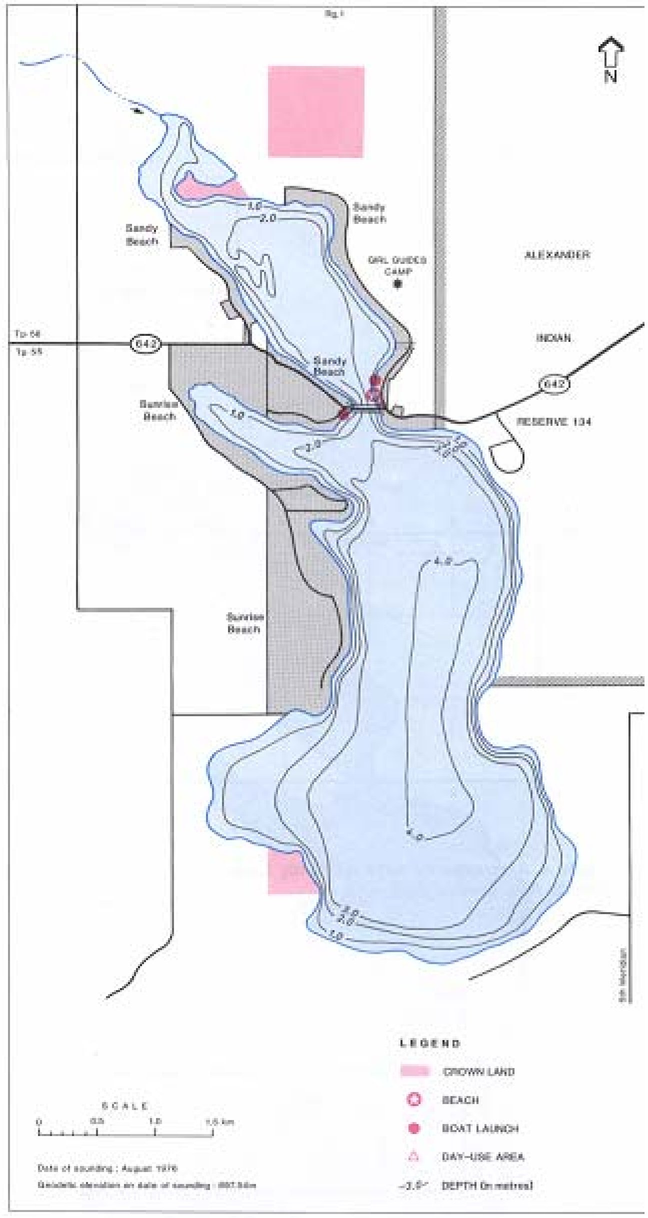


Fig. 1: Bathymetry of Sandy Lake. From Mitchell and Prepas 1990.

Sandy Lake is split into two basins with a causeway over the constriction. The north basin is small and about 2 m deep. The south basin is much larger and about 4 m deep (Fig. 1). Sandy Lake is monomictic or polymictic becoming stratified in the winter but remaining completely mixed through the summer. Regular mixing of water has large implications on the fertility of the lake. The lake has become hypereutrophic and dense algal blooms are known to occur during summer months due to the lakes natural fertility. Sandy Lake has received extensive scrutiny compared to other lakes in Alberta likely because of its recreational importance and its water quality problems. Detailed studies have been done on the nutrient budget for Sandy Lake. Although the drainage basin is relatively small (48.4 km^2), only 4 times larger than the lake, the lake receives enough water to maintain lake levels possibly from regional groundwater sources.

Water levels have been monitored at Sandy Lake since 1959 (Fig. 2). Prior to the last few years, the historic minimum lake level occurred in 1970 (696.8 m a.s.l.) and the maximum lake level occurred during 1974 (698.06 m a.s.l.). Lake water levels were relatively stable, and high, through the late 70s and 80s. After 1992 levels began to decline to 1995 when levels hit a low (696.9 m a.s.l.) but subsequently rose again to 697.8 by 1997. Subsequent dry conditions have apparently resulted in a lack of surface runoff and may have reduced inputs from groundwater springs. Water levels in Sandy Lake are now at historic minima of 696.8 m a.s.l. The low lake levels result in a change in surface area of about 20% from maximum historic size of Sandy Lake.

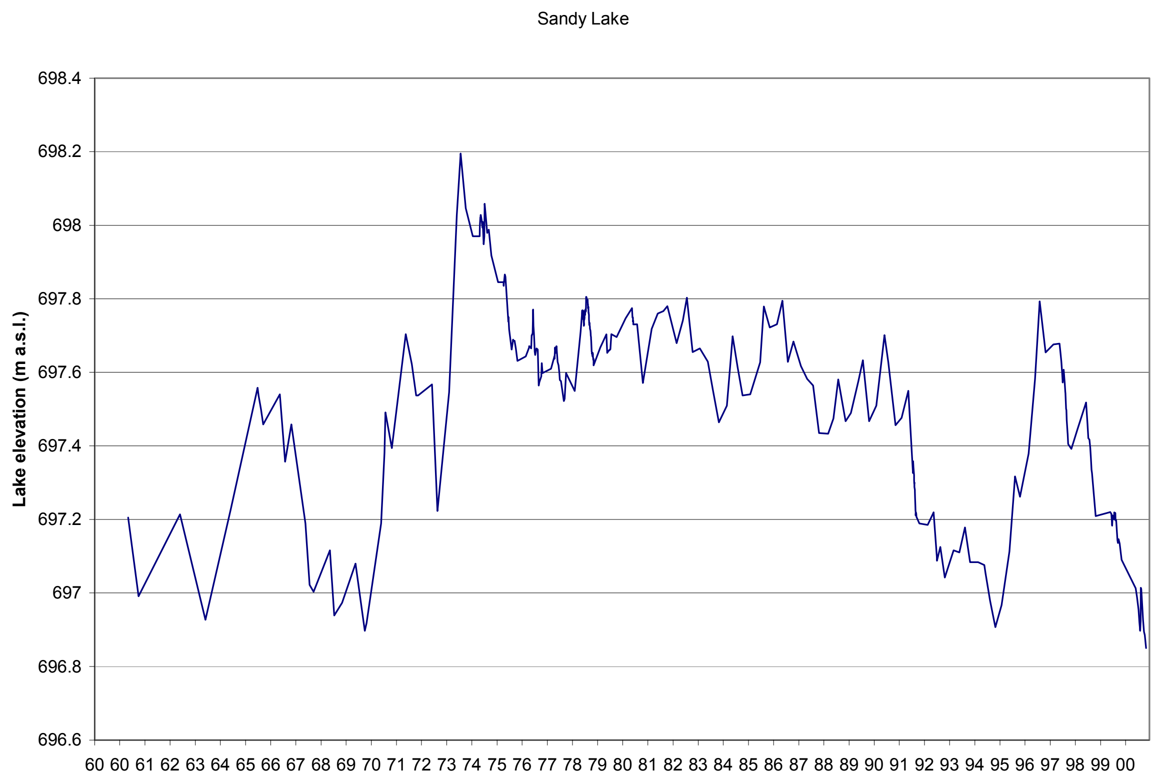


Fig. 2: Lake elevation above sea level over the period of record (1959 – 2001).

Nutrient budget

The high concentration of nutrients in Sandy Lake has long been known to contribute to the water quality concerns faced by this lake. As a result a detailed investigation of phosphorus loading to Sandy Lake was undertaken. The total phosphorus load from the Sandy Lake basin is approximately 1100 kg/yr. Roughly three-quarters of the total external phosphorus load to Sandy lake comes from cottages and agriculture both of which supply equal proportions to the phosphorus load. These estimates were later revised and inputs from sewage to roughly 7% of the total external load (Mitchell and Prepas 1990). By far the largest contributor to phosphorus concentrations and hence poor water quality in Sandy Lake is derived from lake bottom sediments. Recycling from bottom sediments may contribute about 3000 kg/yr of phosphorus – 3 times more than all other sources combined!

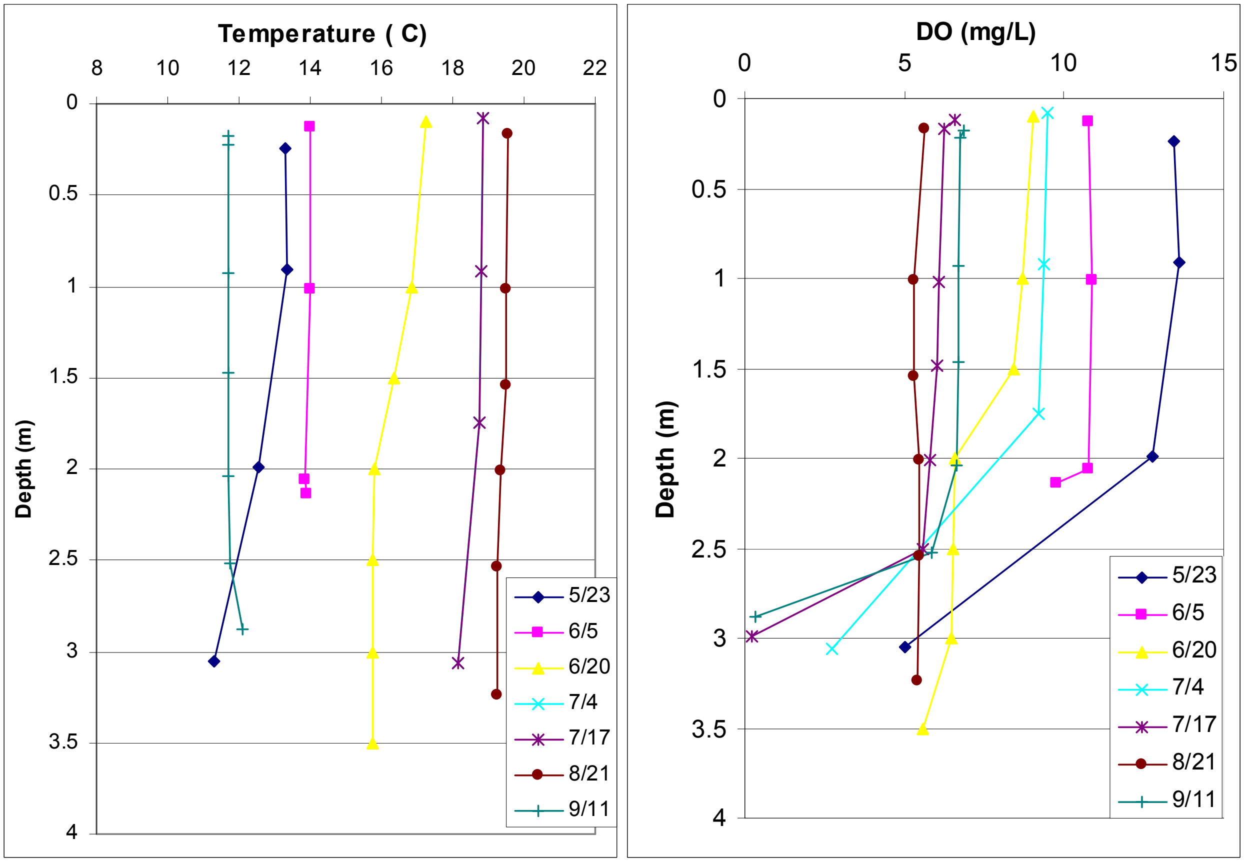


Figure 3: Temperature and dissolved oxygen profiles for Sandy Lake South Basin in 2001.

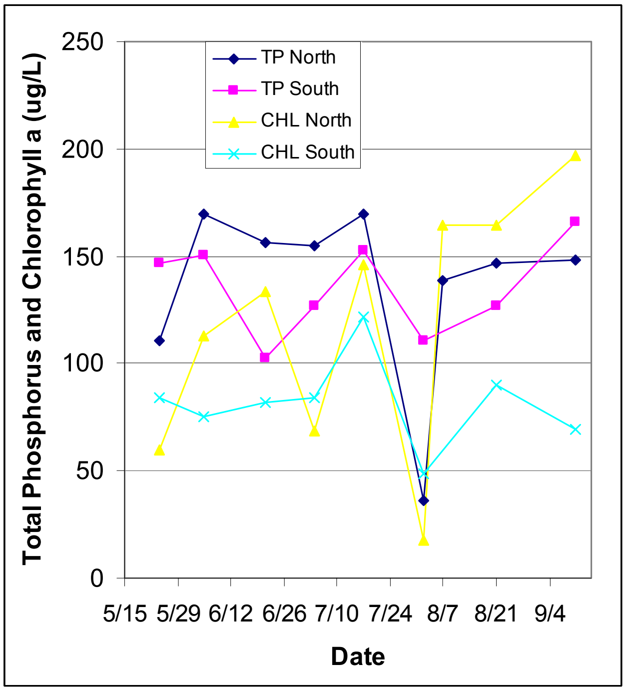
Results

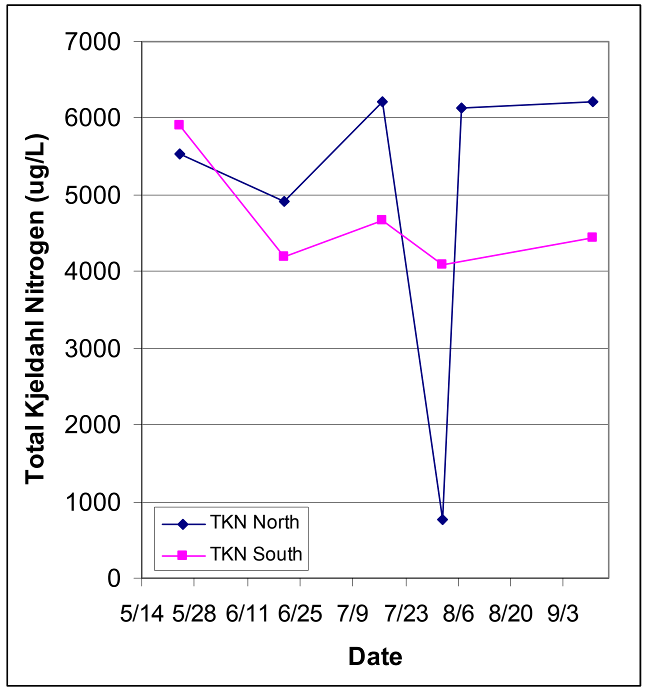
Water temperature and dissolved oxygen

Thermal stratification was not observed in Sandy Lake's north basin, however, temperatures did decline at the sediment interface which is typical in shallow lakes. In the south basin, stratification in May disappeared in June but was restored by late June. As waters warmed through, stratification in the southern basin was weakened and disappeared by August. Despite the lack of stratification in the north basin, dissolved oxygen concentrations dropped to near zero by 1.5 m depth from concentrations that typically exceeded 8 mg•L^{-1} in surface waters. In the southern basin, dissolved oxygen concentrations declined from relatively uniform concentrations above 2 m depth to concentrations below 4 mg•L^{-1} at 3 m depth. The loss of stratification in August resulted in uniform oxygen concentrations throughout the water column. The loss of the thermocline seems to coincide with the dilution event which was likely due to a storm.

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 Sandy Lake, the Secchi depth was less than 0.5 m in both basins throughout the summer. Although there seemed to be a decline in algal biomass in August, there was no increase in Secchi depth. Other factors, perhaps turbidity from mineral soils, may have risen during this period to offset reduced algal growth.





Figures 4 & 5: Total phosphorus, chlorophyll *a* and Kjeldahl nitrogen for Sandy Lake, summer 2001.

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

Parameter	1988 North	1988 South	2001 North	2001 South
TP ($\mu g \bullet L^{-1}$)	221	88	137	135
Chl ($\mu g \bullet L^{-1}$)	68	30	118	82
Secchi (m)	0.6	1.5	0.29	0.44
TKN ($\mu g \bullet L^{-1}$)	3736	2876	4963	4657
TDN ($\mu g \bullet L^{-1}$)	-	-	3621	3731
$NO_{2+3}N$ ($\mu g \bullet L^{-1}$)	3	9	3	6
NH_4^+ N ($\mu g \bullet L^{-1}$)	111	105	20	129
Ca ($mg \bullet L^{-1}$)	13	13	17	8
Mg ($mg \bullet L^{-1}$)	10	11	10	10
Na ($mg \bullet L^{-1}$)	109	114	79	134
K ($mg \bullet L^{-1}$)	13	14	11	18
SO_4^{2-} ($mg \bullet L^{-1}$)	< 8	< 5	6	3
Cl^- ($mg \bullet L^{-1}$)	4	4	6	8
Total Alkalinity ($mg \bullet L^{-1}$ $CaCO_3$)	304	322	255	374

Water chemistry

Higher ion concentrations were expected in 2001 due to the drier conditions and loss of water volume from Sandy Lake. However, ion concentrations have remained relatively unchanged in Sandy Lake since data were collected in 1988. Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The stable ion concentrations suggest Sandy Lake has remained in equilibrium with its hydrology over the period of data records despite the fluctuation in water level. Other impacts such as acid deposition from power plants or oil and gas processing plants typically cause increases in sulfate concentrations, however, SO_4^{2-} concentration is very low in Sandy Lake indicating that these types of impacts are not occurring in the lake.

Sandy Lake is hypereutrophic with what is considered excessive nutrient concentration and algal biomass compared to lakes throughout Canada. In the Alberta context, Sandy Lake contains about average total phosphorus concentrations when compared to other hypereutrophic lakes and one of the highest algal biomasses of currently sampled lakes. Hypereutrophic lakes represent a relatively small fraction of lakes in Alberta and they are generally considered to have water quality that impairs recreational activity. Phosphorus concentrations have increased moderately in the south basin when compared to 1988 (Table 1) whereas phosphorus concentrations in the north basin seem to have declined since 1988. Nitrogen concentrations on the other hand have increased substantially since 1988. A substantial dilution event occurred in the north basin during early August. At this time, phosphorus, nitrogen and chlorophyll *a* declined more than 3-fold. Interestingly, the dilution event did not seem to improve water quality in the southern basin.

Despite the small changes in phosphorus in Sandy Lake occurring between 1988 and 2001, chlorophyll *a* (CHL) concentrations increased markedly. There is no indication that phosphorus availability was a factor as dissolved phosphorus concentrations which averaged 35 and 30 µg/L in 1988 (north and south, respectively) averaged 22 and 29 µg/L in 2001. There may have been a switch in algal communities in Sandy Lake that are more productive under high nutrient concentrations. In August, CHL concentration exceeded TP indicating that Sandy Lake was experiencing bloom conditions. Bloom conditions appear to have continued through September with steadily increasing chlorophyll *a* concentrations from late August.

Sandy Lake is a classic example of problems encountered in extremely productive lakes. Shallow depth is one contributing factor that has been exacerbated by recent dry conditions. However, recent low water levels have been approached at other periods in the history of Sandy Lake and may be part of an entirely natural fluctuation. Continued monitoring of nutrient concentrations in Sandy Lake are likely not required at this time. However, future studies on algal community composition may be helpful in determining if algal blooms contain potentially toxin producing cyanobacteria. Additional analyses of water samples for the toxins microcystin or cyanotoxin may be warranted during bloom periods in September.

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