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Lakewatch

Ghost Reservoir

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 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. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred.

Fig. 1:Lakewatch volunteer Mel defying gravity on Ghost Reservoir

Photo: Susan Cassidy

Ghost Reservoir

Ghost Reservoir is located about 45 km west of Calgary on the Bow River. The reservoir was constructed in 1929, primarily for power generation. Like most reservoirs, it is deep, having a mean depth of 14.5 m and a maximum depth of 34 m. The drainage basin for the Bow River above the dam is 6460 km^2 resulting in a drainage to lake area ratio of almost 600 to 1. The lake volume (159.1 million cubic meters) is replaced every 22 days as an annual mean. However, water flow into the reservoir is of course much higher in the spring and lower during the winter.

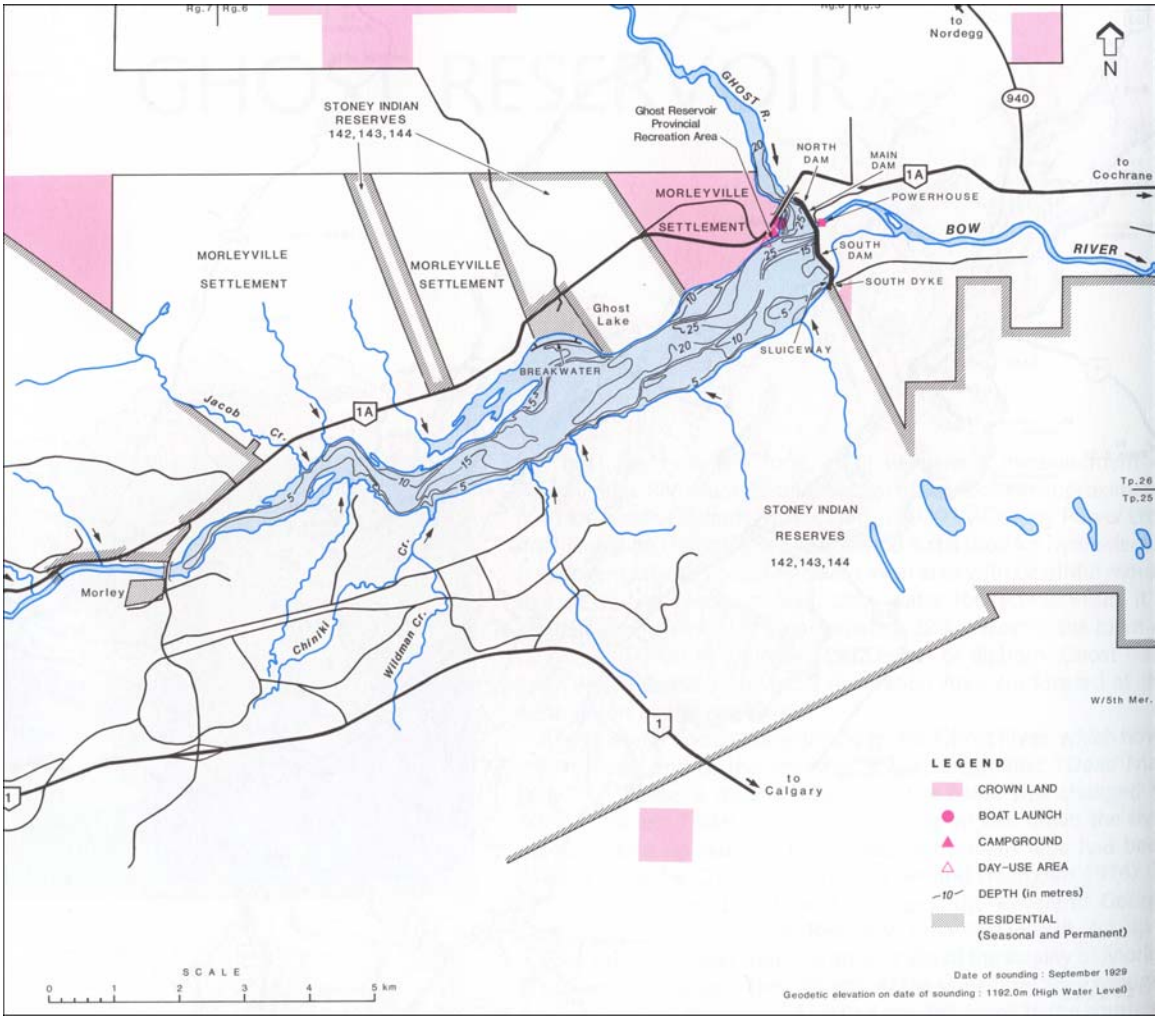


Fig. 2: Bathymetry of Ghost Reservoir. From Mitchell and Prepas 1990.

Water Levels

Water levels in the Ghost Reservoir have been regulated consistently except for the period stating in the winter of 1985 and extending through 1989. The reservoir is typically drawn down through the winter and early spring to allow partial capture of snowmelt. Typical winter drawdown is about 5.3 m which exposes most of the bay behind the breakwater at the summer village of Ghost Lake. A large portion of snowmelt is allowed to discharge from the dam for habitat reasons in the Bow River. During the summer, the water level is regulated to a higher elevation for recreational use. Stored water is released during the winter to maintain flows in the Bow River that are adequate for maintaining downstream water quality and to maintain fish and riparian habitat.

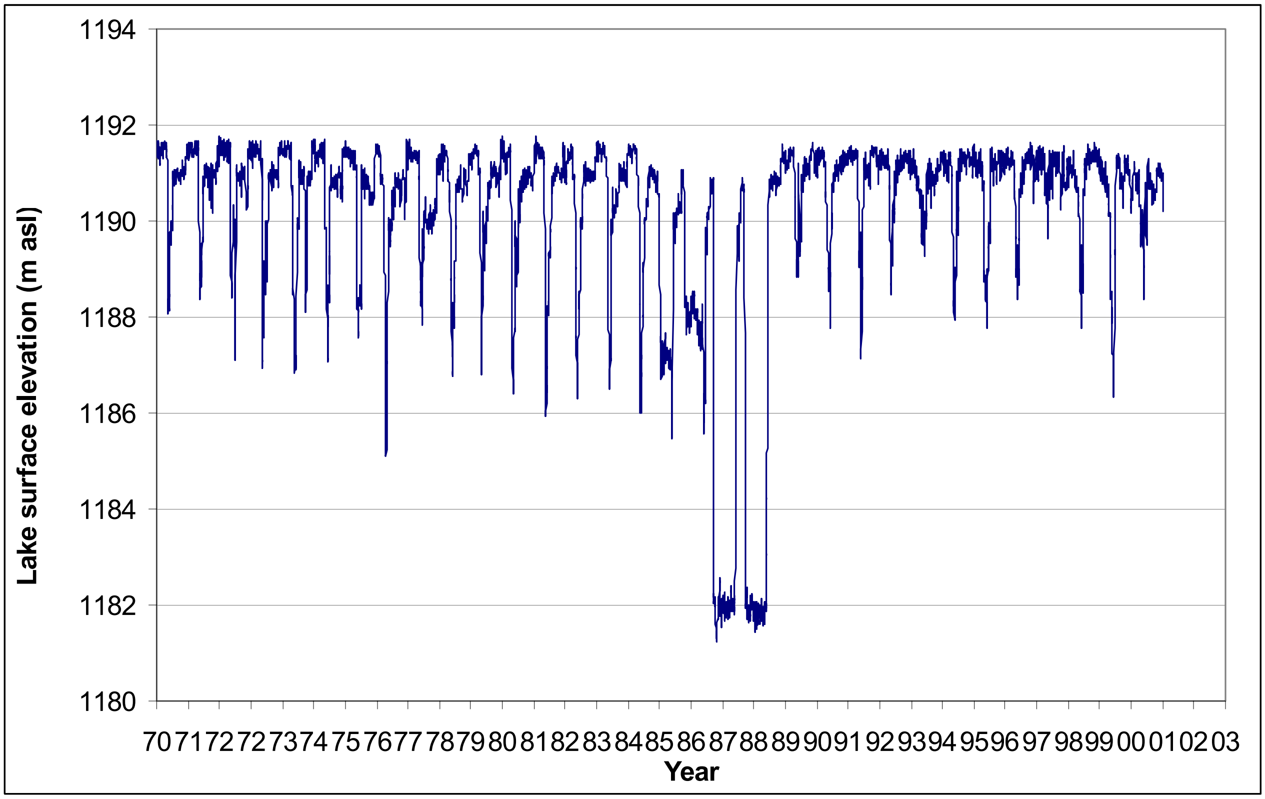
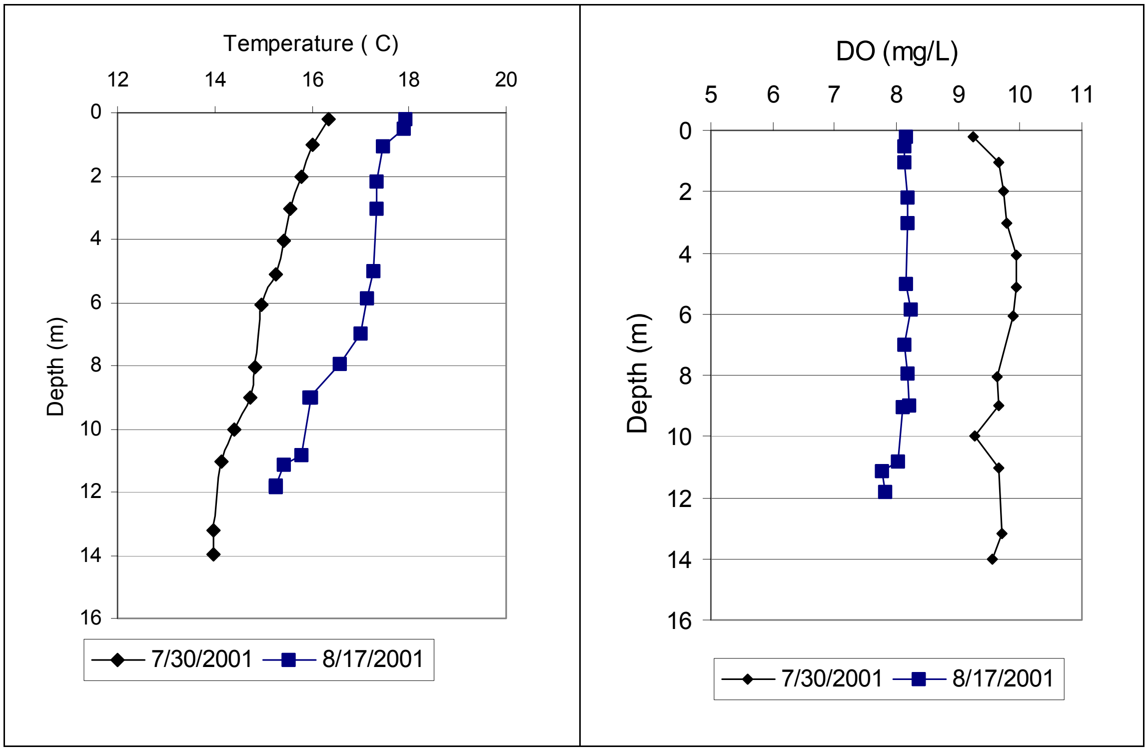


Fig. 3: Water levels in Ghost Reservoir for the period of record from 1970 through January 2002.



Figs. 4 & 5: Temperature and dissolved oxygen profiles for Ghost Reservoir for the summer 2001.

Results

Sampling at Ghost Reservoir did not occur at the planned frequency. Access to boats and bad weather limited collection of samples to July 30 and August 17. Fortunately these mid-summer samples likely capture mean conditions. They would not capture the high turbidity expected in spring or the more productive period usually occurring in lakes in September.

Water Temperature and Dissolved Oxygen

Temperature and dissolved oxygen profiles for the Ghost Reservoir are typical for mountain reservoirs with high water volume passing through them. These reservoirs are usually oligotrophic, meaning they have low biological activity, and Ghost is no exception. Dissolved oxygen profiles can increase a small amount with depth due to increasing pressure and declining temperature effects. These small effects are masked in other waterbodies by higher biological activity. Although there was a 2 degree spread in temperatures at the surface and at 14 m (the depth limit of our equipment) there was no evidence of a true thermocline. The Ghost Reservoir may be cold monomictic, meaning it only stratifies under ice in the winter. It may also demonstrate polymixis with temporary stratification of surface waters during hot periods in the summer, particularly in west of the breakwater. The significance of these temporary events to water chemistry is likely to be small given the high volume of water flowing into the reservoir and the small sediment area to water volume ratio in the reservoir.

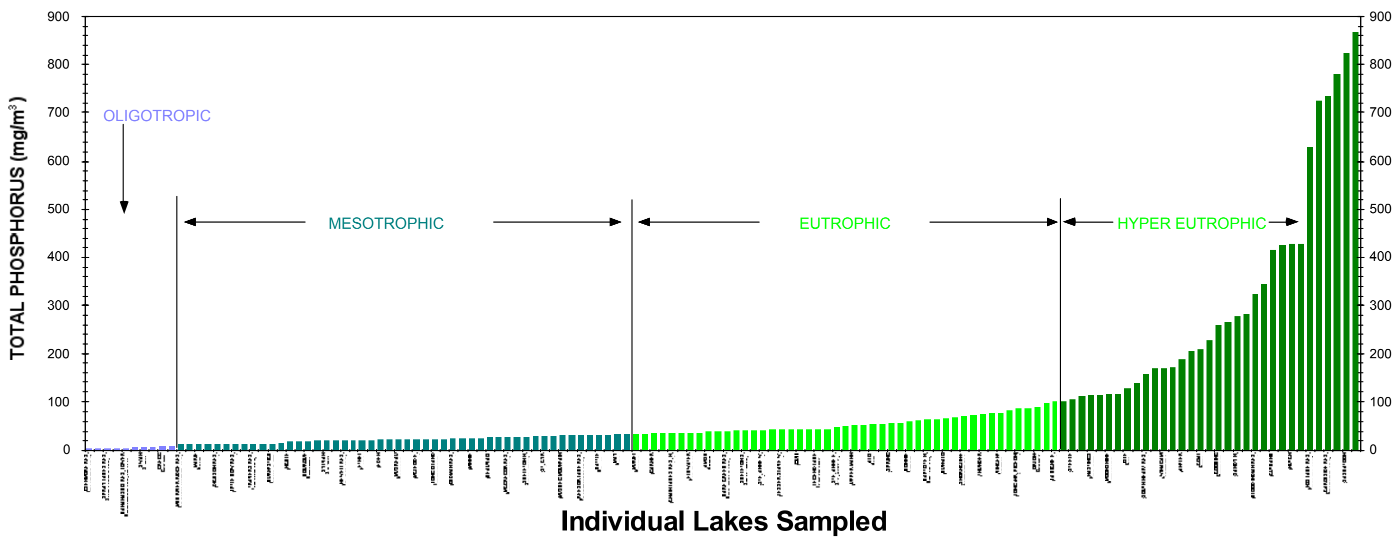


Fig. 6: Ghost Reservoir total phosphorus concentration relative to other lakes in Alberta. Ghost Lake is at the far left of the figure.

Table1: Mean values from summer 2001 samples compared to values reported in the Atlas of Alberta Lakes (1985) and AENV data (1994).

Parameter	1985	1994	2001
TP ($\mu g \bullet L^{-1}$)	7	5	4
TDP ($\mu g \bullet L^{-1}$)	4	-	4
Chl ($\mu g \bullet L^{-1}$)	2	0.5	0.6
Secchi (m)	6.4	7.3	8.75
TN ($\mu g \bullet L^{-1}$)	462	-	1314
$NO_{2+3}N$ ($\mu g \bullet L^{-1}$)	30	-	46
NH_4^+ N ($\mu g \bullet L^{-1}$)	30	-	5
Ca ($mg \bullet L^{-1}$)	37	33	33.4
Mg ($mg \bullet L^{-1}$)	10	11	11.2
Na ($mg \bullet L^{-1}$)	2	2	1.5
K ($mg \bullet L^{-1}$)	0.4	0.3	0.4
SO_4^{2-} ($mg \bullet L^{-1}$)	31	26	29.8
Cl^- ($mg \bullet L^{-1}$)	1	1.2	1.5
Si (mg/L)	-	2.8	1.23
HCO_3 (mg/L)	137	124	118.06
CO_3 (mg/L)	<1	3	2.33
Total Alkalinity ($mg \bullet L^{-1}$ $CaCO_3$)	135	106	100.7
Conductivity (µS/cm)	277	252	254.30
pH	7.3-7.9	8.46-8.52	8.38
Color (mg/L Pt)	-	-	3
TSS (mg/L)	-	<1	2

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 late spring but then becomes less clear as algae grow through the summer. During mid-Summer, Ghost Reservoir had exceptional water clarity with Secchi depths of 8 m in July and 9.5 m in August. Few lakes in Alberta have Secchi depths and water clarity of this level.

Water chemistry

Water chemistry in Ghost Reservoir is exceptionally good within the context of Alberta. The concentration of phosphorus and correspondingly of algae (represented by chlorophyll concentration) are very low. Nitrogen concentrations are surprisingly high for an oligotrophic system. Nitrate concentrations were slightly elevated for an oligotrophic system but ammonia concentrations were normal. The high total nitrogen concentrations are not related to suspended material as concentrations of suspended solids (TSS) was low. Concentrations of nitrate were similar to those in the Bow River downstream of Canmore but total nitrogen concentrations in the reservoir were elevated by several to 10-fold.

Concentrations of the major ions (calcium, sulfate etc.) have remained relatively unchanged over the past two decades. Water quality in Ghost Reservoir is exceptional and, except for total nitrogen, there does not appear to have been any degradation over the past two decades.

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.