The Alberta Lake Management Society Volunteer Lake monitoring report

Goose Lake

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2008 Report

Completed with support from:

Alberta Environment

Alberta Lake Management Society

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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

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. Lakewatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in Lakewatch and readers requiring more information are encouraged to seek these sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Lakewatch Chairs, Théo Charette and Ron Zurawell. We would like to thank Dan Merrils and Dale McQueen for their efforts in collecting data in 2008. We would also like to thank Lisa Brodziak and Sophie Damlencour who were summer interns with ALMS in 2008. Project Technical Coordinator, Jill Anderson was instrumental in planning and organizing the field program. Technologists, Shelley Manchur, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Théo Charette (ALMS President) and Jill Anderson (Program Manager) were responsible for program administration and planning. This report was updated by Sarah Lord for 2008. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Goose Lake

Goose Lake (**Figure 1**) is located 20km west of Fort Assiniboine in the Athabasca River Basin. It is both fed and drained by Goose Creek, which enters the lake in the northwest corner and exits in the southwest. Public access is on the south shore at Lone Pine. Some private ownership exists on the south shore as cottages with sporadic clearings for agricultural purposes elsewhere around the lake. Most of the remaining lakeshore is crown land.

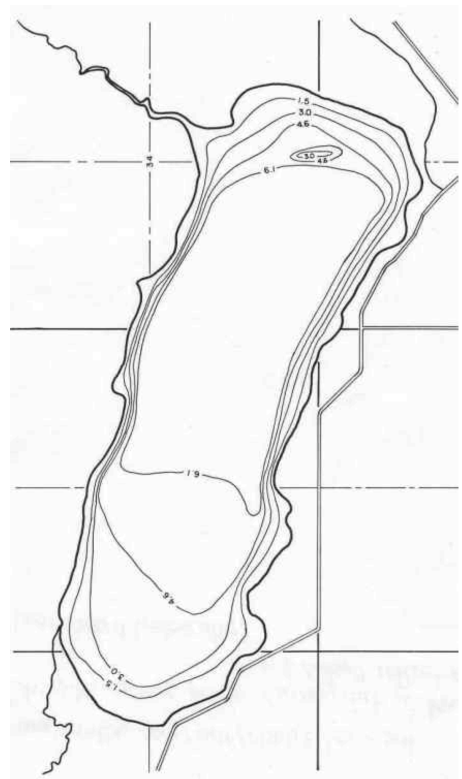

Figure 1. Bathymetry map of Goose Lake, Alberta.

Soil near the lake is sandy, gradually moving to heavier clay further out in the drainage basin. Goose Lake is located in the High Boreal Mixedwood ecoregion, and topography around the lake is best described as gently rolling. It is suspected that the lake has a good connection with groundwater, but this has not yet been monitored (Mitchell, 1993). The lake itself lies on a slight northwest to southeast axis with a steeper northern shore. Water is generally shallow throughout, and the lake is fairly exposed to prevailing winds with only small bays and coves along its shoreline (**Figure 1**). The drainage basin is very large relative to lake size, and the runoff the lake receives is probably considerable as a result. Northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) occur naturally and there have been attempts in the 1960s and 1970s to introduce walleye (*Stizostedion viteum*) and more perch, none very successful.

Goose Lake has been investigated in the past. In 1960, the lake was surveyed to assess recreation potential after a request from a local landowner for the introduction of more sport fish species (Paterson, 1960). It was visited again in the late 1960s for a routine physical survey and sounding, at which time it was noted that the shallowness of the lake probably left it susceptible to winterkill (Erikson and Smith, 1969). As a response to public concerns at the time, a weir was installed at the outlet in 1976. Throughout the 1980s, letters between Alberta government departments indicated growing divisions between lake users over recreation conflicts, specifically between water skiing and angling, and perception problems over lake levels, fish stocks, and appropriate corrective measures to both (Alberta Environment Historical Library). In 1992 the lake was sampled by the Volunteer Citizens' Lake Monitoring Program, a precursor to the ALMS Lakewatch Program (Mitchell, 1993).

Water Level

Water levels in Goose Lake have been monitored by Environment Canada since 1968 under the joint Federal-Provincial Hydrometric agreement. Water level increased sharply from 723.8 m asl to 725.0 m asl between 1968 – 1975, after which a weir was installed in 1976 to help regulate water levels. Sill height of the weir in 1992 was estimated at 724.51 m asl. Water levels have been more stable since that time, fluctuating between a maximum of 725.12 m asl in 2001 and a minimum of 724.3 m asl in 1991 (**Figure 2**). Average water level from 1968 – 2009 was 724.6 m asl.

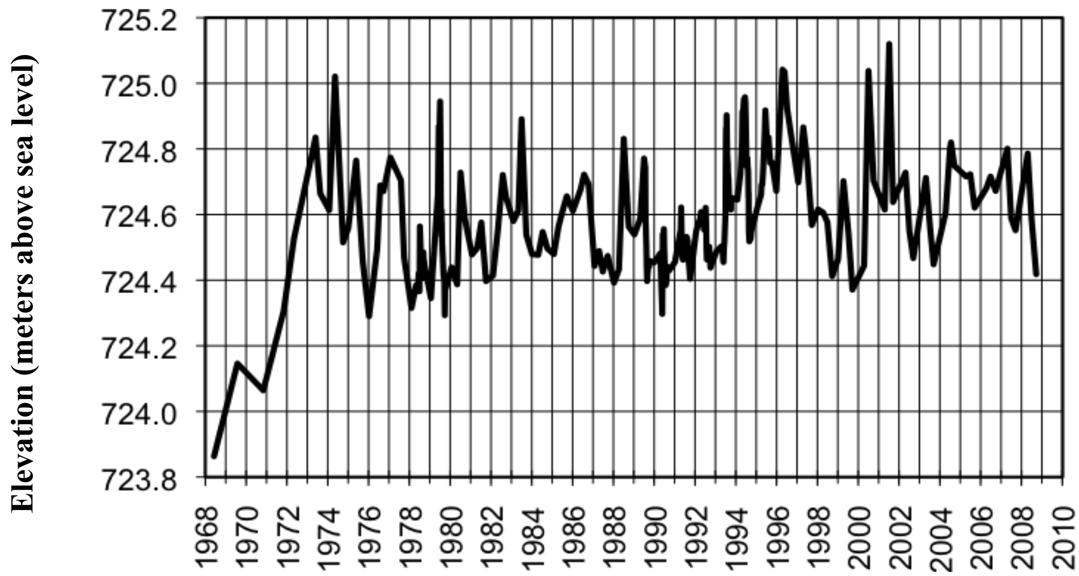

Figure 2. Historical water levels (meters above sea level (asl)) in Goose Lake, Alberta 1968 – 2009.

Results

Water temperature and dissolved oxygen

Thermal stratification in Goose Lake was not observed during the summer 2008 (e.g. the lake was isothermic) (**Figure 3**). Water temperature on 24 June was 19.4°C at 0.1 m below the surface, and cooled very gradually down to 13.5°C at the lakebed. Surface waters on 14 July were 18.7°C, and the difference between surface and deep waters was only 1.5°C. Surface waters warmed slightly to 21.1°C on 11 August, but water temperature at the lakebed was the same temperature as in July. Surface water temperatures declined to 15.1°C by 14 September and 12.1°C on 28 September; on these dates there was no difference in temperature between the surface and deepest waters of the lake, indicating complete mixing (fall turnover) had occurred.

Dissolved oxygen (DO) concentrations in upper layers of surface waters of Goose Lake were ≥ 7 mg/L on all sampling dates through the summer, well within the acceptable range for surface water quality (DO ≥ 5.0 mg/L) (**Figure 3**). DO concentrations declined slowly at a depth of 3 m in early June, indicating a weak chemocline was present, and water at the lakebed was anoxic. This weak chemocline dropped to 7 m in July, and then re-formed at 3 m again in August. No chemocline was present in September, indicating fall turnover and complete mixing of lake waters.

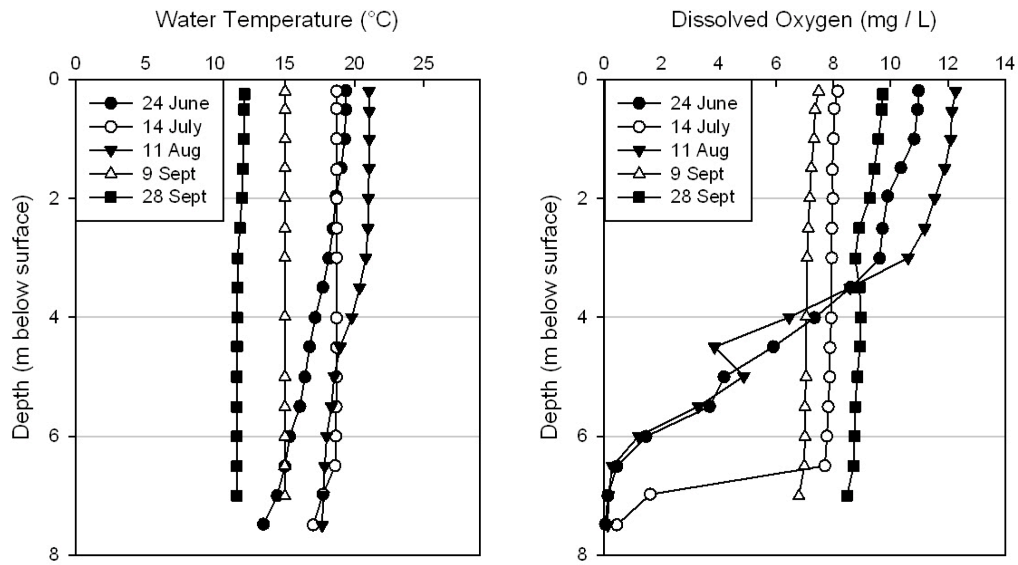

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Goose Lake during the summer of 2008.

Water clarity and Secchi Disk Depth

Water clarity is influenced by 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 disk depth. Following the period of ice and snowmelt, a lake can have low clarity due to spring runoff and the inflow of suspended sediments into the lake. Lake water usually clears in the spring but then becomes more turbid due to algal growth taking place throughout the summer open water season.

Water clarity data for Goose Lake was measured five times during the summer of 2008. Goose Lake was somewhat murky compared to other lakes in Alberta, with average Secchi disk depth = 1.5 m (**Table 1**). In late June, Goose Lake was relatively clear, with a Secchi disk depth of 2.55 m or ~32% of the total lake depth, which allowed for algal growth in the upper two-thirds of the lake. By 14 July, Secchi disk depth had decreased to 1.25 m, corresponding with an increase in algal growth. Secchi disk depth remained at 1.25 m for the remainder of the open water season. Water clarity appears to have declined since monitoring began in 1987.

Water chemistry

Based on lake water characteristics, Goose Lake is considered highly eutrophic (see *A Brief Introduction to Limnology* at the end of this report). Average total phosphorus (TP = 43.2 µg/L) was within the eutrophic range, while total Kjeldahl nitrogen (TN = 1218 µg/L) and chlorophyll *a* (chl *a* = 29.9 µg/L) concentrations were within the hypereutrophic range in 2008 (**Table 1**).

Total phosphorous increased from 53 µg/L on 24 June to 116 µg/L on 14 July, then declined to 100 µg/L on 11 August as a steep increase in algal growth consumed nutrients in the water column. Total phosphorous recovered to a maximum of 155 µg/L on 9 September (**Figure 4**), then declined back to 100 µg/L by 28 September. Total nitrogen increased from 0.96 mg/L on 24 June to 1.13 mg/L on 14 July, reaching a maximum of 1.49 mg/L on 11 August. Total nitrogen declined to 1.36 mg/L on 9 September, and further to 1.15 mg/L by 28 September. As the depletion of phosphorous in late July to early August by algal growth was not accompanied by a significant decrease in nitrogen, algal growth in Goose Lake is probably phosphorous-limited and not nitrogen-limited, at least in the first half of the open water season.

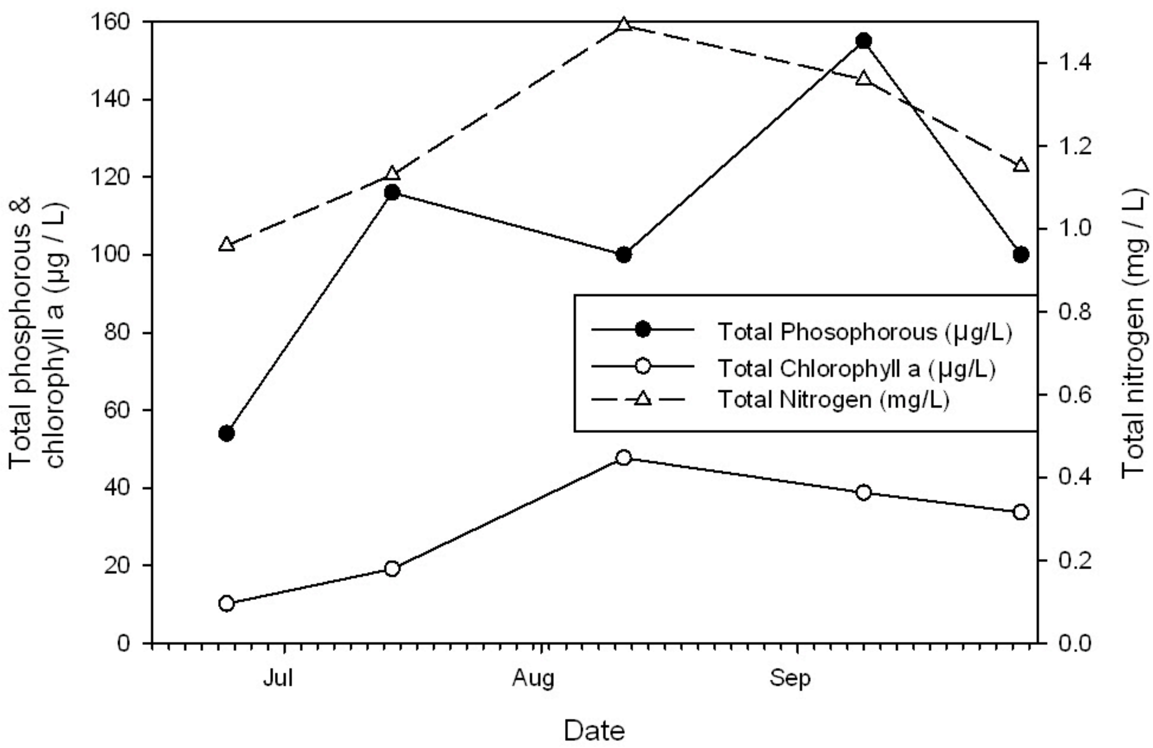

Figure 4. Total phosphorous, chlorophyll a (a measure of algal biomass), and total nitrogen concentrations for Goose Lake during the summer of 2008.

Goose Lake follows the typical pattern in Alberta lakes of an increase in nutrient and algae over the summer due to the release of nutrient from underlying sediments. Nutrients (i.e., total N and P) and water greenness appear to have decreased over the past two decades, but water clarity has also decreased. Further sampling of Goose Lake is required to determine if these apparent changes are due to year-to-year variation or a long-term trend in water quality (**Table 1**), but total N and P in summer 2008, although high, were only one-third of the maximum values seen in 1987. Chlorophyll a concentrations in 2008 were the middle value in the 1987 – 2008 data set.

During the summer 2008, Goose Lake was well buffered from acidification with an average pH = 8.5, which is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, carbonate, calcium, sodium, and magnesium (**Table 1**). Water chemistry for Goose Lake has been sampled 8 times since 1987, and while water chemistry parameters have varied widely year-to-year, there appear to be no significant overall trends in ion concentrations. The average concentrations of various heavy metals (as total recoverable concentrations) were not measured in Goose Lake in 2008.

Table 1. Water chemistry values for Goose Lake, summer 2008.

Parameter	1987	1988	1989	1992	1993	1994	1995	2005	2008
TP (μg/L)	322.3	203.3	125.5	71.8	62.8	62.5	54.8	110.8	105.0
TDP (μg/L)	260.4	147.1	85.8	20.8	32.3	35.8	22.3	50.8	43.2
Chlorophyll-*a* (μg/L)	43.6	37.3	28.6	51.5	17.9	22.6	14.8	50.6	29.9
Secchi disk depth (m)	2.3	2.8	3.2	2.7	2.9	2.0	3.1	1.1	1.5
TKN (μg/L)	1500	1700	1700	1500	1000	1400	900	1500	1218
$NO_{2,3}$ (μg/L)9	9	31	15	12	4	31	19	27	15
NH_4 (μg/L)	63	126	181	17	55	163	45	52	34.2
Dissolved organic C (mg/L)	-	-	-	-	-	-	-	-	19.1
Ca (mg/L)	37	38.7	34.6	33.6	33.1	32.2	35.4	31.4	34.5
Mg (mg/L)	10.0	10.9	10.0	10.7	10.9	10.2	10.1	7.8	8.4
Na (mg/L)	9.0	9.0	9.0	11.3	11.7	9.8	9.4	8.0	8.9
K (mg/L)	2.4	2.4	2.2	2.4	2.3	2.2	2.1	2.8	2.9
SO_4^{2-} (mg/L)	<5	4.7	2.2	4.0	<3	<3	3.0	5.0	3.0
Cl^- (mg/L)	<1	0.5	1.1	0.7	0.7	0.7	0.7	0.8	1.0
TDS (mg/L)	153.0	161.0	151.0	149.9	151.9	141.4	148.3	136.0	143.0
pH	9.2	8.5	8.3	8.5	8.4	8.3	8.1	8.3	8.5
Conductivity (μS/cm)	263.0	293.7	272.2	267.6	280.7	262.9	270.3	354.0	260.3
Hardness (mg/L)									
HCO_3 (mg/L)	107.0	176.5	164.2	178.6	182.3	168.4	179.0	158.5	160.7
CO_3 (mg/L)	37.0	38.7	34.6	33.6	33.1	32.3	35.4	31.4	8.5
Total Alkalinity (mg/L $CaCO_3$)	148.0	156.9	146.2	150.2	151.7	140.1	147.1	134.0	141.3

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TKN = total Kjeldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate.

*Atlas of Alberta Lakes (Mitchell and Prepas, 1990).

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A brief introduction to Limnology

Indicators of water quality

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are affected (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

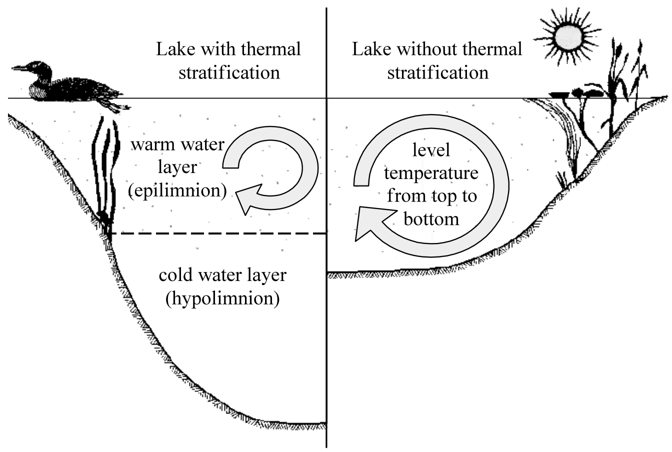

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

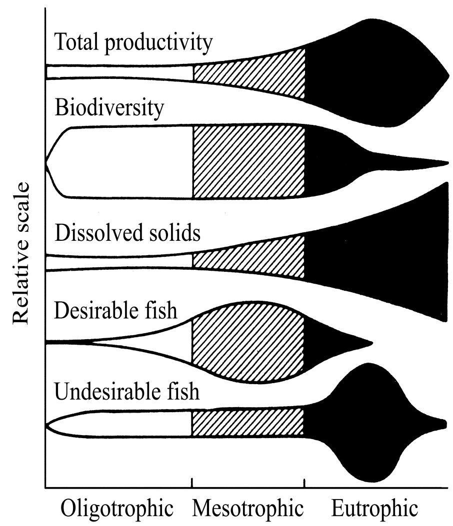

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.