Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Beaver Lake Report

COMPLETED WITH SUPPORT FROM:

Government of Alberta

Beaver River Watershed Alliance

LICA
Lakeland Industry & Community Association

Lac La Biche Sporting Goods

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 those 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, Stephanie Neufeld and Ron Zurawell. We would like to thank Dave Lozinski for his efforts in collecting data in 2010. In addition, we would like to thank Lac La Biche sporting goods for their generous donation of a boat and motor which was used for the 2010 sampling. We would also like to thank Bradley Peter and Emily Port who were summer interns with ALMS in 2010. 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 training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Jill Anderson (Program Manager) was responsible for program administration and planning. Théo Charette, Ron Zurawell (Limnologist, AENV), Lori Neufeld, and Sarah Lord prepared the original report, which was updated for 2010 by Bradley Peter and Arin Dyer. Alberta Environment, the Beaver River Watershed Alliance (BRWA), and the Municipal District of Wainwright were major sponsors of the Lakewatch program.

BEAVER LAKE:

Beaver Lake is a large lake located near the town of Lac La Biche. Beaver Lake lies within the Lakeland region, is the headwater of the Beaver River, and is rich in history including various missions, hunting, trapping, and both European and Native settlements. In 1919, a settler named Max Huppie purchased a large tract of land on the northwest corner of Beaver Lake, an area that supports a provincial campground, a forest firefighter base camp, and one large residential sub-division.

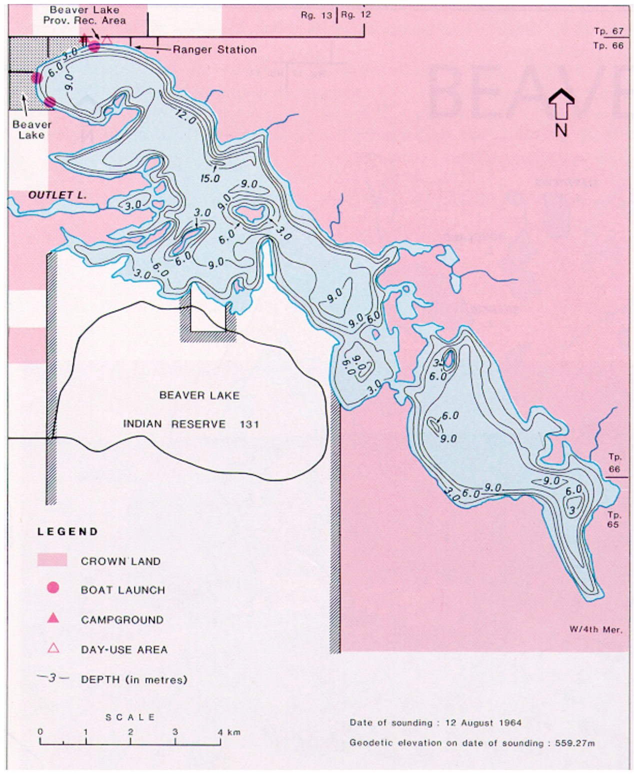

Figure 1 – Bathymetric map of Beaver Lake (Mitchell and Prepas 1990).

Beaver Lake is popular for fishing. Nine species of fish have been reported in Beaver Lake including: northern pike (*Esox lucius*), walleye (*Sander vitreus*), yellow perch *(Perca flavescens*), lake whitefish (*Coregonus clupeaformis*), burbot *(Lota lota*), white sucker (*Catostomus commersoni*), brook stickleback (*Culaea inconstans*), Iowa darter (*Etheostoma exile*), and spottail shiner (*Notopis hudsonius*).

Beaver Lake is a large body of water with a surface area of 33 km^2. It consists of two large basins linked by a narrow, shallow channel, with a northwest to southeast orientation (Figure 1). Depth is generally 6 to 9 m in both basins, with a narrow trough reaching 15 m in depth on the northeast side of the north basin. Access to the south basin is limited to boats with very shallow draft or during times of higher water. Beaver Lake contains several islands, the number of which varies with the water level. Both basins slope quite steeply to their greatest depth; the bottom of each basin is quite flat, except in the vicinity of the islands.

The area of Beaver Lake's watershed is 9 times larger than that of the lake itself. The terrain surrounding Beaver Lake is gently rolling and heavily forested. Trembling aspen (*Populus tremuloides*) is dominant in areas with well-drained soils while trembling aspen and balsam poplar (*Populus balsamifera*) co-dominate in less well-drained areas. Jack pine (*Pinus banksiana*) grows on well-drained ridges near wetlands and black spruce (*Picea mariana*) and tamarak (*Larix laricina*) grow on poorly drained organic soils. Soil in the drainage basin is most commonly Orthic Gray Luvisol of a clay or loamy type.

WATER LEVELS:

Water levels at Beaver Lake have shown a declining trend since Alberta Environment began monitoring the lake in 1972 (Figure 2). In the 1970's, water levels remained quite stable, reaching a maximum of 559.4 meters above sea level (m asl). However, in 2009, Beaver Lake reached a historical minimum of 556.5 m asl. Compared to 30 years ago, Beaver Lake's surface area has been reduced by approximately four km^2.

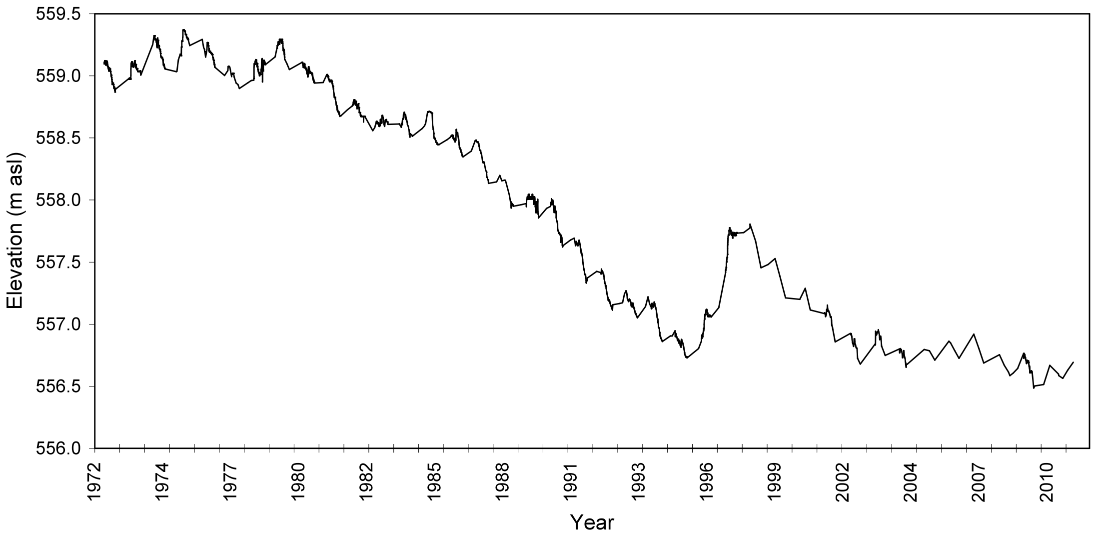

Fig 2 – Historical Water Levels for Beaver Lake. Data retrieved from Alberta Environment.

WATER CLARITY AND SECCHI DEPTH:

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

Average secchi depth at Beaver Lake measured 3.20 m in 2010. A minimum secchi depth of 2.00 m was recorded on September 3rd and a maximum secchi depth of 5.00 m was recorded on June 25th. Larger secchi depths are common in June when temperatures are not high enough to promote large algal blooms, and typically decrease throughout the summer as the concentration of algae increases. Relative to previous years (Table 1), an average secchi depth of 3.20 m is high for Beaver Lake. Higher-than-normal water clarity was common throughout the province in 2010 due to mild summer temperatures.

WATER TEMPERATURE AND DISSOLVED OXYGEN:

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

In June, surface water temperature at Beaver Lake was 19.48 °C and decreased steadily to 16.11 °C at the lakebed (Figure 3a). Weak thermal stratification was observed between 2.5-3.5 m and 5.5-6.5 m, though thermal stratification was not observed during any other sampling trip. In late-July, surface water temperature reached a seasonal maximum of 20.97 °C and decreased steadily to 18.42 °C at the lakebed. In mid-August, surface water temperature decreased slightly to 20.09 °C and measured 19.94 °C at the lakebed. On September 3rd, the water column became quite uniform, measuring 16.67 °C at the surface and 16.00 °C at the lakebed. Finally, on September 24th, surface water temperature had dropped to 11.17 °C at the surface and 10.90 °C at the lakebed. Due to the weak thermal stratification observed in June and the well-mixed water column throughout the rest of the summer, Beaver Lake is likely polymictic (mixes multiples times per year).

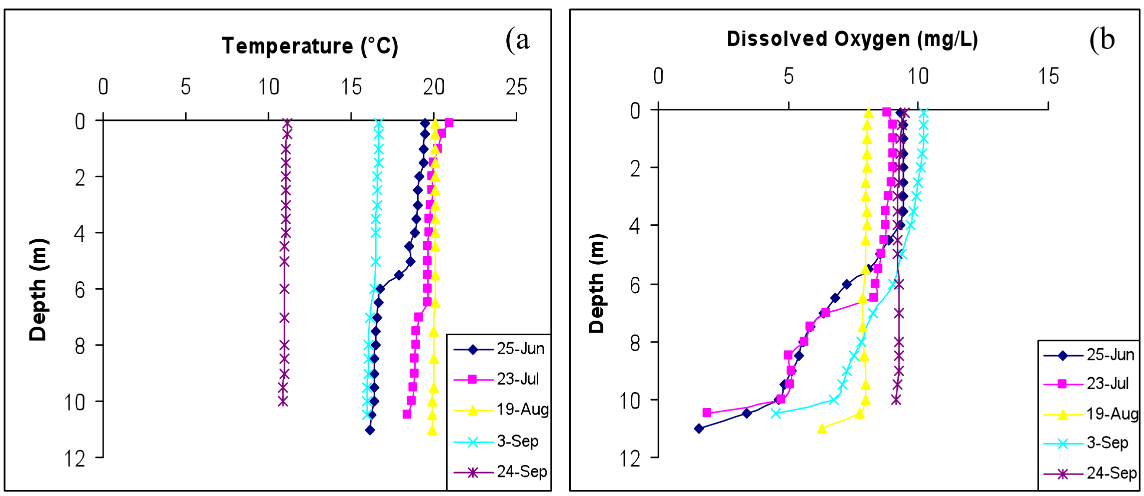

Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Beaver Lake obtained during the summer of 2010.

In late-June, dissolved oxygen measured 9.34 mg/L at the surface and 1.57 mg/L at the lakebed (Figure 3b). Similarly, in late-July, dissolved oxygen measured 8.83 mg/L at the surface and 1.90 mg/L at the lakebed. In August, oxygen became much more evenly distributed throughout the water column, measuring 8.07 mg/L at the surface and 6.28 mg/L at the lakebed. In early September, surface oxygen levels began to increase, measuring 10.23 mg/L at the surface and 4.51 mg/L at the lakebed. Finally, in late-September, dissolved oxygen became uniform throughout the water column, measuring 9.48 mg/L at the surface and 9.12 mg/L at the lakebed. Decomposition of algae at the lakebed, an oxygen consuming process, contributes to the low oxygen levels seen at lower depths. The Canadian Council for Ministers of the Environment (CCME) recommends 6.5 mg/L dissolved oxygen for the protection of aquatic life.

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorous, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 1 for a complete list of parameters.

Based on average total phosphorous measured in 2010 (50.8 μg/L), Beaver Lake is considered eutrophic, or highly productive (Table 1). Though phosphorous concentrations have fluctuated greatly between years at Beaver Lake (33.0 μg/L in 1986, 56.0 μg/L in 2004), the eutrophic classification has remained unchanged. Total phosphorus reached a minimum of 33 μg/L on June 25th and a maximum of 65 μg/L on August 19th (Figure 4), indicating a probable transfer of phosphorus from the sediments to the euphotic zone. Chlorophyll-*a* trends over the summer paralleled that of the phosphorus concentration. However, average total chlorophyll-*a* at Beaver Lake in 2010 was 9.32 μg/L, which is relatively low compared to previous years. Due to a mild summer, chlorophyll-*a* levels in 2010 were relatively low at many lakes across the province. Average total nitrogen concentration at Beaver Lake was 1.51 mg/L in 2010, and showed little fluctuation throughout the summer, with a minimum of 1.40 mg/L in June and a maximum of 1.57 mg/L in July (Figure 4). Based on total nitrogen, Beaver Lake would be classified as hypereutrophic, or extremely productive – a classification that has not changed since at least 2003. It is important to note that Beaver Lake can be thought of as two basins, and throughout the summer it was observed that the north basin had markedly less algae than the south basin. Water samples were combined from both the north and south basins; therefore, results should be viewed as an average between basins and are not representative of just the north basin.

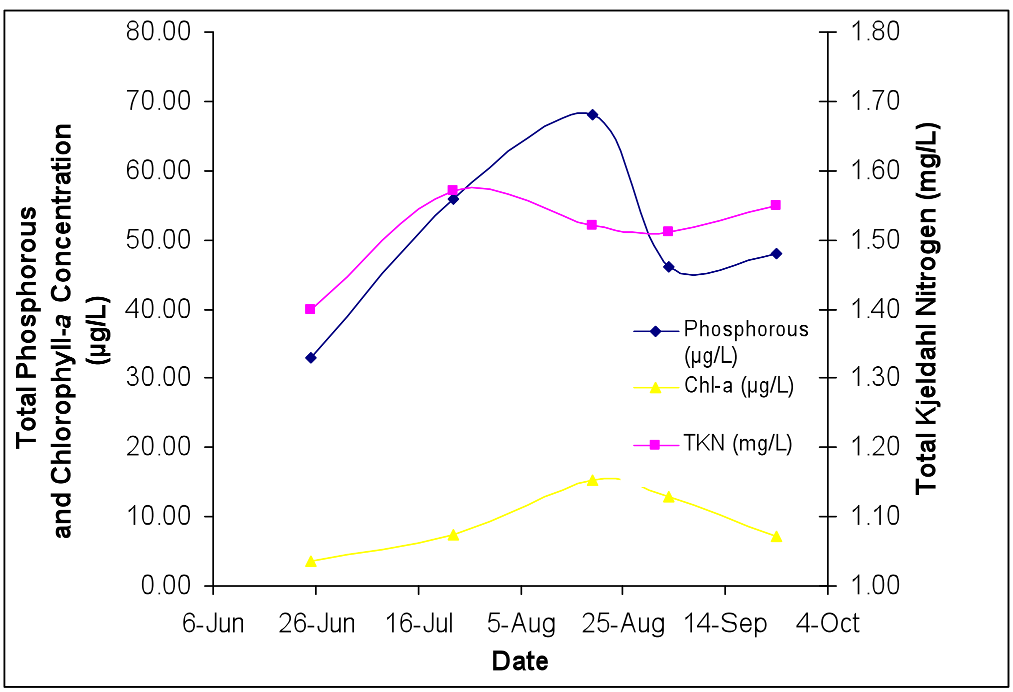

Figure 4 – Total phosphorous (μg/L), total Kjeldahl nitrogen (mg/L), and chlorophyll-*a* concentration (μg/L) measured five times over the course of the summer at Beaver Lake.

Average pH at Beaver Lake was 8.54 which is well above neutral (Table 1). The pH has changed very little since 1986, likely because high alkalinity (204 mg/L $CaCO_3$) helps to buffer the lake against changes. Dominant ions at Beaver Lake include bicarbonate, carbonate, calcium, and magnesium. Since ALMS last sampled Beaver Lake in 2008 there has been little change in most water chemistry parameters. Metals were sampled at Beaver Lake twice throughout the summer (Table 2), and all concentrations fell within their respective guidelines.

Table 1 – Average secchi depth and water chemistry values for Beaver Lake. Previous years averages are provided for comparison.

Parameter	1986	2003	2004	2008	2010
TP (μg/L)	33	47	56	36.6	50.8
TDP (μg/L)	12	17	13	14.4	21.6
Chlorophyll-*a* (μg/L)	11	18	24	6.09	9.316
Secchi depth (m)	2.9	2.4	1.8	5.6	3.2
TKN (μg/L)	1137	1358	1510	1292	1510
NO_2 and NO_3 (μg/L)	5.6	17	13	32	6
NH_3 (μg/L)	3	2.8	3.1	31.8	44.4
DOC (mg/L)	/	/	/	17.3	18.1
Ca (mg/L)	35	31	32	32.5	27
Mg (mg/L)	23	31	30	32.3	34.97
Na (mg/L)	13	13	21	22.5	24.23
K (mg/L)	10	10	14	13.4	14.77
SO_4^{2-} (mg/L)	29	42	62	65.7	72
Cl^- (mg/L)	0.5	1.6	2.3	2.77	3.07
CO_3 (mg/L)	6.3	15	10	6	5.67
HCO_3 (mg/L)	222	222	239	242.7	237
pH	8.5	8.7	8.5	8.4	8.54
Conductivity (μS/cm)	409	492	499	1171	518
Hardness (mg/L)	/	/	/	213.7	211
TDS (mg/L)	/	/	/	294.3	298
Microcystin (μg/L)	/	/	/	0.15	0.30
Total Alkalinity (mg/L $CaCO_3$)	191	206	499	208.7	204

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO_{2+3} = nitrate+nitrite, NH_3 = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. A forward slash (/) indicates an absence of data.

Table 2 - Concentrations of metals measured in Beaver Lake on July 23rd and September 24th 2010. Values shown for 2010 are an average of those dates. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	**2004**	**2008**	**2010**	**Guidelines**
Aluminum µg/L	10.7	10.9	17.15	100[a]
Antimony µg/L	0.068	0.051	0.04775	6[e]
Arsenic µg/L	1.47	1	1.685	5
Barium µg/L	57.1	58.2	52.75	1000[e]
Beryllium µg/L	<0.003	<0.003	0.00265	100[d,f]
Bismuth µg/L	<0.001	0.003	0.0016	/
Boron µg/L	79.6	81.5	74.05	5000[e,f]
Cadmium µg/L	<0.002	0.0029	0.0035	0.085[b]
Chromium µg/L	0.14	0.165	0.093	/
Cobalt µg/L	0.019	0.0186	0.021	1000[f]
Copper µg/L	0.42	0.23	0.2265	4[c]
Iron µg/L	8	7.4	10.815	300
Lead µg/L	0.0278	0.0221	0.0302	7[c]
Lithium µg/L	32.3	31.4	31.8	2500[g]
Manganese µg/L	138	26.9	36.7	200[g]
Molybdenum µg/L	0.169	0.249	0.2065	73[d]
Nickel µg/L	<0.005	<0.005	0.01335	150[c]
Selenium µg/L	<0.1	0.121	0.09	1
Silver µg/L	<0.0005	0.0022	0.0045	0.1
Strontium µg/L	231	235.5	211.5	/
Thallium µg/L	0.0007	0.0014	0.002475	0.8
Thorium µg/L	0.00071	0.0127	0.00835	/
Tin µg/L	0.036	0.0854	0.015	/
Titanium µg/L	1.07	1.4	0.906	/
Uranium µg/L	0.162	0.223	0.199	100[e]
Vanadium µg/L	0.285	0.337	0.2995	100[f,g]
Zinc µg/L	4.85	0.693	0.441	30

Values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentrations $[Ca^{+2}]$ ≥ 4 mg/L; and dissolved organic carbon concentration [DOC] ≥ 2 mg/L.

[b] Based on water Hardness of 300 mg/L (as $CaCO_3$)

[c] Based on water hardness > 180mg/L (as $CaCO_3$)

[d] CCME interim value.

[e] Based on Canadian Drinking Water Quality guideline values.

[f] Based on CCME Guidelines for Agricultural use (Livestock Watering).

[g] Based on CCME Guidelines for Agricultural Use (Irrigation).

A forward slash (/) indicates an absence of data or guidelines.

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:

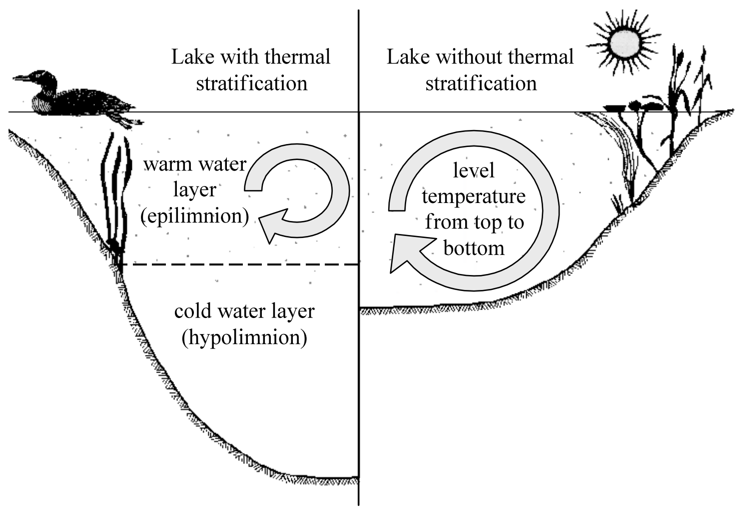

Figure A: Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. 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 (Table 2)**.

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.

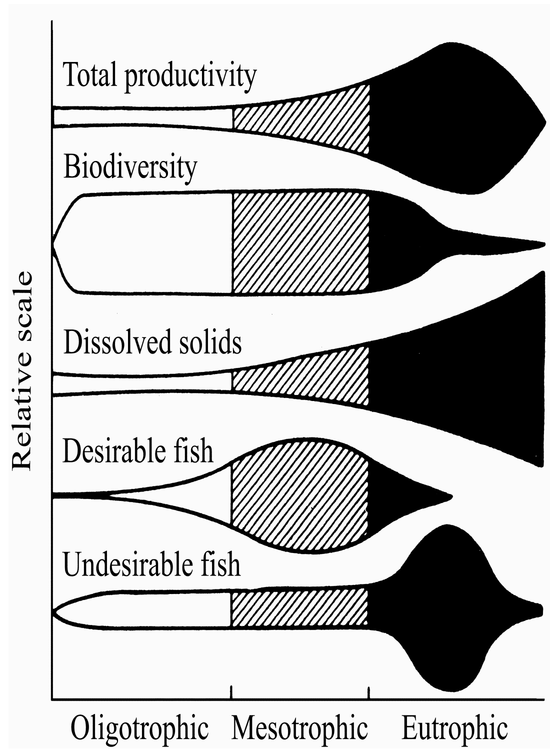

Figure B: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

Table A - Trophic status classification based on lake water characteristics.

Trophic state	Total Phosphorus ($\mu g \cdot L^{-1}$)	Total Nitrogen ($\mu g \cdot L^{-1}$)	Chlorophyll *a* ($\mu g \cdot L^{-1}$)	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.