Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Marie Lake Report

COMPLETED WITH SUPPORT FROM:

Beaver River Watershed Alliance

Government of Alberta

LICA
Lakeland Industry & Community Association

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, Al Sosiak and Ron Zurawell. We would like to thank Julian and Harriet Nowicki, Hal Martin, Hal Bekolay, Marian Gracas, Dean Wood, and all the family and neighbours who assisted with the sampling of Marie Lake. A special thanks to Robina Sobey, who not only assisted on the boat but was instrumental in coordinating the volunteers. 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, 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.

Marie Lake:

Marie Lake is located in the Beaver River Drainage Basin. It lies approximately 26 km northeast of the town of Cold Lake. Marie Lake is named after the Cree word *Methae* or *Merai* meaning “a fish”, and may specifically refer to burbot (*Lota lota*) prevalent throughout most of Alberta. The Cree arrived in the late eighteenth century displacing Beaver, Blackfoot, and Slavey tribes that were common in the area. The Cree arrived during the growth of the fur trade along a popular route from Waterhen, Saskatchewan by way of the Beaver River (Mitchell and Prepas 1990).

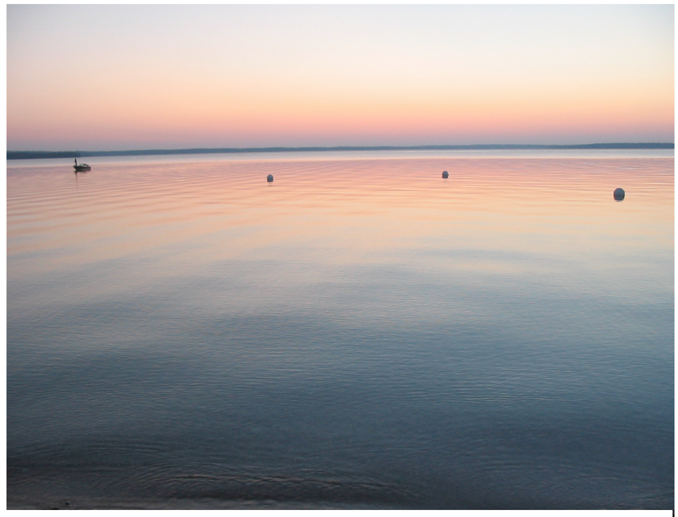

Figure 1 – Marie Lake, July 2004. Photo: Theo Charette.

Marie Lake is over 26.0 m deep (Figure 2) with a slow flushing rate (a residence time of 14.5 years). It is mesotrophic and has a small littoral zone for its surface area of 36 km^2. The shoreline is primarily sandy with macrophytes limited to a couple areas. A large macrophyte bed is located along the west shore stretching towards the north, and another lies on the western edge of the south bay. Macrophyte beds are dominated by bulrush, pondweed, and northern watermilfoil (Mitchell and Prepas 1990). The low productivity of the shoreline does not provide suitable habitat for semi-aquatic wildlife; however, the macrophytes beds are very important for maintaining a productive fishery.

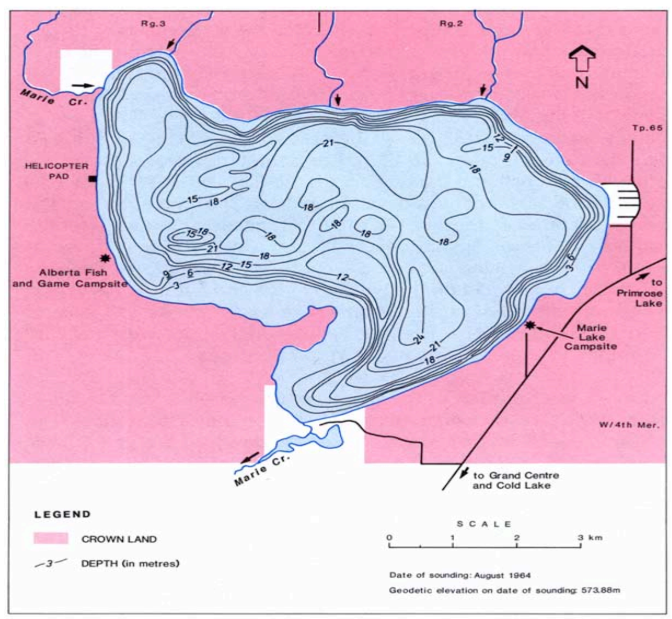

Figure 2 – Bathymetric map of Marie Lake obtained from Alberta Environment.

Currently, Marie Lake supports a domestic fishery; commercial fishing licenses have not been issued in this last decade. Sport fish include lake whitefish, tullibee, walleye, ling, suckers, northern pike, and yellow perch (Mitchell and Prepas 1990).

The water in Marie Lake is clear with little algal growth. Phytoplankton have been identified in previous studies: six species of Cyanophyta (blue-green algae) were present but comprised a low proportion of total algal biomass throughout the open-water season. Bacilliariophyta (diatoms), Crysophyta (golden-brown algae), and Pyrrhophyta (dinoflagellates) were abundant in late summer through fall.

Marie Lake is in the Central Mixedwood natural subregion, in the Boreal Forest natural region (Natural Regions Committee 2006). Orthic Grey Luvisols are found in the upper to mid slopes of the Marie Lake watershed. Poorly drained organic soils associated with moist areas known as fibrisols and meisols are found in depressions and flat areas making peatlands, bogs, fens, and marshes an important component of the Marie Lake watershed (Mitchell and Prepas 1990).

Although largely undeveloped, Marie Lake has individual private cottages along the southern shore and a subdivision on the eastern shore on private land. Also on the east shore is a members only National Defense/RCMP recreational campground. Additional private property and a campground are located at Shelter Bay on the north shore. Within the watershed, forestry and oil & gas extraction industries are the main land uses. The Marie Lake Air & Watershed Society is spearheading the protection and enhancement of the lake's watershed.

WATER LEVELS:

Water levels at Marie Lake have changed little since monitoring began in 1980 (Figure 3), though there have been large fluctuations, namely in 1992-1993 when water levels reached a minimum of 573.1 m above sea level (m asl), and in 2007, when water levels reached a maximum of 573.9 m asl. In a historical context, the 2010 water levels (573.8 m asl) at Marie Lake sit at the high end of the historical variation.

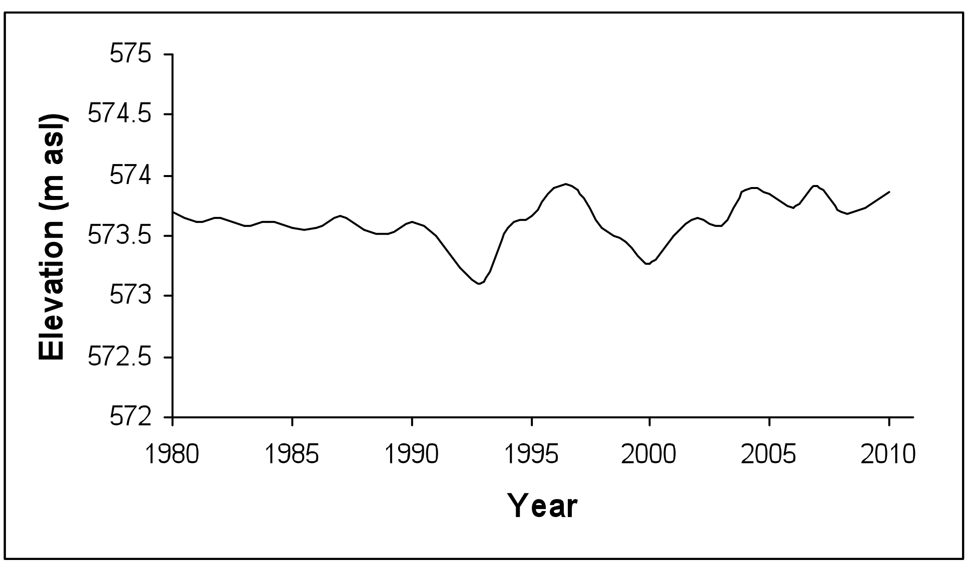

Figure 3 – Water levels at Marie Lake measured in meters above sea level (m asl). Data obtained from Environment Canada

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.

Water clarity at Marie Lake is quite good – the average secchi disc depth measured in 2010 was 2.95 m (Table 1). Secchi depth ranged from a maximum of 4.00 m on September 11th and a minimum of 1.75 m on July 24th. Low secchi disc depths are typical in July as algal blooms are often at their peak densities, resulting in reduced clarity. Water clarity at Marie Lake may also be affected by suspended sediments as a glacial blue-green colour was observed while sampling. An average secchi disc depth of 2.95 m is the lowest seen in recent years, though not beyond the natural variation for Marie Lake, as a secchi disc depth of 2.50 m was recorded in 1980.

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.

Due to its depth, Marie Lake maintained thermal stratification throughout most of the summer (Figure 4a). On June 26th, surface water temperature was 16.41 °C and stratification was present between 7.5-9.5 m. Temperature at the lakebed measured 6.63 °C. On July 24th, surface water temperature measured 19.19 °C and the range of thermal stratification increased to 7.5-11.0 m. On August 21st, surface water temperature decreased to 18.06 °C, resulting in a more uniform temperature in the upper water column, though stratification still persisted between 8.0-9.5 m. On September 11th, surface water temperature decreased to 13.85 °C. This drop in temperature resulted in uniform density throughout most of the water column, pushing stratification to 15.5-16.5 m. Finally, on September 25th, surface temperature had dropped to 11.13 °C. This drop in temperature decreased the density difference between the surface and bottom waters, allowing a total mixing of the water column and break down of stratification. At the lakebed, the temperature increased to 10.75 °C.

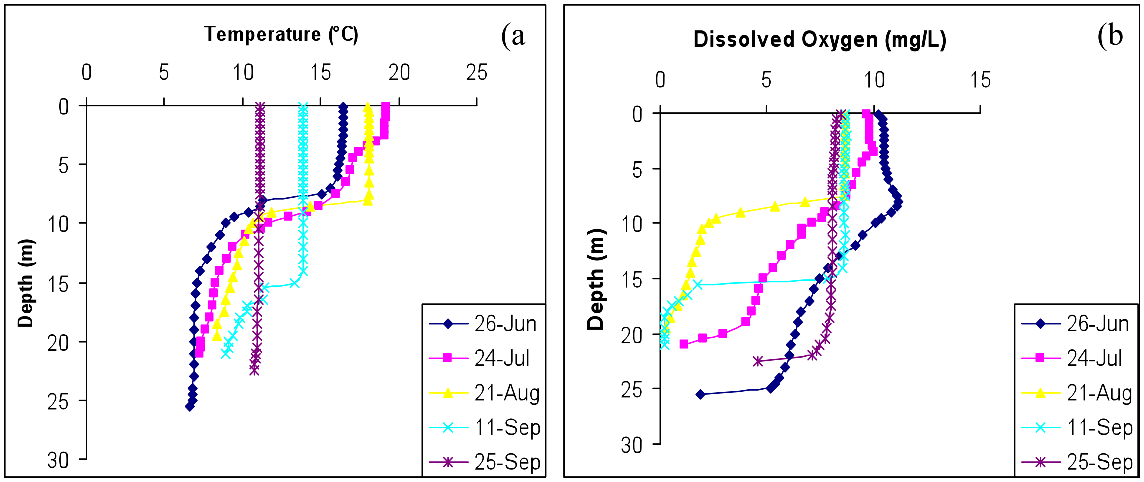

Figure 4 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Marie Lake measured five times throughout the summer of 2010.

Dissolved oxygen concentrations fluctuated greatly throughout the summer (Figure 4b). Dissolved oxygen on June 26th measured 10.25 mg/L at the surface and decreased steadily to 5.18 mg/L at 25.0 m; a well oxygenated water column. In July, surface dissolved oxygen decreased to 9.68 mg/L, decreasing much faster than in June to 1.13 mg/L at the lakebed. This is typical of July when oxygen-consuming decomposition on the lakebed, coupled with thermal stratification, causes a reduction in oxygen levels deeper in the water column. On August 21st, oxygen levels continued to decline, measuring 8.66 mg/L at the surface, with a sharp decrease to anoxic conditions around 15.5 m, and a final 0.19 mg/L at the lakebed. In September, with the mixing of the water column, oxygen became more evenly distributed, measuring ~8.00 mg/L for the first 15.0 m of the water column. After 15.0 m there was a sharp decrease towards anoxia. Finally, on September 25th, dissolved oxygen became mixed throughout the water column with the breakdown of the density difference caused by thermal stratification. Surface dissolved oxygen measured 8.5 mg/L and remained quite uniform for much of the water column, with a final reading of 4.60 mg/L at the lakebed.

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 during the summer of 2010 (19.6 μg/L), Marie Lake would be considered mesotrophic, or moderately productive (Table 1). Marie Lake's classification of mesotrophic has not changed since sampling began in 1981 (Table 1). Total phosphorous at Marie Lake had a seasonal maximum of 23 μg/L on June

26th, and a seasonal minimum of 16 µg/L (Fig 5). Total Kjeldahl nitrogen (TKN) had a seasonal maximum of 0.72 mg/L on June 26th, and a seasonal minimum of 0.61 mg/L on September 25th (Fig 5). An average TKN of 0.65 mg/L is higher than that seen in recent years (Table 1), and sits on the cusp between a mesotrophic and eutrophic classification. Finally, average chlorophyll-*a* at Marie Lake was 3.07 µg/L (Table 1). This value is well within the historical variation measured since 1981 and falls within the oligotrophic (low productivity) classification.

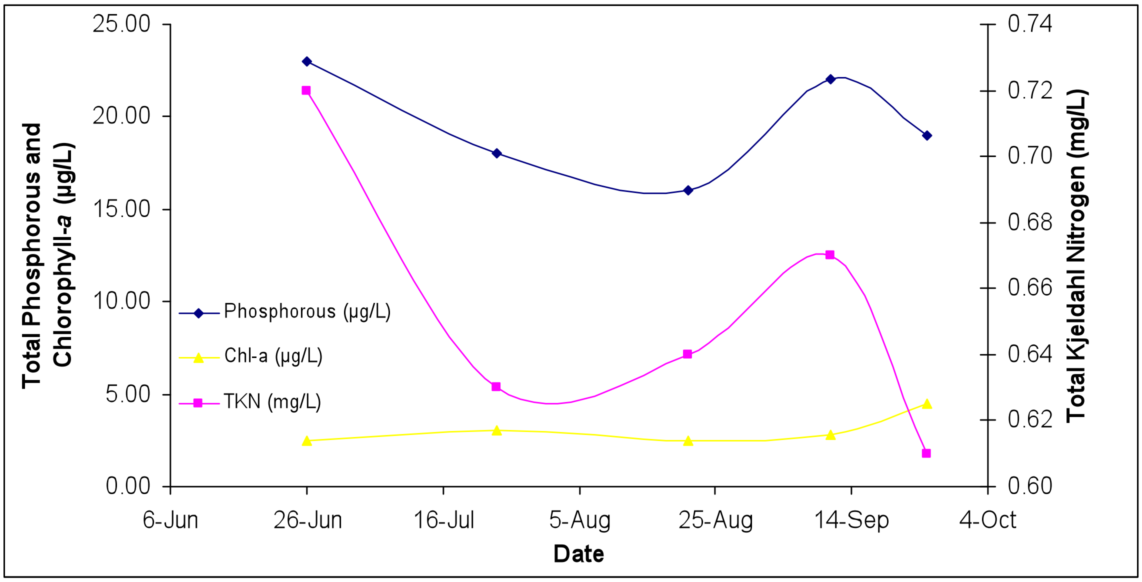

Figure 5 – Total Phosphorous (µg/L), chlorophyll-*a* (µg/L), and total Kjeldahl nitrogen (mg/L) measured five times over the course of the summer at Marie Lake.

Average pH at Marie Lake was 8.3 in 2010, almost no change from previous year's values. Marie Lake is likely well buffered against changes in pH due to high alkalinity (146 mg/L $CaCO_3$) and a high concentration of bicarbonate (173 mg/L HCO_3). There has been very little change in ion concentration over the years of sampling, suggesting Marie Lake's hydrology has remained quite stable. Ultimately, ion concentrations at Marie Lake are quite low. Metals were also sampled for twice during the summer of 2010 and all concentrations fell within their recommended guidelines (Table 2).

Table 1 – Average secchi depth and water chemistry values for Marie Lake in 2010, as compared to previous years.

Parameter	1980	1981	2002	2003	2004	2007	2008	2009	2010
TP (µg/L)	/	15	13	12	19	15	17.4	19.8	19.6
TDP (µg/L)	/	8	5	4	3	5.5	6.6	11.3	5.6
Chlorophyll-*a* (µg/L)	6.5	4.6	2.1	4	4.8	2.6	2.7	3.3	3.072
Secchi depth (m)	2.5	3	4.6	5.75	3.7	3.4	3.8	3.4	2.95
TKN (µg/L)	/	/	517	495	550	495	552	624	654
NO_2 and NO_3 (µg/L)	<1	/	1.8	4.8	5.2	<5	8	6.3	6.2
NH_3 (µg/L)	/	<22	9.3	6.5	9	9	15.2	16.3	11.2
DOC (mg/L)	/	/	/	/	/	10.8	11.4	10.4	11.37
Ca (mg/L)	30	/	35	34	33	34.2	32.9	31.5	26.95
Mg (mg/L)	12	/	12	14	12	12.2	12.2	11.7	12.775
Na (mg/L)	6	/	6	6	6.6	6.9	6.4	6.5	6.375
K (mg/L)	2	/	2	2	2	2	1.9	1.7	1.9
SO_4^{2-} (mg/L)	<3	/	0.69	<3	<3	<3	3.3	3.7	4.75
Cl^- (mg/L)	<1	/	0.56	0.47	0.6	0.8	0.6	0.83	0.8
CO_3 (mg/L)	/	/	/	/	/	5	4	9	0.5
HCO_3 (mg/L)	/	/	/	/	/	171	173	165	174
pH	/	/	/	/	8.44	8.4	8.4	8.5	8.3325
Conductivity (µS/cm)	/	/	/	/	/	267	266	263	263
Hardness (mg/L)	/	/	/	143.6	132.6	134	132.5	146	119.75
TDS (mg/L)	/	/	/	/	/	146.5	144.3	144.3	139
Microcystin (µg/L)	/	/	/	/	/	0.13	0.07	0.12	0.06
Total Alkalinity (mg/L $CaCO_3$)	135	/	147	152	171	148	146	146	143

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 – Average concentrations of metals measured in Marie Lake on July 24th and September 25th 2010, average values from samples taken from 2007 to 2009 are included for comparison. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	**2007**	**2008**	**2010**	**Guidelines**
Aluminum µg/L	9.1	4.2	12.25	100[a]
Antimony µg/L	0.012	0.024	0.0232	6[e]
Arsenic µg/L	0.51	0.67	0.6575	5
Barium µg/L	33.3	32.1	32.2	1000[e]
Beryllium µg/L	<0.003	<0.003	0.0062	100[d,f]
Bismuth µg/L	<0.001	0.0013	0.00195	/
Boron µg/L	17.7	23	18.95	5000[e,f]
Cadmium µg/L	<0.002	0.0029	0.01085	0.085[b]
Chromium µg/L	0.08	0.139	0.05285	/
Cobalt µg/L	<0.001	0.0073	0.0009	1000[f]
Copper µg/L	0.13	<0.05	0.1555	4[c]
Iron µg/L	39.9	3.28	23.15	300
Lead µg/L	0.021	0.0674	0.0161	7[c]
Lithium µg/L	4.37	7.25	6.31	2500[g]
Manganese µg/L	21.9	9.07	19.785	200[g]
Molybdenum µg/L	0.154	0.172	0.19	73[d]
Nickel µg/L	<0.005	0.086	0.0025	150[c]
Selenium µg/L	0.06	<0.1	0.05	1
Silver µg/L	<0.0005	<0.0005	0.00655	0.1
Strontium µg/L	90.8	91	84.35	/
Thallium µg/L	<0.0003	<0.003	0.002575	0.8
Thorium µg/L	0.007	<0.003	0.00545	/
Tin µg/L	0.03	0.0315	0.015	/
Titanium µg/L	1.38	1.03	1.095	/
Uranium µg/L	0.08	0.0662	0.0676	100[e]
Vanadium µg/L	0.14	0.112	0.12055	100[f,g]
Zinc µg/L	0.64	0.175	0.798	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5; calcium ion concentrations $[Ca^{+2}] \geq 4$ 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:

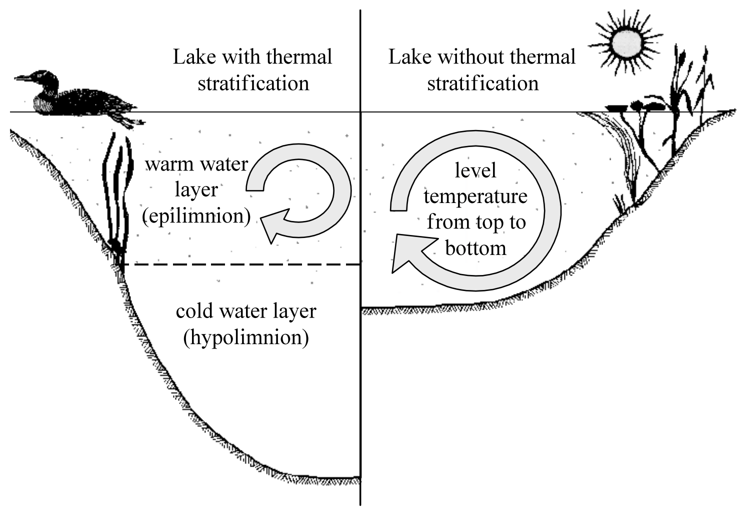

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

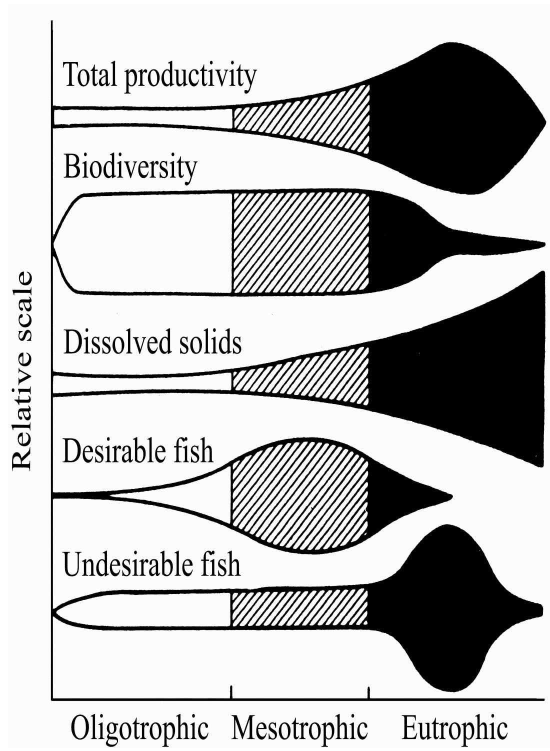

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

Trophic state	Total Phosphorus (μg•L^{-1})	Total Nitrogen (μg•L^{-1})	Chlorophyll *a* (μg•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.