Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2012 Battle Lake Report

COMPLETED WITH SUPPORT FROM:

Alberta Government

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

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Battle Lake:

Figure 1 – Photo from the dock at Battle Lake. Photo by Brad Peter, 2012.

Battle Lake, located 102 km southwest of Edmonton, is a long lake nestled within a glacial meltwater channel which was formed during the Pleistocene. Battle Lake, the headwater for the Battle River, is fed by Battle Creek and several tributaries with an overall drainage basin of ~103 km^2.

Battle Lake derives its name from the frequent territorial battles which took place there between Blackfoot and Cree tribes. In 1900, settlers began arriving in the area, and logging activity began in 1904.[1] The industry warranted a small sawmill operation that was established in the 1920's. By 1944, logging had ended and today the area is maintained as a natural area for secondary recreational use (hiking, canoeing, relaxation, and sight seeing). It is zoned by the County of Wetaskiwin as a watershed protection district. Battle Lake's steep sided valley is connected to a steep ravine carved by a creek that formed a delta along the west side of the lake. The terrain limits extensive agricultural use and few cottages are developed along the shoreline, except near the outlet (the lowest elevation). There is also a 4-H facility located on the southwestern shore and a public campground with boat launch on the southeastern shore. Oil and gas operators in the area restrict their activities through a unique watershed development plan that outlines restrictions in the lakes' riparian areas.[2] The Battle Lake Watershed Synergy Group (BLWSG), whose goal is to ensure effective and sensitive planning of oil and gas development, was key to the development and implementation of the plan. More information, published reports, and maps of current oil and gas activity in the watershed can be found at the BLSWG website.[3]

Battle Lake is 13.1 m in the deepest area (Fig. 1) of the basin. The substrate is sand and a few gravel shoals. Battle Lake is classified as eutrophic, or high nutrient levels, with clear water early in the summer and algal blooms occurring by late summer due to the mixing of phosphorus released from the sediments. Fishing for sport fish such as lake whitefish, pike, perch, and walleye is a popular activity. Walleye stocking programs have been

[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/
[2] http://www.synergyalberta.ca/docs/resources/battle_lake_watershed_pilot.pdf
[3] http://synergyalberta.ca/group/battle-lake-watershed-synergy-group

implemented in the past, though today, only domestic fishing is maintained. Fish netting reports can be viewed on Environment and Sustainable Resource Developments website.[4]

WATER QUANTITY:

There are many factors influencing water quantity. Some of these factors include the size of the lakes drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake.

Water levels in Battle Lake have been regularly monitored since 1961 (Figure 2). Despite obvious year to year fluctuations, there is no apparent long-term trend in water levels at Battle Lake. Minimum water levels were observed in 1981 when the lake reached 836.2 m asl, while maximum water levels were observed in 1991, when the lake reached 838 m asl, resulting in flooding along the Battle River. In the past few years, water levels have fluctuated slightly above the historical average.

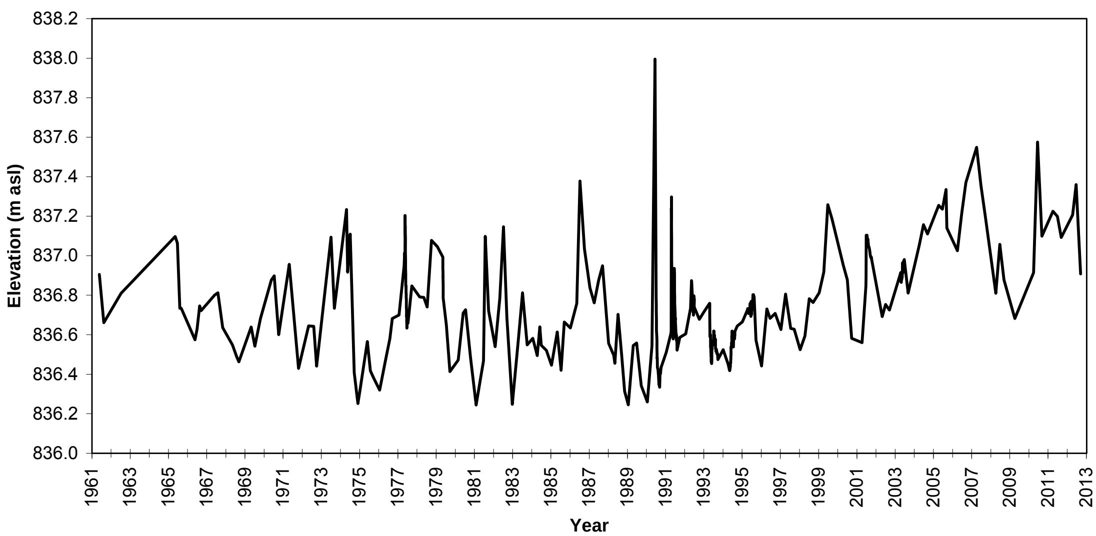

Figure 2 - Water levels measured at Battle Lake from 1961 to 2012 in meters above sea level (m asl). Data retrieved from Alberta Environment.

WATER CLARITY & 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

[4] http://srd.alberta.ca/FishWildlife/FisheriesManagement/FallWalleyeIndexNetting/Default.aspx

growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

Average Secchi disk depth at Battle Lake during the summer of 2012 measured 1.50 m; this value is lower than the averages measured during previous years (Table 1). Throughout the summer, Secchi disk depth ranged from a maximum of 3.00 m on June 12th to a minimum of 0.50 m on August 27th. Changes in Secchi disk depth corresponded closely to changes in concentrations of chlorophyll-*a* and total suspended solids, suggesting that algae/cyanobacteria blooms were a key factor affecting water clarity.

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.

Surface water temperature at Battle Lake changed greatly throughout the summer (Figure 3a). On July 11th surface water temperature was at a maximum of 23.83 °C, versus September 21st when surface water temperature was at a minimum of 15.24 °C. Thermal stratification was observed on both July 11th and August 13th. This was most pronounced on July 11th, when water temperatures changed six degrees between 1.00 and 5.00 m. Battle Lake is likely dimictic, stratifying once throughout the summer. Measuring the patterns of stratification is important as they directly impact a lake's dissolved oxygen concentrations.

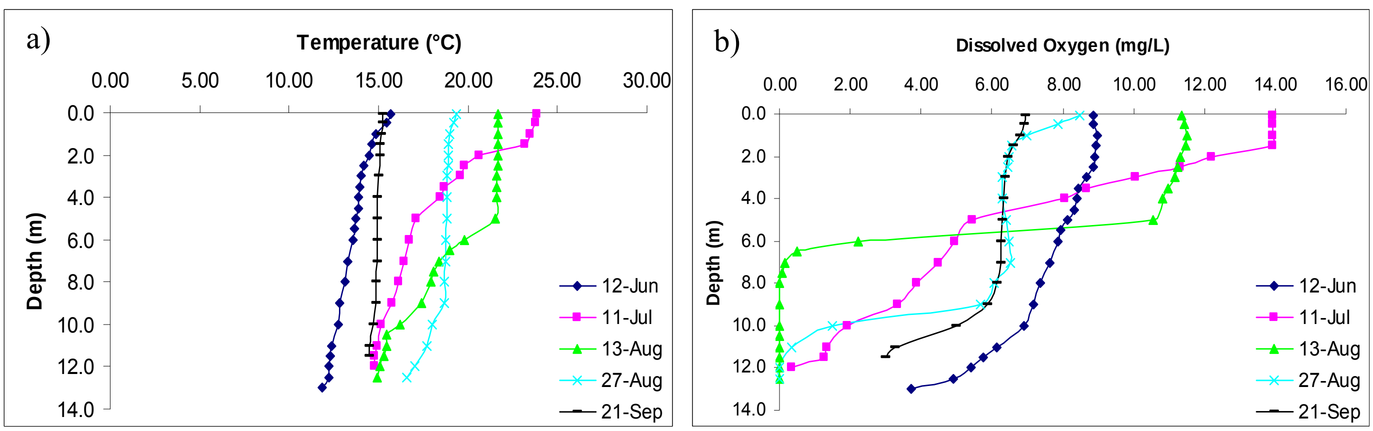

Figure 3 – a) Surface water temperature (°C) and b) dissolved oxygen concentrations (mg/L) measured five times over the course of the summer at Battle Lake.

Dissolved oxygen concentrations at Battle Lake showed dramatic reductions below the thermocline (Figure 3b). On each sampling trip, with the exception of June 12th, dissolved oxygen concentrations were below the Canadian Council for Ministers of the Environment (CCME) Guidelines of 6.5 mg/L for the Protection of Aquatic Life for at least half of the water column. In fact, on August 13th, anoxia was observed at the relatively shallow depth of 6.50 m. This means less than 50% of the lake would be available for fish habitat. The decomposition of algae/cyanobacteria on the lakebed, an oxygen consuming process, coupled with separation from atmospheric oxygen by the thermocline can result in dramatic reductions in dissolved oxygen concentrations. Low levels of dissolved oxygen near the lakebed may increase the amount of phosphorus released from lake sediments, which may result in peak phosphorus levels late in the summer.

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorus, 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.

Average Total Phosphorus (TP) concentration measured at Battle Lake during 2012 was high at 72.2 µg/L; this is much higher than previous year's averages and falls into the eutrophic or nutrient rich, classification (Table 1). TP concentration increased steadily throughout the summer, measuring 27 µg/L on June 12th and 139 µg/L on September 21st (Figure 5).

Similar to TP, chlorophyll-*a* concentrations were much higher in 2012 than in previous years (Table 1). The average chlorophyll-*a* concentration measured during 2012 was 36.95 µg/L, which falls into the hypereutrophic, or extremely productive, classification. Thick surface blooms of cyanobacteria were observed on multiple sampling trips (Figure 4); The highest measured concentration was 68.6 µg/L on August 27th (Figure 5). Because the lake is not routinely monitored for cyanobacteria blooms, these conditions were reported to Alberta Health Services who acknowledged the need for a blue-green algae advisory (pers. comm.).

Figure 4 – A bloom of cyanobacteria covering the surface of Battle Lake. Photo by Erin Rodger, 2012.

Finally, total Kjeldahl nitrogen (TKN) measured an average of 1174 μg/L, which falls into the hypereutrophic classification. As with TP and chlorophyll-*a*, the 2012 TKN average is much higher than previous year's averages.

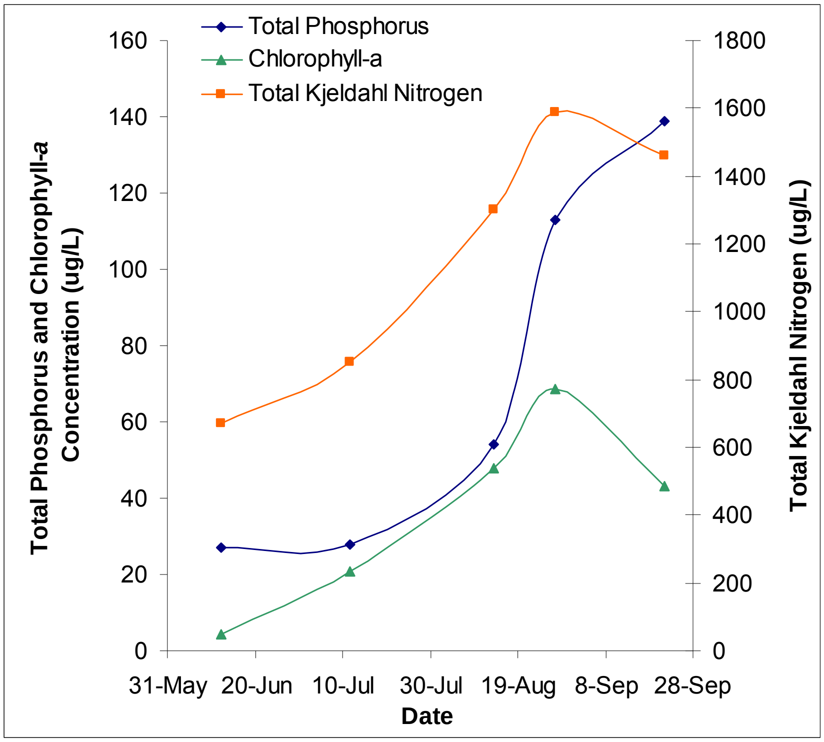

Figure 5 – Total phosphorous (μg/L), total Kjeldahl nitrogen (μg/L), and chlorophyll-*a* concentration (μg/L) measured five times throughout the course of the summer at Battle Lake.

Average pH measured at Battle Lake during 2012 was 8.44, well above neutral (Table 1). High alkalinity (169.2 mg/L $CaCO_3$) and bicarbonate (196.2 HCO_3μg/L) concentrations may help to buffer the lake from changes to pH. Because Battle Lake is a headwater it has a low conductivity (341.2 μS/cm), and therefore a low concentration of dissolved ions such as calcium (30.83 mg/L), magnesium (11.0 mg/L) and sulphate (9.67 mg/L). Microcystin, a toxin produced by cyanobacteria, had an average concentration of 4.21 μg/L, well above the drinking water quality guidelines (1.0 μg/L), and a maximum of 8.28 μg/L on August 27th – though this falls below the recreational water quality guidelines (20 μg/L), although it is still high relative to other lakes sampled in Alberta in 2012. More information regarding toxic cyanobacterial blooms can be found through the following Alberta Health Services fact-sheet: http://www.albertahealthservices.ca/EnvironmentalHealth/wf-eh-blue-green-algae-handout.pdf.

Metals were measured twice throughout the summer at Battle Lake and all concentrations fell within their respective guidelines (Table 2). With only three years of sampling in the past decade, we would encourage increased monitoring of Battle Lake to establish accurate baselines.

Table 1 – Average Secchi disk depth and water chemistry values for Battle Lake. Previous years averages are provided for comparison.

Parameter	1983	1984	2003	2005	2012
TP (μg/L)	29.7	33.3	38.4	46.0	72.2
TDP (μg/L)	13	13	15	10.3	27
Chlorophyll-*a* (μg/L)	13.1	9.37	22.76	18.8	36.95
Secchi depth (m)	3.72	3.79	2.15	3.13	1.5
TKN (μg/L)	901	608	726	806.7	1174
NO_2 and NO_3 (μg/L)	2.4	5.7	9.25	4.5	10.5
NH_3 (μg/L)	30.6	13.7	22	25	19
DOC (mg/L)	9.1	8.5	/	8.3	11.45
Ca (mg/L)	38.8	36.7	33.7	28.2	30.83
Mg (mg/L)	9.8	10.2	11.45	11.13	11
Na (mg/L)	20.4	20.3	23.15	24.43	22.87
K (mg/L)	2.88	3.08	3.85	3.83	3.7
SO_4^{2-} (mg/L)	10.2	9.2	10.5	8.5	9.7
Cl^- (mg/L)	1.1	1.25	3.1	4.33	5.2
CO_3 (mg/L)	3.1	3.68	7.25	3.65	5.4
HCO_3 (mg/L)	207.8	215.7	187	202.3	196.2
pH	8.4	8.4	8.57	8.38	8.44
Conductivity (μS/cm)	348.2	352.3	333	338	341.2
Hardness (mg/L)	137.2	133.7	202.5	123.3	184.3
TDS (mg/L)	188.6	189.9	187	187.3	122.3
TSS	/	5.35	/	5	6.44
Microcystin (μg/L)	/	/	/	/	
Total Alkalinity (mg/L $CaCO_3$)	175	181.6	165.5	171.7	169.2

Note: TP = total phosphorus, TDP = total dissolved phosphorus, 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 Battle Lake on August 13th and September 21st 2012. Values shown for 2012 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)	2003	2005	2012	Guidelines
Aluminum μg/L	17.86	28.2	12.26	100[a]
Antimony μg/L	0.09	0.083	0.08055	6[e]
Arsenic μg/L	1.64	1.41	3.125	5
Barium μg/L	70.9	69	60.25	1000[e]
Beryllium μg/L	0.089	0.0015	0.015	100[d,f]
Bismuth μg/L	0.0052	0.0005	0.0005	/
Boron μg/L	27.4	27.6	38.7	5000[ef]
Cadmium μg/L	0.0187	0.0106	0.01005	0.085[b]
Chromium μg/L	0.22	0.132	0.1203	/
Cobalt μg/L	0.0307	0.047	0.0303	1000[f]
Copper μg/L	0.96	0.56	0.4365	4[c]
Iron μg/L	21	25	10.15	300
Lead μg/L	0.084	0.079	0.05725	7[c]
Lithium μg/L	5.47	7.7	6.505	2500[g]
Manganese μg/L	28.3	17	85.2	200[g]
Molybdenum μg/L	1.31	1.26	1.054	73[d]
Nickel μg/L	0.297	0.45	0.05575	150[c]
Selenium μg/L	0.37	0.05	0.0785	1
Silver μg/L	0.0037	0.00025	0.0011	0.1
Strontium μg/L	307.7	341	280	/
Thallium μg/L	0.0126	0.029	0.00095	0.8
Thorium μg/L	0.0015	0.0006	0.00015	/
Tin μg/L	0.05	0.015	0.04815	/
Titanium μg/L	0.83	0.88	0.841	/
Uranium μg/L	0.5793	0.584	0.4335	100[e]
Vanadium μg/L	0.35	0.295	0.26	100[f,g]
Zinc μg/L	1.76	2.8	0.4415	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:

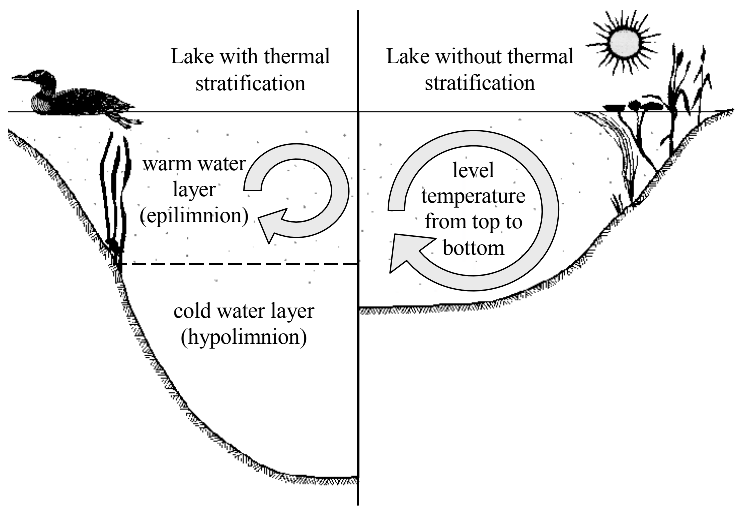

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

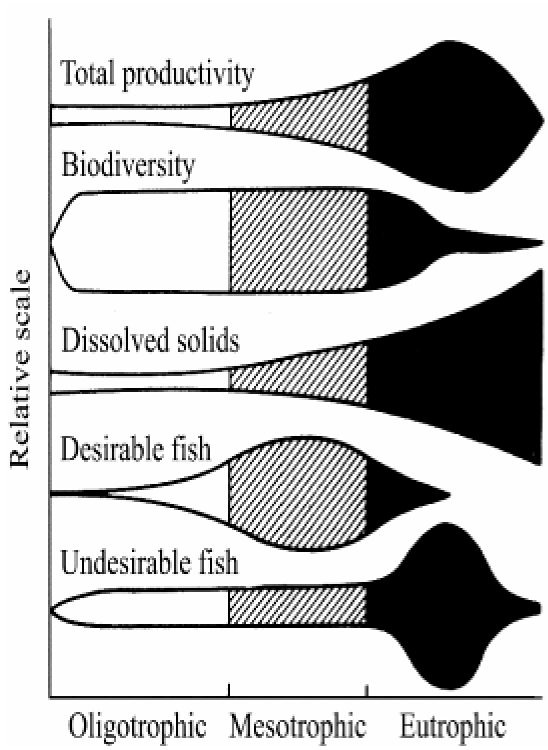

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

Trophic state	Total Phosphorus (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