The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Skeleton Lake

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2009 Report

Completed with support from:

Lakeland Industry & Community Association

Alberta Environment

Beaver River Watershed Alliance

Alberta Lake Management Society

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> *Water is integral to supporting and maintaining life on this planet as it moderates the climate, creates growth and shapes the living substance of all of Earth's creatures. It is the tide of life itself, the sacred source.*
> David Suzuki (1997). The Sacred Balance.

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, Al Sosiak and Ron Zurawell. We would like to thank Dustin Sherman, Peter Sherman, and Jackie & Rick Tiedeman for their efforts in collecting data in 2009. We would also like to thank Noemie Jenni and Cristen Symes who were summer interns with ALMS in 2009. 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. Théo Charette, Ron Zurawell (Limnologist, AENV), and Lori Nuefeld prepared the original report, which was updated by Sarah Lord for 2009. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Skeleton Lake

Skeleton Lake (**Figure 1**) is located in the western portion of the Beaver River Basin, in the County of Athabasca, 160 km northeast of the city of Edmonton and 6.5 km northeast of the village of Boyle. Skeleton Lake has an extensively developed shoreline, and is the source of drinking water for Boyle. To reach the lake from Edmonton, take Highway 28 northeast to Highway 63. Travel north on Highway 63 to its junction with Secondary Road 663, then turn east and drive until you are about 5 km past Boyle. Local roads from Secondary Road 663 lead north to the summer villages of Mewatha Beach and Bondiss on the southern shore of the lake. The lake's name is a translation of the Cree *Cheply Sakhahigan*, which means "place of the skeletons".

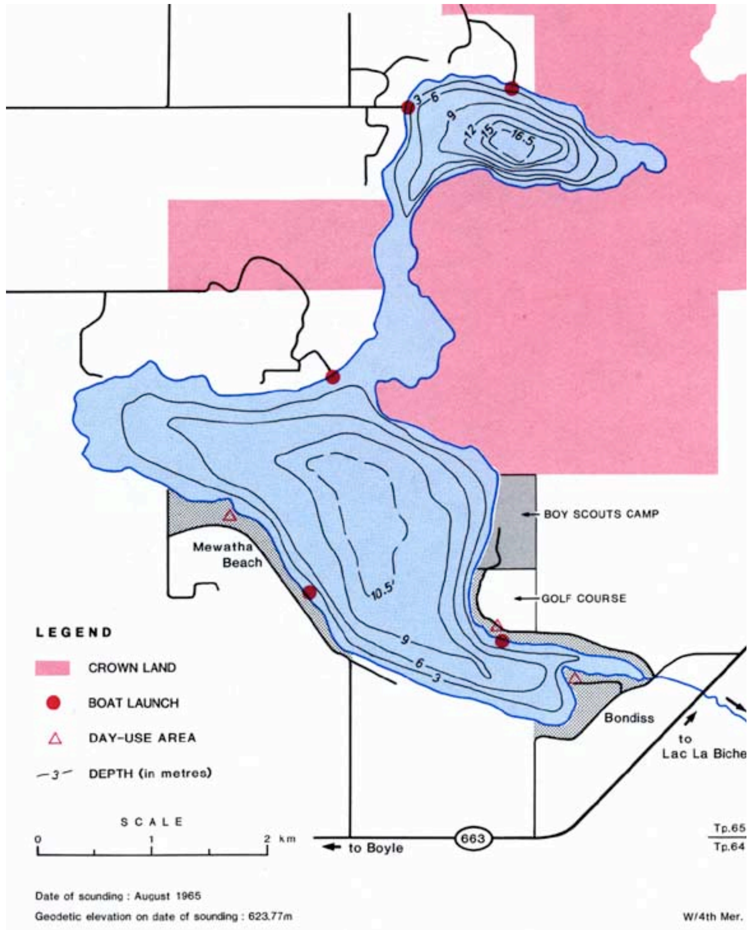

Figure 1. Bathymetry of Skeleton Lake. Contour intervals represent 3 meters depth.

Public access to Skeleton Lake is available through two public boat launches located in the north and south basins. The summer village of Mewatha Beach has a day-use area and a shallow, sandy beach with a designated swimming area. The summer village of Bondiss offers two day-use areas. One is located south of the golf course and the second area is located on the point of land that extends into the southeast bay. Two commercial campgrounds, one within Bondiss and the other just west of the boundary of Bondiss on the southern shore, offer a variety of facilities to overnight campers and day users.

The watershed is located in the dry mixedwood subregion of the boreal mixedwood ecoregion. Several small intermittent streams flow into the lake and drain a watershed that is four times the size of the lake. The outlet is a small creek located at the southeast end of the lake, and drains eastward into Amisk Lake. Beaver dams often block the outlet. Tree cover in the watershed consists primarily of trembling aspen and secondarily of white spruce, balsam poplar and white birch. Peatlands are also significant, and most agricultural activities in the watershed taker place in the southern and northwestern sections. The lakeshore has been extensively developed for residential use.

Skeleton Lake is divided into two basins. The north basin is separated from the south basin by a shallow, weedy narrows. During the late 1940s, when lake levels were low, the two basins were separated by exposed land at the narrows. The north basin is small and deep, with steeply sloping sides that reach a maximum depth of about 17 m. The larger south basin slopes gradually to a maximum depth of only 11 m. Skeleton Lake is very fertile and blooms of blue-green algae turn the water green in both basins during summer months. The average concentrations of algae in the south basin are higher than in the north basin. Large aquatic plants are common along the entire shoreline and are particularly dense throughout the narrow and very shallow channel that joins the two basins.

Results

Water Level

Water levels in Skeleton Lake have been monitored by Environment Canada since 1965 under the joint Federal-Provincial Hydrometric agreement (**Figure 2**). Consistent with other lakes in the area, water levels have decreased steadily by about 1.6 meters since the 1970s, with the exception of 1997, an extremely wet period, during which the water level increased to 1974 levels. Over the past thirteen years, water levels in Skeleton Lake have declined from a maximum of 623.8 m (recorded in July 1974 and June 1997) to a historical minimum of 621.8 m asl in late 2009.

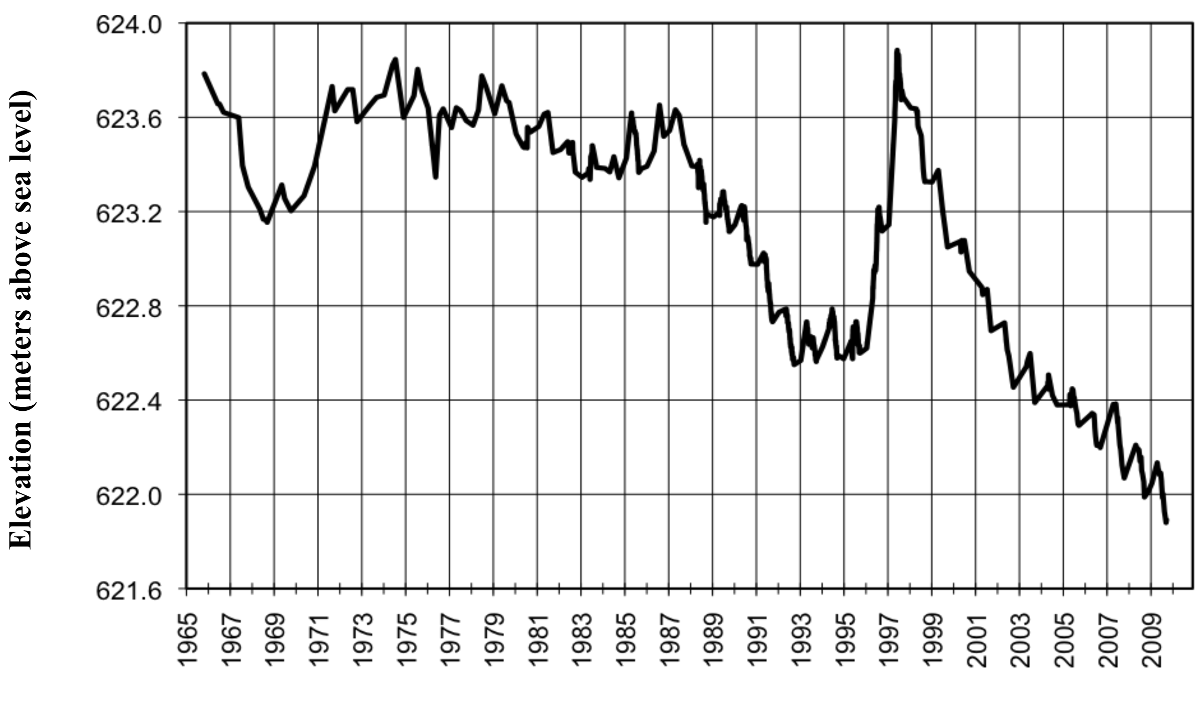

Figure 2. Historical water levels (m asl) in Skeleton Lake, Alberta 1965 – 2009.

Water Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. Please refer to the end of this report for descriptions of technical terms.

In 2009, the South basin of Skeleton Lake did not show significant thermal stratification of the water column (**Figure 3**). Weak thermal stratification was observed at the surface in early June, but the actual change in temperature from the lake surface to lakebed was less than four degrees Celsius. The maximum surface water temperature was 20.4°C, observed on 15 August.

Dissolved oxygen (DO) concentrations decreased with depth in the south basin, and concentrations in deeper waters dropped to near zero (e.g. anoxic) within 1 m of the lakebed on all sampling dates (**Figure 3**). Deep-water anoxia is common during the summer, as bacterial decomposition of organic matter in lake sediments consumes oxygen. On 12 June, surface waters were very well oxygenated, and DO declined rapidly at 6 m depth. On 8 July the boundary between well-oxygenated and poorly-oxygenated water occurred within 0.5 m of the lakebed. On 15 August a decline in DO was observed at 2.5 m depth, in addition to the rapid decline near the lakebed. By 5 September, surface waters had reached the lowest DO concentration observed at Skeleton Lake this season, but were still above the provincial Guidelines for Protection of Freshwater Aquatic Life (DO ≥ 5.0 mg/L).

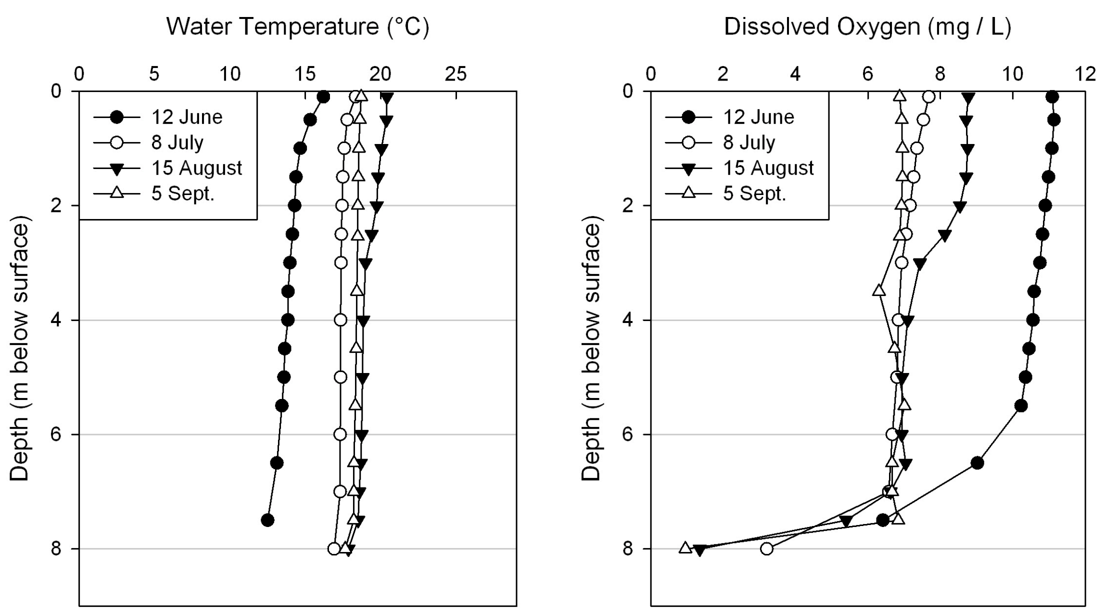

Figure 3. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Skeleton Lake during the summer of 2009.

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.*

Skeleton Lake is of average turbidity compared to other lakes in Alberta, with an average Secchi depth of 1.63 m in the south basin in 2009. That year, light penetrated ~20% of the total lake depth (**Table 1**), allowing algal growth in the top 3.5 m of the water column. The seasonal maximum Secchi depth of 2.25 m was observed on 12 June. Water clarity decreased over the summer, declining to 1.5 m Secchi depth on 8 July and 15 August, and reaching a seasonal minimum of 1.25 m on 5 September.

Water Chemistry

Based on lake water characteristics, Skeleton Lake is considered eutrophic (see *A Brief Introduction to Limnology* at the end of this report). In 2009, Skeleton Lake had high concentrations of total phosphorus (average TP = 40.3 μg/L), total nitrogen (average TN = 1147.5 μg/L), and algal biomass (average chlorophyll *a* = 12.4 μg/L) (**Table 1**). Total nitrogen and phosphorous concentrations increased steadily over the summer, reaching a maximum in early September (**Figure 4**). Chlorophyll *a* (a measure of algal biomass) concentration was relatively low at < 10 μg/L from June through July, then increased to 13.2 μg/L in August, and reached a seasonal maximum of 21.8 μg/L in September.

Like most lakes in Alberta, Skeleton Lake is well buffered from acidification. In 2009, lake pH = 8.8, well above that of pure water (i.e., pH 7). Bicarbonate, magnesium, and calcium are the dominant ions in Skeleton Lake (**Table 1**). The concentrations of most ions and nutrients have remained fairly constant since the 1980s, despite the recorded drastic reduction in water levels. Concentrations of major nutrients (e.g. P, N) have not changed significantly since the 1980s, indicating no significant change in nutrient inputs to the lake.

In summer 2005, it appeared that the south basin had ameliorated in terms of algae and phosphorus concentration when compared to the 1986 average. However, sampling in 2008 showed an algal bloom in August and the highest TP on record, so the 2005 decrease in TP may have simply been part of the system's natural variability. Chlorophyll *a* concentrations in 2009 were similar to those in 2005, but TP in 2009 was higher than observed in 2005.

The average concentrations of various metals (as total recoverable concentrations) in Skeleton Lake were measured twice in the summer of 2009. All values were well within the CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

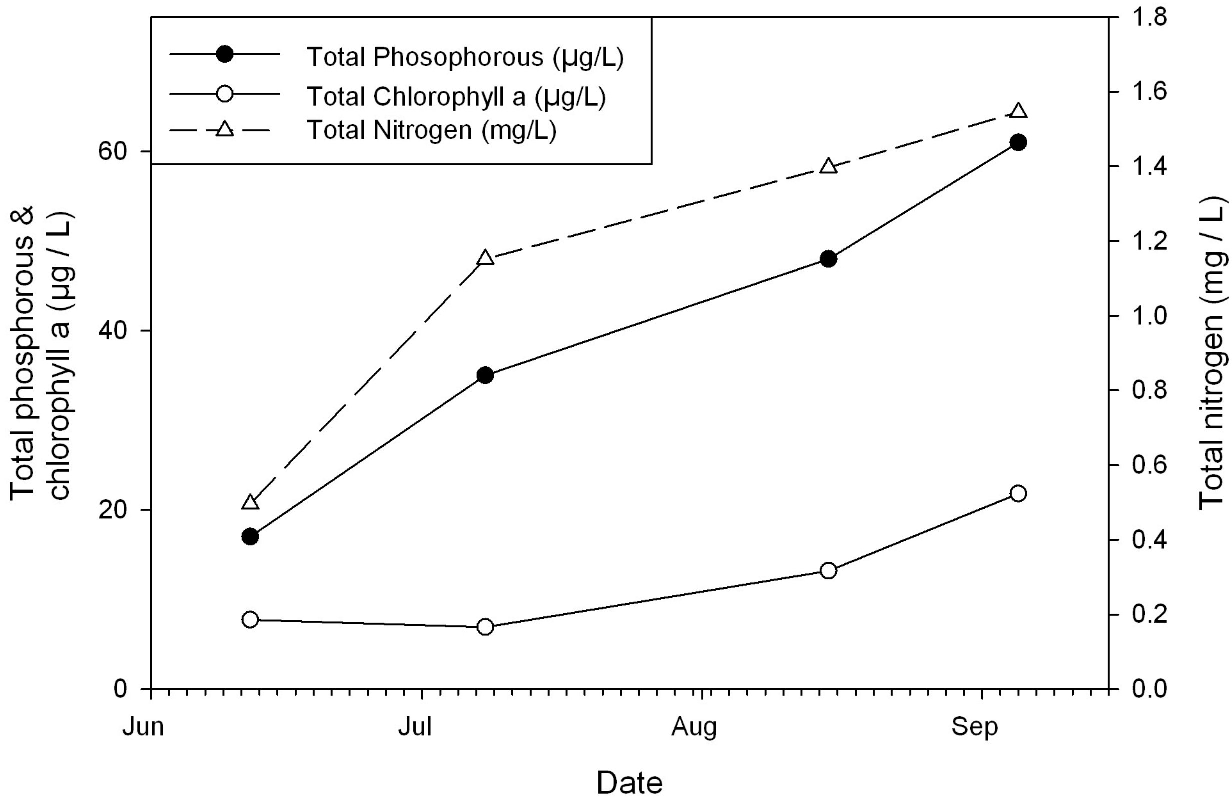

Figure 4. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Skeleton Lake during the summer of 2009.

Table 1. Mean water chemistry and Secchi depth values for Skeleton Lake, Alberta, summer 2009 compared to previous years.

Parameter	North Basin			South Basin					
	1985	**1986**	**2005**	**1985**	**1986**	**2005**	**2006**	**2008**	**2009**
Total P (µg/L)	-	36	33	-	47	29	41	45.4	40.3
TDP (µg/L)	-	10	11	-	11	8.4	12.5	13.4	13.5
Chlorophyll *a* (µg/L)	9.2	11	11	16	24	12	17	19.3	12.4
Secchi depth (m)	2.5	2.5	2.6	2.0	1.6	2.3	1.4	1.65	1.63
Total N (µg/L)	1160	1140	1300	1139	1318	1158	1290	1324	1135
NO_{2+3} (µg/L)	<3	<4	4	<3	<3	6.8	<5	<5	12.5
NH_4 (µg/L)	21	32	13	13	37	13	29	19.2	26.7
Ca (mg/L)	23		21	26		22	25	22.8	23.6
Mg (mg/L)	19		24	19		23	23	26.9	24.4
Na (mg/L)	13		18	14		19	20	20.2	21.3
K (mg/L)	8		11	9		11	11	11.5	12.5
SO_4 (mg/L)	<5		5	<5		3	6	5	6
Cl (mg/L)	<2		3.2	<2		3.1	3.4	3.8	4.2
CO_3 (mg/L)	<5		12	<6		11	15	13	12.7
HCO_3 (mg/L)	198		204	208		226	231	223.6	231.3
Total Alkalinity (mg/L $CaCO_3$)	170		187	178		203	210	205.3	211
Total Dissolved Solids (mg/L)	172		193	181		204	213	211.3	218.3
pH	8.4-8.8		8.8	8.5-8.8		8.7	8.7	8.7	8.76
Dissolved Organic C (mg/L)	15		17	14		14	-	16.4	14.6
Hardness ($CaCO_3$)							158	168	159
Conductivity (µS/cm)							389	374	381

Note. TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = carbonate.

Appendix 1

The concentrations of metals were measured in Skeleton Lake on 8 July and 5 September, 2009; here the mean value of those two sampling dates is compared to mean values in 2008. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (total)	2008	2009	Guidelines
ALUMINUM μg/L	24.1	12.8	100[a]
ANTIMONY μg/L	0.033	0.032	6[e]
ARSENIC μg/L	1.01	0.983	5
BARIUM μg/L	55.8	57.3	1000[e]
BERYLLIUM μg/L	0.0045	<0.003	100[d,f]
BISMUTH μg/L	0.0036	0.0040	
BORON μg/L	102.5	109.6	5000[e,f]
CADMIUM μg/L	<0.002	0.0023	0.085[b]
CHROMIUM μg/L	0.115	0.188	
COBALT μg/L	0.023	0.0203	1000[f]
COPPER μg/L	0.171	0.270	4[c]
IRON μg/L	49.2	70.4	300
LEAD μg/L	0.0285	0.0283	7[c]
LITHIUM μg/L	30.6	36.1	2500[g]
MANGANESE μg/L	44.5	62.1	200[g]
MOLYBDENUM μg/L	0.103	0.114	73[d]
NICKEL μg/L	<0.005	0.204	150[c]
SELENIUM μg/L	0.144	0.120	1
STRONTIUM μg/L	185	185	
SILVER μg/L	0.0036	0.0069	
THALLIUM μg/L	0.00115	0.00185	0.8
THORIUM μg/L	0.0093	0.0017	
TIN μg/L	0.0483	<0.03	
TITANIUM μg/L	1.21	0.762	
URANIUM μg/L	0.121	0.110	100[e]
VANADIUM μg/L	0.207	0.208	100[f,g]
ZINC μg/L	0.373	0.996	30

Values represent means of total recoverable metal concentrations.
[a] Based on pH ≥ 6.5; calcium ion concentration [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 > 180 mg/L (as $CaCO_3$).
[d] CCME interim value.
[e] Based of Canadian Drinking Water Quality guideline values.
[f] Based of CCME Guidelines for Agricultural Use (Livestock Watering).
[g] Based of CCME Guidelines for Agricultural Use (Irrigation).

References

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press.

Nürnberg, G.K. 1996. Trophic state of clear and colored, soft and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12(4):432-447.

Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Alberta Energy and Natural. Resources. 64 pp.

Vollenweider, R.A., and J. Kerekes, Jr. 1982. Eutrophication of Waters. Monitoring, Assessment and Control. Organization for Economic Co-Operation and Development (OECD), Paris. 156 pp.

Welch, E.B. 1980. Ecological Effects of Waste Water. Cambridge University Press.

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

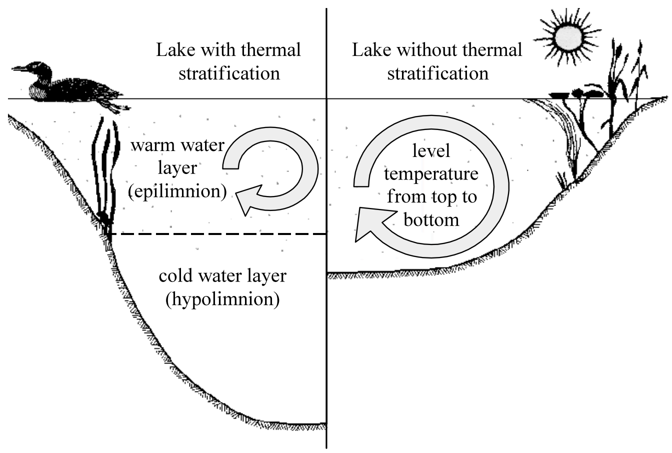

Figure 6: Difference in the circulation of the water column depending on thermal

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.

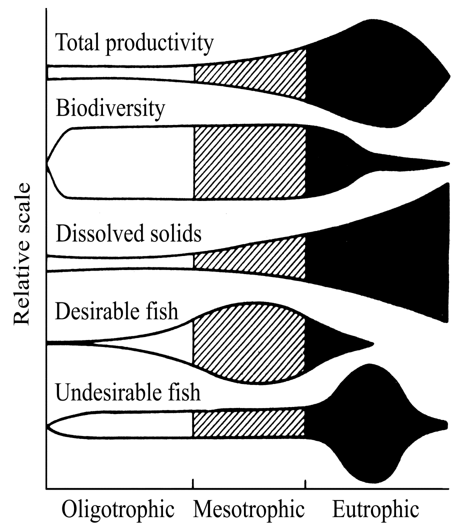

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.