Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2014 Skeleton Lake Report

LAKEWATCH IS MADE POSSIBLE WITH SUPPORT FROM:

Beaver River Watershed Alliance

Alberta Government

LICA
Lakeland Industry & Community Association

Ce projet a été réalisé avec l'appui financier de :
This project was undertaken with the financial support of:

Environnement Canada Environment Canada

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. We would like to thank Orest Kitt, Peter Sherman, Jay McGuire and Sylvia and Brian Lestus for their assistance with sampling Skeleton Lake in 2014. We would also like to thank Jackson Woren, Brittany Kereliuk, and Kara MacAulay who were summer technicians with ALMS in 2014. Program Coordinator Bradley Peter was instrumental in planning and organizing the field program. Mike Bilyk was involved in the training aspects of the program. Lisa Reinbolt was responsible for data management. This report was prepared by Jackson Woren and Bradley Peter. Alberta Environment, the Beaver River Watershed Alliance (BRWA), the Lakeland Industry and Community Association (LICA), and Environment Canada, were major sponsors of the program.

SKELETON LAKE:

Skeleton Lake is located in the western portion of the Beaver River watershed. The lake's name is a translation of the Cree *Cîpay Sâkâhikan*, which means "place of the skeletons". It is thought that a Cree chief is buried along the shores of the lake.[1]

The lake is located within 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 with the summer villages of Mewatha and Bondiss on the southern shore of the lake and additional cottage developments on the north shore. Skeleton Lake used to be the main source of drinking water for the Town of Boyle but has received its drinking water from the Athabasca River since 2007.

The watershed is located in the Dry Mixedwood subregion of the Boreal Mixedwood natural region.[2] Several small intermittent streams flow into the lake and drain a watershed that is four times the size of the lake.[3] The outlet is a small creek located at the southeast end of the lake, and drains eastward into Amisk Lake. Beaver dams, however, often block the outlet. Tree cover in the watershed is primarily trembling aspen and secondarily white spruce, balsam poplar, and white birch. Peatlands are also significant, and most agricultural activities in the watershed take place in the southern and northwestern sections.

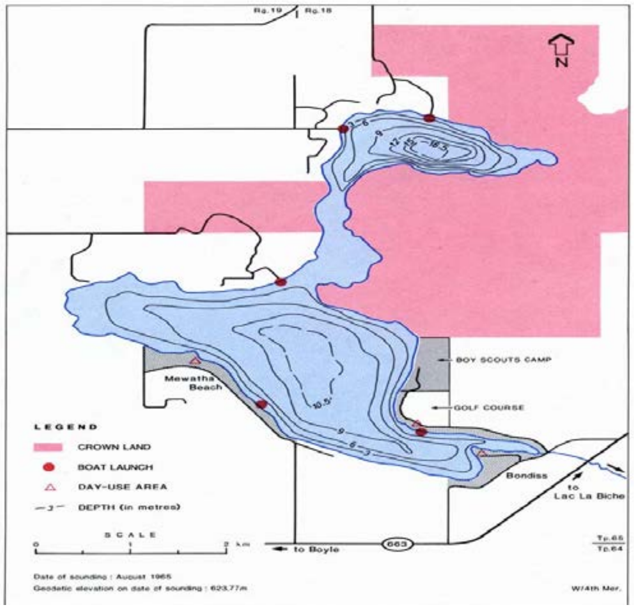

Figure 1 – Bathymetric map of Skeleton Lake obtained from Alberta Environment.

Figure 2 – A view of the north bay of Skeleton Lake. Photo: Pauline Pozsonyi.

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[1] Aubrey, M. K. 2006. Concise place names of Alberta. Retrieved from http://www.albertasource.ca/placenames/resources/searchcontent.php?book=1

[2] Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Alta. En. Nat. Resour., Resour. Eval. Plan. Div., Edmonton.

[3] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/

Skeleton Lake is divided into two basins. The North basin (Figure 2) is nearly entirely separated from the South basin by a shallow, weedy narrows. During the late 1940's, when lake levels were low, the two basins were separated by exposed land at the narrows. In 2008, the lake levels were again low enough that the narrows were dry and have remained relatively dry to date. The North basin is small and deep, with steeply sloped sides that reach a maximum depth of about 17 m. The larger South basin slopes gradually to a maximum depth of 11 m. Skeleton Lake is very fertile and blooms of blue-green algae turn the water green in both basins during the summer months. The average concentrations of algae in the South basin are higher than in the North basin. Because the basins are almost disconnected and the morphology and water quality characteristics of the two basins differ, the water quality of the North and South basins are monitored separately. The results for both basins are presented in this report.

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.

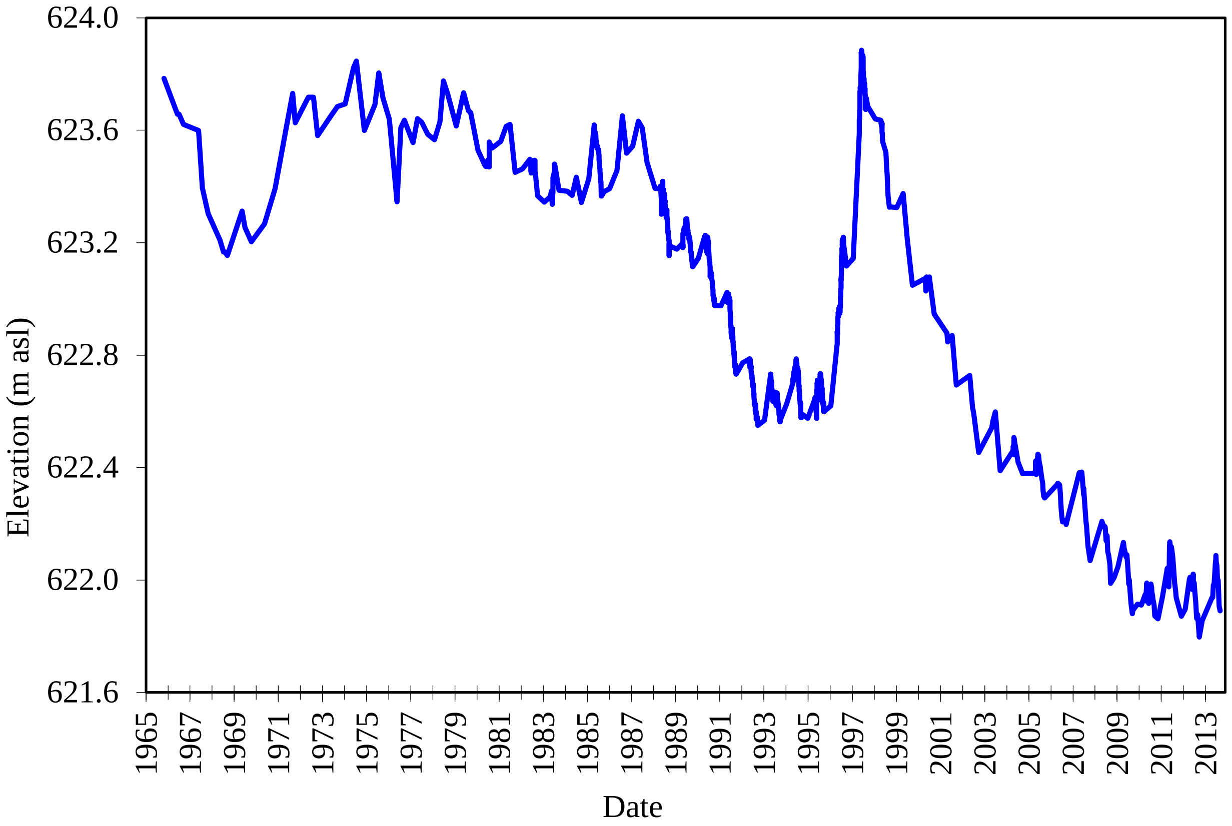

Figure 3 – Water levels at Skeleton Lake measured in meters above sea level (m asl). Data obtained from Alberta Environment.

Water levels in Skeleton Lake have been monitored in the south basin since 1965 under the joint Federal-Provincial Hydrometric agreement (Figure 3). Consistent with other lakes in the area, water levels have decreased steadily by about 1.6 m since the 1970s, with the exception of 1997, an extremely wet period, during which the water level increased to a historical maximum of 623.9 meters above sea level (m asl). Over the past 14 years, water levels in Skeleton Lake have declined to a historical minimum of 621.797 m asl in 2012. Declining water levels are a major stakeholder concern for this lake. In 2011, monitoring of water levels by Environment and Sustainable Resource Development began in the North basin of Skeleton Lake – average elevation in 2013 was 621.907 m asl.

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

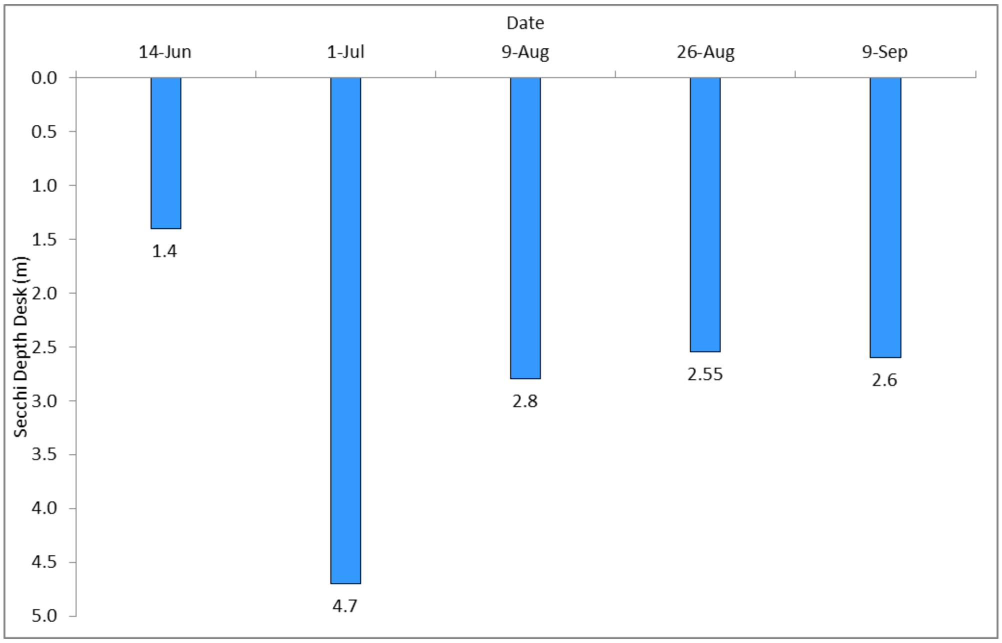

Figure 4 - Secchi depth readings from the profile site at Skeleton Lake North during 2014.

North: Average Secchi disk depth measured 2.81 m during the summer of 2014 (Figure 4, Table 3). This value falls on the high end of the historical variation observed at Skeleton Lake North. Throughout the summer, Secchi disk depth fluctuated between a minimum of 1.4 m on June 14th and a maximum of 4.7 m on July 1st. Changes in Secchi disk depth did not appear closely correlated with changes in chlorophyll-*a* concentration suggesting that algae/cyanobacteria may not have been the primary factors affecting water clarity in the North basin of Skeleton Lake during 2014.

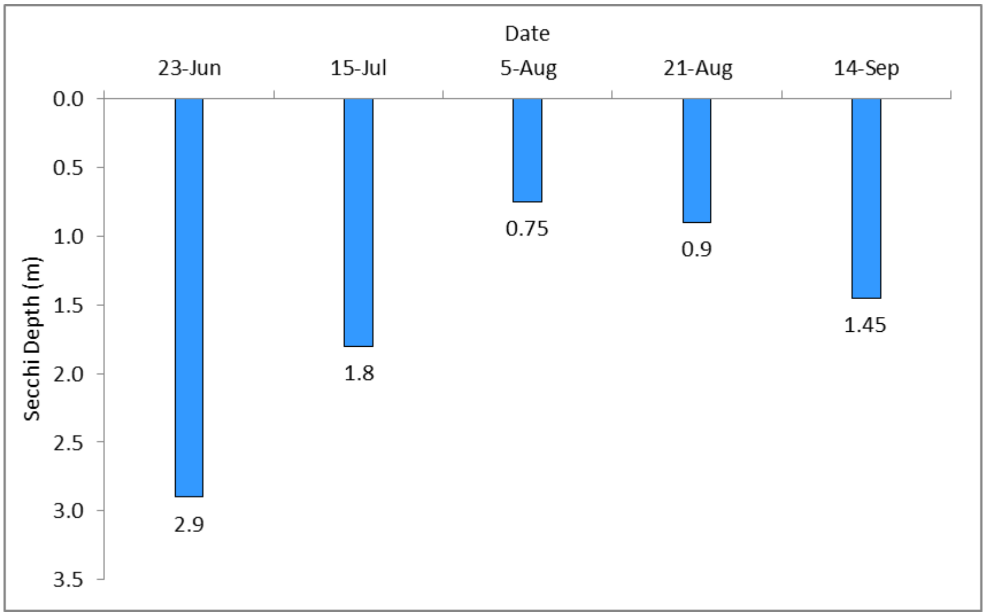

Figure 5 - Secchi depth readings from the profile site at Skeleton Lake South during 2014.

South: Average Secchi disk depth in the South basin of Skeleton Lake measured 1.56 m, which is lower than that measured in the North basin (Figure 5, Table 1). The 2014 value falls well within the historical variation previously measured at Skeleton Lake South. Throughout the summer, Secchi disk depth fluctuated between a minimum of 0.75 m on August 5th and a maximum of 2.9 m on June 23rd. As the South basin of Skeleton Lake has higher average concentrations of both chlorophyll-*a* and, historically, total suspended solids than the North basin, a lower water clarity is to be expected.

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.

North: As with 2013, thermal stratification was observed on each sampling trip, beginning as early as 4.0 m on June 14th and as late as 7.5 m on September 9th (Figure 4a). Thermal stratification remained strong in September, and it is unknown whether the lake became fully mixed later in the year (dimictic), or if the lake remains stratified year round (meromictic). Weaker stratification observed in June may suggest a brief mixing event after ice off. This pattern of thermal stratification is typical of small, deep lakes in Alberta. Surface water temperature ranged from a minimum of 15.04 °C on September 9th to a maximum of 21.76 °C on August 9th. On each trip, water temperature proceeded to less than 10 °C at the lake-sediment interface.

South: In contrast to the North basin of Skeleton Lake, the South basin of Skeleton Lake only experienced very weak thermal stratification on the three of the five sampling trips (Figure 4b). Given the shallow depth of the South basin of Skeleton Lake, it is easy for wind energy to mix the water column. Temperature in the South basin of Skeleton Lake reached a higher maximum than the North basin – reaching 24.36 °C on August 5th. Maximum water temperature at the lake-sediment interface measured 20.30 °C on August 21st.

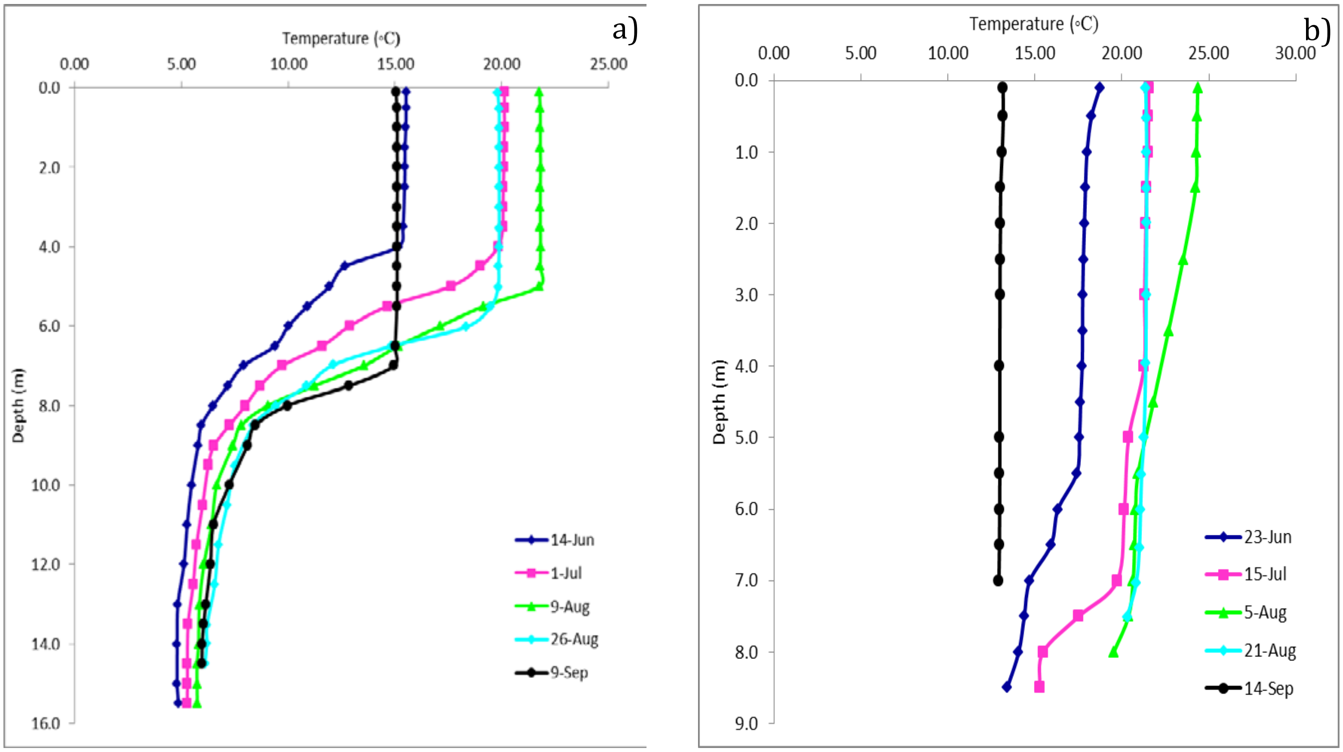

Figure 6 – Temperature profiles from the North a) and South basins b) of Skeleton Lake.

North: As is typical of strongly stratified lakes, dissolved oxygen concentrations were high above the thermocline and low below the thermocline. At the surface, dissolved oxygen concentrations measured as high as 10.46 mg/L – well above the Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life (PAL) of 6.5 mg/L (Figure 5a). Concentrations of dissolved oxygen at the surface appear elevated with increased concentrations of algae or cyanobacteria, as photosynthesis is an oxygen producing process. We were unable to collect dissolved oxygen data for one of the trips due to an equipment failure. Below the thermocline, dissolved oxygen concentrations decreased dramatically, reaching anoxia as early as 6.0 m.

South: In contrast, concentrations of dissolved oxygen remained high much deeper in the South Basin of Skeleton Lake due to the absence of strong thermal stratification. Throughout the summer, concentrations of dissolved oxygen remained above the CCME PAL guidelines for more than half of the water column (Figure 5b). The highest dissolved oxygen observed was on August 5th with a concentration of 18.06 mg/L. Near the sediments, however, dissolved oxygen concentrations declined, likely due to the weak thermal stratification separating deeper waters from atmospheric oxygen and the oxygen-consuming process of decomposition that occurs at the lake-sediment interface. Low concentrations of oxygen near the lake sediments may contribute to the release of phosphorus from the sediments.

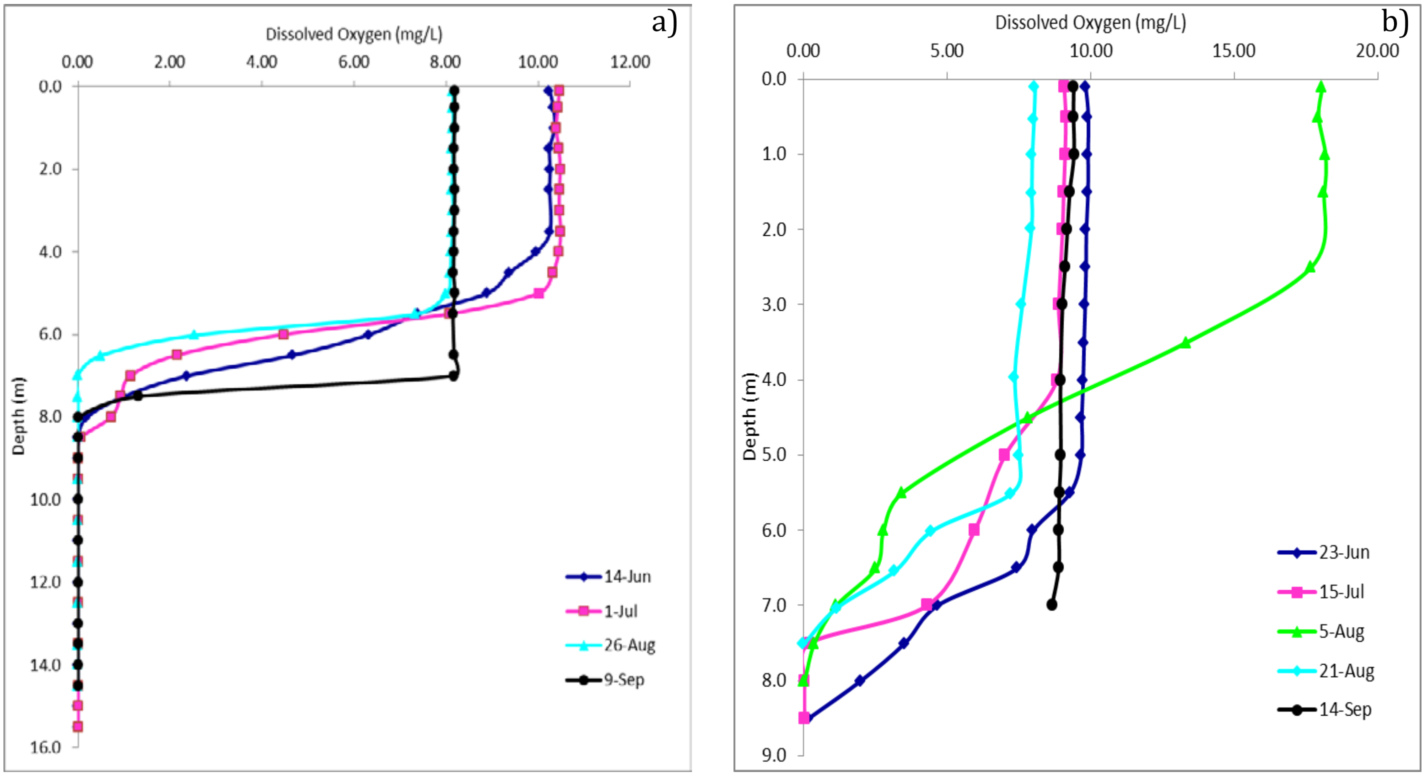

Figure 7 – Dissolved oxygen profiles from the North a) and South basins b) of Skeleton Lake.

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.

North: Average Total Phosphorus (TP) in the North Basin of Skeleton Lake measured 25.2 µg/L in 2014 (Table 3). An average of 25.2 µg/L falls into the mesotrophic (moderately productive) classification and is one of the lowest TP concentrations to be measured at Skeleton Lake since 1985. The north basin of Skeleton Lake experienced its highest TP concentrations early in the season, measuring a maximum of 59 µg/L on June 14th and a minimum of 16 µg/L on July 1st (Figure 6). High nutrient concentrations at the beginning of the season are common in lakes which remained stratified for most of the open-water season such as Skeleton North.

Average chlorophyll-*a* concentration in the north basin of Skeleton Lake measured 5.76 µg/L in 2014, which falls into the mesotrophic (moderately productive) classification (Table 3, Figure 6). An average of 5.76 falls on the lower end of the natural variation historically observed in the North basin of Skeleton Lake. The highest chlorophyll-*a* concentration in Skeleton Lake North was observed early in the season and measured 7.1 µg/L on June 14th. High concentrations of chlorophyll-*a* early in the season are usually due to blooms of green algaes and diatoms, not cyanobacteria.

Total Kjeldahl Nitrogen (TKN) fluctuated little throughout the summer, measuring a maximum of 1590 µg/L on June 14th and a minimum of 1380 µg/L on September 9th (Table 3). On average, TKN measured 1230 µg/L in 2014.

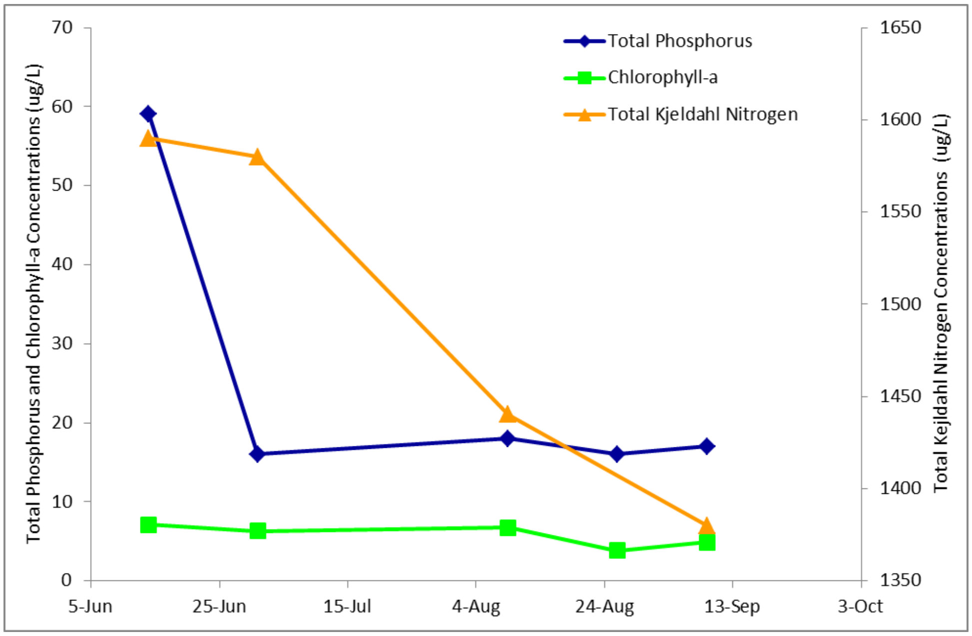

Figure 8 - Total phosphorus (µg/L), chlorophyll-*a* (mg/L), and total Kjeldahl nitrogen (µg/L) measured five times over the course of the summer in the north basin of Skeleton Lake.

South: In 2014, the analytical laboratory used by ALMS exceeded the hold time for a number of our samples. Due to this, two TP values from the South basin have been flagged as suspicious – these values have been included in Figure 7 as outliers, however, for the purpose of calculating the average TP, these values have been excluded. Average TP in the South basin of Skeleton Lake measured 50.667 µg/L – unlike the North basin of Skeleton Lake, this value falls into the eutrophic (nutrient rich) classification (Table 3). Total phosphorus concentrations increased throughout the summer, measuring a minimum of 35 µg/L on June 23rd and a maximum of 62 µg/L on September 14th (Figure 7).

Average chlorophyll-*a* concentration in the South basin of Skeleton Lake measured 29.76 µg/L in 2014, falling into the eutrophic classification (Table 3). The 2014 chlorophyll-*a* concentration average lies on the high end of the historical variation observed in the South basin of Skeleton Lake. Chlorophyll-*a* concentration spiked during the middle of summer, measuring a maximum of 65 µg/L on August 5th. A minimum chlorophyll-*a* concentration of 5.2 µg/L was observed on June 23rd (Figure 7).

Average TKN in the South basin of Skeleton Lake measured 1374 µg/L in 2014, which falls into the hypereutrophic (extremely productive) classification (Table 3). TKN spiked similar to chlorophyll-a throughout the season, measuring a maximum of 1990 µg/L on August 5th and a minimum of 870 µg/L on July 15th (Figure 7).

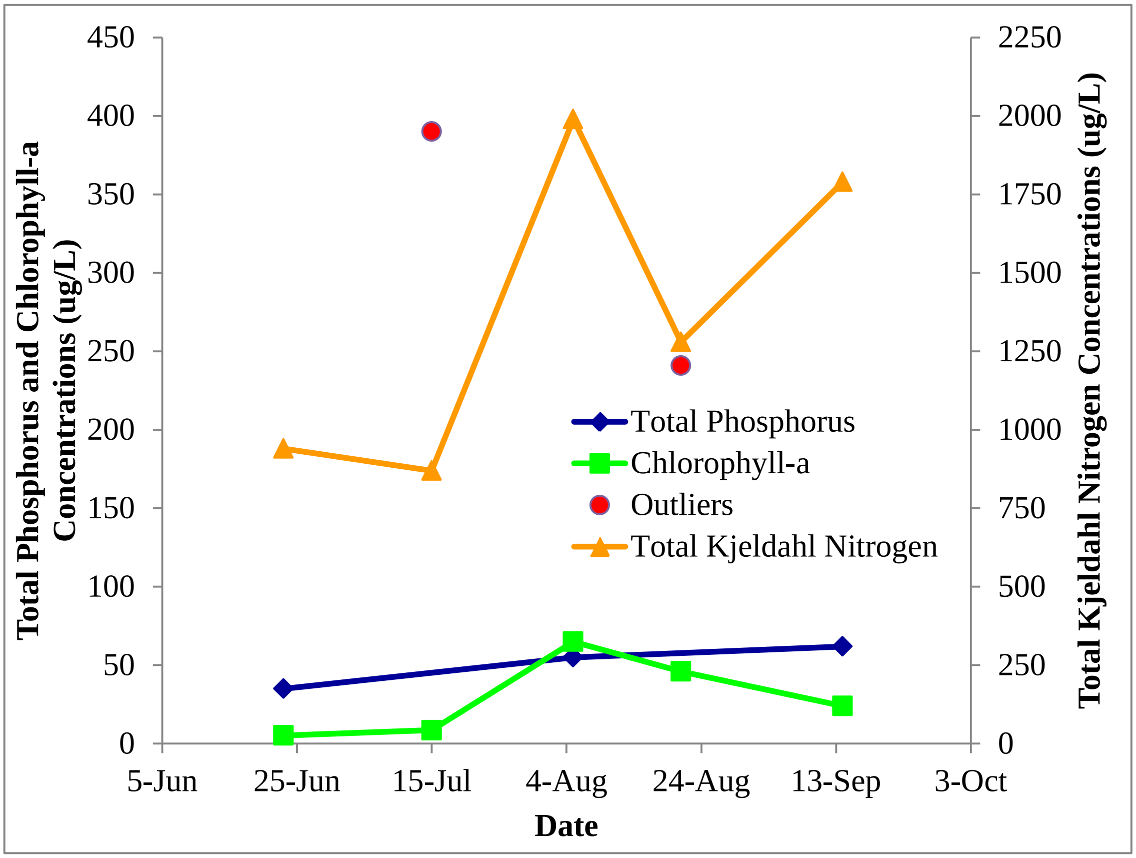

Figure 7 - Total phosphorus (µg/L), chlorophyll-*a* (mg/L), and total Kjeldahl nitrogen (µg/L) measured five times over the course of the summer in the south basin of Skeleton Lake.

North: Average pH in the north basin of Skeleton Lake measured 8.578 which is well above neutral (Table 3). The North basin of Skeleton Lake has moderate alkalinity (192.6 mg/L) and bicarbonate concentrations (235.6 mg/L) which will help to buffer the lake against changes to pH. Conductivity in the north basin of Skeleton Lake is also moderate, measuring an average of 390 µS/cm in 2014. Conductivity has been increasing over the years at Skeleton Lake, likely due to the concentration of salts increasing with decreasing water levels. Contributing to the north basin's conductivity are the dominant ions of magnesium (21.23 mg/L), calcium (31 mg/L) and sodium (20.8 mg/L).

Metals were monitored for twice throughout the summer and all values fell within their respective guidelines.

South: Average pH in the south basin of Skeleton Lake measured 8.794 which is well above neutral (Table 3). The south basin of Skeleton Lake has moderate alkalinity (209.2 mg/L) and bicarbonate concentrations(255.2 mg/L) which will help to buffer the lake against changes to pH. Conductivity in the South basin of Skeleton Lake is also moderate, measuring an average of 398 µS/cm in 2014. Conductivity has been increasing over the years at Skeleton Lake South, likely due to decreasing water levels. Contributing to the south basin's conductivity are the dominant ions of magnesium (25.76 mg/L), calcium (21.3 mg/L) and sodium (24.36 mg/L).

Metals were monitored for twice throughout the summer and all values fell within their respective guidelines (Table 4).

MICROCYSTIN:

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to Alberta's Lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 µg/L.

Concentrations of microcystins were low throughout the summer, and therefore well below the recreational guideline of 20 µg/L (Table 1, Table 2). The maximum concentration of microcystin observed in the South basin of Skeleton lake (0.70 µg/L) was higher than that observed in the North basin (0.10 µg/L).

INVASIVE SPECIES:

Quagga and Zebra mussels are invasive species which, if introduced to our lakes, will have significant negative ecological, economical, and recreational impacts. ALMS collects water samples which are analyzed for mussel veligers (juveniles) and monitors substrates for adult mussels. In order to prevent the spread of invasive mussels, always clean, drain, and dry your boat between lakes. To report mussel sightings or mussel-fouled boats, call the confidential Alberta hotline at 1-855-336-BOAT.

In 2014, no zebra or quagga mussels were detected in Skeleton Lake.

Table 1 – Microcystin concentrations (µg/L) measured at Skeleton Lake North during the summer of 2014. Values represent samples taken as whole-lake composites.

Date	**Microcystin (µg/L)**
14-Jun	0.08
1-Jul	0.09
9-Aug	0.10
26-Aug	0.09
9-Sep	0.06

Table 2 – Microcystin concentrations (µg/L) measured at Skeleton Lake South during the summer of 2014. Values represent samples taken as whole-lake composites.

Date	**Microcystin (µg/L)**
23-Jun	0.13
15-Jul	0.12
5-Aug	0.45
21-Aug	0.61
14-Sep	0.70

Table 3 - Average Secchi disk depth and water chemistry values for Skeleton Lake. Previous years averages are provided for comparison.

	South											**North**							
Parameter	**1985**	**1986**	**2005**	**2006**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**1985**	**1986**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
TP (µg/L)	31.4	46.7	28.8	39.8	45.4	40.3	58.8	44.5	40.3	39.6	50.7	24.3	36.3	32.7	47.8	44.5	36.0	47.6	25.2
TDP (µg/L)	7.8	10.7	8.4	12.6	13.4	13.5	14.8	11.8	11.8	20.2	59.0	7.8	10.7	11.0	16.0	11.8	14.4	28.2	10.6
Chlorophyll-*a* (µg/L)	14.8	24.2	12.1	15.0	19.3	12.4	22.3	17.2	17.3	12.12	29.8	9.2	10.7	11.0	8.6	17.2	8.6	7.56	5.76
Secchi depth (m)	2.00	1.60	2.28	1.60	1.65	1.63	1.40	1.40	1.81	1.59	1.56	2.50	2.50	2.63	1.75	1.40	2.45	2.35	2.81
TKN (µg/L)	1139	1318	1152	1248	1324	1135	1564	1398	1393	1304	1374	1160	1140	1297	1612	1398	1484	1470	1230
NO_2 and NO_3 (µg/L)	2.1	2.8	6.0	14.0	12.7	12.5	24.8	6.0	3.5	2.5	38.0	2.25	3.67	3.00	4.40	6.00	2.50	2.5	22
NH_3 (µg/L)	13.6	37.2	12.8	27.0	19.2	26.8	22.0	24.3	21.0	21	55.6	21.2	32.5	12.7	82.8	24.3	21.2	23.2	33.4
DOC (mg/L)	13.6	14.6	14.4	14.9	16.5	14.6	15.8	14.3	14.2	14.3	17.4	14.8	14.6	16.6	18.6	14.3	17.8	18.2	18.97
Ca (mg/L)	26.3	25.0	23.4	25.5	22.8	23.6	21.3	22.1	25.8	25	21.3	23.3	24.3	21.3	23.0	22.1	25.1	24.17	31
Mg (mg/L)	19.0	19.0	23.4	23.0	26.9	24.4	25.1	26.7	25.7	25.6	25.8	18.7	18.8	23.5	25.9	26.7	25.0	26.9	21.23
Na (mg/L)	13.6	13.8	19.2	20.1	20.2	21.3	21.7	19.6	20.9	21.77	24.4	13.3	13.5	17.5	18.7	19.6	17.6	18.7	20.8
K (mg/L)	8.59	8.64	10.85	11.50	11.50	12.50	11.93	11.60	13.25	17.7	14.1	8.43	8.45	10.60	10.77	11.60	11.90	13.5	12.24
SO_4^{2-} (mg/L)	2.5	2.5	3.0	3.7	3.0	5.0	2.9	1.5	1.5	4.83	2.2	2.5	2.5	5.0	6.3	1.5	4.2	7.5	2.17
Cl^- (mg/L)	1.8	1.4	3.1	3.4	3.8	4.2	4.7	4.4	4.8	4.33	5.3	1.5	1.3	3.2	3.4	4.4	5.6	5.1	6
CO_3 (mg/L)	4.6	9.0	5.7	9.7	8.8	10.1	9.0	11.8	9.4	16	21.88	4.1	10.8	12.0	9.7	11.8	8.7	17.4	9.78
HCO_3 (mg/L)	208.40	191.62	226.00	232.50	223.67	231.33	229.33	229.25	246.75	227.8	255.2	198.08	194.43	204.00	217.67	229.25	226.40	212.8	235.6
pH	8.53	8.72	8.66	8.71	8.73	8.76	8.80	8.72	8.64	8.75	8.8	8.533	8.58	8.79	8.71	8.72	8.67	8.86	8.58
Conductivity (µS/cm)	333.4	327.2	360.0	389.3	374.3	381.3	390.7	388.0	405.8	410.2	398.0	318.3	323.7	334.5	372.3	388.0	388.4	390.4	390
Hardness (mg/L)	143.4	140.4	152.0	158.3	168.0	159.0	156.7	165.0	170.0	168	159	134.8	138.0	150.0	164.0	165.0	165.7	171	165
TDS (mg/L)	181.1	178.1	204.0	213.8	211.3	218.3	214.0	210.0	222.0	230.3	233	172.2	174.5	192.5	205.0	210.0	210.0	217.3	214.667
Microcystin (µg/L)	/	/	0.148	0.178	0.240	0.340	0.306	0.230	0.218	0.2356	0.402	/	/	0.078	0.142	0.230	0.169	0.129	0.08
Total Alkalinity (mg/L $CaCO_3$)	178.2	175.2	202.5	210.0	205.3	211.0	210.3	208.0	218.0	213.6	209.2	169.8	171.5	186.5	195.0	208.0	200.0	204	192.6

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 4 - Concentrations of metals measured at the north and south basins of Skeleton Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	South							North					
	2008	2009	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	Guidelines
Aluminum µg/L	24.1	12.8	22.95	23.2	7.88	12.655	18.5	26.04	13.9	14.75	11.735	10.75	100[a]
Antimony µg/L	0.033	0.032	0.03335	0.0326	0.0236	0.02795	0.0455	0.03635	0.02885	0.0307	0.0326	0.032	6[e]
Arsenic µg/L	1.01	0.983	1.065	0.948	0.367	1.0065	1.36	0.8565	0.8685	0.574	0.8165	0.7735	5
Barium µg/L	55.8	57.3	55.55	56.2	44	57.7	45.8	48.95	50.85	51.1	49.05	48.5	1000[e]
Beryllium µg/L	0.0045	<0.003	0.0015	0.0048	0.0015	0.0015	0.004	0.00585	0.0052	0.00645	0.0015	0.004	100[d,f]
Bismuth µg/L	0.0036	0.004	0.002	0.0014	0.0057	0.0038	0.0005	0.00195	0.00215	0.0321	0.0143	0.00225	/
Boron µg/L	102.5	109.6	97	106	87.2	100.9	94.75	122.5	105.5	104.85	93.5	97.05	5000[ef]
Cadmium µg/L	<0.002	0.0023	0.00695	0.0045	0.0035	0.0024	0.008	0.0057	0.001	0.001	0.001	0.002	0.085[b]
Chromium µg/L	0.115	0.188	0.1395	0.15	0.106	0.196	0.215	0.242	0.0765	0.1535	0.28	0.105	/
Cobalt µg/L	0.023	0.0203	0.01325	0.0171	0.0084	0.0285	0.022	0.01845	0.01115	0.00955	0.02615	0.007	1000[f]
Copper µg/L	0.171	0.27	0.1303	0.181	0.508	0.1805	0.535	0.1633	0.154	0.3698	0.1402	0.13	4[c]
Iron µg/L	49.2	70.4	41	53.4	48.5	40.2	13.45	7.73	3.59	7.2	21.95	2.875	300
Lead µg/L	0.0285	0.0283	0.02505	0.0327	0.0126	0.02665	0.0265	0.0151	0.0137	0.01055	0.0168	0.0135	7[c]
Lithium µg/L	30.6	36.1	28.05	33.2	21.9	29.15	39.7	31.7	33	28.1	26.65	27.95	2500[g]
Manganese µg/L	44.5	62.1	49.75	58.1	40.3	50.15	34.15	35.4	43.9	29	16.05	12.55	200[g]
Molybdenum µg/L	0.103	0.114	0.09395	0.103	0.0643	0.0823	0.087	0.0627	0.05335	0.02955	0.03915	0.037	73[d]
Nickel µg/L	<0.005	0.204	0.0025	0.0025	0.0025	0.16175	0.0595	0.0025	0.0025	0.0025	0.05425	0.004	150[c]
Selenium µg/L	0.144	0.12	0.076	0.138	0.05	0.05	0.07	0.05	0.096	0.05	0.082	0.03	1
Silver µg/L	0.0036	0.0069	0.00255	0.00025	0.0022	0.02725	0.001	0.0013	0.003175	0.001525	0.007125	0.001	0.1
Strontium µg/L	185	185	188	186	134	197.5	208.5	176	187	166	180	180	/
Thallium µg/L	0.00115	0.00185	0.001	0.001	0.00015	0.000365	0.00068	0.000725	0.0006	0.001225	0.0004	0.00045	0.8
Thorium µg/L	0.0093	0.0017	0.0096	0.0066	0.0084	0.00655	0.00563	0.008025	0.00625	0.0313	0.01075	0.001175	/
Tin µg/L	0.0483	<0.03	0.03015	0.015	0.0327	0.015	0.0195	0.015	0.015	0.38175	0.0377	0.0065	/
Titanium µg/L	1.21	0.762	0.904	1.1	0.26	1.43	0.985	0.336	0.676	0.2735	0.7785	0.2025	/
Uranium µg/L	0.121	0.11	0.1145	0.12	0.0612	0.09055	0.196	0.1965	0.202	0.18	0.1995	0.211	100[e]
Vanadium µg/L	0.207	0.208	0.2095	0.217	0.101	0.145	0.265	0.214	0.1855	0.2035	0.1865	0.19	100[f,g]
Zinc µg/L	0.373	0.996	0.5025	0.399	0.361	0.346	1.3	0.3085	0.41	0.4175	0.2805	0.55	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.

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:

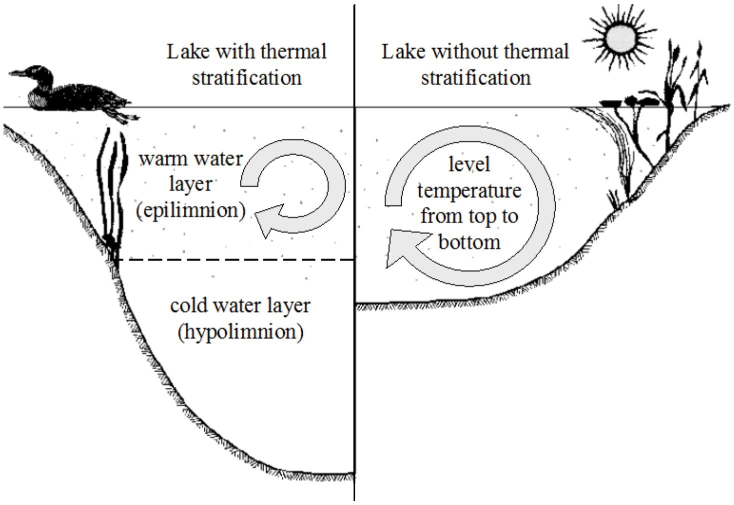

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

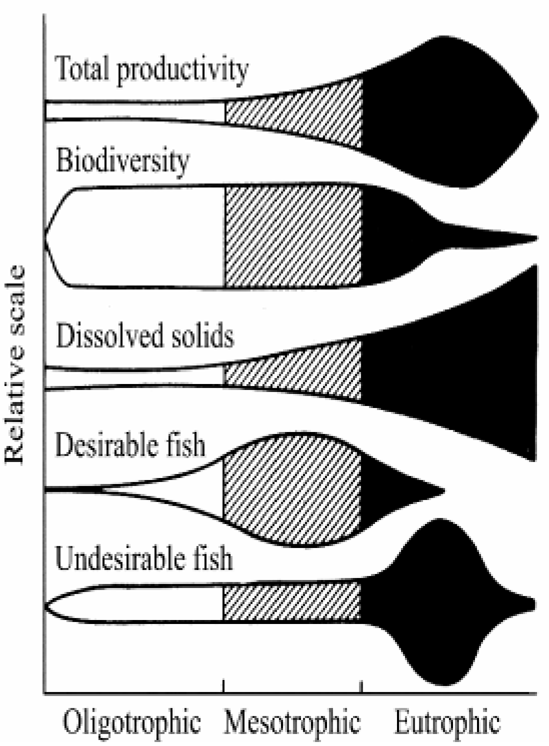

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Waste Water".

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