Lakewatch

THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2011 Pigeon Lake Report

COMPLETED WITH SUPPORT FROM:

PIGEON LAKE WATERSHED ASSOCIATION

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.

2011 data presented in this report should be considered preliminary until the data validation process is complete.

Acknowledgements

This report was commissioned by the Pigeon Lake Watershed Association and is intended as a summary for all stakeholders of data collected in 2011. We would like to thank Pigeon Lake's Summer Villages whose support and donations made this report possible. We would also like to thank Alberta Environment for their data and Chris Teichreb for reviewing the report. The report was prepared by Bradley Peter and Arin Dyer.

PIGEON LAKE:

Pigeon Lake is a large (96.7 km^2), shallow (average depth = 6m) lake located in the counties of Wetaskiwin and Leduc. It is a very popular recreational lake within easy driving distance from the cities of Edmonton, Leduc, and Wetaskiwin.

Pigeon Lake lies within the Battle River watershed. Water flows into the lake through intermittent streams draining the west and northwest portions of the watershed. The outlet, Pigeon Lake Creek, at the southeast margin of the lake, drains toward the Battle River.[2] The lake's drainage basin is small (187 km^2) but heavily developed with agriculture, oil and gas, as well as recreational development throughout the watershed.

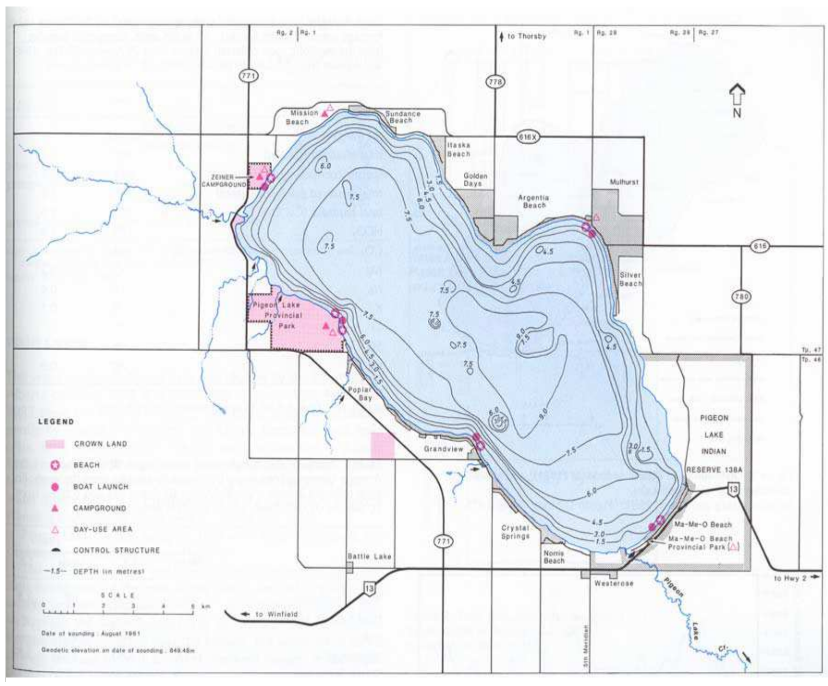

Figure 1 – Bathymetric map of Pigeon Lake.[2]

The lake name is a translation from the Cree Mehmew Sâkâhikan, which means 'Dove Lake', but by 1858 the name Pigeon Lake was in use[1]. It has been suggested that the name Pigeon Lake refers to the huge flocks of Passenger Pigeons that once ranged in the area.[2] The lake was also previously known as Woodpecker Lake, and the Stoney name is recorded as Ke-gemni-wap-ta.[1]

The water quality of Pigeon Lake is typical of large, productive, shallow lakes in Alberta, with water remaining quite green for most of the summer. However, residents have recently expressed concern over perceptions of deteriorating water quality as a result of recurring toxic blue-green algal blooms and beach advisories[3].

This report details water quality for Pigeon Lake for the summer of 2011.

[1] Aubrey, M. K. 2006. Concise place names of Alberta. Retrieved from http://www.albertasource.ca/placenames/resources/searchcontent.php?book=1
[2] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/
[3] Aquality Environmental Consulting. 2008. Pigeon Lake State of Watershed Report. Prepared for Pigeon Lake Watershed Alliance. Retrieved from: www.plwa.ca.

WATER LEVELS:

Water levels in Pigeon Lake tend to fluctuate within a one-meter interval (Figure 2). Because the watershed of Pigeon Lake is relatively small, only twice the size of the lake area, water levels in Pigeon Lake are likely less affected by run-off and more affected by ground water input. There has been a general trend towards decline in water quantity since the early 1980's, though in 2011, a particularly wet year, water levels increased to 849.87 meters above sea level.

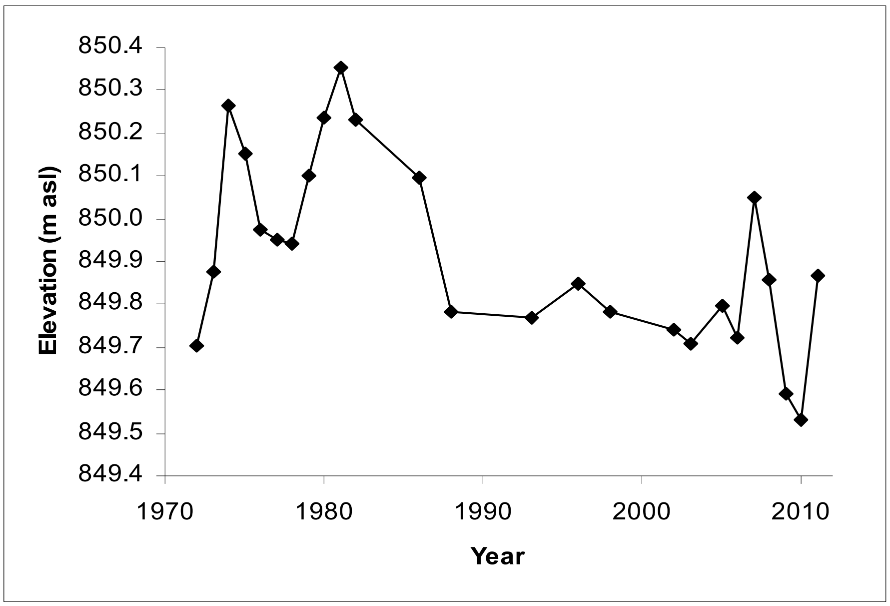

Figure 2 – Historical water levels in meters above sea level measured from 1972-2011. Measurements taken at the Pigeon Lake Provincial Park by Environment Canada.

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.

Average Secchi disk depth at Pigeon Lake was measured three times over the course of the summer and averaged to 1.25 meters (Table 1). A seasonal average of 1.25 m falls on the low end of historical measurements from Pigeon Lake. In 2011, water clarity was likely reduced compared to previous years due to high amounts of run-off. High amounts of run-off can contribute to increased nutrient concentrations and suspended sediments, both of which can impair water clarity.

Secchi disk depth measurements fluctuated greatly throughout the summer. On July 7th, Secchi disk depth measured 1.7 m. By August 10th, Secchi disk depth had decreased to 0.65 m, likely due to a large algae/cyanobacteria bloom which greatly impaired water clarity. Finally, on September 15th, Secchi disk depth recovered slightly after the collapse of the algae/cyanobacteria bloom, measuring 1.4 m. Because Pigeon Lake is quite shallow, resuspension of bottom sediments due to wind and boating activities can negatively influence Secchi disk depth.

WATER TEMPERATURE AND DISSOLVED OXYGEN:

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

In the summer of 2011, no thermal stratification was observed at Pigeon Lake. However, because the lake is large and shallow, it is easy for winds to mix the water column completely, preventing stratification. On July 7th, surface water temperature measured 18.80 °C at the surface and 17.09 °C at the lakebed. On August 10th, temperatures had increased throughout the water column, measuring 19.34 °C at the surface and 18.05 °C at the lakebed. Finally, by September 15th, water temperatures decreased dramatically and the water column became relatively uniform, measuring around 15 °C throughout the entire water column.

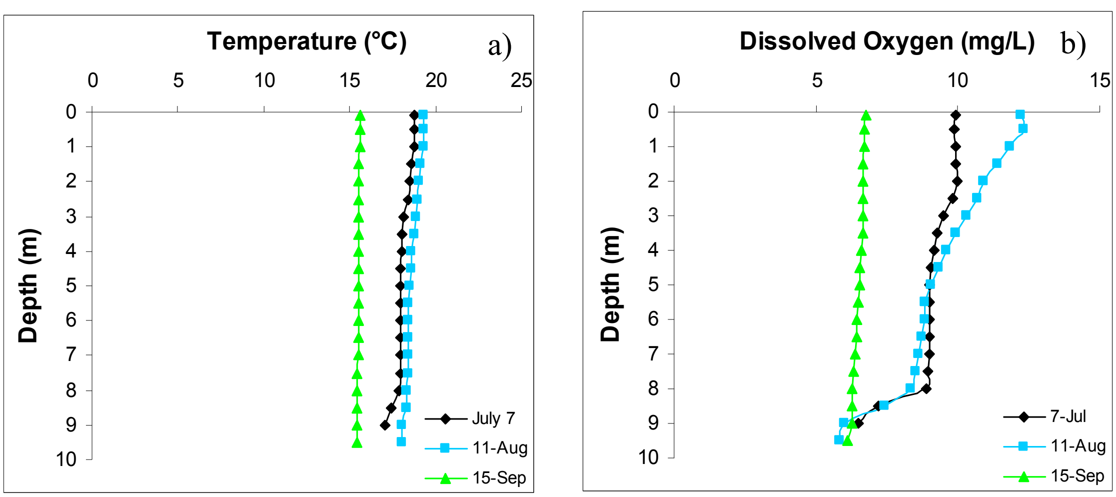

Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles measured three times over the course of the summer of 2011.

Dissolved oxygen varied greatly throughout the summer at Pigeon Lake. On July 7th, surface dissolved oxygen measured 9.90 mg/L, which declined steadily to 6.47 mg/L at the lakebed. On August 10th, surface dissolved oxygen had increased to 12.22 mg/L, likely due to large amounts algae/cyanobacteria performing photosynthesis, an oxygen producing process. At the lakebed, however, dissolved oxygen concentrations were lower than in July, measuring 5.84 mg/L. Low concentrations of dissolved oxygen at the lakebed can lead to the release of phosphorous from the sediments. On September 15th, dissolved oxygen concentrations had declined dramatically, measuring 6.76 mg/L at the surface and 6.10 mg/L at the lakebed. Thus, by September, half of the water column fell below the Canadian Council for Ministers of the Environment guideline of 6.5 mg/L for the Protection of Aquatic Life. The decomposition of algae/cyanobacteria from August, which is an oxygen consuming process, is likely the biggest factor contributing to the reduced oxygen levels measured in September.

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.

Average Total Phosphorous (TP) measured at Pigeon Lake in 2011 was 74.7 µg/L, which falls well into the eutrophic, or nutrient rich, classification (Table 1). This average is much higher than recorded in previous years, and is likely due to large amounts of run-off received in 2011 (Figure 5). Total phosphorous ranged from 26 µg/L on July 7th to 110 µg/L on August 10th (Figure 4).

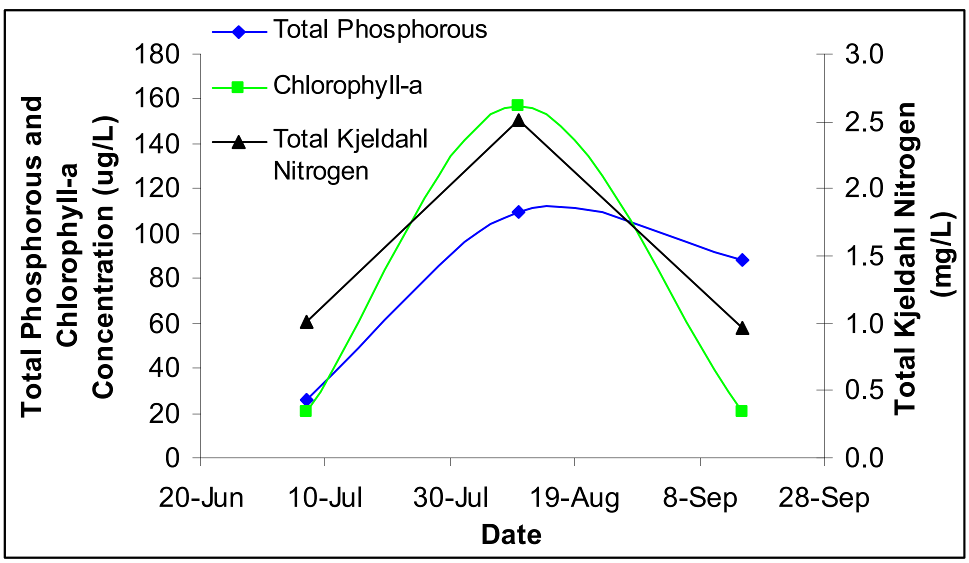

Figure 4 – Chlorophyll-*a* (µg/L), total phosphorous (µg/L) and total Kjeldahl nitrogen (mg/L) measured over the course of the summer in 2011.

Total Kjeldahl nitrogen (TKN) concentration averaged 1494 µg/L in 2011, which falls into the hypereutrophic classification. Similar to TP, this average is much higher than values recorded in previous years. TKN ranged from 961 µg/L on September 15th to 2510 µg/L on August 15.

Finally, chlorophyll-*a* concentration changed dramatically over the course of the summer. On July 7th, chlorophyll-*a* measured 20.8 µg/L, while on August 15th concentrations reached 157 µg/L. It is common for algal blooms to occur in August when nutrient and temperature concentrations are often the highest. On September 15th, chlorophyll-*a* concentration remained high, measuring 88 µg/L. Such high concentrations of algae/cyanobacteria led to a Blue-Green Algae Advisory which was posted by Alberta Health Services for the entire lake on August 4th. The advisory was later lifted on October 7th. On average, chlorophyll-*a* concentration measured 66.2 µg/L during the summer of 2011. This value is much higher than measured in previous years and falls into the hypereutrophic classification.

Though Pigeon Lake is subject to large fluctuations in both its total phosphorous and chlorophyll-*a* concentrations, a report released by Richard Casey of Alberta Environment, which analyzed Pigeon Lake data from 1983-2008, showed no statistically significant trend in either total phosphorous or chlorophyll-*a* concentrations.[4]

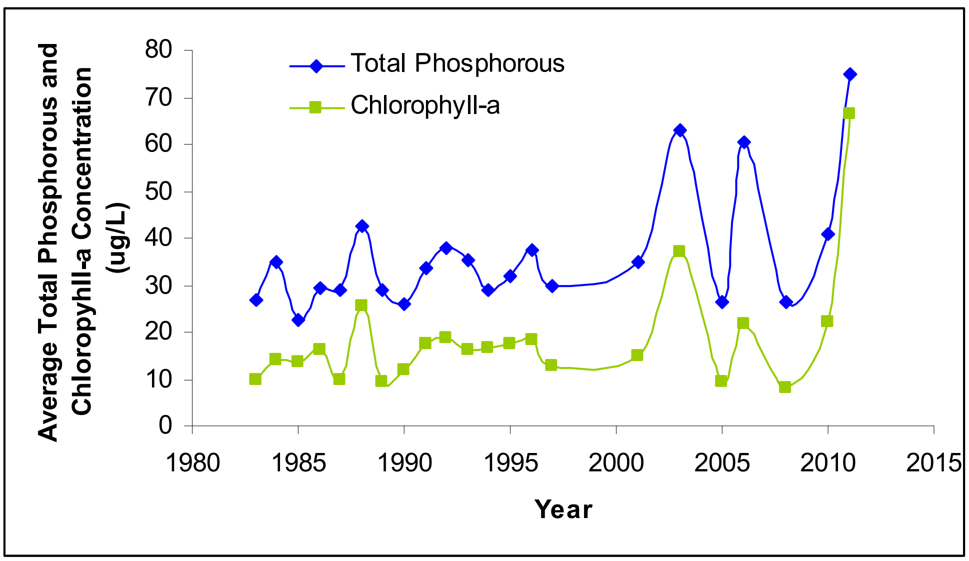

Figure 5 – Average total phosphorous (µg/L) and chlorophyll-*a* concentrations measured by ALMS and Alberta Environment from 1983-2011.

The pH in Pigeon Lake has changed little in recent years, with an average of 8.74 in 2011 (Table 1). The high alkalinity (146.7 mg/L $CaCO_3$) and bicarbonate concentrations (161 mg/L) measured in Pigeon Lake help to buffer the water from changes to pH. The

[4] Casey, R. 2011. Water quality conditions and long-term trends in Alberta lakes. Retrieved from: http://environment.gov.ab.ca/info/library/8544.pdf

concentration of ions in Pigeon Lake is low, which is reflected in a low conductivity (286.7 μS/cm), and have not changed appreciably compared to historical measurements.

Table 1 – Average secchi depth and water chemistry values for Pigeon Lake measured by ALMS and Alberta Environment from 1983-2011. Methods of analysis, sampling protocol, and number of samples collected may vary between years.

Parameter	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	2001	2003	2005	2006	2008	2010	2011*
TP (μg/L)	27	34.9	22.5	29.3	29	42.6	29.1	26.1	33.8	38	35.5	29.1	32.1	37.5	29.9	35	63	26.5	60.3	26.3	40.7	74.7
TDP (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	6	38	9	13	19.1
Chlorophyll-*a* (μg/L)	9.91	14.1	13.8	16.13	9.85	25.7	9.2	11.94	17.4	18.6	16.08	16.6	17.53	18.5	12.77	15	36.9	9.2	21.9	7.98	21.92	66.2
Secchi depth (m)	3.19	1.94	2.19	3.08	2.25	1.63	2.35	2.32	2.14	1.72	1.98	2.13	2.2	1.8	2.5	1.5	1.38	1.9	2.7	4.42	2.75	1.25
TKN (μg/L)	945	/	640	/	/	/	/	/	/	/	/	/	850	/	/	611	1075	710	1100	670	1033	1493
NO_2 and NO_3 (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	1	/	3	29	13	7.67	15.9
NH_3 (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	3	/	2.5	124	16	72.3	108.9
DOC (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	7	/	7.35	/
Ca (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	28.85	21.13	27.2	23.75	19.5
Mg (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	12.65	14.12	12.87	13.85	12.5
Na (mg/L)	15	15.3	16.3	15	15	17.1	16.12	14.33	14	17	17	17	17.5	14.6	18.6	/	18.7	20	21	20.33	21.95	20.1
K (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	6.1	6.63	6.17	6.3	6.2
SO_4^{2-} (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	7.3	10.2	5.47	9	3.38
Cl^- (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	4	3.33	3.33	3.05	3.03
CO_3 (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	8	4.67	3.33	0.5	8.7
HCO_3 (mg/L)	180.5	178.2	184	168.62	176.15	170.52	187.3	175.3	176.7	174	174.7	176.5	167.5	163	190	/	168.5	183	180	198	195	161
pH	8.37	8.43	8.35	8.57	8.5	8.36	8.32	8.5	8.46	8.45	8.56	8.6	8.61	8.66	8.17	/	8.56	8.6	8.5	8.37	8.57	8.74
Conductivity (μS/cm)	283.25	288	292.25	280.3	293	279	302.2	293.7	292.7	285.7	286.7	290	281.5	293	304	/	/	313	287	321.7	309.5	286.7
Hardness (mg/L)	112.13	103.25	113	109.7	111	109.25	119.95	122	120.7	110.7	113.3	113.5	110.5	106	130	/	103	125	119	121	116	100.2
Microcystin (μg/L)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	0.087	0.173
TDS (mg/L)	156.7	153.7	157.9	151.21	157.41	151.1	163	157.7	155.7	152.3	154	154.5	156	151	169	/	/	176.5	173	175.33	173.5	153
Total Alkalinity (mg/L $CaCO_3$)	151.75	152.95	152.58	147	153.5	144.9	155.8	152.7	150	146	148	149.5	148.5	149	156	/	151	163	155.3	165.7	160	146.7

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate. A "/" indicates un-queried or absent data.

*2011 data should be considered preliminary until the validation process is complete.

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:

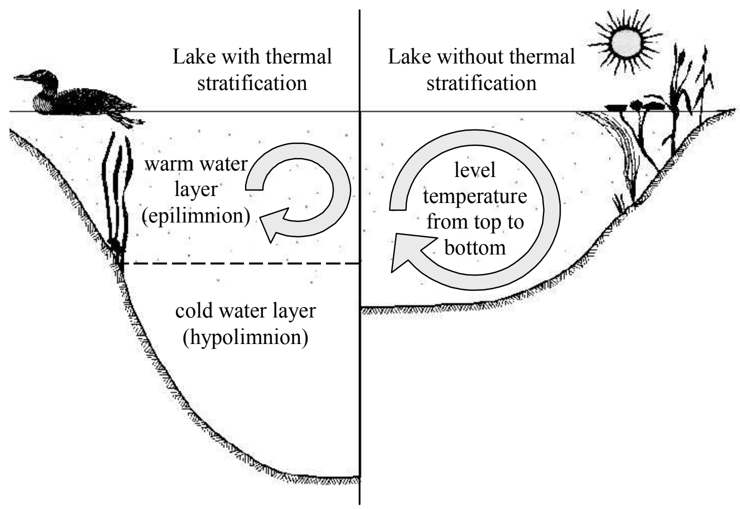

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

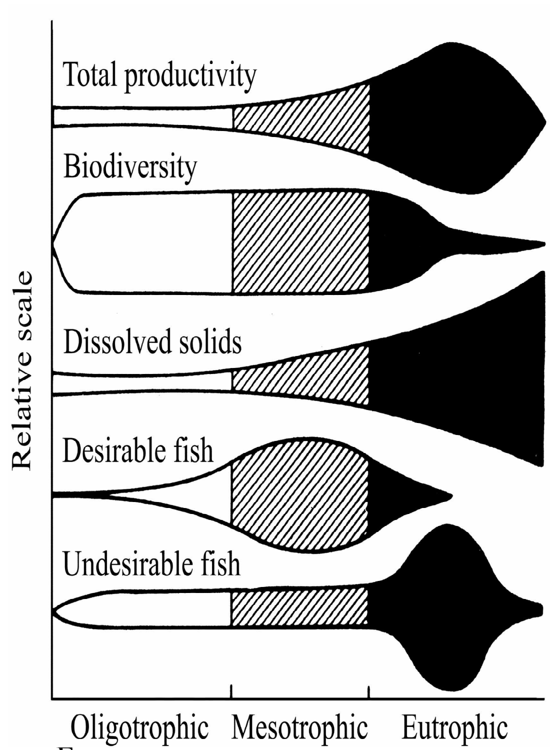

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Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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