THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM

2010 Pigeon Lake Report

COMPLETED WITH SUPPORT FROM:

Government of Alberta

Alberta Lake Management Society's Lakewatch Program

Lakewatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. Lakewatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in Lakewatch and readers requiring more information are encouraged to seek those sources.

ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Lakewatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Abe Silverman for his efforts in collecting data in 2010. We would also like to thank Bradley Peter and Emily Port who were summer interns with ALMS in 2010. Project Technical Coordinator Jill Anderson was instrumental in planning and organizing the field program. Technologists Shelley Manchur, Mike Bilyk, Brian Jackson, and John Willis were involved in the training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Jill Anderson (Program Manager) was responsible for program administration and planning. Théo Charette, Ron Zurawell (Limnologist, AENV), Lori Neufeld, and Sarah Lord prepared the original report, which was updated for 2010 by Bradley Peter and Arin Dyer. Alberta Environment, the Beaver River Watershed Alliance (BRWA), and the Municipal District of Wainwright were major sponsors of the Lakewatch program.

PIGEON LAKE:

Pigeon Lake is a large, shallow lake located in the counties of Wetaskawin and Leduc. It is a very popular recreational lake within easy driving distance from the cities of Edmonton, Leduc, and Wetaskawin. It is approximately 60 km southwest of Edmonton following Highway 2, then Highway 13 west to Ma-Me-O Beach on the south-end of the lake.

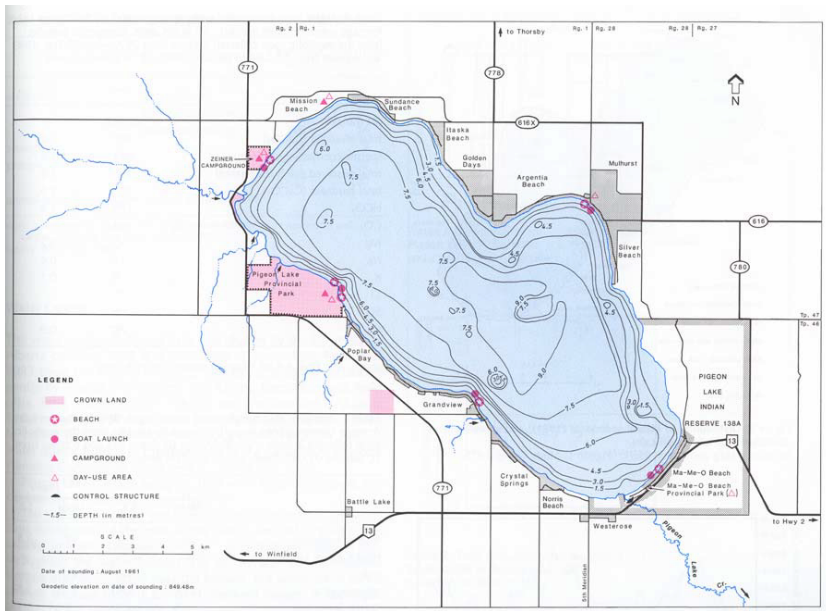

Figure 1 – Bathymetry of Pigeon Lake. From Mitchell and Prepas 1990.

The lake was once known as "Woodpecker Lake", translated from the Cree name Hmi-Hmoo, but by 1858, the name Pigeon Lake was in use (Holmgren and Holmgren 1976). It has been suggested that this latter name originates from the huge flocks of Passenger Pigeons that once ranged in the area (Falun Hist. Soc. 1974). Reverend Robert Rundle established Rundle Mission on the northwest shore of the lake in 1847. This was both an agricultural settlement and the first Protestant mission in Alberta and is commemorated by a cairn at Mission Beach (Warburg Dist. Hist. Soc. 1977). There was a Hudson's Bay Company trading post on the west shore of the lake built in 1868 and only in operation until 1875 (Falun Hist. Soc. 1974). A First Nations Reserve was established on the southeast shore in 1896 and was followed by a summer village, known as Ma-Me-O, from the Cree, meaning "white pigeon". Logging, commercial fishing, and farming were important livelihoods of residents of the area in the early 1900's. Near the hamlet of Mulhurst, there was a year-round sawmill and a winter operational fish-packing plant (Millet Dist. Hist. Soc. 1978).

The water quality of Pigeon Lake is typical of large, shallow lakes in Alberta, with water remaining quite green for most of the summer. Burbot, Emerald Shiner, Lake Whitefish, Northern Pike, Spottail Shiner, Walleye, White Sucker, and Yellow Perch are all currently found in Pigeon Lake.

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 (Mitchell and Prepas 1990). Wide, sandy beaches occur along one-quarter of the shoreline, 42% of the shoreline has a gentle slope without sandy beaches, and another 19% of shoreline is associated with wetlands (Mitchell and Prepas 1990). Submersed plant cover is generally low at depths less than 1.5 meters but is highest where fine sediments accumulate. Common species include northern water milfoil (*Myriophyllum exalbescens),* stonewort (*Chara* spp.) and Richardson pondweed (*Potamogeton richardsonii).*

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 likely affected by ground water input. There has been a general trend towards decline in water quantity since the early 1980's, though the 2010 water level (849.5 m above sea level) is only 0.2 meters less than the historical 1972 level (849.7 m above sea level).

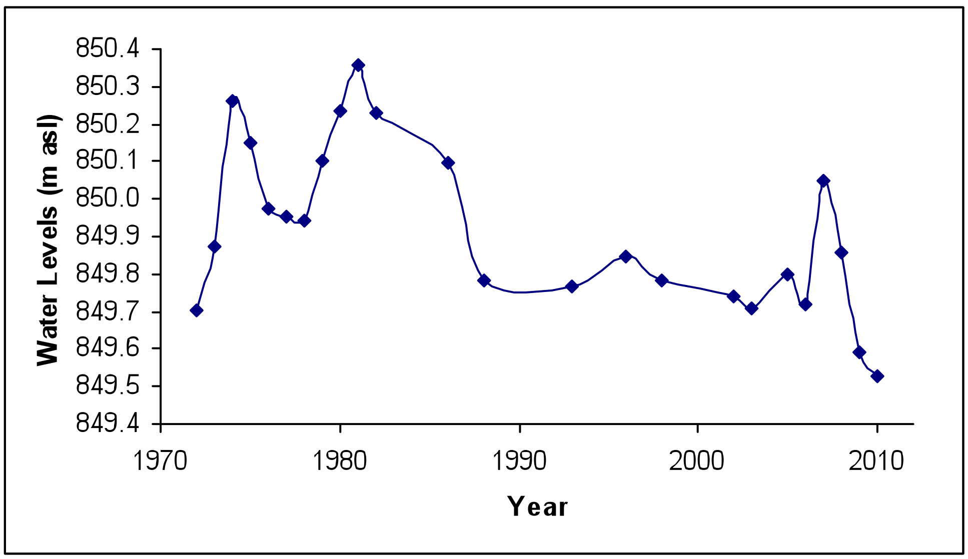

Figure 2 – Historical water levels in meters above sea level measured from 1972-2010 for Pigeon Lake. Data obtained from Environment Canada.

WATER CLARITY AND SECCHI DEPTH:

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

Average secchi disc depth in Pigeon Lake was measured three times over the course of the summer and averaged to 2.75 meters (Table 1). In June, secchi depth was at a seasonal maximum of 4.50 m, likely due to low levels of algae caused by mild June temperatures. In August, secchi disc depth decreased to 1.75 m, and increased slightly in September to 2.00 m. Because Pigeon Lake is quite shallow, re-suspension of bottom sediments due to wind and boating activities can negatively influence the secchi disc depth. Compared to historical averages, an average of 2.75 m is not uncommon for Pigeon Lake.

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 June, temperature was 13.55 °C at the surface and declined steadily to 10.81 °C at the lakebed (Figure 3a). No thermal stratification was observed in June. In August, temperatures had increased to 18.19 °C at the surface and remained stable until the bottom of the lake, where the temperature decreased by 0.05 °C to 18.14 °C. Because no data was collected in July, it is unknown whether the lake became stratified in 2010. However, because the lake is large and shallow, it is easy for winds to mix the water column completely, preventing thermal stratification. Finally, in September, surface temperature had decreased to 10.14 °C and remained relatively uniform until the lakebed where they were again 10.14 °C.

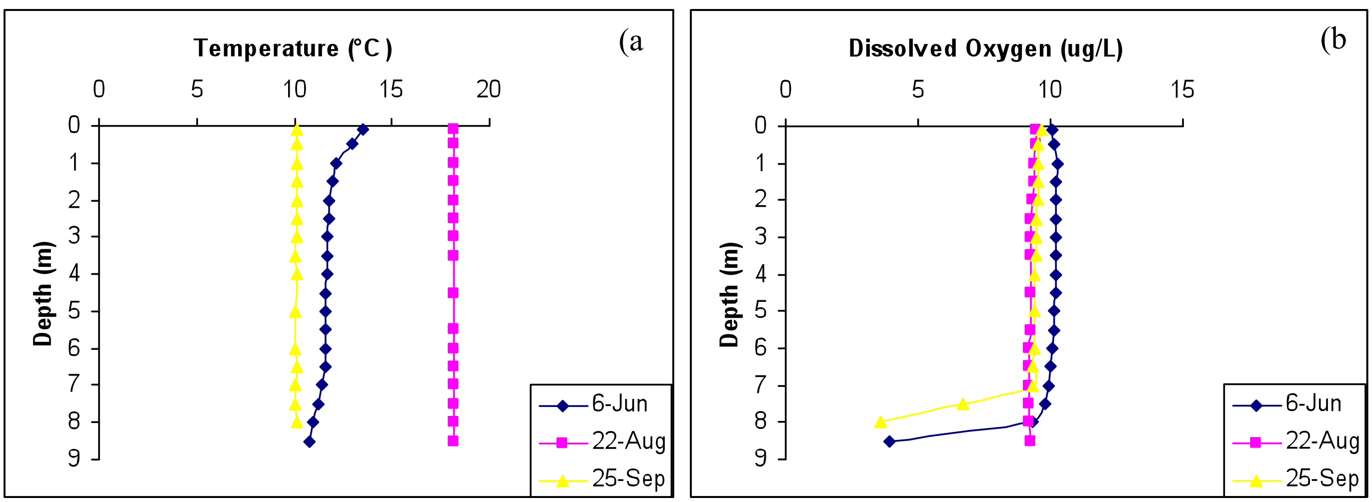

Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles measured three times over the course of the summer of 2010.

Dissolved oxygen in Pigeon Lake remained relatively constant at the surface, measuring 10.10 mg/L in June, 9.45 mg/L in August, and 9.63 mg/L in September (Figure 3b). In June, oxygen at the lakebed was low (3.93 mg/L), likely due to decomposition and a lack of mixing over the winter. Low oxygen levels may also be a result of respiring cyanobacteria which can cause large daily fluctuations in oxygen levels. Unfortunately, two sampling trips were missed due to high winds and no data was collected in July or early-August when algal blooms often peak and dissolved oxygen can change dramatically. In late-August, dissolved oxygen was mixed uniformly throughout the water column and was 9.24 mg/L at the lakebed. Finally, in September, oxygen levels had dropped to 3.60 mg/L at the lakebed, likely due to the oxygen demand associated with the decomposition of algae or due to respiration of cyanobacteria.

WATER CHEMISTRY:

ALMS measures a suite of water chemistry parameters. Phosphorous, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 1 for a complete list of parameters.

Based on total phosphorous concentrations measured in 2010, Pigeon Lake is considered eutrophic (Table 1). Total phosphorous was at a seasonal minimum in June, at 31 µg/L (Figure 4). In late-August, phosphorous concentration peaked at 48 µg/L, and decreased slightly to 43 µg/L in late-September. Average total phosphorous measured over 2010 was 40.7 µg/L. Total nitrogen concentration measured in 2010 averaged to 1.03 mg/L. Total nitrogen was at a seasonal minimum in June of 0.79 mg/L, and at a seasonal maximum in late-September of 1.18 mg/L. Finally, chlorophyll-*a* concentration changed dramatically over the course of the summer. In June, chlorophyll-*a* was 3.25 µg/L. Low chlorophyll-*a* values are typical in June as temperatures are often too low for algal blooms to arise. In late-August, however, chlorophyll-*a* reached a seasonal maximum of 36.2 µg/L. This concentration would be classified as hypereutrophic, or extremely productive. In late-September, chlorophyll-*a* concentrations declined slightly to 26.3 µg/L.

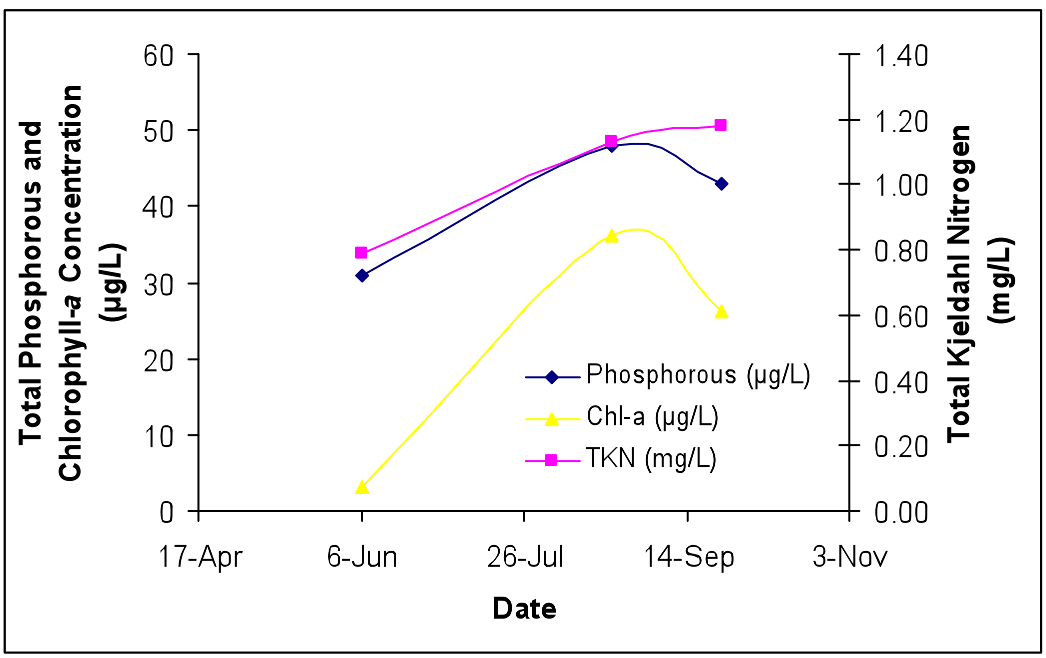

Figure 4 – Chlorophyll-*a* (µg/L), total phosphorous (µg/L) and total Kjeldahl nitrogen (mg/L) measured over the course of the summer in 2010.

The pH in Pigeon Lake has changed little in recent years, with an average of 8.57 in 2010 (Table 1). The high alkalinity measured in Pigeon Lake (195 mg/L $CaCO_3$) helps to buffer the water from changes to pH. Dominant ions include sodium, magnesium, calcium, and bicarbonate, none of which have changed appreciably over recent years in Pigeon Lake.

Table 1 – Average secchi depth and water chemistry values for Pigeon Lake measured in the Lakewatch program from 2001 to 2010.

Parameter	2001	2005	2006	2008	2010
TP (µg/L)	35	26.5	60.3	26.3	40.7
TDP (µg/L)	/	6	38	9	13
Chlorophyll-*a* (µg/L)	15	9.2	21.9	7.98	21.92
Secchi depth (m)	1.5	1.9	2.7	4.42	2.75
TKN (µg/L)	611	710	1100	670	1033
NO_2 and NO_3 (µg/L)	1	3	29	13	7.67
NH_3 (µg/L)	3	2.5	124	16	72.3
DOC (mg/L)	/	/	7	/	7.35
Ca (mg/L)	/	28.85	24.13	27.2	23.75
Mg (mg/L)	/	12.65	14.16	12.87	13.85
Na (mg/L)	/	20	21	20.33	21.95
K (mg/L)	/	6.1	6.63	6.17	6.3
SO_4^{2-} (mg/L)	/	7.3	10.2	5.47	9
Cl^- (mg/L)	/	4	3.33	3.33	3.05
CO_3 (mg/L)	/	8	4.67	3.33	0.5
HCO_3 (mg/L)	/	183	180	198	195
pH	/	8.6	8.5	8.37	8.57
Conductivity (µS/cm)	/	313	287	321.7	309.5
Hardness (mg/L)	/	125	119	121	116
Microcystin (µg/L)	/	/	1.17	0.59	0.087
TDS (mg/L)	/	176.5	173	175.333	173.5
Total Alkalinity (mg/L $CaCO_3$)	/	163	155	166	160

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 an absence of data.

2010 Fish Kill

A fish kill (mainly whitefish) occurred late-July/early-August of 2010. High chlorophyll-*a* concentrations indicate large amounts of algal biomass, which, when decomposing or respiring, can lead to near depletion of oxygen at the bottom of the lake. Sampling in 2010 did not detect lake stratification, indicating the temperature was consistently warm to the deepest parts of the lake. Warm temperatures lead to a higher metabolic rate in fish, and therefore a higher oxygen demand, which, in already low oxygen conditions, could have resulted in a fish-kill.

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:

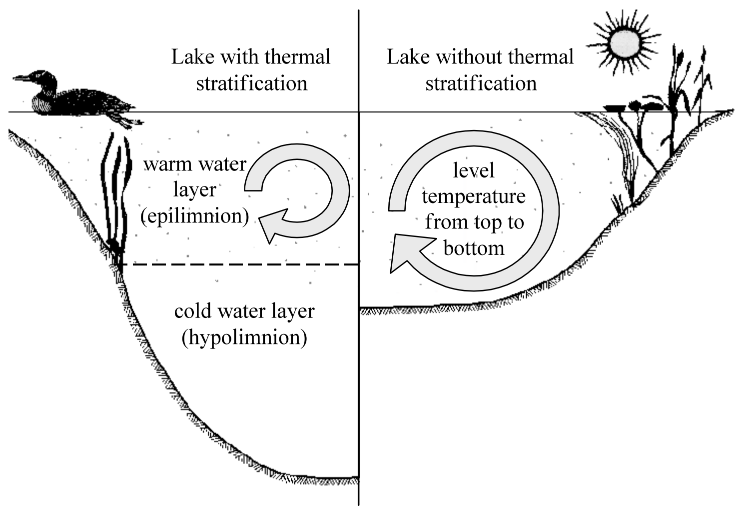

Figure A: Difference in the circulation of the water column depending on thermal stratification.

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.

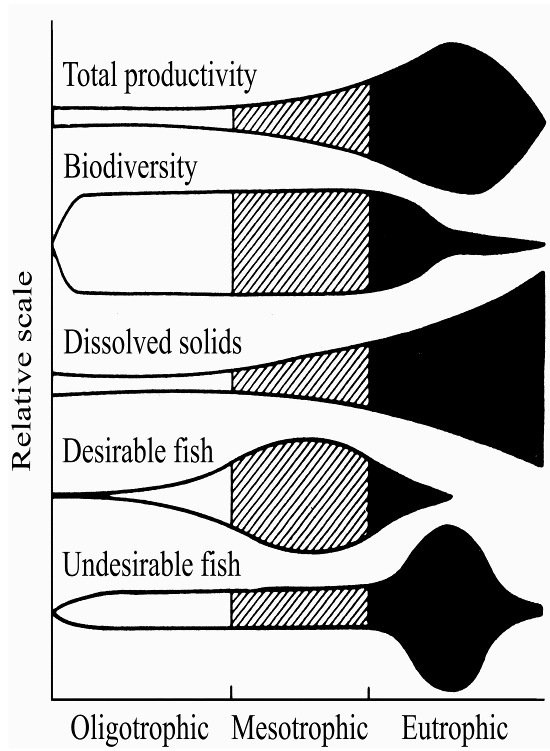

Figure B: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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

Trophic state	Total Phosphorus ($\mu g \cdot L^{-1}$)	Total Nitrogen ($\mu g \cdot L^{-1}$)	Chlorophyll *a* ($\mu g \cdot L^{-1}$)	Secchi Depth (m)
Oligotrophic	< 10	< 350	< 3.5	> 4
Mesotrophic	10 – 30	350 - 650	3.5 - 9	4 - 2
Eutrophic	30 – 100	650 - 1200	9 - 25	2 - 1
Hypereutrophic	> 100	> 1200	> 25	< 1

Note: These values are from a detailed study of global lakes reported in Nurnberg 1996. Alberta Environment uses slightly different values for TP and CHL based on those of the OECD reported by Vollenweider (1982). The AENV and OECD cutoffs for TP are 10, 35 and 100; for CHL are 3, 8 and 25. AENV does not have TN or Secchi depth criteria. The corresponding OECD exists for Secchi depth and the cutoffs are 6, 3 and 1.5 m.

References

Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes. University of Alberta Press. Available at: http://alberta-lakes.sunsite.ualberta.ca/

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.

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.