



*THE ALBERTA LAKE MANAGEMENT SOCIETY
VOLUNTEER LAKE MONITORING PROGRAM*

2011 Pine Lake Report

COMPLETED WITH SUPPORT FROM:





Alberta Lake Management Society's LakeWatch Program

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

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

Acknowledgements

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PINE LAKE:

Pine Lake (Figure 1) is a small eutrophic lake southeast of Red Deer, Alberta. Pine Lake is subject to cyanobacterial blooms, and public concern over deteriorating water quality prompted the Alberta government to initiate a lake restoration program in 1991. The Pine Lake Restoration Program was designed as a pilot project for future lake and watershed projects in Alberta.

An advisory committee that represented all members of the community directed early planning and problem diagnosis by the Alberta government. A diagnostic study in 1992 determined that approximately 61% of the total phosphorous (TP) loading was from sediment release and other internal sources, compared to about 36% from surface runoff, and determined that algal growth in Pine Lake was mainly limited by the supply of phosphorous¹. Four critical areas for watershed restoration were identified on four streams affected by livestock operations and sewage release. These streams contributed 72% of the phosphorous loading from streams in 1992.

The advisory committee later formed the Pine Lake Restoration Society, a non-profit organization with representatives from all stakeholders which raised funds and worked with technical advisors from the Alberta government. The Pine Lake Restoration Society implemented a four-year work plan in 1995 that addressed phosphorous loading from all sources. The main objective of the restoration program was to restore Pine Lake to a 'natural' level of algal productivity. The Pine Lake Restoration Society and other individuals in the basin completed beneficial management practices (BMPs) projects at various agricultural sites. Other organizations also improved wastewater treatment at a resort and two camps near the shoreline of Pine Lake.

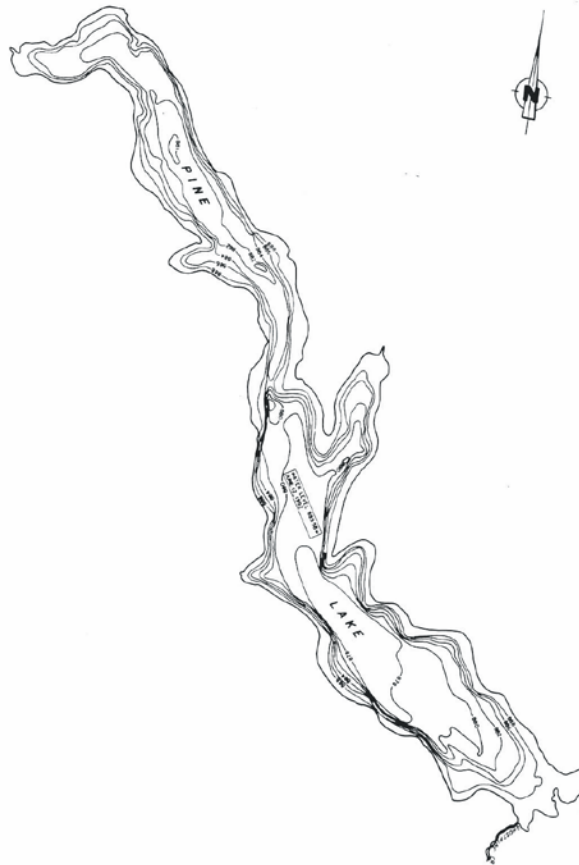


Figure 1 – Bathymetric map of Pine Lake¹.

¹ Sosiak, A. J and D.O. Trew. 1996. Pine Lake restoration project. Diagnostic Study (1992). Obtained from: <http://environment.gov.ab.ca/info/library/7764.pdf>

Following an evaluation of the different alternatives to remove or treat phosphorous released from lake sediments, hypolimnetic withdrawal was selected as the preferred method of treatment. Hypolimnetic withdrawal has been successfully used to reduce TP concentration in various lakes, mainly in Europe, but had never been attempted in Alberta.

The hypolimnetic withdrawal system at Pine Lake, installed in 1998, consists of a weir that regulates lake levels, and a gravity-fed pipeline that withdraws cool, phosphorous-rich water from near the bottom of the lake (the hypolimnion) of the south basin and discharges through a vault with control valves to a stilling basin on Ghostpine Creek.

WATER QUANTITY:

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

Water levels at Pine Lake have been monitored since 1965 (Figure 2). Under the approval to operate the hypolimnetic withdrawal system, the Pine Lake Restoration Society tries to maintain water levels within a range that was recommended in the engineering report for the system. The weir operator for the Society accomplishes this by adding or removing boards to the weir at the lake outfall and by operating control valves. Overall, lake levels have fluctuated very little and are maintained around 889.5 meters above sea level.

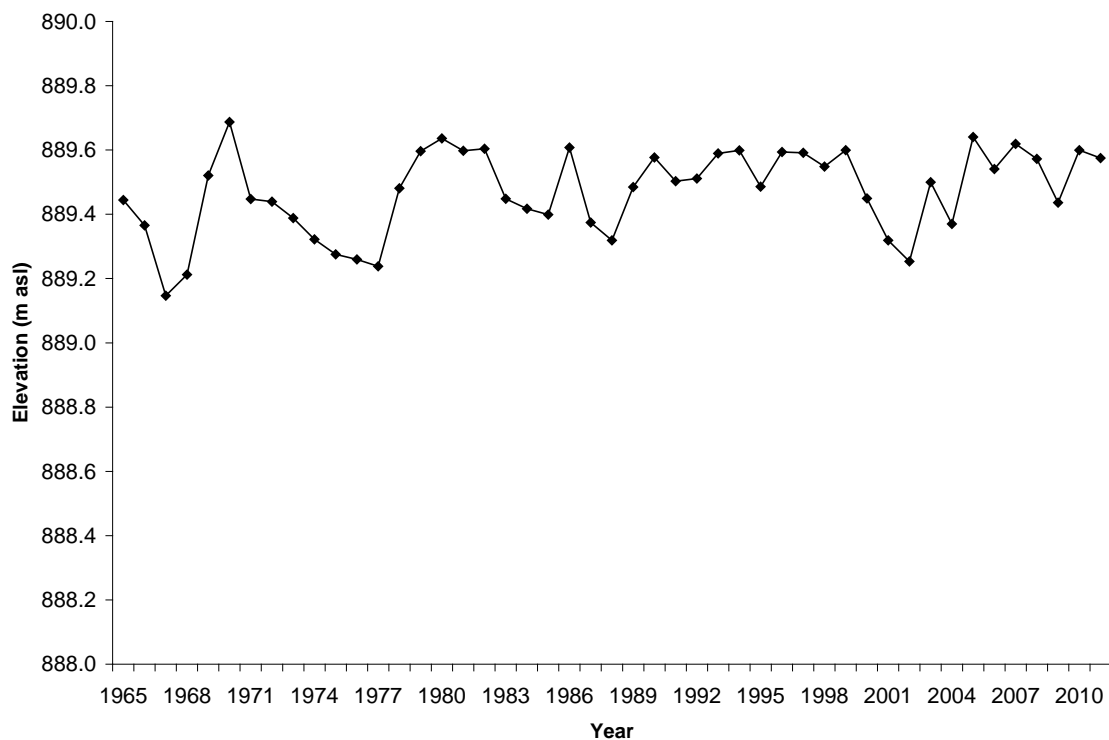


Figure 2 – Water levels at Pine Lake measured in meters above sea level (m asl). Data obtained from Alberta Environment.

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 measured at Pine Lake in 2011 was poor, at only 1.29 m. An average of 1.29 m is well within the range of historical variation measured at Pine Lake. Secchi disk depth ranged from a minimum of 0.75 m on July 29th to a maximum of 1.5 m on September 16th. It is common at lakes throughout Alberta for Secchi disk depth to decrease mid-summer due to the presence of thick algae/cyanobacteria blooms which thrive in the summer.

WATER TEMPERATURE AND DISSOLVED OXYGEN

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

Surface water temperature measured at Pine Lake changed greatly throughout the summer, ranging from a minimum of 14.7 °C on June 10th to a maximum of 21.77 °C on July 6th (Figure 3a). Throughout the water column, temperatures were high, reaching a minimum of only 10.39 °C at the lakebed on June 10th. Weak thermal stratification was present on each of the sampling trips with the exception of September 16th. Intermittent periods of stratification can contribute to the depletion of dissolved oxygen near the lakebed and the release of phosphorous from the sediments.

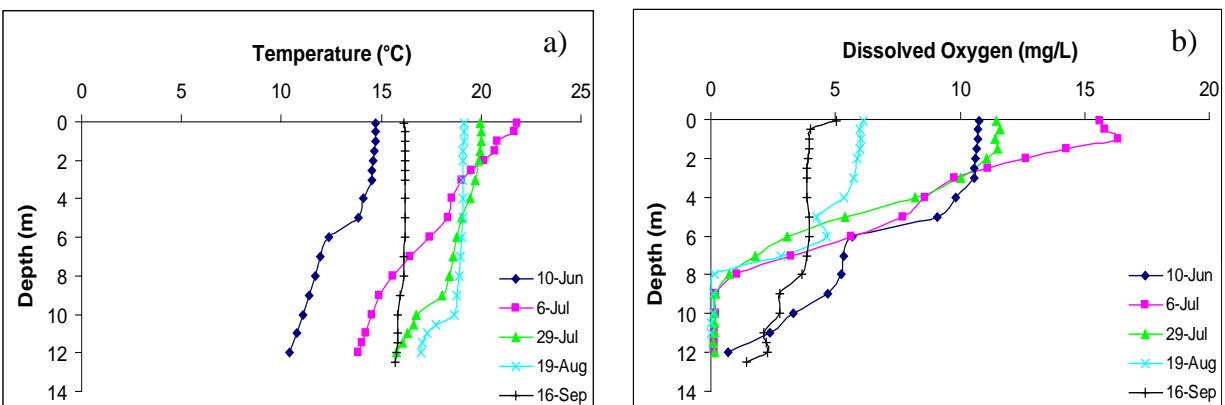


Figure 2 – Temperature (°C) and dissolved oxygen (mg/L) profiles measured at Pine Lake during the summer of 2011.

Dissolved oxygen was poor at Pine Lake in 2011, with often half of the water column falling below the Canadian Council for Ministers of the Environment (CCME) guidelines for the Protection of Aquatic Life of 6.5 mg/L (Figure 3b). Surface dissolved oxygen showed large variation, ranging from a minimum of 5.03 mg/L on September 16th to 15.62 mg/L on July 6th. Algae/cyanobacteria blooms tend to raise levels of surface dissolved oxygen due to high amounts of photosynthesis. However, when the algae sink to the lakebed and decay, they consume oxygen, the concentration of which can become dangerously low. For example, on September 16th, the entire water column was below the CCME guidelines.

In early September of 2011, Pine Lake experienced a fish kill. Members of the Pine Lake Restoration Society reported collecting at least 457 dead walleye (*Sander vitreus*) and 7 northern pike (*Esox lucius*) from the lake. Causes of mortality may be due to a combination of low dissolved oxygen levels and high temperatures.

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 Pine Lake in 2011 was 92.8 µg/L, which falls into the eutrophic, or nutrient rich, classification (Table 1). While this average falls on the high end of the historical variation, it is not the highest TP recorded at Pine Lake. In 1996, an average value of 104 µg/L was recorded. Given that 2011 was an extremely high runoff year, it is likely that more nutrients than normal were transported to the lake from the watershed. These high levels of nutrients no doubt contributed to the high levels of cyanobacteria observed in 2011. TP increased throughout the summer, measuring a minimum of 77 µg/L on June 10th and 113 µg/L on September 16th.



Figure 3 – Decaying cyanobacteria in September of 2011 at Pine Lake. Photo by Jessica Davis.

Similarly, total Kjeldahl nitrogen (TKN) increased throughout the summer, measuring a minimum of 1590 µg/L on June 10th and a maximum of 2510 µg/L on September 16th. On

average, TKN measured 1972 $\mu\text{g/L}$ which falls into the hyper-eutrophic, or extremely productive, classification. Again, this average value falls on the high end of Pine Lake's historical variation.



Figure 4 – Decaying cyanobacteria in September of 2011 at Pine Lake. Photo by Jessica Davis.

Average chlorophyll-*a* measured at Pine Lake was 30.8 $\mu\text{g/L}$. This value falls into the hyper-eutrophic classification. Cyanobacteria blooms were a nuisance in 2011, coating the shoreline with a bright blue-green pigment which is typical of decaying cyanobacteria (Figure 3,4). Chlorophyll-*a* peaked mid-summer, measuring a maximum of 46.0 $\mu\text{g/L}$ on July 29th.

Cyanobacteria blooms are common at Pine Lake; in 1992, the cyanobacteria species *Aphanizomenon flos-aquae*, *Anabena lemmermanii*, and *Microcystin aeruginosa* were the dominant species identified in the lake². A blue-green algae advisory

was posted by Alberta Health Services in early September.

Average pH measured at Pine Lake in 2011 was 8.598, which is well above neutral. High alkalinity (293 mg/L CaCO_3) and high bicarbonate concentration (334 mg/L HCO_3) likely help to buffer the lake against changes to pH. Dominant ions in the lake included sodium (83.6 mg/L) and sulphate (56.0 mg/L)

² Watson, S. 1994. The phytoplankton biomass of Pine Lake 1992-1993. Retrieved from: <http://environment.gov.ab.ca/info/library/7980.pdf>

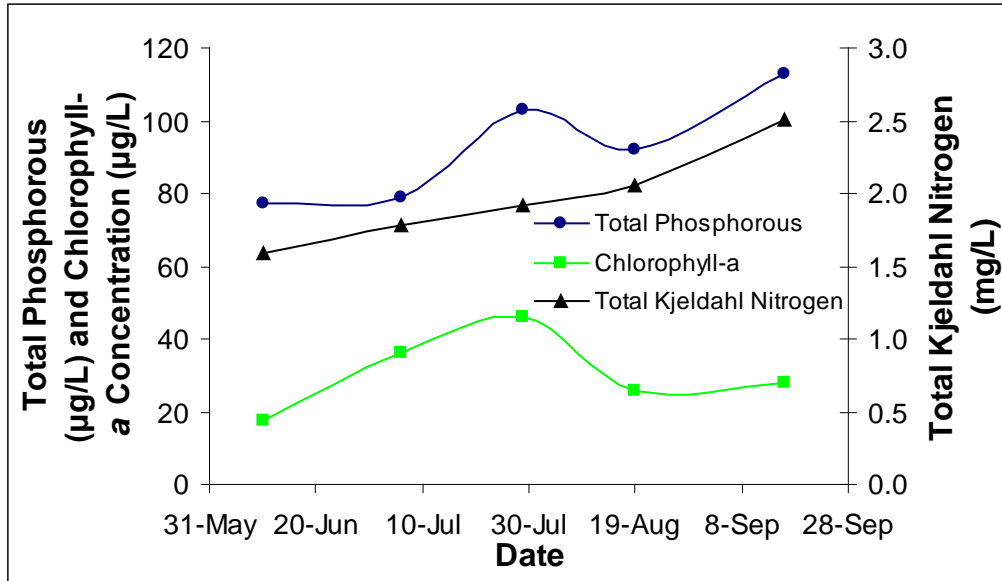


Figure 5 – Total phosphorous ($\mu\text{g/L}$), total Kjeldahl nitrogen (mg/L), and chlorophyll-*a* concentration ($\mu\text{g/L}$) measured at Pine Lake during the summer of 2011.

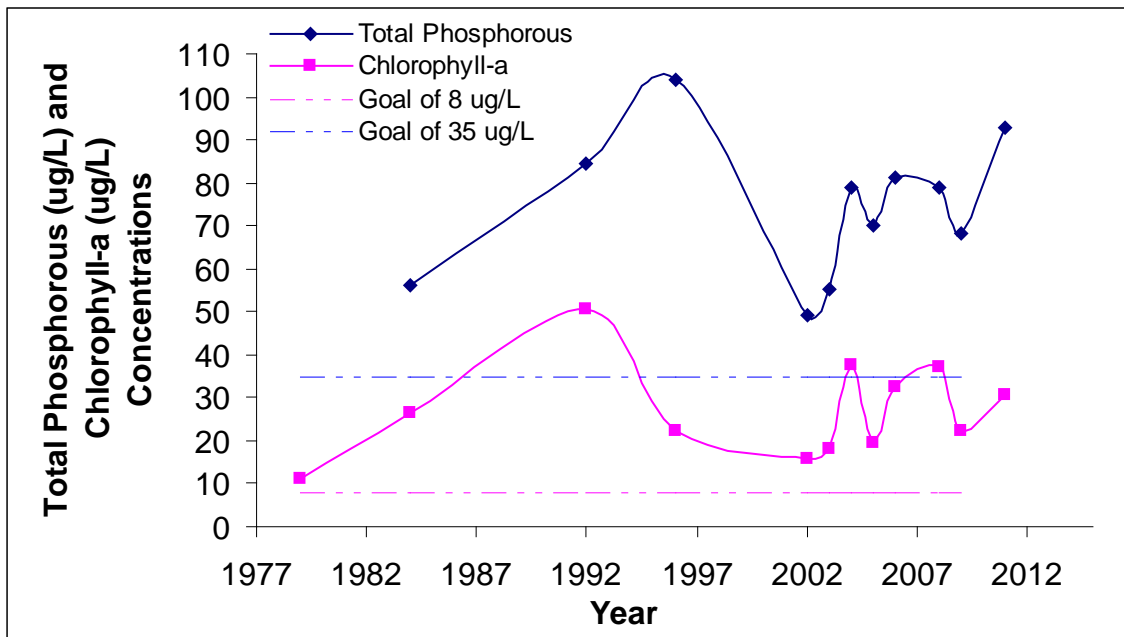


Figure 6 – Historical values of total phosphorous ($\mu\text{g/L}$) and chlorophyll-*a* concentration ($\mu\text{g/L}$) measured at Pine Lake. Goal values described in Sosiak 2002 are provided for comparison.¹

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

Parameter	1979	1984	1992	1996	2002	2003	2004	2005	2006	2008	2009	2011
TP (µg/L)	/	56	84.7	104	49.3	55	79	70	81.2	78.8	68	92.8
TDP (µg/L)	/	/	38.6	57.9	18.4	26.2	26.2	33.3	32.4	33.8	34.5	31.4
Chlorophyll- <i>a</i> (µg/L)	11.3	26.3	50.4	22.1	15.6	17.9	37.8	19.3	32.7	37.2	22.5	30.8
Secchi depth (m)	3.4	1.8	1.8	2.1	1.7	3.1	1.7	2.5	1.8	1.2	1.86	1.29
TKN (µg/L)	1293	1302	2052	1360	1442	1474	1880	1750	1856	1908	1760	1972
NO ₂ and NO ₃ (µg/L)	13	<10	36	11	3	10	9.7	11	2	13	15.5	6.2
NH ₃ (µg/L)	/	59	146	120	11	98	136	156	134	135	65	134
DOC (mg/L)	/	/	/	/	/	/	22.3	17.3	18.8	17.3	17.8	18.7
Ca (mg/L)	/	23	25	28	20	21	21.7	21	24	29.1	27.3	31.2
Mg (mg/L)	/	25	25	24	26	24	25	23	23	23.5	24.3	23.3
Na (mg/L)	/	108	99	103	112	124	132	129	128	109	115.3	83.6
K (mg/L)	/	10	9	10	11.5	10	10	10	10.7	9.7	10.4	9.1
SO ₄ ²⁻ (mg/L)	/	84	69	63	90	79	85	78	82.3	68.3	75.6	56
Cl ⁻ (mg/L)	/	6	7	8	11	10	11	10	12	12.8	13.46	12.4
CO ₃ (mg/L)	/	/	/	/	/	22.8	20.5	17.7	17	9.7	14.3	11.3
HCO ₃ (mg/L)	/	/	/	/	/	/	374	381	387	370	371.6	334
pH	/	/	/	/	/	/	8.8	8.7	8.7	8.5	8.61	8.6
Conductivity (µS/cm)	/	/	/	/	/	/	787.75	764	786	729.3	754.7	659
Hardness (mg/L)	/	/	/	/	/	163	156	148.3	153.3	169.6	168	174
TDS (mg/L)	/	/	/	/	/	469	489	477.3	487.3	457.6	463.6	393
Microcystin (µg/L)	/	/	/	/	/	/	/	0.876	0.2925	0.4275	1.19	0.27
Total Alkalinity (mg/L CaCO ₃)		319	308	313	321	331	341	342	346	319.7	328.3	293

Note: TP = total phosphorous, TDP = total dissolved phosphorous, Chl-*a* = chlorophyll-*a*, TKN = total Kjeldahl nitrogen. NO₂₊₃ = nitrate+nitrite, NH₃ = ammonia, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO₄ = sulphate, Cl = chloride, CO₃ = carbonate, HCO₃ = bicarbonate. A forward slash (/) indicates an absence of data.

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:

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

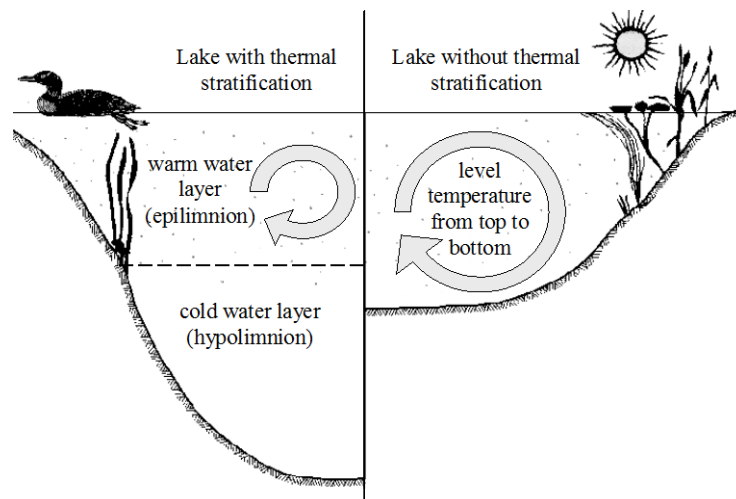


Figure A: Difference in the circulation of the water column depending on thermal stratification.

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•L⁻¹ and should not average less than 6.5 mg•L⁻¹ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg•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.

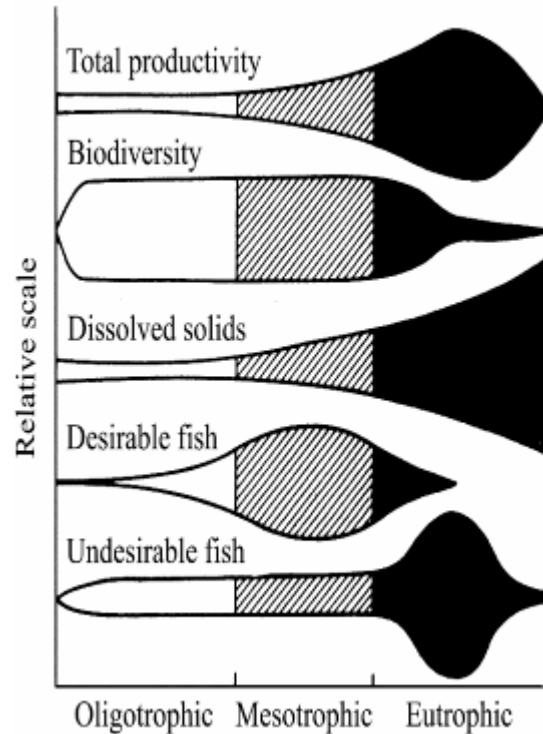


Figure B: Suggested changes in various lake characteristics with eutrophication.

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