*The Alberta Lake Management Society*
*Volunteer Lake Monitoring Program*

# Wolf Lake

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## 2007 Report

*Completed with support from:*

**Alberta Lake Management Society**

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

# Alberta Lake Management Society's Lakewatch Program

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

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

# Acknowledgements

The Lakewatch program is made possible through the dedication of volunteers and the Lakewatch Chairs, Théo Charette and Ron Zurawell. We would like to thank Troy Furukawa and Shane Wood for their time and effort in collecting field data during 2007. Troy conducted the creel survey in Wolf Lake. Numerous Alberta Environment staff also contributed to successful completion of the 2007 program. We would like to thank Jill Anderson and Wendy Markowski who were summer interns with ALMS in 2007. Project Technical Coordinator, Megan McLean was instrumental in planning and organizing the field program. Technologists, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair was responsible for data management. Théo Charette (ALMS Director) was responsible for program administration and planning. Théo Charette, Ron Zurawell (Limnologist, AENV), and Lori Nuefeld prepared the original report, which was updated by Heather Powell in 2007. Alberta Environment and the Lakeland Industry & Community Association (LICA) were the main sponsors for the Lakewatch program.

# Wolf Lake

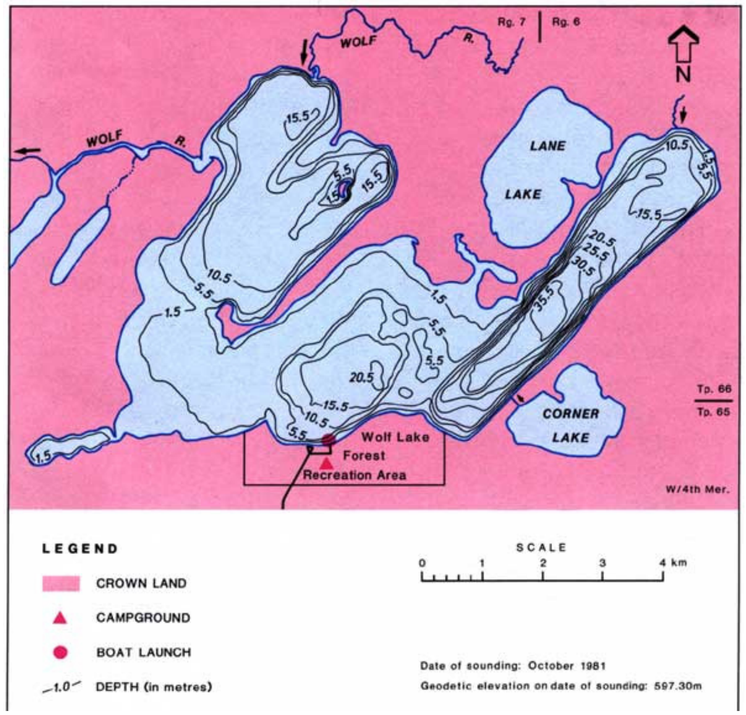


**Figure 1.** Bathymetry of Wolf Lake, Alberta.

Wolf Lake is a beautiful lake located just south of the Primrose Lake Air Weapons Range. It is popular for its northern pike and walleye fishery, low-density campground and minimal boat traffic. The lake is situated approximately 70 km north of the town of Bonnyville and 310 km northeast of the city of Edmonton. To reach the lake from Edmonton, take Highway 28 northeast to Bonnyville, then Highway 41 north to the hamlet of La Corey. Drive west on Highway 55 and once the hamlet of Iron River is reached, continue for 5.5 km heading west, then turn north onto an all weather road that eventually winds its way to Wolf Lake. The lake's name is a translation from the Cree *Mahikan Sakhahegan.* In 1911, wolves near the lake were reported to have chased a fur-buyer's sleigh for quite a distance (Chipeniuk 1975).

A road to the lake was built in 1963 by the Department of Lands and Forests. A campground, Wolf Lake Provincial Recreation Area, is located on the south shore. It is open from 1 May to 30 September and provides 65 campsites, pump water, a sewage disposal facility, a boat launch and a sandy beach. The campground is heavily forested and has been left, as much as possible, in its natural state. There is no defined swimming area and no day-use area, but day-users are welcome to use the facilities at a campsite.

The drainage basin of Wolf Lake is 22 times the size of the lake (**Figure 1**). Most of the watershed is located northeast of the lake. The outlet, the Wolf River, flows east to the Sand River, which eventually joins the Beaver River. Wolf Lake is located in the Moist-mixedwood subregion of the Boreal-mixedwood Ecoregion. The dominant trees in dry areas are trembling aspen, balsam poplar, jack pine, and white spruce. In wet areas, black spruce, willows, and sedges are dominant.

Wolf Lake is a large lake (31.5 $km^2$) and consists of three distinct basins. The northwest basin slopes rapidly to a maximum depth of 15.5 m and most of it is deeper than 10 m. The central basin has a maximum depth of 20.5 m, but a large part of it is less than 6 m deep. The eastern basin is long and narrow and contains the deepest part of the lake. It drops off steeply to a maximum depth of about 38 m.

Large areas of dense aquatic vegetation are present in the western basin of the lake, whereas other areas support a low density of plants.

# Results

*Water Levels*

Water levels in Wolf Lake fluctuated by ~0.7 m between 1993 and 2007 (**Figure 2**). The maximum water level (597.758 m above sea level (asl)) for this period was measured in June 1996. Minimum water level (597.098 m asl) was recorded in October 1999. From 1996 to 1999, the lake water level briefly declined. Water levels then increased in 2000 and remained somewhat constant for the last 6 years, with the exception of a peak in 2005, measuring 597.671 m asl.

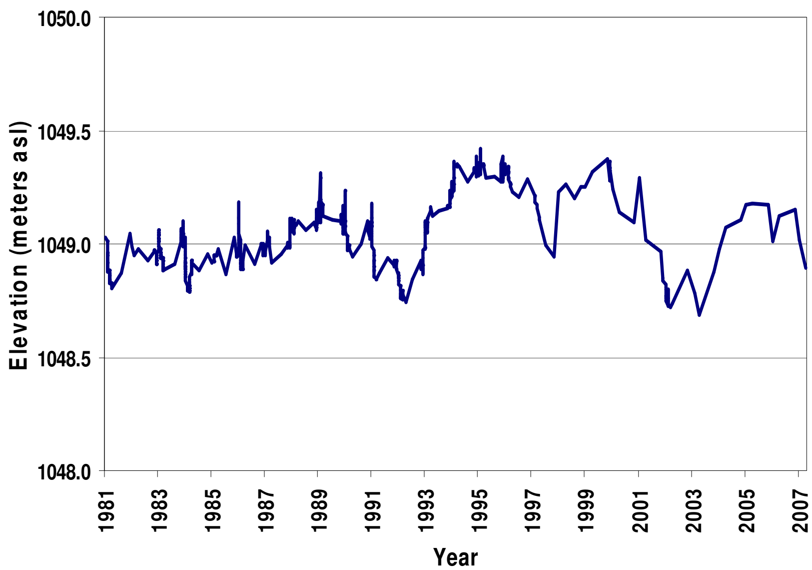


**Figure 2.** Historical water level elevation (meters above sea level (asl)) in Wolf Lake, Alberta, 1981-2007.

*Water Temperature and Dissolved Oxygen*

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

Wolf Lake was thermally stratified throughout most of summer 2007 (**Figure 3**). Maximum surface water temperate occurred on 18 June ($T_{water}$ = 17.9º C). The upper, warm layer of water (e.g. epilimnion) extended to 8m in June, 10m in late August, and ~11m in September. Water temperature was < 6º C below 19m depth on all sample dates. Wolf Lake did not mix between mid-June and mid-September.

Dissolved oxygen (DO) concentrations peaked on 18 June, with a slight increase in DO at 6m depth, which indicated a phytoplankton layer was concentrated at the thermocline (**Figure 3**). DO concentrations declined at 10m depth on all sample dates. DO approached zero (e.g. anoxic) at the lake bed on 18 June, and below 15m depth in August and September. DO concentrations increase slightly from 16 to 27 m in August. This pattern and a similar one in September may reflect decomposition occurring at 15m depth. Low DO concentrations below 15m depth in late summer reflect microbial decomposition, which consumes oxygen. The oxygen levels in surface layers (above 10 m depth) of Wolf Lake were within the acceptable range for surface water quality in 2007, according to Alberta Environment guidelines (DO ≥ 5.0 mg/L).

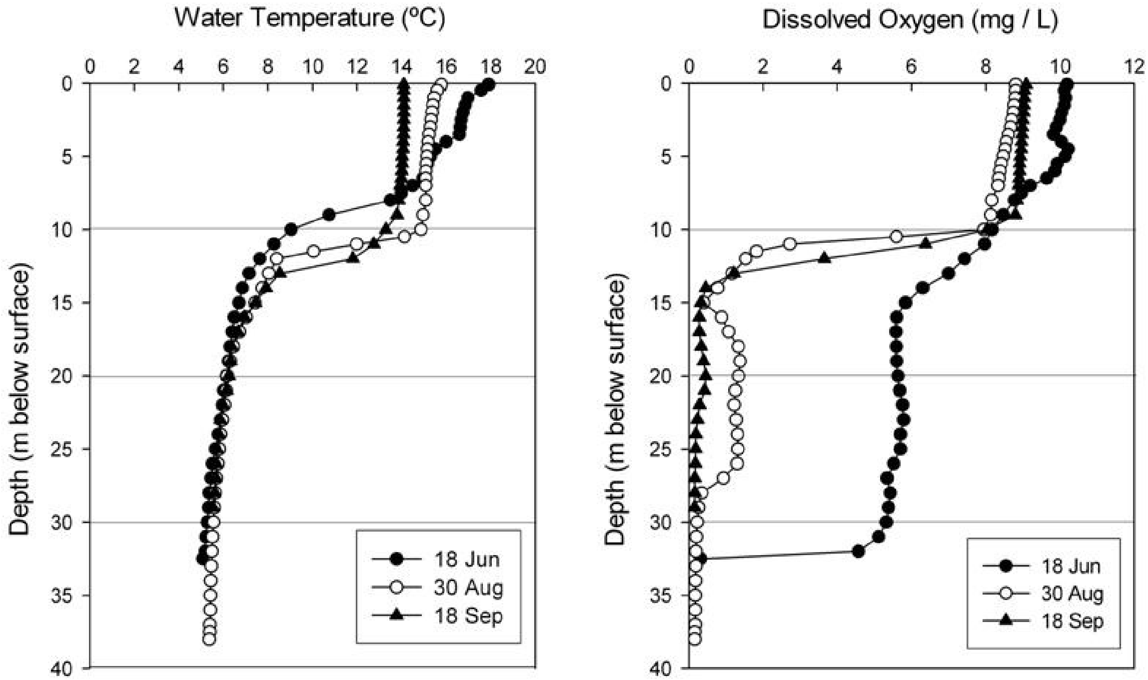


**Figure 3.** Water temperature (°C) and dissolved oxygen (mg /L) profiles for Wolf Lake during the summer of 2007.

*Water clarity and Secchi disk depth*

*During the melting of snow and ice in spring, lake water can become cloudy from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.*

Wolf Lake is a deep lake compared to many lakes in Alberta. Compared to shallower lakes, Wolf Lake appears relatively clear, with an average Secchi depth = 3.6 meters. During the summer 2007, light penetrated to an average 11% of the total lake depth (**Table 1**). Thus, algal growth was primarily limited to the upper layers of the lake. The thermo- and chemo-clines evident at 10 m depth may be an area of where dead algae settle (Figure 3). As dead algae settle, the water can become turbid, blocking light to lower depths and reducing water temperature. The decomposition process also consumes oxygen and is the likely mechanism that drives the oxygen profile observed in Wolf Lake (Figure 3)

*Water chemistry*

Based on lake water characteristics, Wolf Lake is considered mesotrophic (see *A Brief Introductory to Limnology* at the end of this report). This was evidenced by moderate concentrations of total phosphorus (average TP = 17.5 µg/L) and algal biomass (average chl *a* = 2.7 µg/L) (**Figure 4**) in 2007. Total Kjeldahl nitrogen (average TN = 758 µg/L) values were within the hypereutrophic range. Typically, phosphorus concentrations in Alberta lakes increase in summer due to recycling of nutrients from bottom sediments. In 2007, an increase in TP occurred on 30 August, although an increase in algae biomass was not found. Compared to other Alberta lakes, Wolf Lake has lower than average algae and nutrients concentrations.

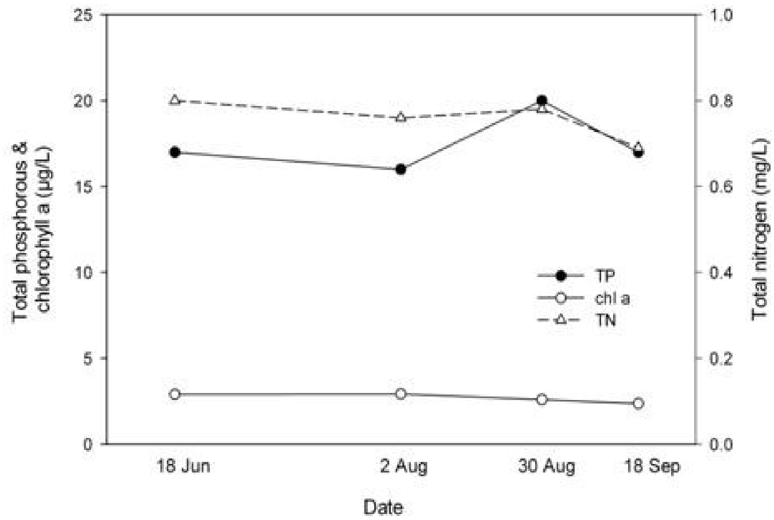


**Figure 4.** Total phosphorus, total nitrogen, and chlorophyll *a* (a measure of algae biomass) concentrations for Wolf Lake during the summer of 2007.

Like most lakes in Alberta, Wolf Lake is well buffered from acidification. Lake pH = 8.4 is well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, calcium, magnesium, and sodium (**Table 1**). The concentrations of most ions and nutrients remained constant since the 1980s, indicating no change in hydrology. Major nutrients (P, N) and water clarity have not changed much, although data for Wolf Lake are scant. Further sampling of Wolf Lake is required to detect long-term trends in water quality.

The average concentrations of various heavy metals (as total recoverable concentrations) were below CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**). Average metal concentrations are from 2 sampling dates, 2 August and 18 September. Due to lack of data, it is unclear whether metal concentrations have changed in Wolf Lake.

# References

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**Table1.** Mean water chemistry characteristics of Wolf Lake, Alberta summer 2007 compared to previous years.

| Parameter | 1981 | 2005 | 2006 | 2007 |
|---|---|---|---|---|
| Total P (µg/L) | 25 | 22 | 19 | 17.5 |
| TDP (µg/L) | 10 | 6.6 | 8.3 | 7.3 |
| Chlorophyll *a* (µg/L) | 7.9 | 4.6 | 3.3 | 2.7 |
| Secchi disk depth (m) | 2.8 | 3.5 | 3.3 | 3.6 |
| TN (µg/L) | 911 | 830 | 825 | 758 |
| $NO_{2+3}$ (µg/L) | <8 | 6 | <5 | <7 |
| $NH_4$ (µg/L) | <35 | 25 | 14 | 17 |
| Dissolved organic C (mg/L) | 13 | 14 | - | 15.1 |
| Ca (mg/L) | 30 | 30 | 30 | 29.3 |
| Mg (mg/L) | 16 | 15 | 16 | 16.8 |
| Na (mg/L) | 11 | 12 | 12 | 13.1 |
| K (mg/L) | 2 | 2.1 | 2.0 | 2.2 |
| $SO_4$ (mg/L) | 2 | 3 | 5 | <3 |
| Cl (mg/L) | 1 | 0.9 | 1.15 | 1.2 |
| $CO_3$ (mg/L) | 0.3 | 7 | 7.7 | 7.5 |
| $HCO_3$ (mg/L) | 189 | 180 | 182 | 192 |
| Conductivity (µS/cm) | - | - | - | 297 |
| Total Alkalinity (mg/L $CaCO_3$) | 156 | 159 | 162 | 165 |
| pH | 7.4-8.5 | 8.5 | 8.6 | 8.4 |
| Total dissolved solids (mg/L) | 156 | 156 | 161 | 164 |

Note: TP = total phosphorus, TDP = total dissolved phosphorous, Chla = chlorophyll *a*, TN = 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, Cond = Specific conductivity, TDS = Total dissolved solids.
(Atlas of Alberta Lakes, Mitchell and Prepas, 1990).

# Appendix 1

Mean concentrations of metals in Wolf Lake, summer of 2007, compared to 2005-2006. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life are presented for reference.

| Metals (total) | 2005 | 2006 | 2007 | Guidelines |
|---|---|---|---|---|
| ALUMINUM µg/L | 4.04 | 18.99 | 4.6 | 100[a] |
| ANTIMONY µg/L | 0.021 | 0.0153 | 0.02 | 6[e] |
| ARSENIC µg/L | 0.944 | 0.9525 | 0.98 | 5 |
| BARIUM µg/L | 32 | 31.5 | 31.8 | 1000[e] |
| BERYLLIUM µg/L | <0.003 | <0.003 | <0.003 | 100[d,f] |
| BISMUTH µg/L | <0.001 | 0.0061 | 0.003 | |
| BORON µg/L | 54.7 | 55.5 | 40.6 | 5000[e,f] |
| CADMIUM µg/L | 0.0024 | 0.0029 | <0.003 | 0.085[b] |
| CHROMIUM µg/L | 0.123 | 0.07 | 0.15 | |
| COBALT µg/L | 0.0188 | 0.01125 | 0.01 | 1000[f] |
| COPPER µg/L | 0.176 | 0.241 | <0.39 | 4[c] |
| IRON µg/L | 35.4 | 34 | 9.9 | 300 |
| FLUORIDE mg/L | 0.17 | - | - | 1.5 |
| LEAD µg/L | 0.0366 | 006445 | 0.12 | 7[c] |
| LITHIUM µg/L | 11.3 | 13.6 | 11.8 | 2500[g] |
| MANGANESE µg/L | 33.5 | 19.25 | 23.3 | 200[g] |
| MOLYBDENUM µg/L | 0.328 | 0.331 | 0.32 | 73[d] |
| NICKEL µg/L | <0.005 | 0.172 | <0.005 | 150[c] |
| SELENIUM µg/L | 0.104 | <0.1 | <0.1 | 1 |
| STRONTIUM µg/L | 121 | 115.5 | 116 | |
| SILVER µg/L | 0.0022 | 0.0022 | 0.007 | |
| THALLIUM µg/L | <0.0003 | 0.00165 | <0.0001 | 0.8 |
| THORIUM µg/L | 0.0039 | 0.00695 | 0.004 | |
| TIN µg/L | 0.0332 | <0.03 | 0.08 | |
| TITANIUM µg/L | 0.481 | 0.6485 | 0.65 | |
| URANIUM µg/L | 0.103 | 0.105 | 0.11 | 100[e] |
| VANADIUM µg/L | 0.0845 | 0.1078 | 0.08 | 100[f,g] |
| ZINC µg/L | 8.35 | 2.315 | 0.55 | 30 |

With the exception of fluoride (which reflects the mean concentration of dissolved fluoride), values represent means of total recoverable metal concentrations.

[a] Based on pH ≥ 6.5; calcium ion concentration $[Ca^{+2}]$ ≥ 4 mg/L; and dissolved organic carbon concentration [DOC] ≥ 2 mg/L.

[b] Based on water Hardness of 300 mg/L (as $CaCO_3$).

[c] Based on water Hardness > 180 mg/L (as $CaCO_3$).

[d] CCME interim value.

[e] Based of Canadian Drinking Water Quality guideline values.

[f] Based of CCME Guidelines for Agricultural Use (Livestock Watering).

[g] Based of CCME Guidelines for Agricultural Use (Irrigation).

# A brief introduction to Limnology

## *Indicators of water quality*

Water samples are collected in Lakewatch to determine the water quality of lakes. 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*

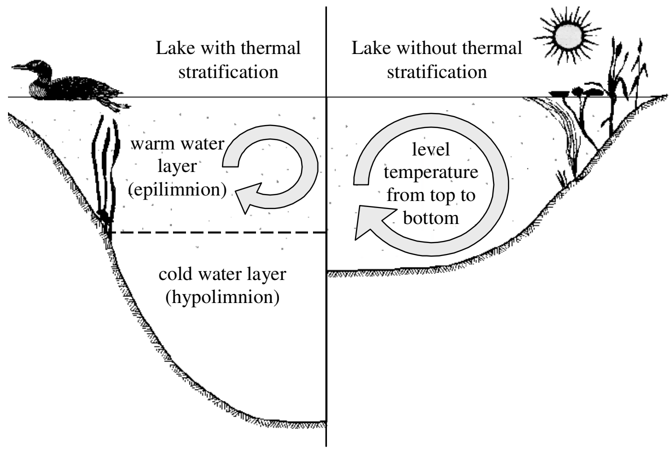


**Fig. 1**: Difference in the circulation of the water column depending on thermal stratification.

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 called a **turnover** event. Surface water cools further as ice forms and again a thermocline develops this time with 4°C water at the bottom and 0°C water on the top.

Another turnover event occurs in spring when surface waters warm to 4°C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are termed **polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic** meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice free season the lake is polymictic.

## *Dissolved Oxygen*

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 mg/L and should not average less than 6.5 mg/L over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 mg/L in areas where early life stages of aquatic biota, particularly fish, are present.

### *General Water Chemistry*

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

### *Phosphorus and Nitrogen*

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

### *Chlorophyll a*

Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the amount of algae in the water. Some highly productive lakes are dominated by larger aquatic plants, known as macrophytes, rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. As a result, lakes like Chestermere which are dominated by macrophytes can be at a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

### *Secchi Disk Depth*

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. Secchi disk depth is the oldest, simplest, and quickest quantitative measure of water clarity. A Secchi disk is a black and white disk that is lowered down through the water column until it can no longer be seen. Secchi disk depth is the midpoint between the depth at which it disappears when lowered and reappears when it is pulled up again. The Secchi disk depth in lakes with high algal biomass will generally be shallow. However, Secchi disk depth is not only affected by algae. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly shallow Secchi disk depths despite low algal growth and nutrient concentrations.

The euphotic zone, calculated as twice the Secchi disk depth, is the portion of the water column that has sufficient light for aquatic plants to grow. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Aquatic plants are important because they ensure clear lake water by reducing shoreline erosion and stabilizing lake bottom sediments. Many lakes in Alberta are shallow and have bottom sediments with high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment-laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and fish, depend on aquatic plants for food and shelter.

## *Trophic state*

Trophic state is a classification system for lakes that depends on fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are: **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. 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. A majority of lakes in Alberta are meso- to eutrophic because they naturally contain high nutrient concentrations due to our deep fertile soils. Thus, lakes in Alberta are susceptible to human impacts because they are already nutrient-rich; any further nutrient increases can bring about undesirable conditions illustrated in Fig 2.

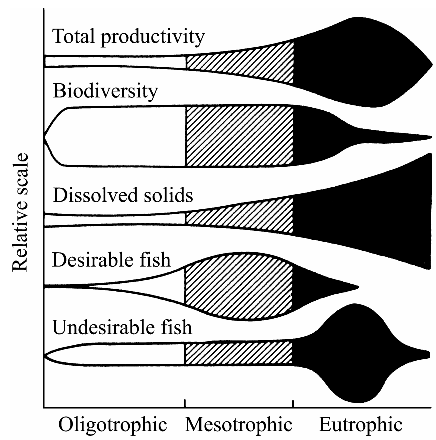


**Fig. 2**: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980

**Trophic status based on lake water characteristics.**

| Trophic state | Total Phosphorus (µg/L) | Total Nitrogen (µg/L) | Chlorophyll a (µg/L) | Secchi Depth (m) |
|---|---|---|---|---|
| Oligotrophic | < 10 | < 350 | < 3.5 | > 4 |
| Mesotrophic | 10 - 30 | 350 - 650 | 3.5 - 9 | 4 - 2 |
| Eutrophic | 30 - 100 | 650 - 1200 | 9 - 25 | 2 - 1 |
| Hypereutrophic | > 100 | > 1200 | > 25 | < 1 |

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