



*The Alberta Lake Management Society
Volunteer Lake monitoring report*

Lac Bellevue



2007 Report

Completed with support from:



Alberta Lake Management Society

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And you really live by the river? What a jolly life!"

"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." Kenneth Grahame The Wind in the Willows

"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water."

BBC World Water Crisis Homepage

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

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Lac Bellevue

Lac Bellevue is located south of St. Paul west of Highway 881 (**Figure 1**). The lake is approximately 4.6 km north of the North Saskatchewan River. Lac Bellevue is located in the low-aspen parkland ecosystem and is a mosaic of developed pastures and deciduous upland forests. The lake is also within the St. Paul Provincial Grazing Reserve.

Lac Bellevue has four camping-recreational facilities. Fishing is a popular pastime, and sport fish include walleye, pike, perch, and whitefish.

Lac Bellevue has a maximum width of ~3 km and perimeter ~ 9.7 km, as measured on a digital map (Tele Atlas 2008, **Figure 2**).

Results

Water Levels

Water levels in Lac Bellevue have been monitored since 1969. Peak water level occurred in July 1974 (646.9 meters above sea level (asl)). Water level elevation has steadily declined since 1974 (**Figure 3**). The lowest water level was recorded in October 2002 (elevation = 643.7 m asl). Changes in lake water levels may be an important concern for Lac Bellevue.



Figure 1. Lac Bellevue, Alberta. From Google Earth 2008.

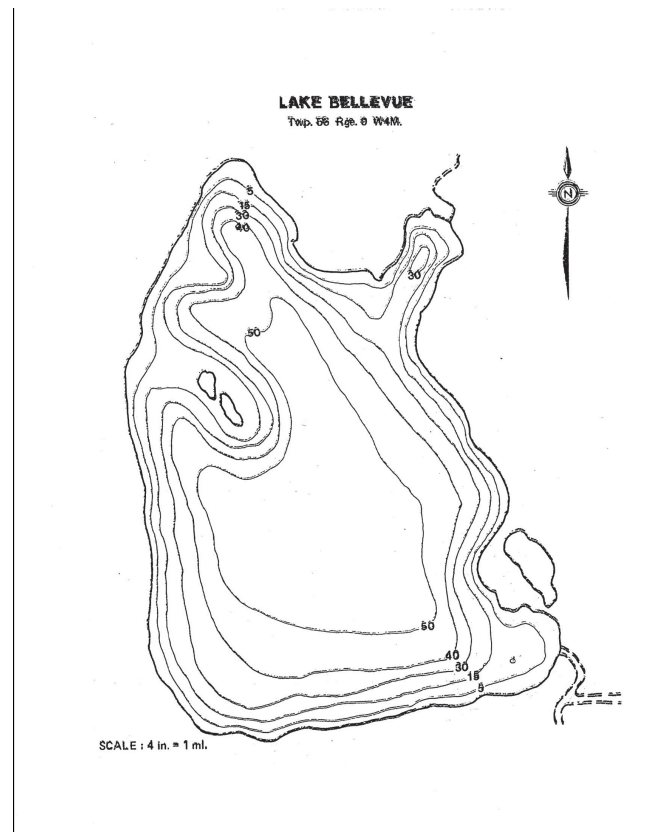


Figure 2. Bathymetry of Lac Bellevue, Alberta. From Angler's Atlas 2008.

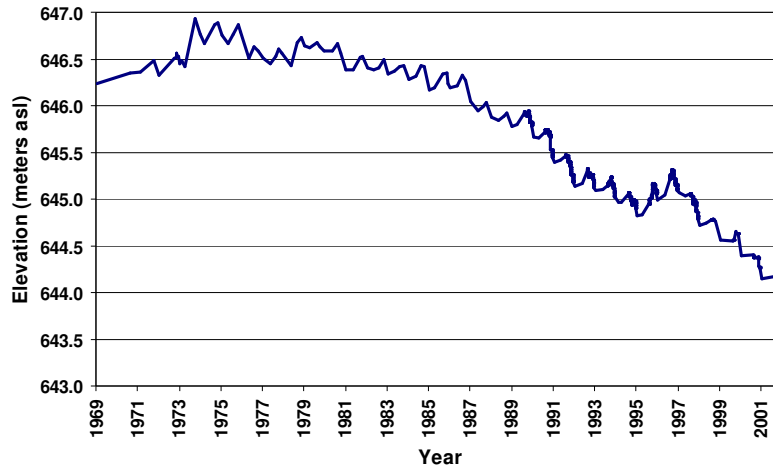


Figure 3. Lake water elevation (meters above sea level (asl)) in Lac Bellevue, Alberta, 1969-2002.

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.

Lac Bellevue mixed at least once during the summer as was evidenced by the lack of strong thermal stratification in summer 2007 (**Figure 4**). In June and early July, water temperature was similar at all depths. Surface waters warmed in mid-July and there was ~10° C difference between surface and bottom waters. Lac Bellevue mixed prior to 18 August, as evidenced by homogeneity of water temperature at all depths.

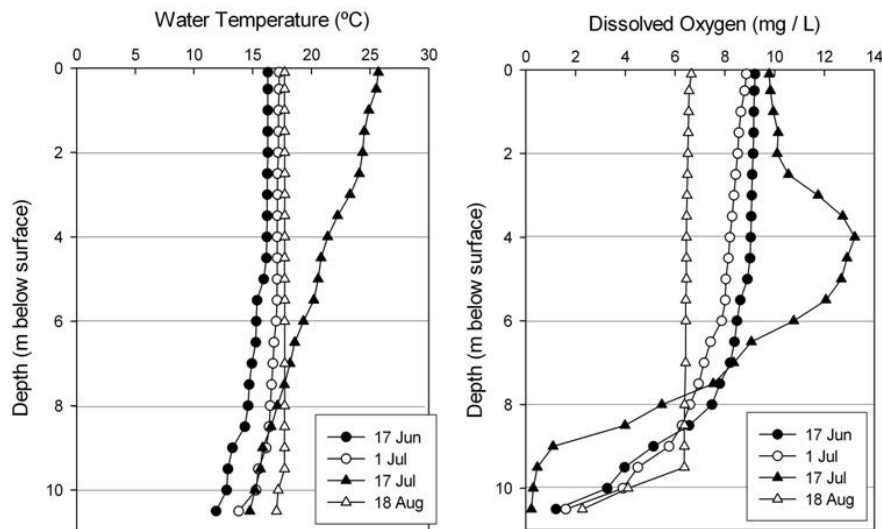


Figure 4. Water temperature (°C) and dissolved oxygen (mg /L) profiles for Lac Bellevue during the summer of 2007.

Surface waters in Lac Bellevue were well oxygenated during all sample dates (**Figure 4**). In June and early July, dissolved oxygen (DO) concentrations were nearly the same from 0 to 7 m depth. Below 7m, DO gradually declined and was <1 mg/L near the lake bed (e.g. approaching anoxic conditions). In mid-July, DO concentrations increased below 2 m with a peak at 4 m depth. This indicates phytoplankton activity between 2 and 6 m depth. In mid-August, DO concentrations declined to ~ 6.5 mg/L from the lake surface to 9.5 m depth. Below 9.5 m, DO declined rapidly to 2.3 mg/L at the lake bed.

The lack of anoxic conditions in mid-September suggest the lake recently mixed and decomposing material had not yet settled to the lake bed before the sample date. The oxygen levels in the surface layer were within the acceptable range for surface water quality, according to Alberta Environment guidelines ($DO \geq 5.0$ mg/L). The anoxic conditions near the lake bed reflect decomposition processes which consume oxygen.

Water Clarity and Secchi Depth

Water clarity is influenced by suspended materials, both living and dead, as well as some coloured dissolved compounds in the water column. 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.

Compared to shallower lakes, Lac Bellevue is relatively clear, with an average Secchi depth = 4.4 meters. In 2007, light penetrated to an average ~42% of the total lake depth (**Table 1**), thus algae were able to grow through nearly half of the water column. As algae grew throughout the summer, water clarity declined by 0.5 m over the late summer (Secchi disk depth (SDD) = 2.3m on 20 September). Water clarity peaked on 17 June (Secchi disk depth = 5 m), declined on 1 July (SDD = 4 m) and increased again on 17 July (SDD = 4.3 m). The pattern reflects the polymictic nature of Lac Bellevue. Mixing re-suspended particles in the water column, which reduces water clarity. The pattern also reflects changes in water clarity due to dense algal growth. Minimum water clarity corresponded to peak algal biomass in Lac Bellevue (**Figure 5**).

Water Chemistry

Based on lake water characteristics, Lac Bellevue is classified as mesotrophic (see *A Brief Introduction to Limnology* at end of this report). This was evidenced in 2007 by moderate concentrations of total phosphorus (average TP = 28.3 µg/L) and total Kjeldahl nitrogen (average TN = 1.1 mg/L) and moderate algal biomass (average chl *a* = 6.6 µg/L) (**Figure 5**).

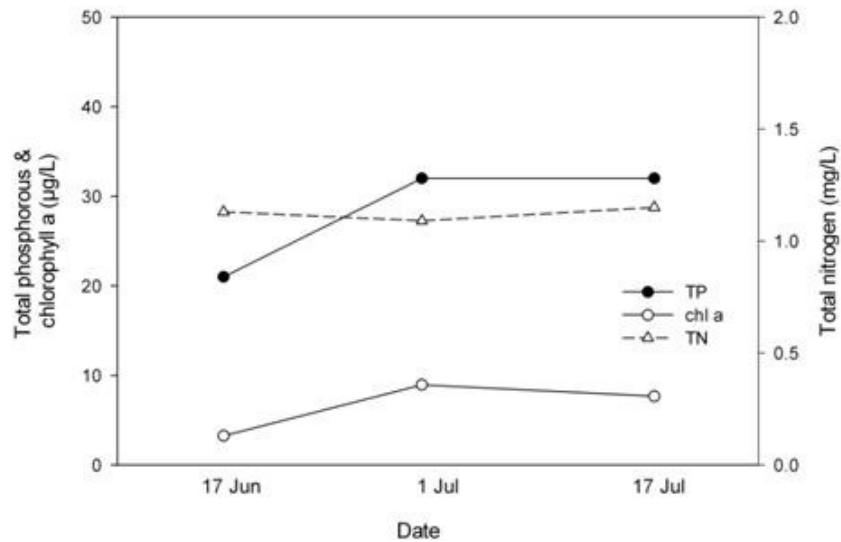


Figure 5. Total phosphorus, total nitrogen, and chlorophyll *a* (a measure of algae biomass) concentrations for Lac Bellevue during the summer of 2007.

Phosphorous concentrations peaked on 1 July, while nitrogen peaked in mid-July (**Figure 5**). As phosphorous increased, so did phytoplankton biomass, as measured by chlorophyll *a* concentration. Nutrient concentrations may be influenced by surrounding land-use activities, such as agriculture and recreation.

Lac Bellevue is well-buffered from acidification. In 2007, lake pH = 8.7 was well above that of pure water (i.e., pH 7). Dominant ions were bicarbonate, magnesium, and carbonate (**Table 1**). As no historical data were available for Lac Bellevue, it is difficult to detect changes in water chemistry.

The average concentrations of heavy metals were not measured in Lac Bellevue during 2007, except for iron. Iron (as total recoverable concentrations) was below CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

Table 1. Mean water chemistry in Lac Bellevue, Alberta from June and July 2007.

Parameter	2007
TP ($\mu\text{g/L}$)	28.3
TDP ($\mu\text{g/L}$)	13.3
Chlorophyll <i>a</i> ($\mu\text{g/L}$)	6.6
Secchi disk depth (m)	4.4
TN (mg/L)	1.1
NO ₂₊₃ ($\mu\text{g/L}$)	<0.09
NH ₄ ($\mu\text{g/L}$)	35
Dissolved organic C (mg/L)	13.4
Ca (mg/L)	23.5
Mg (mg/L)	58.7
Na (mg/L)	18.8
K (mg/L)	20.3
SO ₄ (mg/L)	7
Cl (mg/L)	2.2
CO ₃ (mg/L)	24
HCO ₃ (mg/L)	363
Total Alkalinity (mg/L CaCO ₃)	337
pH	8.7
Conductivity ($\mu\text{S/cm}$)	592
Total dissolved solids (mg/L)	-

Note: TP = total phosphorus, TDP = total dissolved phosphorus, Chla = chlorophyll *a*, TN= total Kjeldahl nitrogen, NO₂₊₃ = nitrate+nitrite, NH₄ = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO₄ = sulphate, Cl = chloride, CO₃ = carbonate, HCO₃ = bicarbonate.

From *Atlas of Alberta Lakes* (Mitchell and Prepas, 1990).

References

Angler's Atlas. 2008. Last accessed February 2008. <http://www.anglersatlas.com/>

Mitchell, P. and E. Prepas, eds. 1990. *Atlas of Alberta Lakes*. University of Alberta Press.

Tele Atlas. 2008. Google Earth. Last accessed March 2008. Width and perimeter measured using 'Path' tool.

Appendix 1

Mean concentrations of metals, Lac Bellevue 2007, compared to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals (total)	2007	Guidelines
ALUMINUM µg/L	-	100 ^a
ANTIMONY µg/L	-	6 ^e
ARSENIC µg/L	-	5
BARIUM µg/L	-	1000 ^e
BERYLLIUM µg/L	-	100 ^{d,f}
BISMUTH µg/L	-	
BORON µg/L	-	5000 ^{e,f}
CADMIUM µg/L	-	0.085 ^b
CHROMIUM µg/L	-	
COBALT µg/L	-	1000 ^f
COPPER µg/L	-	4 ^c
IRON µg/L	19.3	300
LEAD µg/L	-	7 ^c
LITHIUM µg/L	-	2500 ^g
MANGANESE µg/L	-	200 ^g
MOLYBDENUM µg/L	-	73 ^d
NICKEL µg/L	-	150 ^c
SELENIUM µg/L	-	1
SILVER µg/L	-	
STRONTIUM µg/L	-	
THALLIUM µg/L	-	0.8
THORIUM µg/L	-	
TIN µg/L	-	
TITANIUM µg/L	-	
URANIUM µg/L	-	100 ^e
VANADIUM µg/L	-	100 ^{f,g}
ZINC µg/L	-	30
FLUORIDE mg/L	-	1.5

With the exception of fluoride (which reflects the mean concentration of dissolved fluoride only), 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 CaCO₃).

^c Based on water Hardness > 180 mg/L (as CaCO₃).

^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

The goal of **Lakewatch** is to collect water samples necessary to determine the water quality of lakes. Though not all encompassing, the variables measured in **Lakewatch** are sensitive to human activities in watersheds that may cause impacts to 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 affected (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 fish habitat and production of noxious odors. Large increases in nutrients over time may also indicate sewage inputs, which in turn, may result in other human health concerns such as harmful bacteria or protozoans (e.g. *Cryptosporidium*).

Temperature and mixing

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 6). 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.

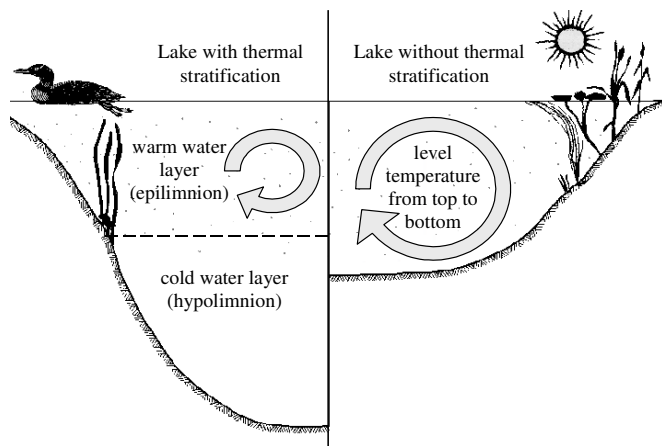


Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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 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. Larger aquatic plants, known as macrophytes, rather than algae, dominate some highly productive lakes. 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 exist 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-*a*) concentrations, the trophic states are: **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. The nutrient and algal biomass concentrations that define these categories are shown in table 2 and a graph 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 Figure 7.

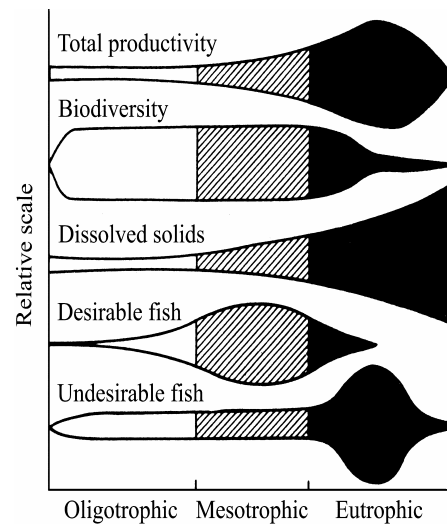


Figure 7: Suggested changes in various lake characteristics with eutrophication. From “Ecological Effects of Wastewater”, 1980.

Table 2: 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.