The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Muriel Lake

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2006 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

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Muriel Lake

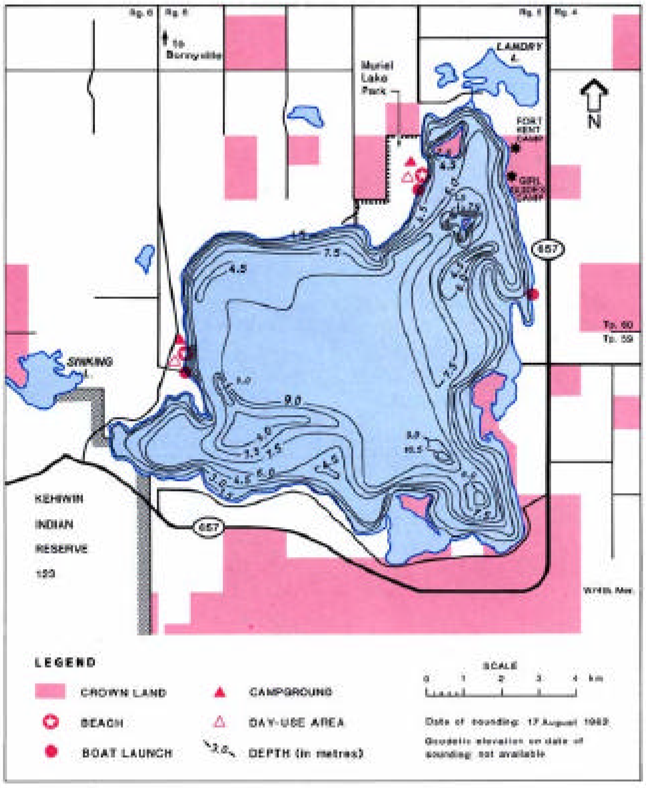


Figure 1: Bathymetry of Muriel Lake. From Mitchell and Prepas 1990.

Muriel Lake is located 13 km south of the town of Bonnyville and 250 km northeast of Edmonton. The first non-native establishment in the area was a fur-trading post in 1781 by the North West Company near the present-day hamlet of Beaver Crossing, about 35 km northeast of Muriel Lake. The first settlers came to the Bonnyville area in 1907, and established an economy based on the timber industry. Two sawmills were located at Muriel Lake, one at the northeastern tip and the other on the large island/peninsula on the eastern shore. In the 1920s, a large fire forced the economic base to switch to agriculture. There are several subdivisions (391 lots) around the lakeshore, mostly on the south and east sides of the lake. Much of the watershed is occupied by Kehiwin Indian Reserve 123, located on 8200 ha of land southwest of the lake. The largest recreational facility on Muriel Lake is Muriel Lake Park, which is operated by the Municipal District of Bonnyville. Muriel Lake is managed for domestic, sport and commercial fisheries. Northern pike, yellow perch, lake whitefish, and walleye are the sport fish found in the lake. Lake whitefish were stocked in 1937 (Alta. For. Ld. Wild. N.d.) and walleye are stocked periodically. The primary commercial species is lake whitefish, which consitutes about 95% of the total catch (Alta. Rec. Parks Wild. 1976).

Muriel Lake is a large (64.1 km^2) but relatively shallow (mean and maximum depth 6.6 and 10.7 m, respectively) water body. The shoreline consists primarily of steep rocky slopes, but there are also several attractive sandy beaches (Alta. Mun. Aff. 1979). Water levels have been monitored since the late 1960s and since then, have fluctuated by as much as 1.5 m. Muriel Lake is mesotrophic, with a moderate supply of nutrients and relatively low concentration of algae, and mixes periodically throughout the summer.

Phytoplankton succession during the summer goes from golden-brown algae (Dinobryon sp.) in May, to diatoms (Fragilaria crotonensis) and dinoflagellates (Ceratium hirundinella) in June, and diatoms (Fragilaria crotonensis), blue-green, and green algae (Closterium sp.) in late summer. Emergent aquatic vegetation is not abundant in most areas. As a result of its clear water (Secchi disk depth 2.2 m), aquatic plants can grow to a depth of 7 m in Muriel Lake and the littoral zone can cover almost 50% of the lake's area. Emergent vegetation is largely restricted to areas sheltered from the wind. The northwest shore, although somewhat protected, has no emergent stands because of its rocky or sandy substrate. The dominant emergent species in 1978 were common great bulrush (Scirpus validus), and common cattail (Typha latifolia) and sedges (Carex spp.) closer to shore. The dominant submergent species was large-sheath pondweed (Potamodeton vaginatus).

Water Level

Water levels are measured as the elevation in meters above sea level (m asl) of the surface of the lake. Water level in Muriel Lake has declined steadily since 1981 (**Figure 2**), at which time the maximum lake elevation was recorded, measuring 559.85 m asl. Water level has since declined by 3.5 m to it's current elevation of 556.2 m asll. This enormous decline is unprecedented for natural lakes in Alberta, even in the face of recent trends of declining lake levels observed across the Province. In many lakes the wet years of 1996 and 1997 resulted in peak water levels within the context of historical records (spanning the last 3 decades). These wet years barely registered at Muriel Lake. Over all, water level declines in Muriel Lake have been above-average. Measurements from the last few years may be cause for hope, as they appear to show lake levels remaining somewhat constant.

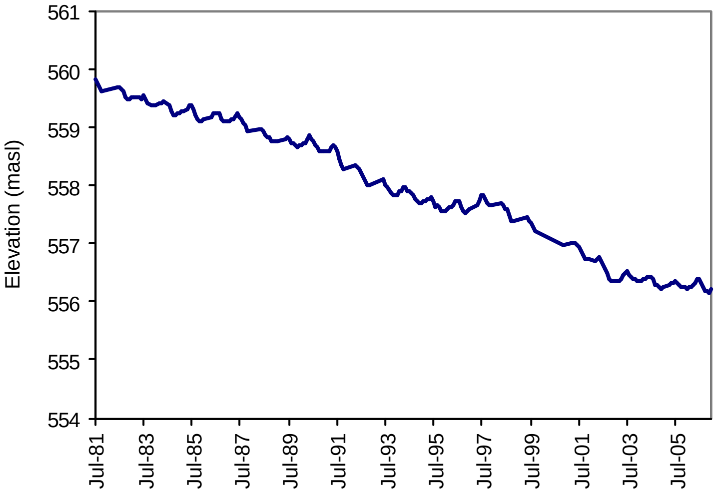
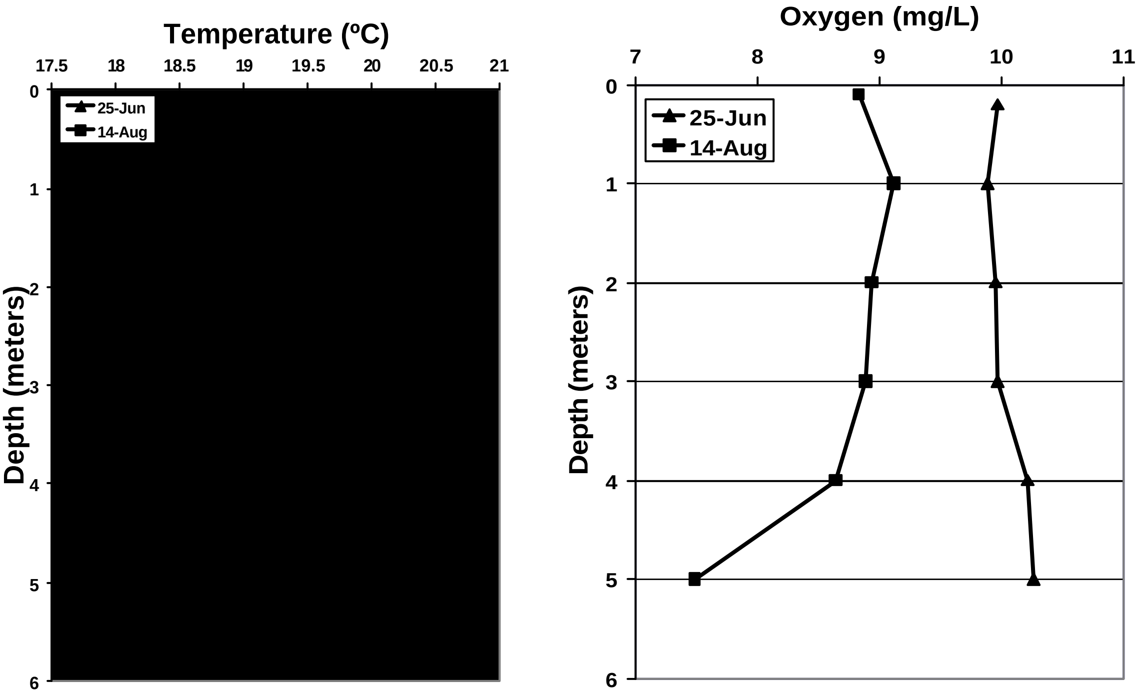


Figure 2: Historic water level for Muriel Lake, 1981 to 2006.

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.

Despite water temperatures exceeding 20 ?C in July, there was no record of thermal stratification in Muriel Lake during the 2006 summer months (**Figure 3**). Thus, the entire water column was well aerated and dissolved oxygen concentrations were well above 5 mg/L, the acute provincial protection of aquatic life guideline (**Figure 4**). Unfortunately, Muriel Lake was sampled on only two occasions during the summer of 2006.



Figures 3 & 4: Temperature and dissolved oxygen profiles for Muriel Lake, summer 2006.

Water clarity and Secchi Depth

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved coloured 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 biomass as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth.

In 2006, the water quality of Muriel Lake was classified as turbid, with a Secchi disk depth of 2 m by late June and of 1 m by mid-August. The decrease in water clarity was mirrored by the pattern of increase in algal biomass, or water greenness, during the summer of 2006 (**Figure 5**).

Water chemistry

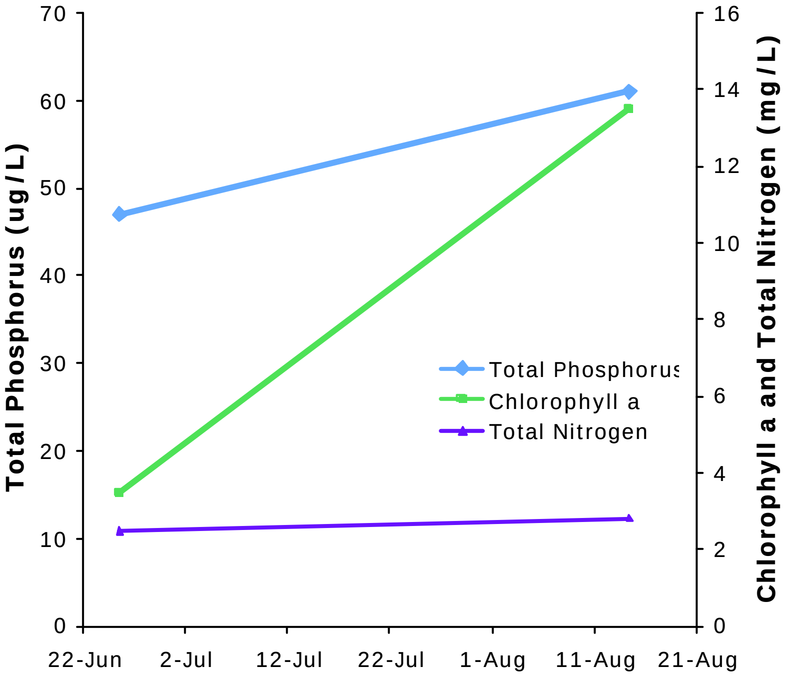


Figure 5: Total phosphorus, Chlorophyll *a* and Total Nitrogen for Muriel Lake, summer 2006.

Muriel Lake has high nutrient concentrations and algal biomass in comparison to other lakes in Canada, and as such, is considered to be a eutrophic lake (Refer to: *Trophic status based on lake water characteristics: A brief introduction to Limnology*). In the context of the province of Alberta, however, Muriel Lake is considered average in terms of lake productivity. In 2006, total phosphorus, total nitrogen, and consequently, algal biomass, all increased from July to August. The algal biomass increased nearly 4-fold during this time. The observed increase in both nutrient concentrations and algal productivity is a pattern typical of Albertan lakes and due in part to nutrient loading from the sediment. In general, metal concentrations were low and few surpassed provincial and federal Water Quality Guidelines for the Protection of Aquatic Life. Arsenic was one exception with a value of 8.5 µg/L in 2006, which is slightly higher than the guideline value of 5 µg/L and represents a 0.9 µg/L increase since 2003. These elevated arsenic values are likely due to naturally high arsenic levels in groundwater in the Cold Lake area. Arsenic is produced when pyrite in soils derived from marine shale is oxidized after exposure to oxygen. In general, the water quality of Muriel Lake is fair.

Muriel Lake is well buffered from acidification with a pH of 9.2, well above that of pure water (pH = 7). Bicarbonate, sulphate, sodium, carbonate, and magnesium are the dominant ions in Muriel Lake. The concentration of these ions increased over the last two decades, which is an indication that Muriel Lake is presently not at a hydrologic equilibrium. Since runoff has been quite low in the Cold Lake region during this same time period, evaporative concentration is likely responsible for the change in ion concentration. The water level chart (**Figure 2**) confirms this speculated reduction in surface water catchment discharge. In addition, groundwater, which is a significant contributor to the water budget of this lake, increases in flow during periods of drought and may thus explain observed trends in ion concentrations as it is typically elevated in magnesium, sodium, sulfate and/or chloride. Thus, an increase in groundwater flow will result in an increase in the concentration of these above-mentioned ions. Acidifying pollutants derived from atmospheric deposition are plausible sources of sulphate, causing the observed increase in this ion, and furthermore, increases in sodium chloride levels result from sewage effluent and road salt application. Interestingly, ions that are not by-products of petroleum burning or road salt application also doubled during this time, thereby indicating that these activities are likely not the sole factors at play. Despite these increases in ion concentrations, nutrients and algae have changed only slightly over the last two decades, which is impressive given the large decrease in water level of Muriel Lake. An important variable to consider in future surveys is the density of aquatic plants, which may also impact the eutrophication process of this lake.

Table1: Mean summer water quality in Muriel Lake.

Parameter	1988	1997	2001	2003	2003	2006
TP (?g/L)	36	42	62	48	48	54
TDP (?g/L)	12	16	29	18	18	21.5
Chl a (?g/L)	6.7	6.7	12	9.2	9.2	8.5
Secchi (m)	2.2	1.9	0.9	1.1	1.1	1.5
TKN (?g/L)	1532	1998	1826	2470	2470	2655
NO$_{2+3}$ (?g/L)	<2	3	6	2.5	2.5	<5
NH$_4$ (?g/L)	21	23	< 1	20	20	45
Ca (mg/L)	11	7.5	-	5	5	5.6
Mg (mg/L)	98	126	-	173	173	164
Na (mg/L)	118	160	-	238	238	245
K (mg/L)	21	30	-	39	39	40.6
SO$_4$ (mg/L)	116	154	-	239	239	257
Cl (mg/L)	17	23	-	34	34	35.7
HCO$_3$ (mg/L)	535	620	-	746	746	800
CO$_3$ (mg/L)	70	115	-	210	210	181
Total Alkalinity (mg/L CaCO$_3$)	556	696	-	961	961	957
Conductivity (? S/cm)	1143	1354	-	1908	1908	1925
pH	8.2-9.6	9.2	-	9.3	9.3	9.2

Note. TDP = total dissolved phosphorus, Chla = chlorophyll *a*, TKN = total kjehldahl nitrogen, NO$_{2+3}$ = nitrate+nitrite, NH$_4$ = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO$_4$ = sulphate, Cl = chloride, HCO$_3$ = bicarbonate, CO$_3$ = carbonate, Cond = conductivity, TDS = total dissolved solids.

Appendix 2

Metals (total)	2006	Guidelines
ALUMINUM ug/L	31.8	100[a]
ANTIMONY ug/L	0.183	6[e]
ARSENIC ug/L	8.54	5
BARIUM ug/L	5.13	1000[e]
BERYLLIUM ug/L	?0.003	100[d,f]
BISMUTH ug/L	0.0032	
BORON ug/L	290	5000[e,f]
CADMIUM ug/L	0.0088	0.085[b]
CHROMIUM ug/L	0.696	
COBALT ug/L	0.23	1000[f]
COPPER ug/L	1.87	4[c]
IRON ug/L	26.3	300
LEAD ug/L	0.0944	7[c]
LITHIUM ug/L	132	2500[g]
MANGANESE ug/L	4.26	200[g]
MOLYBDENUM ug/L	1.49	73[d]
NICKEL ug/L	0.206	150[c]
SELENIUM ug/L	1.41	1
STRONTIUM ug/L	11	
SILVER ug/L	0.0024	
THALLIUM ug/L	0.0098	0.8
THORIUM ug/L	0.0134	
TIN ug/L	?0.03	
TITANIUM ug/L	2.58	
URANIUM ug/L	1.44	100[e]
VANADIUM ug/L	0.597	100[f,g]
ZINC ug/L	2.46	30

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

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

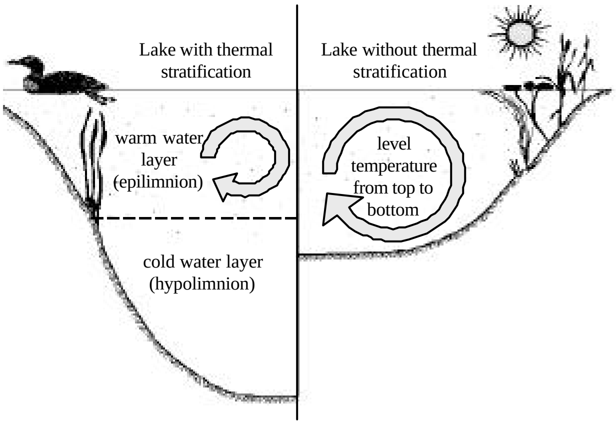

Figure 5 : Difference in the circulation of the water column depending on thermal stratification.

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality (Figure 5). 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. A third layer, known as the metalimnion, provides an effective barrier between the epi- and hypolimnion. The metalimnion reflects a rapid transition in water temperature known as the **thermocline**. A thermocline typically occurs when water temperature changes by several degrees within one-meter of depth. The thermocline acts as an effective physico-chemical barrier to mixing between the hypolimnion and epilimnion, restricts downward movement of elements, such as oxygen, from the surface 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.

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 state 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 terrestrial plants and plants and algae of tropical lakes, phosphorus is usually in shortest supply in temperate 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, reflect lower-nutrient trophic states than would otherwise result if macrophyte-based chlorophyll were 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 low. Secchi disk depth, however, is not only affected by algae, high concentrations of suspended sediments, particularly fine clays or glacial till common in plains or mountain reservoirs of Alberta, also impact water clarity. 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.

Figure 6: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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. 6.

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 and Kerekes (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.

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