Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Beaver Lake

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2004 Report

Completed with support from:

Alberta Lake Management Society
CW 315,
Biological Science Building,
University of Alberta,
Edmonton, Alberta T6G 2E9

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 its volunteers. Wendee Herrick from Lakeland County Office was the primary volunteer for Beaver Lake and made sampling possible through the dedication of her time and of course watercraft. Our summer field technician and volunteer coordinator, Heather Jones, was a valuable addition and contributor to this year's program. Numerous Alberta Environment staff also contributed to successful completion of the 2004 program. Project Technical Coordinator, Shelley Manchur 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. Heather Jones and Ron Zurawell (Limnologist, AENV) prepared this report. Al Sosiak (Limnologist, AENV) provided critical review of the draft report and insight information contained in this report. Alberta Environment and Lakeland County financially supported the Lakewatch program.

Beaver Lake

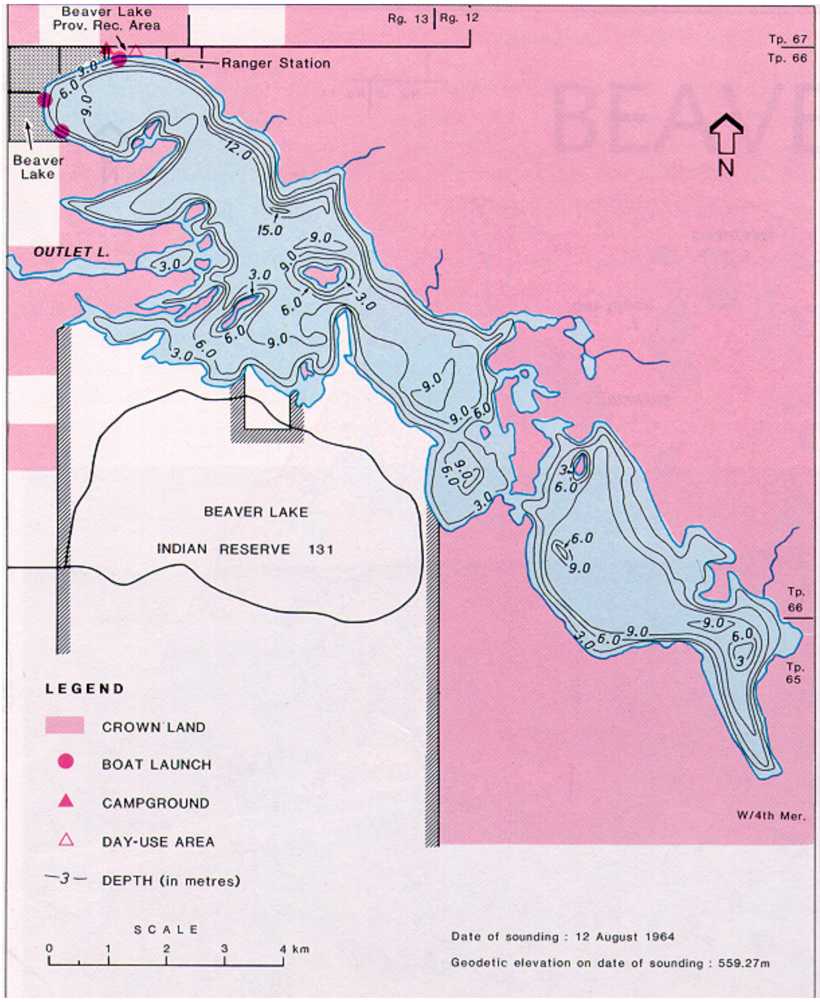

Figure 1: Depth contours (3 m intervals) and shoreline features of Beaver Lake (Mitchell and Prepas 1990)

Beaver Lake is a large lake located near the Town of Lac La Biche (east on secondary highway 663 from highway 36). Beaver lake lies within the Lakeland region, which is rich in history including various missions, hunting, trapping, and both European and Native settlements. In 1919 a settler named Max Huppie purchased a large tract of land on the northwest corner of Beaver Lake, an area that, today, supports a provincial campground, a forest firefighter base camp and one large residential sub-divison. Beaver Lake is popular for fishing. Nine species of fish have been reported in Beaver Lake including: northern pike (*Esox lucius)*, walleye (*Stizostedion viteum)*, yellow perch (*Perca flavescens)*, lake whitefish (*Coregonus clupeaformis)*, burbot (*Lota lota)*, white sucker (*Catostomus commersoni)*, brook stickleback (*Culaea inconstans)*, Iowa darter (*Etheostoma exile*) and spottail shiner (*Notopis hudsonius*).

Beaver Lake is a large body of water with a surface area of 33km^2 (Figure 1). It consists of two large basins linked by a shallow, narrow channel, with a northwest to southeast orientation. Depth is generally 6 to 9 meters in both basins, with a narrow trough reaching 15 meters in depth on the northeast side of the north basin. Access to the south basin is limited to boats with very shallow draft or times of higher water. Beaver Lake contains several islands, the number of which varies with the water level. Both basins slope quite steeply to their greatest depth; the bottom of each basin is quite flat, except in the vicinity of the islands.

The area of Beaver Lake's watershed is 9 times larger than that of the lake itself. The terrain surrounding Beaver Lake is gently rolling and heavily forested. Trembling aspen

(*Populus tremuloides*) is dominant in areas with well-drained soils while trembling aspen and balsam poplar (*Populus balsamifera*) co-dominate in less well-drained areas. Jack pine (*Pinus banksiana*) grows on well-drained ridges near wetlands and black spruce (*Picea mariana*) and tamarac (*Larix laricina*) grow on poorly drained organic soils. Soil in the drainage basin is most commonly Orthic Gray Luvisol of a clay or loamy type.

Water Levels

Water levels in Beaver Lake have been monitored by Environment Canada since 1972 under the joint Federal-Provincial Hydrometric agreement. Water levels were quite stable during the 1970s and reached a maximum of 559.4 m in August 1975 (Figure 2). Since then, water levels have declined steadily, except for an increase in 1997, one of the wettest years on record. The lowest water level occurred in October 2002 when it dropped to 556.7 m. Compared to 30 years ago, the surface area of Beaver Lake has been reduced by approximately 4 km^2.

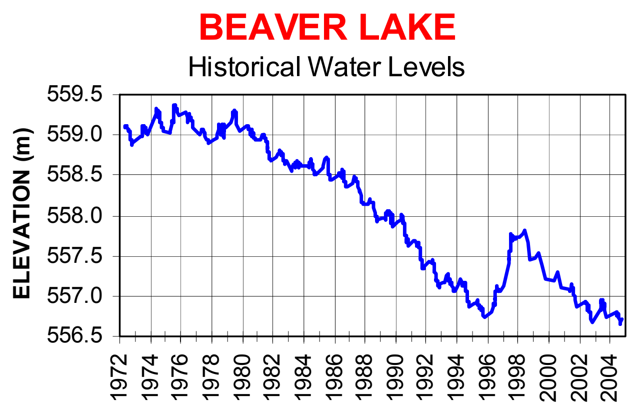

Figure 2. Historical water levels of Beaver Lake

Results

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.

Weak thermal stratification formed in early and mid-summer in Beaver Lake (Figure 3). In mid-July, the lake weakly stratified at a depth of about 3 meters as evidenced by the temperature drop of about 2^oC. Dissolved oxygen concentrations, which were uniform from top to bottom of the lake during periods of mixing dropped rapidly below the thermocline (i.e. depth of greatest water temperature and density change) in mid-July. This reflects both the depletion of oxygen via bacterial decomposition at the lake bottom and the inability of atmospheric oxygen to enter deeper waters below the thermocline. Despite this, the water column of Beaver Lake remained well aerated.

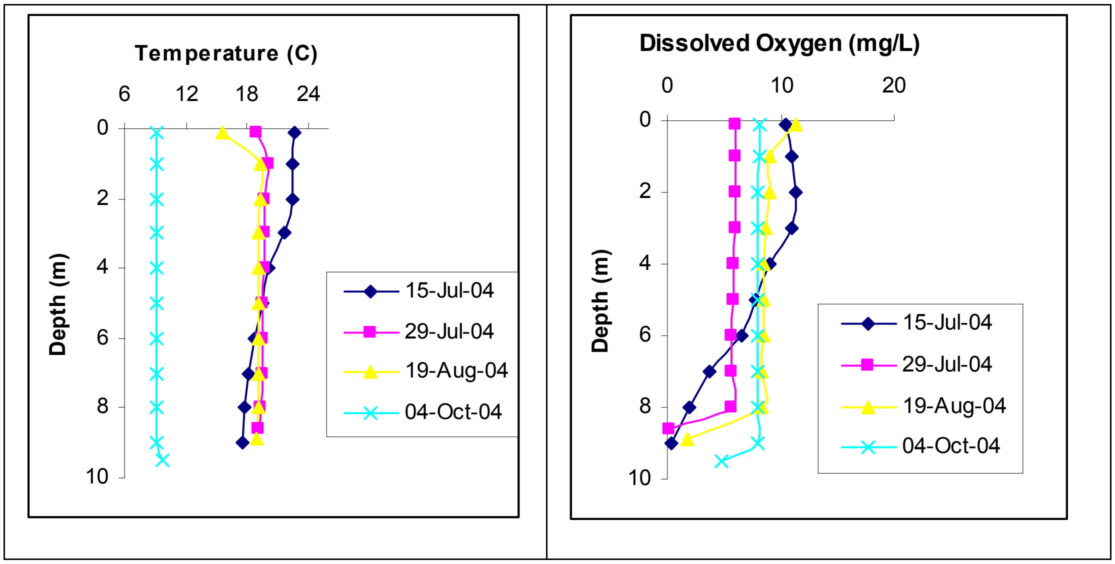

Figure 3. Temperature and dissolved oxygen concentrations with depth in Beaver Lake, summer 2004

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 2004, Beaver Lake's water was reasonably clear with an average Secchi disk depth of 1.8 m. Water clarity followed patterns in water greenness, or the chlorophyll *a* concentration (Figure 4). Water clarity was lowest in early July (Secchi 1.10 m) and was highest in early October (Secchi 3.25 m).

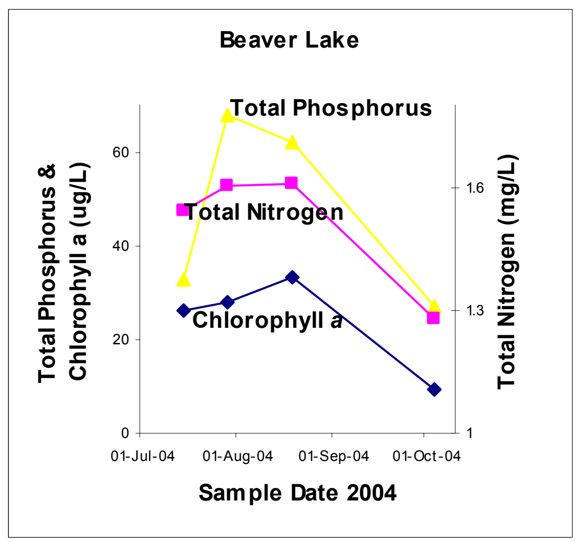

Figure 4: Total phosphorus, total nitrogen and chlorophyll-*a* (amount of algae) concentrations, summer 2004

Water chemistry

Beaver Lake contained high nutrient concentrations and algal biomass compared to lakes throughout Canada, and is considered eutrophic (*see details on trophic status classification at end of this report*). In the Alberta context, Beaver Lake is about average in these characteristics. In 2004, total phosphorus, total nitrogen and consequently, algal biomass, all increased from early July to late August (Figure 4). Algal biomass increased 10-fold during this time. Beaver Lake follows the typical pattern in Alberta lakes of an increase in nutrient and algae over the summer due to the release of nutrient from underlying sediments. Nutrients (i.e., total N and P) and water greenness appear to have increased over the past two decades, while water clarity decreased. Further sampling of Beaver Lake is required to determine if this apparent increase is due to year-to-year variation or a long-term trend in water quality (Table 1).

Beaver Lake is well protected from acidification; its pH of 8.5 is well above that of pure water (i.e., pH 7). Bicarbonate, sulphate, calcium, and magnesium are the dominant ions in Beaver Lake. The moderate increase in ion concentrations observed in Beaver Lake over the past two decades, especially sulfate and chloride, are likely related to changing hydrology and an increase in the relative contribution of groundwater, as groundwater is generally magnesium and sodium sulfate or chloride dominated. In general, lakes in the Cold Lake/Lac La Biche area have shown a significant increase in salinity and ion concentrations likely due to reduced runoff. The sufficient volume of Beaver Lake seems to have buffered the climate-induced increase in ion content that was experienced by other lakes of the area.

In general, metal concentrations were low and none surpassed provincial and federal Water Quality Guidelines for the protection of Aquatic Life (Appendix 1).

Table 1: Mean values from summer 2004 samples compared to values reported previously.

Parameter	1986*	2003	2004
TP (μg/L)	33	47	56
TDP (μg/L)	12	17	13
Chla (μg/L)	11	18	24
Secchi (m)	2.9	2.4	1.8
TKN (μg/L)	1137	1358	1510
NO_{2+3} (μg/L)	5.6	17	13
NH_4 (μg/L)	3.0	2.8	3.1
Ca (mg/L)	35	31	32
Mg (mg/L)	23	31	30
Na (mg/L)	13	13	21
K (mg/L)	10	10	14
SO_4 (mg/L)	29	42	62
Cl (mg/L)	0.5	1.6	2.3
HCO_3 (mg/L)	222	222	239
CO_3 (mg/L)	6.3	15	10
Total Alkalinity (mg/L $CaCO_3$)	191	206	205
Conductivity (μS/cm)	409	492	499
pH	8.5	8.7	8.5

Note: TP = total phosphorus, TDP = total dissolved phosphorus, Chla = chlorophyll *a*, 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.
*Atlas of Alberta Lakes (Mitchell and Prepas, 1990).

References

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

Appendix 1

Mean concentrations of metals, Beaver Lake, 2004 compared to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals	2004	Guidelines
ALUMINUM ug/L	10.7	100[a]
ANTIMONY ug/L	0.068	6[e]
ARSENIC ug/L	1.47	5
BARIUM ug/L	57.1	1000[e]
BERYLLIUM ug/L	<0.003	100[d,f]
BISMUTH ug/L	<0.001	
BORON ug/L	79.6	5000[e,f]
CADMIUM ug/L	<0.002	0.085[b]
CHROMIUM ug/L	0.14	
COBALT ug/L	0.019	1000[f]
COPPER ug/L	0.42	4[c]
IRON ug/L	8	300
LEAD ug/L	0.0278	7[c]
LITHIUM ug/L	32.3	2500[g]
MANGANESE ug/L	138	200[g]
MOLYBDENUM ug/L	0.169	73[d]
NICKEL ug/L	<0.005	150[c]
SELENIUM ug/L	<0.1	1
SILVER ug/L	<0.0005	0.1
STRONTIUM ug/L	231	
THALLIUM ug/L	0.0007	0.8
THORIUM ug/L	0.0071	
TIN ug/L	0.036	
TITANIUM ug/L	1.07	
URANIUM ug/L	0.162	100[e]
VANADIUM ug/L	0.285	100[f,g]
ZINC ug/L	4.85	30
FLUORIDE mg/L	0.2	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 $CaCO_3$).

[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

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

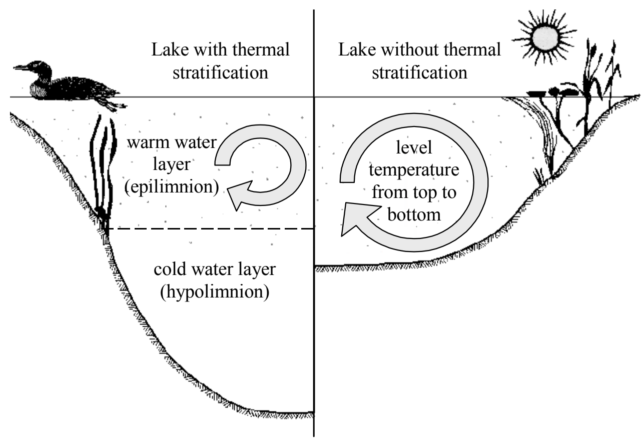

Figure 5: Difference in the circulation of the water column depending on thermal stratification.

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.

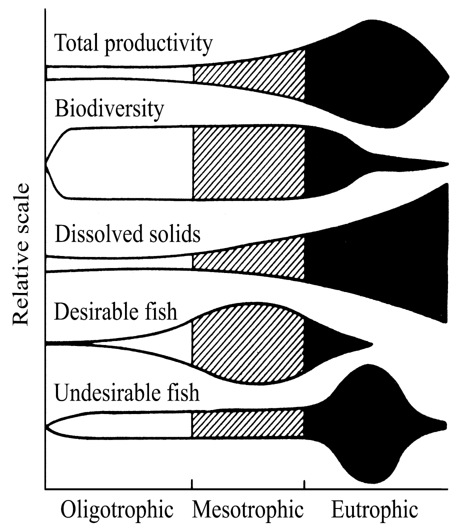

Figure 6: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.

References

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