Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Kehewin Lake

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2005 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 its volunteers. Ed and Ken Dion were our volunteers at Kehewin Lake and made sampling possible through the dedication of their time and of course watercraft. Our summer field technician and volunteer coordinator, Vien Lam, was a valuable addition and contributor to this year's program. Numerous Alberta Environment staff also contributed to successful completion of the 2005 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, Théo Charette and Lori Neufeld prepared this report. The Lakewatch program was financially supported by Alberta Environment and Lakeland Industry and Community Association (LICA).

Kehewin

Kehewin Lake is a beautiful long narrow lake, located on Highway 41 north of Elk Point (**Figure 1**).

The lake is surrounded by rolling pasture, and hay lands, the Kehewin Indian Reserve is to the north of the lake. Kehewin Lake has two recreational facilities: one located on the southeast shore just off highway 41, and the other located on the southwest shore.

Figure 1. Kehewin Lake at sunset. Courtesy of heather jones ALMS Tech. 2004.

Alternate spellings for Kehewin Lake are found in various literature. Official documents and spellings even differ on the two highway signs for the lake. *"Kehew*" is a Cree word meaning eagle, indicating that "Kehewin" is likely the most appropriate spelling (Dion 2002, Personal Communication). Kehewin is actually named after an Indian chief, who in 1876, signed treaty No.6 for the Kehewin Indian Reserve No.123 (Mitchell and Prepas, 1990). The Kehewin Indian Reserve is 8212.2 ha with 863 residents of 1,581 members in October 2002 (INAC, 2002). Kehewin Indian Reserve is in the county of Bonnyville, while most of Kehewin Lake resides in the County of St. Paul. Kehewin Lake is a long narrow lake that is very shallow in the north and south portions (**Figure 2**). The lake is situated within the Beaver River drainage basin, which is the westernmost part of the Churchill River System. Specifically, it lies in the Moose Lake watershed. The outflow of the lake drains into Bangs Lake to the north via Kehewin Creek, it then joins with Yelling Creek and flows to Thin Lake, which finally, drains into Moose Lake via Thin Lake River. Agriculture in Kehewin's drainage basin is limited to pasture and hay fields. The drainage basin overlies geological formations that are rich in heavy oils; therefore oil extraction is common in the region.

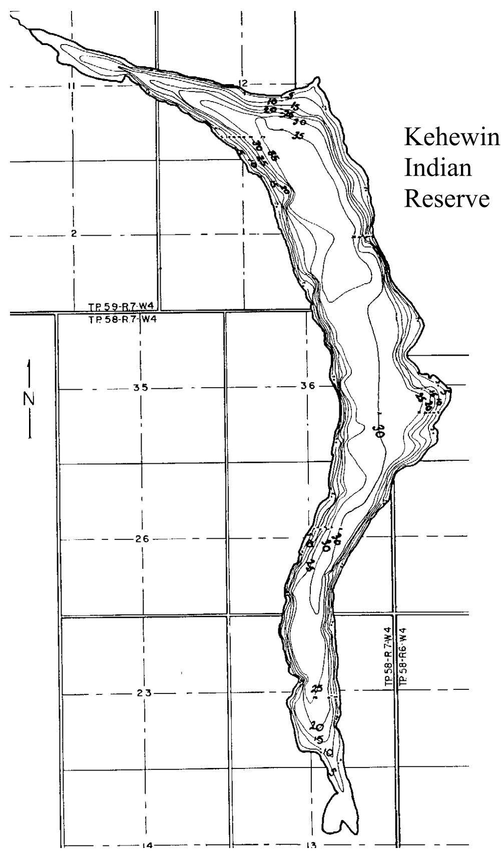

Figure 2. Bathymetry of Kehewin Lake. Each depth contour represents 5 feet.

Kehewin Lake is long and narrow (**Figure 2**.) and lies in a large melt-water channel predominated by glacial till and alluvial deposits. (Mitchell, and Prepas 1990). It is surrounded by rough broken land with steep slopes. The rocky shoreline is dominated by aspen (*Populus spp*.) Extensive marshes on the north and south ends of the lake provide excellent habitat for waterfowl.

Marsh vegetation includes Reed Grass (*Calamagrostis spp.*), Bulrush (*Scirpus spp.*), Sedge (*Carex spp.*), Cattail (*Typha latifolia*) and Arrowhead (*Sagittaria cuneata*). Common submergent and floating aquatic plants include Water Smartweed (*Polygonum natans*), Coontail (*Ceratophyllum demersum*), Richardson's Pondweed (*Potamogeton richardsonii*), Northern Watermilfoil (*Myriophyllun exalbescens*), Sago Pondweed (*Potamogeton pectinatus*), Large Sheath Pondweed (*Potamogeton vaginatus*), Duckweed (*Lemna spp.*) (Wilcox ASRD, 2002). Little is known about the phytoplankton composition, a detailed survey has not been completed, but a dense algal (blue-green) bloom occurred in the summer of 2004 (Heather Jones, personal communication). As a popular sport fishing lake, Kehewin is noted for its large northern pike (*Esox lucius*) (AENV, 1983). Also present, are yellow perch (*perca flavescens*), walleye (*Stizostedion vitreum*), cisco (*Coregonus artedii*), burbot (*Lota lota*), and white suckers (*Catostomus commersoni*) (Wilcox, ASRD, 2002). Commercial and domestic fishing has been active in the last decade (Bodden, ASRD 2002). Commercial fishing has been recorded as far back as 1945 (AENV, 1983).

Results

Water Levels

Water levels in Kehewin Lake have been monitored since 1967. In 2005, the average elevation (539.56 meters above sea level) was a little higher than the 1967-2004 average (539.46 m). Levels increased almost 0.5 meter from 2004 to 2005. In general, Kehewin Lake has maintained stable water levels; minimum water level was 839 m, above sea level in 1993 and reached a maximum of 540.5 m above sea level in 1997, a difference of only 1.5 m over thirty-five years. Kehewin Lake receives a steady inflow of water because its drainage basin is very large (156 km^2) as compared to its surface area

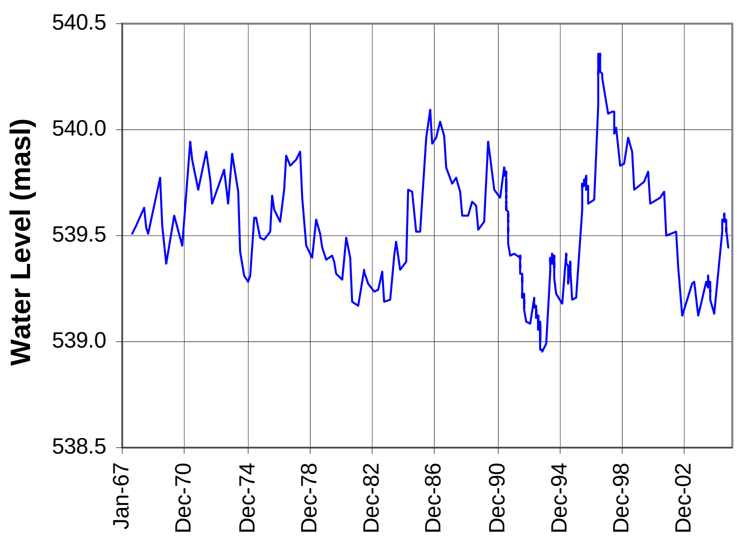

Figure 3. Historical water levels for Kehewin Lake (1967 to 2006).

(7.4 km^2). Thus, unlike other lakes in Alberta, decreasing water levels is not a major problem in Kehewin Lake.

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.

Kehewin Lake's water column mixes intermittently throughout the summer – it is polymictic. A very weak thermal stratification was apparent at 6 meters in mid July (**Figure 4**). Because oxygen-laden water did not travel below 6 meters, a sharp decrease in oxygen concentration also occurred at this depth (**Figure 5**). In productive lakes, such as Kehewin, oxygen is consumed during decomposition at the lake bottom. This is the reason oxygen concentrations were near zero at the deepest depth during all sampling events. Temperatures peaked just above 20 degrees Celsius during the warmest part of the summer, in mid-July. Oxygen was typically lower at this time, likely since oxygen is less soluble in water as temperatures increase.

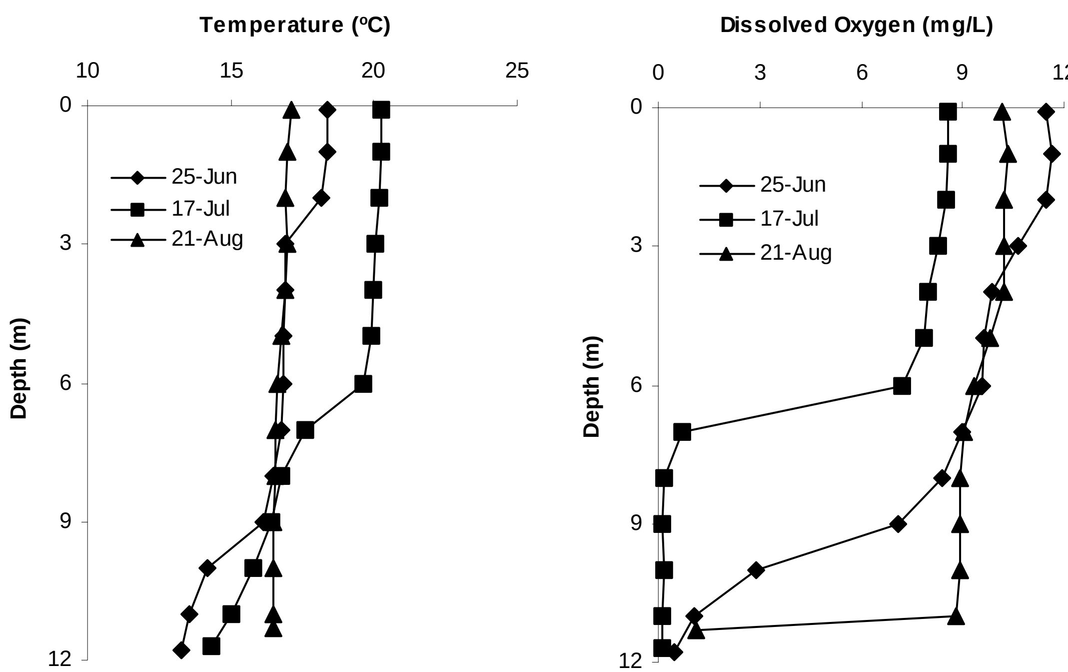

Figure 4 & 5: Temperature and dissolved oxygen profiles for Kehewin Lake, summer 2005.

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.

Kehewin Lake's water was fairly turbid during the summer of 2005: Secchi disk depth averaged less than two meters. Secchi disk depth hovered around 1.8 meters in June and July and then increased slightly in August to 2.2 meters, which means that water clarity was highest in late summer, similar to 2004 (see 2004 report). Water clarity in Kehewin Lake is stable over the past 4 years and does not show any patterns over time (**Table 1**).

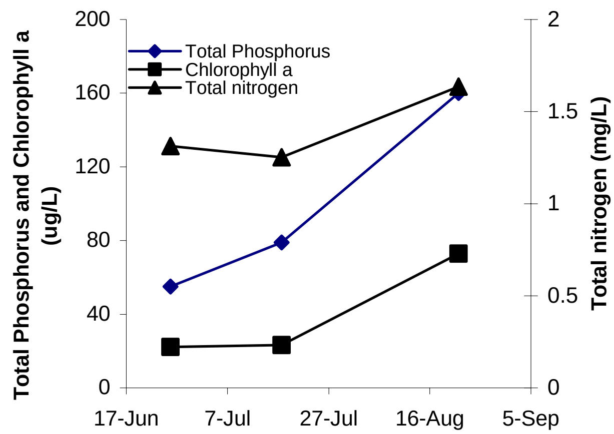

Figure 6. Total phosphorus, total nitrogen and chlorophyll *a* (i.e., water greenness) concentrations, summer 2004.

Water Chemistry

Kehewin Lake had very high nutrient concentrations and algal biomass compared to lakes throughout Canada; it is considered hyper-eutrophic (see details on trophic status classification at end of this report). In the Alberta context, Kehewin Lake is more fertile than a typical lake. In 2005, algal biomass (measured as chlorophyll *a*), and nitrogen and phosphorus concentrations increased over the summer (**Figure 6**). Total Phosphorus and Total Nitrogen peaked in August, and it was during this period that Kehewin Lake experienced a high increase in algal biomass. This pattern of increase in algal biomass and nutrients from spring to late summer is typical for Alberta lakes and indicates release of nutrients from the lake bottom due to decomposition.

Kehewin Lake is well-buffered from acidification: its pH of 8.8 (**Appendix 1**) is well above that of pure water (i.e., pH 7). Its dominant ion is bicarbonate, corresponding to the alkaline nature of the runoff and groundwater in the area. Nutrient concentrations decreased slightly in 2005, which may be the result of the increase in water levels and freshwater input into the lake.

The average concentrations of various heavy metals (as total recoverable concentrations) were below CCME guidelines for the Protection of Freshwater

Aquatic Life. Results of the metal analyses, compared to guideline values, are listed in **Appendix 2**.

Access to historic data from Kehewin Lake was very limited when preparing this report. Therefore, we cannot comment on changes in water chemistry over the long-term. However, Kehewin Lake water quality did not vary much between the last four years.

Appendix 1

Table 1: Historical chemical characteristics of Kehewin Lake. Values are summer averages, except for February sampling event in Winter 2004.

Parameter	2002	2003	Winter 04	2004	2005
Total P (μg/L)	106	105	36	123	98
TDP (μg/L)	65	62	31	67	33
Chlorophyll *a* (μg/L)	30	49	1.3	45	40
Secchi disk depth (m)	2.1	1.9	-	1.9	1.9
Total N (mg/L)	1.4	1.4	1.3	1.5	1.4
NO_{2+3} (μg/L)	20	19	270	35	14
NH_4 (μg/L)	149	69	67	65	15
Ca (mg/L)	25	26	29	24	26
Mg (mg/L)	29	29	33	25	30
Na (mg/L)	32	35	39	36	35
K (mg/L)	14	12	14	12	13
SO_4 (mg/L)	20	27	33	28	26
Cl (mg/L)	16	16	18	17	17
CO_3 (mg/L)	6.2	14	6.7	14	17
HCO_3 (mg/L)	189	245	284	238	234
Total Alkalinity (mg/L $CaCO_3$)	165	224	243	218	220
pH	8.5	8.7	8.4	8.7	8.8

Note. TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = carbonate.

Appendix 2

Mean concentrations of metals, Kehewin Lake, 2003 and 2004 compared to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals (total)	2003	2004	2005	Guidelines
ALUMINUM ug/L	24	13	8.8	100[a]
ANTIMONY ug/L	0.072	0.1	0.105	6[e]
ARSENIC ug/L	2.1	2.0	1.84	5
BARIUM ug/L	54	56	58	1000[e]
BERYLLIUM ug/L	0.037	0.0015	0.0015	100[d,f]
BISMUTH ug/L	0.0037	0.0005	0.054	
BORON ug/L	84	87	81	5000[e,f]
CADMIUM ug/L	0.02	0.0016	0.0043	0.085[b]
CHROMIUM ug/L	0.18	0.25	0.21	
COBALT ug/L	0.04	0.037	0.040	1000[f]
COPPER ug/L	0.43	0.52	0.47	4[c]
IRON ug/L	27	7.7	3.4	300
LEAD ug/L	0.11	0.042	0.354	7[c]
LITHIUM ug/L	26	29	26	2500[g]
MANGANESE ug/L	30	26	32	200[g]
MOLYBDENUM ug/L	0.8	0.83	0.82	73[d]
NICKEL ug/L	0.15	0.16	0.18	150[c]
SELENIUM ug/L	0.42	0.05	0.20	1
STRONTIUM ug/L	229	235	226	
THALLIUM ug/L	0.093	0.001	0.022	0.8
THORIUM ug/L	0.012	0.004	0.060	
TIN ug/L	0.05	0.026	0.015	
TITANIUM ug/L	1.23	1.33	0.98	
URANIUM ug/L	0.57	0.6	0.64	100[e]
VANADIUM ug/L	0.66	0.56	0.40	100[f,g]
ZINC ug/L	2.0	11.8	2.8	30
FLUORIDE mg/L	-	0.20	0.25	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 $\geq$ 6.5; calcium ion concentration [Ca^{+2}] $\geq$ 4 mg/L; and dissolved organic carbon concentration [DOC] $\geq$ 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

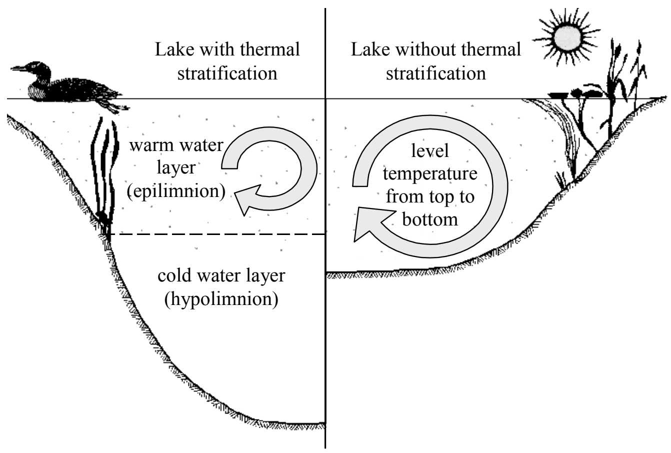

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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

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.

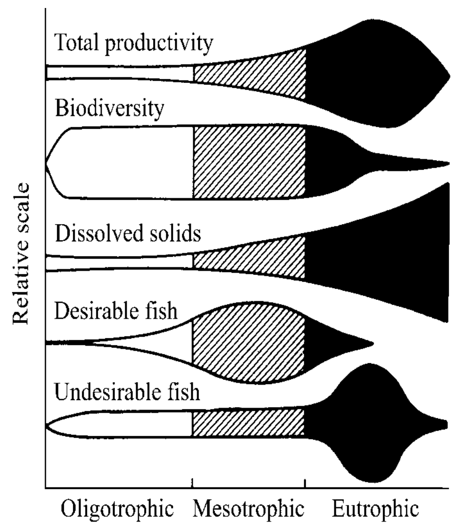

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.