The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Kehewin Lake

2009 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 data 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 and Lakewatch Chairs, Al Sosiak and Ron Zurawell. We would like to thank Ken Dion for his efforts in collecting data during 2009. We would also like to thank Noemie Jenni and Cristen Symes who were summer interns with ALMS in 2009. Project Technical Coordinator, Jill Anderson was instrumental in planning and organizing the field program. Technologists, Shelley Manchur, Mike Bilyk, Brian Jackson and John Willis were involved in the logistics planning and training aspects of the program. Doreen LeClair and Chris Rickard were responsible for data management. Théo Charette (ALMS President) and Jill Anderson (Program Manager) were responsible for program administration and planning. Théo Charette, Ron Zurawell (Limnologist, AENV), and Lori Nuefeld prepared the original report, which was updated by Sarah Lord for 2009. Alberta Environment and the Beaver River Watershed Alliance (BRWA) were major sponsors of the Lakewatch program.

Kehewin Lake

Kehewin Lake is a beautiful long lake, located on Highway 41 north of Elk Point (**Figure 1**). The lake is surrounded by rolling pasture and hay lands. 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, Alberta at sunset. Courtesy of Heather Jones, 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, suggesting that "Kehewin" is likely the most appropriate spelling (K. Dion 2002, personal communication). Kehewin Lake is named after the Indian chief who signed treaty No.6 for the Kehewin Indian Reserve No.123 in 1876 (Mitchell and Prepas, 1990). The Kehewin Indian Reserve is 8212.2 ha to the north of the lake, with 863 residents of 1,581 members in October 2002. The reserve is in the county of Bonnyville, but most of lake is within the County of St. Paul.

Kehewin Lake is very shallow in the north and south portions (**Figure 2**). The lake is situated within the Beaver River drainage basin, which is in the Moose Lake watershed in the westernmost part of the Churchill River system. The outflow of Kehewin Lake drains into Bangs Lake to the north via Kehewin Creek, then joins with Yelling Creek and flows to Thin Lake, finally draining into Moose Lake via Thin Lake

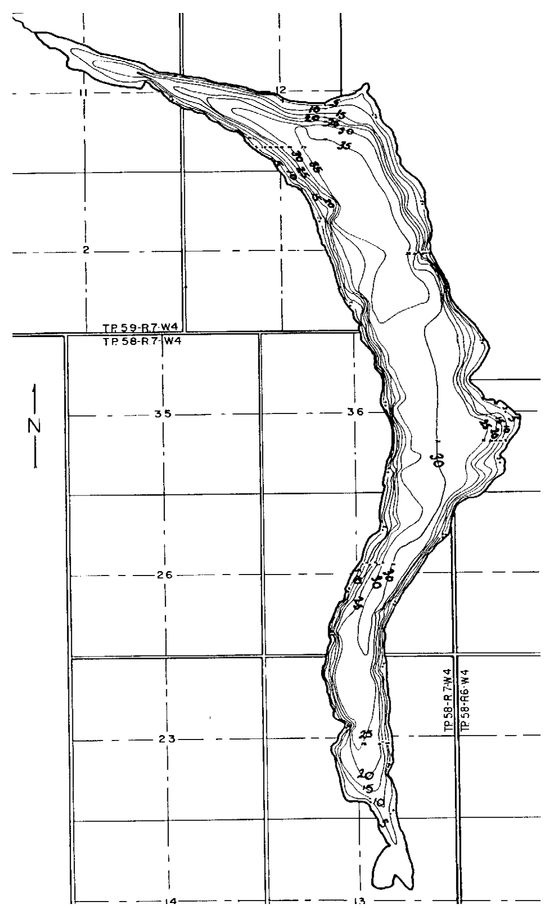

Figure 2. Bathymetry of Kehewin Lake, Alberta. Contours represent 5 feet depth intervals.

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, and oil extraction is common in the region. Kehewin Lake 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 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 submerged 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*), and duckweed (*Lemna* spp.) (Mitchell and Prepas 1990). Little is known about the phytoplankton composition, but dense blue-green algal blooms have occurred in the past (H. Jones 2004, personal communication).

As a popular sport fishing lake, Kehewin is noted for its large northern pike. Also present are yellow perch, walleye, cisco, burbot, and white suckers. Commercial and domestic fishing has been active in the last decade, and commercial fishing has been recorded as far back as 1945 (Mitchell and Prepas 1990).

Results

Water Level

Water levels in Kehewin Lake have been monitored since 1967 and have fluctuated around 539.5 m asl in the past forty years (**Figure 3**). Minimum water level was 538.9 m asl in 1993, and maximum water level was 540.4 m asl in 1997. Kehewin Lake receives a steady inflow of water because its drainage basin is very large (156 km^2) as compared to its surface area (7.4 km^2). Declining water levels are not a 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.

Temperature and dissolved oxygen profiles were taken on Kehewin Lake twice during the summer of 2009. On 24 June, surface water temperature was 19.4ºC, and declined to 13.1ºC at the lakebed. By 25 July, surface waters had warmed to 23.8ºC, and bottom waters had warmed to 17.0ºC. Kehewin Lake mixes intermittently throughout the summer (e.g. is polymictic), as shown by the lack of thermal stratification (**Figure 4**).

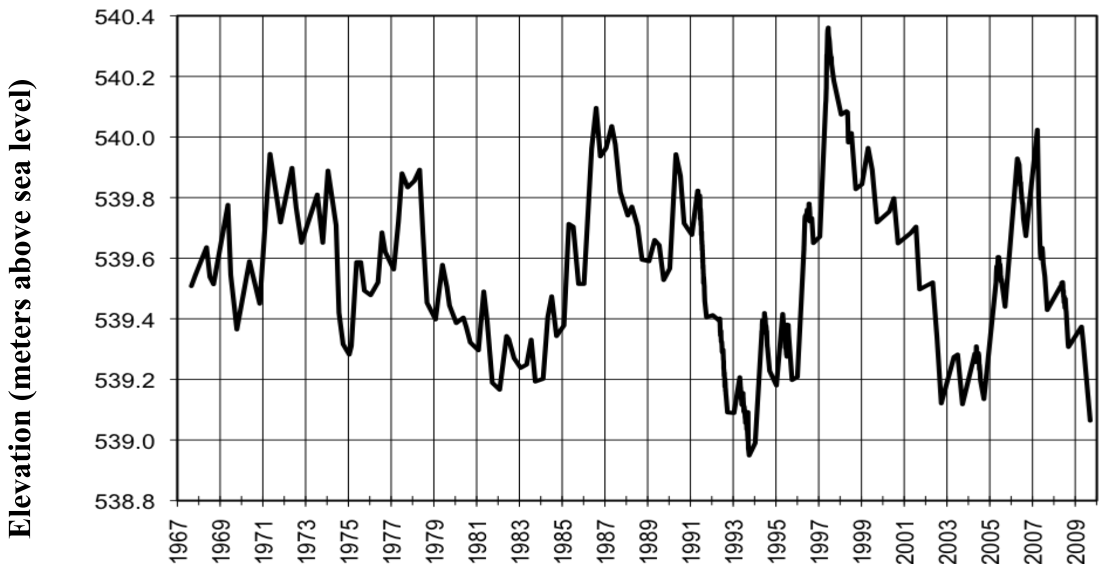

Figure 3. Historical water levels (m asl) for Kehewin Lake, Alberta, 1967 – 2009.

On both sampling dates, the dissolved oxygen levels in surface layers of Kehewin Lake were >10 mg/L, well within the acceptable range for surface water quality according to Alberta Environment guidelines (DO ≥ 5.0 mg/L). Dissolved oxygen (DO) levels declined from 11.39 mg/L at the surface to near-zero (e.g. anoxic) at the lakebed on 24 June (**Figure 4**). On 25 July, surface water remained well-oxygenated, with a more rapid decline in DO concentration at 8 m depth. Deep-water anoxia is common during the summer, as bacterial decomposition of organic matter at the lakebed consumes oxygen.

Water Clarity and Secchi Depth

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

Because Kehewin Lake mixes frequently, the water tends to be turbid (e.g. murky). Average Secchi depth was 1.13 m during the summer of 2009. That year, light penetrated to an average of ~11% of the total lake depth, which allowed algal growth in the top 2.25 m of the water column (**Table 1**). Secchi depth decreased from 1.25 m on 24 June to 1.0 m on 25 July. As there were only two sampling dates on Kehewin Lake in 2009, seasonal patterns in water clarity cannot be discussed.

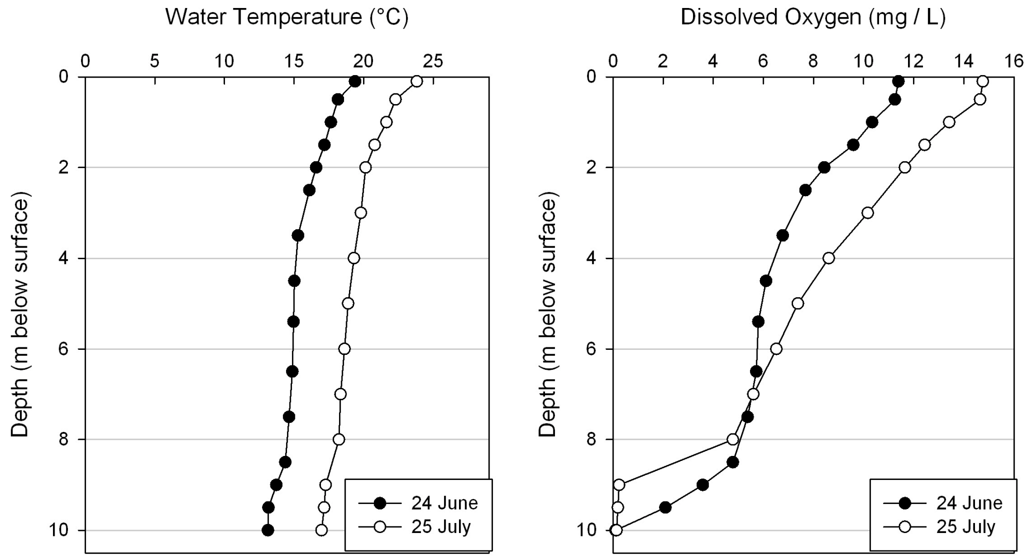

Figure 4. Water temperature (°C) and dissolved oxygen (mg/L) profiles for Kehewin Lake during the summer of 2009.

Water Chemistry

Based on lake water characteristics, Kehewin Lake is classified as hypereutrophic (see *A Brief Introduction to Limnology* at end of this report). In 2009, Kehewin Lake had high concentrations of total phosphorus (average TP = 130 μg/L), total nitrogen (average TN = 1.805 mg/L), and algal biomass (average chlorophyll *a* = 32.9 μg/L) (**Figure 5**). Lake water chemistry was measured only twice during the summer due to logistical constraints. Phosphorous and nitrogen concentrations both increased from 24 June to 25 July, reaching 174 μg/L and 2.225 mg/L respectively (**Figure 5**). Chlorophyll *a* (a measure of algal biomass) was measured only once during the summer, so it is not possible to describe the temporal patterns of algal growth over the summer.

Kehewin Lake is well-buffered from acidification. In 2009, lake pH = 8.9 was well above that of pure water (i.e., pH 7). Dominant ions include bicarbonate, sodium, and calcium, which correspond to the alkaline nature of runoff and groundwater in the area (**Table 1**). The average concentrations of metals (as total recoverable concentrations) were measured once during the summer of 2009, and all values were below CCME guidelines for the Protection of Freshwater Aquatic Life (**Appendix 1**).

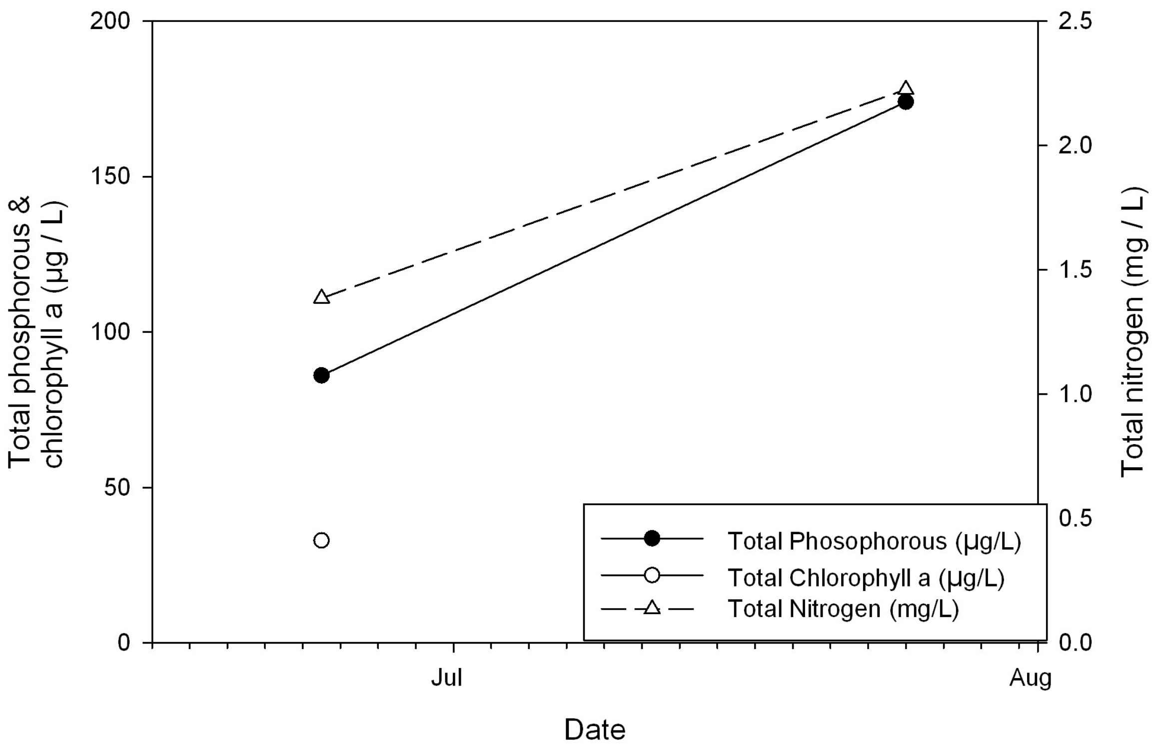

Figure 5. Total phosphorous, chlorophyll *a* (a measure of algal biomass), and total nitrogen concentrations for Kehewin Lake during the summer of 2009.

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Table 1. Mean water chemistry characteristics in Kehewin Lake summer 2009, compared to values reported in previous years. Data were collected in summer months, except for 2004, in which data were collected in February (**W**).

Parameter	2002	2003	2004 (W)	2004	2005	2007	2008	2009
TP (µg/L)	106	105	36	123	98	170.8	162.3	130.0
TDP (µg/L)	65	62	31	67	33	116.3	126.7	52.5
Chlorophyll *a* (µg/L)	30	49	1.3	45	40	50.7	19.58	32.9
Secchi depth (m)	2.1	1.9	-	1.9	1.9	1.1	2.9	1.13
TN (mg/L)	1.4	1.4	1.3	1.5	1.4	1.9	1.6	1.8
NO_{2+3} (µg/L)	20	19	270	35	14	101	19	5.0
NH_4 (µg/L)	149	69	67	65	15	89	261	23.5
Dissolved organic C (mg/L)	-	-	-	-	-	13.6	13.9	13.9
Ca (mg/L)	25	26	29	24	26	24.2	25.2	25.3
Mg (mg/L)	29	29	33	25	30	28.3	26.8	29
Na (mg/L)	32	35	39	36	35	36.2	34.1	35.4
K (mg/L)	14	12	14	12	13	13.1	13.5	11.9
SO_4 (mg/L)	20	27	33	28	26	22.7	26	17
Cl (mg/L)	16	16	18	17	17	18.9	19.2	19.7
CO_3 (mg/L)	6.2	14	6.7	14	17	14	20	21
HCO_3 (mg/L)	189	245	284	238	234	226.3	228.5	228
Total Alkalinity (mg/L $CaCO_3$)	165	224	243	218	220	209	221	222
pH	8.5	8.7	8.4	8.7	8.8	8.7	8.9	8.93
Conductivity (µS/cm)	-	-	-	-	-	481	499	485
Total dissolved solids (mg/L)	-	-	-	-	-	269.3	277.5	272

Note: TP = total phosphorus, TDP = total dissolved phosphorus, Chla = chlorophyll *a*, TN= total Kjeldahl nitrogen, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulphate, Cl = chloride, CO_3 = carbonate, HCO_3 = bicarbonate.

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

Appendix 1

Mean concentrations of metals in Kehewin Lake, 2009, compared to previous years and to CCME Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated).

Metals (total)	2003	2004	2005	2007	2008	2009	Guidelines
ALUMINUM µg/L	24	13	8.8	23.4	12.3	13.2	100[a]
ANTIMONY µg/L	0.072	0.1	0.105	0.09	0.088	0.092	6[e]
ARSENIC µg/L	2.1	2.0	1.84	2.17	2.5	2.84	5
BARIUM µg/L	54	56	58	50.9	51.7	52.3	1000[e]
BERYLLIUM µg/L	0.037	0.0015	0.0015	<0.003	<0.003	<0.003	100[d,f]
BISMUTH µg/L	0.0037	0.0005	0.054	0.002	<0.001	0.0273	
BORON µg/L	84	87	81	79	89	88	5000[e,f]
CADMIUM µg/L	0.02	0.0016	0.0043	0.017	0.0071	0.0137	0.085[b]
CHROMIUM µg/L	0.18	0.25	0.21	0.244	0.324	0.261	
COBALT µg/L	0.04	0.037	0.040	0.056	0.0379	0.0525	1000[f]
COPPER µg/L	0.43	0.52	0.47	1.31	0.675	0.439	4[c]
IRON µg/L	27	7.7	3.4	19.2	10.55	9.3	300
LEAD µg/L	0.11	0.042	0.354	0.07	0.0467	0.0708	7[c]
LITHIUM µg/L	26	29	26	26.5	27.3	29.3	2500[g]
MANGANESE µg/L	30	26	32	23.9	25.6	32.5	200[g]
MOLYBDENUM µg/L	0.8	0.83	0.82	0.77	0.748	0.767	73[d]
NICKEL µg/L	0.15	0.16	0.18	0.27	0.373	0.182	150[c]
SELENIUM µg/L	0.42	0.05	0.20	0.35	0.183	0.214	1
SILVER µg/L	-	-	-	0.005	<0.0005	0.00115	
STRONTIUM µg/L	229	235	226	214	208	222	
THALLIUM µg/L	0.093	0.001	0.022	0.002	0.0005	0.0131	0.8
THORIUM µg/L	0.012	0.004	0.060	0.005	0.0014	0.0033	
TIN µg/L	0.05	0.026	0.015	<0.03	<0.03	0.0358	
TITANIUM µg/L	1.23	1.33	0.98	1.8	0.878	1.42	
URANIUM µg/L	0.57	0.6	0.64	0.56	0.617	0.678	100[e]
VANADIUM µg/L	0.66	0.56	0.40	0.45	0.426	0.458	100[f,g]
ZINC µg/L	2.0	11.8	2.8	1.03	0.646	0.148	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 ≥ 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

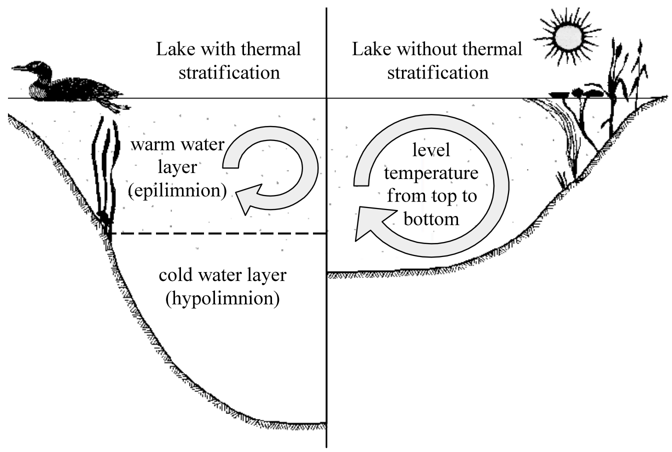

Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

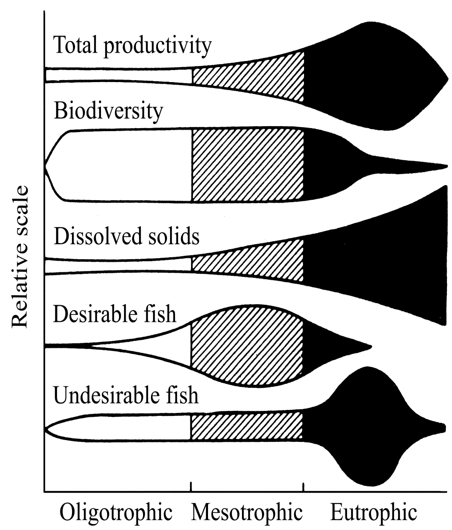

Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.