Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

Frog Lake

. . . .

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 Lakewatch Chairs, Théo Charette, Preston McEachern and Ron Zurawell, and the volunteers. Herb Lehr was the primary contact for Frog Lake. The Frog Lake Fire Department supplied the watercraft and Leon Cardinal made sampling possible through the dedication of his time. 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. Theo Charette (ALMS Director) was responsible for program administration and planning. Heather Jones and Ron Zurawell (Limnologist, AENV) prepared this report. The Lakewatch program was financially supported by Alberta Environment, Lakeland Industry and Community Association (LICA) and Lakeland County.

Frog Lake

Frog Lake Reserve, adjacent to the Whitney Lakes Provincial Park, is where the Frog Lake Massacre occurred on April 2, 1885 (Alberta Recreation, Parks and Wildlife Foundation 1992). After the North West Rebellion, as tensions calmed, settlers began arriving to farm. Frog Lake is a very large (surface area 58 km^2) and deep (maximum depth 28 m) lake located about 200 km east of the city of Edmonton, in the Eastern North Saskatchewan River Basin. Frog Lake has 4 distinct islands (**Figure 1**) that are protected bird sanctuaries, which host nesting sites for one of the largest cormorant colonies in Alberta. Pelicans, various cranes, bald eagles, ducks, geese, and a whole host of other birds make Frog Lake their home. Frog Lake is one of the few lakes in Alberta that remains natural, with a diverse setting of jack pine (*Pinus banksiana*), aspen (*Populus spp.*) groves, willow (*Salix spp.*) thickets, marshes, fens and mixed wood forests. Only a few anglers or campers enjoy the beauty of this lake. Frog Lake is a very important source of subsistence fisheries as it is almost completely surrounded by Indian reserves and Metis settlements. The Puskiakiwenin Indian Reserve 122 and Unipouheos Indian reserve 121 occupy the western shore of Frog Lake, whereas the Fishing Lake Metis Settlement occupies most of the eastern shore (**Figure**

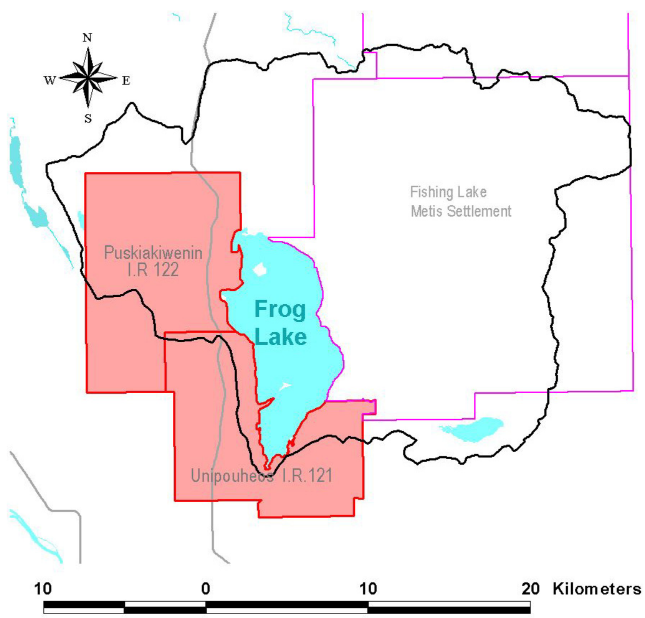


Figure 2. Frog Lake Watershed

2).

Frog Lake's watershed is quite large (613 km^2) and about 10 times larger than the lake surface. The majority of the land cover in the watershed is natural (86% of watershed area), and only about 14% of the watershed has been cleared. The land cover in Frog Lake's watershed has remained relatively unchanged over the past 15 years (Ducks Unlimited, unpublished 1986 and 1998 data).

Results

Water Levels

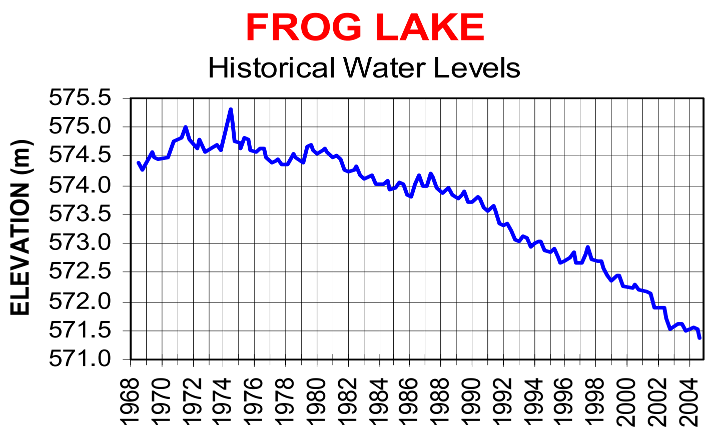


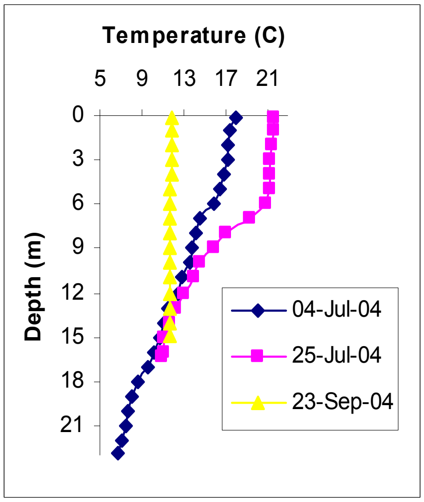
Figure 3. Historical water levels for Frog Lake.

Water levels in Frog Lake have been monitored since 1968 where water levels were at 574.3 m above sea level. An increase continued until 1971, and then began to fall until 1974. Levels peeked in 1975 to 575.3 m above sea level. Since that time, the lake has shown continual decrease in water levels (**Figure 3**). Water levels were lowest in 2004 at 571.4 m above sea level; this is a 3.9 m decrease from 1975 (the highest recorded level). Continued drought conditions in the area are a direct cause for the continued decrease in water levels of Frog 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.

A very weak thermal stratification was apparent at 7 m in early July. A stronger Thermal stratification occurred the later part of July (**Figure 4**). Consequently, a decrease in oxygen concentration also occurred at this depth (**Figure 5**). Fall turnover was observed in late September (**Figure 4**), where the temperature remained constant from the top to bottom of the lake sample area. In each sampling event dissolved oxygen decreased gradually with depth, with anoxic conditions observed near the bottom sediment.



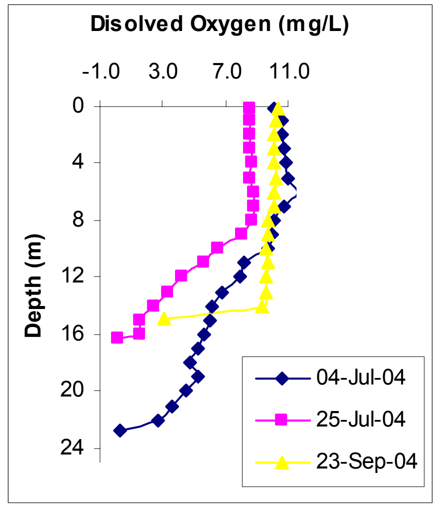


Figure 4 & 5. Temperature and dissolved oxygen profiles for Frog Lake, summer 2004.

Water Clarity and Secchi Depth

Suspended materials, both living and dead, as well as some coloured dissolved compounds in the water column influence water clarity. 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.

Frog Lake's water was clear during the three sample dates of 2004: Secchi disk depth averaged 3.58 m. Water clarity was lowest at the end of September, at 2.25 m. Clarity was highest in late July at 4.5 m. Average Secchi reading for 2004 was higher than in 2003 (**Table 1**).

Water Chemistry

Frog Lake had high nutrient concentrations in the early part of July; chlorophyll *a* concentrations were not available at this time (**Figure 6**). In the Alberta context, Frog Lake is considered mesotrophic (See "A brief introduction to Limnology" at the end of this report). In 2004, algal biomass (measured as chlorophyll *a*), nitrogen and phosphorus concentrations decreased in late July, which corresponds with water clarity at the same sample date. An increase in algal

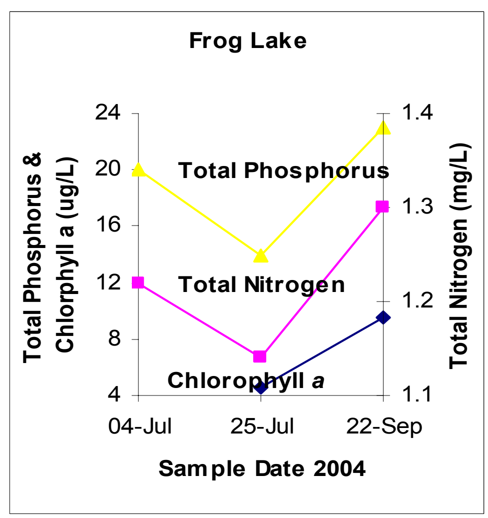


Figure 6. Total phosphorus, total nitrogen and chlorophyll *a* (i.e., water greenness) concentrations, summer 2004.

Table 1. Average chemical characteristics of Frog Lake

Parameter	May 1976	June 1978	March 1986	2003	Feb 2004	2004
Total P (µg/L)	-	-	12	18	-	26
TDP (µg/L)	-	-	-	7.3	-	11
Chla (µg/L)	-	-	-	6.1	-	7.1
Secchi (m)	-	-	-	2.8	-	3.6
Total N (mg/L)	-	-	9.2	1.2	1.3	1.2
NO_{2+3} (µg/L)	29	2	41	23	71	5.3
NH_4 (µg/L)	-	-	29	26	156	22
Ca (mg/L)	-	25	25	18	18	17
Mg (mg/L)	36	43	51	64	66	60
Na (mg/L)	41	73	55	75	87	78
K (mg/L)	12	12	14	17	18	17
SO_4 (mg/L)	48	73	67	91	100	90
Cl (mg/L)	7	28	7	11	11	11
CO_3 (mg/L)	-	11	14	35	25	35
HCO_3 (mg/L)	-	377	360	386	444	388
TDS (mg/L)	347	413	410	500	-	
Conductivity	540	574	691	-	902	834
pH	8.7	8.6	8.7	8.9	8.7	8.9
Total Alkalinity (mg/L $CaCO_3$)	276	266	319	375	405	377

Jote. TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 = mmonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, O_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = carbonate

biomass and nutrients increased in late September (**Figure 6**), this relates to the fall turnover (temperatures constant from top to bottom of the water column, causing a complete mixing of the nutrients) experienced at this time.

Frog Lake is well-buffered from acidification: its pH of 8.89 (**Table 1**) is well above that of pure water (i.e., pH 7). Its dominant ion is bicarbonate, corresponding to the alkaline nature of the groundwater in the area. Total Phosphorus and Total Dissolved Phosphorus increased slightly in 2004, as did the algal biomass (measured as chlorophyll *a*) compared with average readings for 2003. All other chemical measurements remained constant with average readings from 2003 (**Table 1**). Winter chemistry of Frog Lake reflects under-ice decomposition of organic materials. That is, the concentration of dissolved nutrients was high.

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 1.

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

Appendix 1

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

Metals (total)	2003	2004	Guidelines
ALUMINUM ug/L	6.81	20.7	100[a]
ANTIMONY ug/L	0.08	0.123	6[e]
ARSENIC ug/L	1.89	1.78	5
BARIUM ug/L	15.27	14.8	1000[e]
BERYLLIUM ug/L	0.02	0.002	100[d,f]
BISMUTH ug/L	0.0043	0.0005	
BORON ug/L	152	143	5000[e,f]
CADMIUM ug/L	0.03	0.004	0.085[b]
CHROMIUM ug/L	0.206	0.27	
COBALT ug/L	0.025	0.03	1000[f]
COPPER ug/L	0.489	1.15	4[c]
IRON ug/L	1.5	8.0	300
LEAD ug/L	0.151	0.19	7[c]
LITHIUM ug/L	40.17	46.7	2500[g]
MANGANESE ug/L	6.2	4.37	200[g]
MOLYBDENUM ug/L	0.264	0.278	73[d]
NICKEL ug/L	0.03	0.0025	150[c]
SELENIUM ug/L	0.25	0.32	1
SILVER ug/L	0.0025	0.0011	0.1
STRONTIUM ug/L	106	98.3	
THALLIUM ug/L	0.018	0.0006	0.8
THORIUM ug/L	0.005	0.0042	
TIN ug/L	0.07	0.015	
TITANIUM ug/L	1.0	0.45	
URANIUM ug/L	0.287	0.305	100[e]
VANADIUM ug/L	0.513	0.329	100[f,g]
ZINC ug/L	1.14	1.59	30
FLUORIDE mg/L		0.255	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

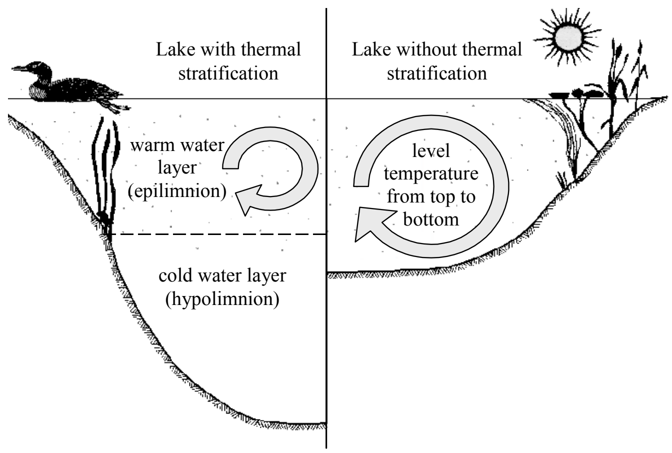


Figure 6: Difference in the circulation of the water column depending on thermal stratification.

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.

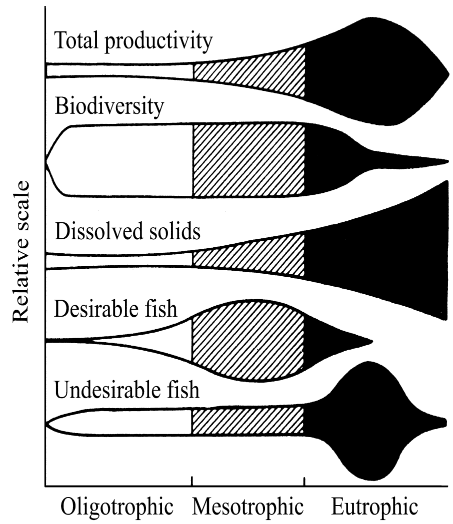


Figure 7: Suggested changes in various lake characteristics with eutrophication. From "Ecological Effects of Wastewater", 1980.

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.

References

Nurnberg, G.K. 1996. Trophic state of clear and colored, soft and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake and Reservoir Management 12(4):432-447.

Vollenweider, R.A., and J. Kerekes, J. 1982. Eutrophication of Waters. Monitoring, Assessment and Control. Organization for Economic Co-Operation and Development (OECD), Paris. 156p.

Welch, E.B. 1980. Ecological Effects of Waste Water. Cambridge University Press.