



Preston McEachern
9637 – 81 Ave.
Edmonton, AB, T6C 0X6
(780) 427-1197
prestonm@telusplanet.net

Lakewatch

Lac Ste. Anne



*The Alberta Lake Management Society
Volunteer Lake Monitoring Report*

And you really live by the river? What a jolly life!"

"By it and with it and on it and in it," said the Rat. "It's brother and sister to me. What it hasn't got is not worth having, and what it doesn't know is not worth knowing." Kenneth Grahame The Wind in the Willows

"The world's supply of fresh water is running out. Already one person in five has no access to safe drinking water." BBC World Water Crisis Homepage

A note from the Lakewatch Coordinator

Preston McEachern

Lakewatch has several important objectives, one of which is to document and interpret water quality in Alberta Lakes. Equally important are the objectives of educating lake users about their aquatic environment; enhancing public involvement in lake management; and facilitating a link between aquatic scientists and lake users. The 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. Substantial additional information is generally available on the lakes that have participated in Lakewatch and readers requiring more information are encouraged to seek these sources.

The 2002 Lakewatch Report has undergone a substantial change in format from previous years. I am no longer the author as much as an editor including text and figures from others who have done an excellent job describing lakes throughout Alberta. I have attempted to give due credit to these outstanding people and apologize for blatant plagiarism where it occurs. As editor, feel free to castigate me for errors. I have included easily accessible information that is likely to have been updated in recent years and readers are encouraged to help update these reports by sending new information to me.

I would like to thank all people who share my love for aquatic environments and particularly those who have helped in the Lakewatch program. These people prove that ecological apathy can be overcome and give us hope that water will not be the limiting factor in the health of our planet.

Acknowledgements

The Lakewatch program is made possible through the dedication of its volunteers and Alberta Environment employees. Mike Bilyk, John Willis, Doreen LeClair and Dave Trew from Alberta Environment were instrumental in funding, training people and organizing with Lakewatch data. Comments on this report by Dave Trew were appreciated. Alberta Lake Management Society members and the board of directors helped in many facets of water collection and management. Sophie Lewin and Lucille Kowalchuk were summer field coordinators and were an excellent addition to the program. Without the dedication of these people and the interest of cottage owners, Lakewatch would not have occurred.

Lac Ste. Anne

A Blessing of the Lake Ceremony is held annually in Lac Ste Anne; people come bathe in water that is believed to have spiritual healing. Christians have been celebrating this pilgrimage since 1889, forty years after Jean Baptist Thibault established a mission on the southern shore. Prior to 1843, the lake was known to the Cree as *Manitou Sakhahigan*, a Cree word meaning, *Lake of the Spirit* (Mitchell and Prepas 1990).

The land surrounding the lake is undulating hummocky moraine with pockets of sand left by the glaciers. These sand lenses are Lac Ste. Anne's most popular beaches for recreation. Agriculture in the basin include canola and cereal crops, primarily in the south and eastern regions of the watershed comprised of Dark Grey Luvisol soils. These soils are a little richer than the Orthic Grey Luvisol soils found in the west and northern areas of the basin. Agricultural activities on the latter soils are limited to pasture land and hay farming. There are many villages, densely developed with cottages along the shoreline. Lac Ste Anne also supports commercial, domestic and recreational fishing (Mitchell and Prepas 1990). Only fifty miles west of the City of Edmonton, Lac Ste. Anne is a very popular recreation area. Popular sport fish in the lake are walleye pike, perch (especially during winter), and lake whitefish.

Lac Ste. Anne has two basins that are connected by a narrow passage. The lake is 15 km long and 7 km wide at its widest point. The east basin is smaller and its deepest point is 6 m. The much larger west basin is 9 m at its greatest depth (Mitchell and Prepas 1990). Phytoplankton are dominated by *Anabaena* spp. in later summer. *A. planktonica* is dominant in the east basin, whereas *A. flos-aquae* and *A. spiroides* are dominant in the west basin. Diatoms, *Stephanodiscus* and *Melosira*, dominate in spring and fall with larger populations in the west basin. Emergent and submergent aquatic plants are typical of many Alberta lakes such as: cattails, sedges, duckweed, bulrush, pondweed, northern milfoil, coontail and duckweed (Mitchell and Prepas 1990).

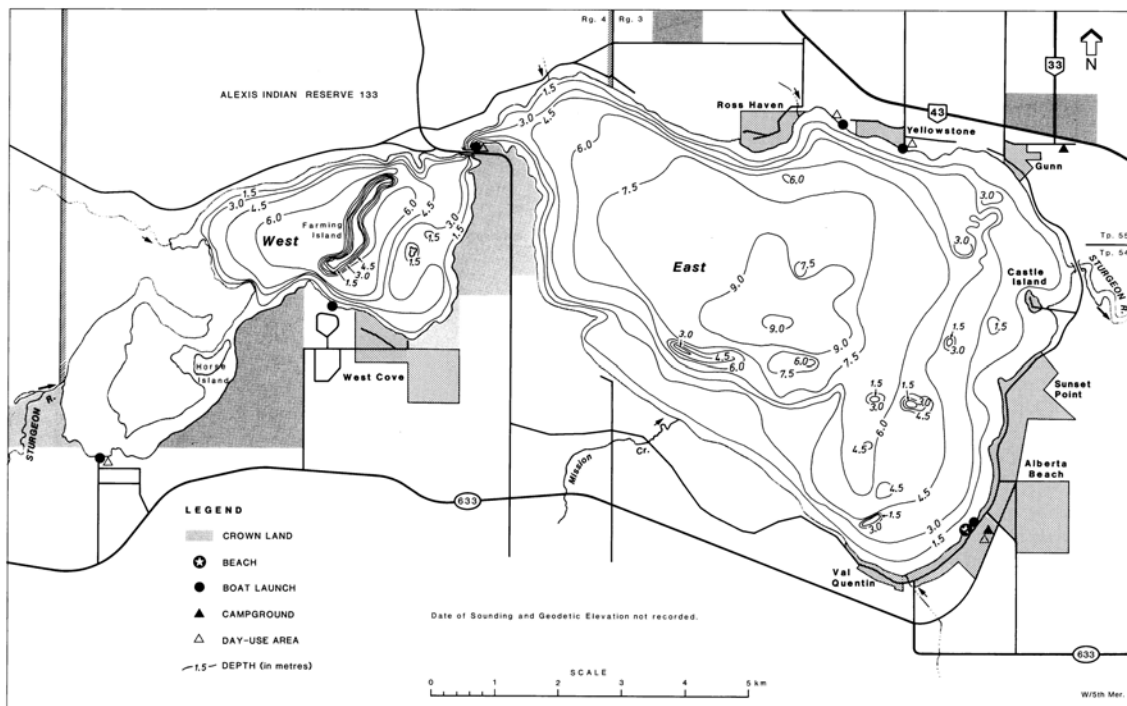
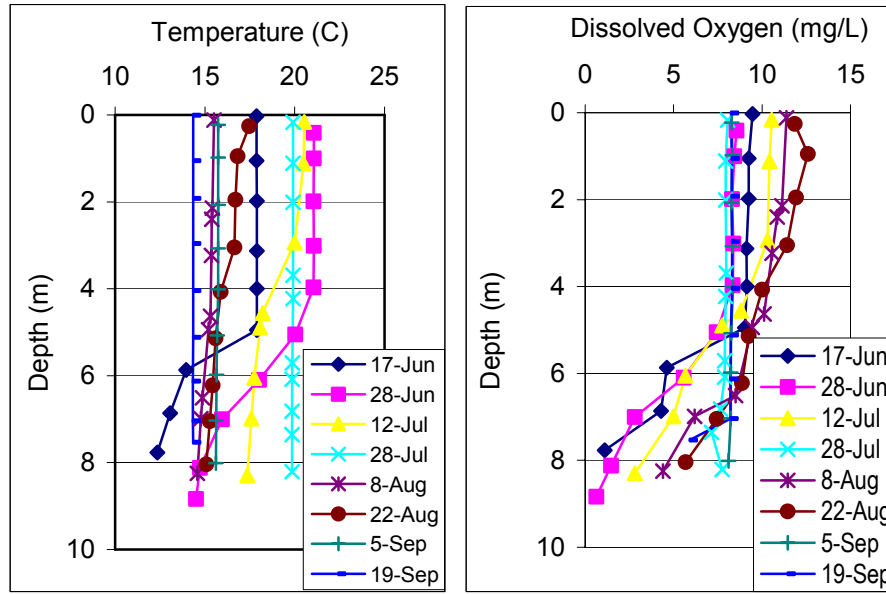


Fig. 1: Bathymetry of Lac Ste Anne (Mitchell and Prepas 1990).



Figs. 2 & 3: Temperature and dissolved oxygen profiles in Lac Ste Anne, summer 2002.

Results

Water Levels

Water levels were last recorded in 2000 where the monthly mean was 722.7 m, 1.1 m less than the maximum recorded 723.8 m 1974. The lowest level recorded was 721.99 m in 1939 (Mitchell and Prepas 1990). Higher water levels were last seen in 1997 (Mitchell 1999). Between 1939 and 1974, variation of 1.8 m occurred; while between years 1980 and 1987, variation of water levels was 0.57 m (Mitchell and Prepas 1990). An estimated 1.1 m variation has occurred during 1987 to 2000.

Water Temperature and Dissolved Oxygen

Thermal stratification began to weaken by mid July and remained weak or nonexistent throughout the summer. Lac Ste Anne was well-aerated: above 4 m depth, dissolved oxygen concentrations were above 8 mg/L through the summer reaching maximum concentrations in August. Although oxygen concentrations varied below 4 m, concentrations were not lower than the critical level of 5 mg/L near lake bottom after mid July, except in early August where the lowest concentration of dissolved oxygen was recorded as 4.4 mg/L at 8 m.

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.

Lac Ste Anne's water was fairly clear during the summer of 2002: Secchi disk depth averaged about two meters. The maximum clarity occurred in the beginning of June when the Secchi disk depth was 4.25 m. Water clarity declined over the summer and became fairly poor by late August when the Secchi disk depth reached 1 m. Average water clarity in the summer of 2002 was about the same as that 20 years ago (Table 1).

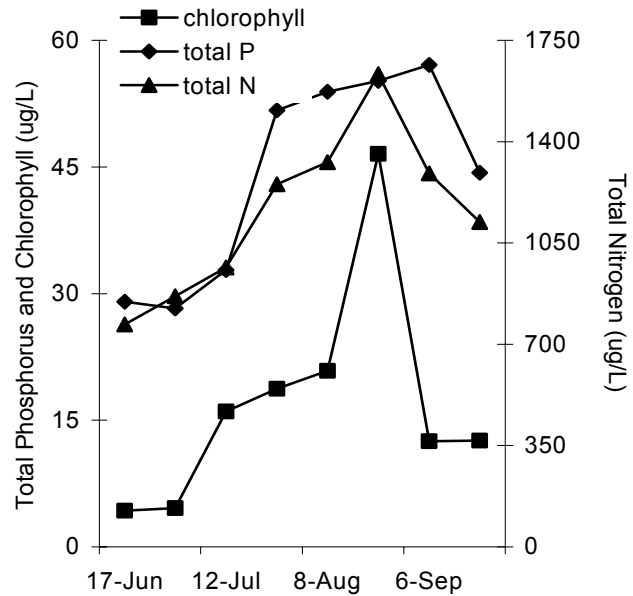


Figure 4: Total phosphorus, chlorophyll *a* and total nitrogen for Lac Ste Anne, summer 2002.

Water chemistry

Because Lac Ste Anne had high nutrient concentrations and algal biomass compared to lakes throughout Canada, it is considered eutrophic (see details on trophic status classification at end of this report). In the Alberta context, the water chemistry of Lac Ste Anne is similar to a typical natural lake.

In 2002, both nitrogen and phosphorus concentrations increased from June to August (Fig. 4), explaining the parallel increase in algal biomass (measured as chlorophyll). This pattern is typical for Alberta lakes. The source of much of the total phosphorus at the end of summer is the bottom sediments, which typically release phosphorus as the water warms and bacterial activity reduces oxygen levels at the bottom of the lake (Mitchell and Prepas 1990).

By comparing data from 1984 and 2002, it seems like the water quality of Lac Ste Anne has been fairly stable over time: phosphorus and nitrogen concentrations and algal biomass in 2002 were very similar to that of 1984 (Table 1). Corresponding to the lack of change in algal biomass, the water clarity of Lac Ste Anne has also remained unchanged over the 20-year time frame. However, sediment cores taken by Alberta Environment show

Table 1: Mean chemical characteristics of Lac Ste Anne during summer 2002, as compared to 1984 (Mitchell and Prepas 1990).

Parameter	1984	2002
Total phosphorus (µg/L)	48	44
TDP (µg/L)	18	8
Chlorophyll <i>a</i> (µg/L)	18	19
Secchi disk depth (m)	2.2	2.0
Total nitrogen (µg/L)	919	1153
NO ₂₊₃ (µg/L)	<3	2.2
NH ₄ (µg/L)	24	12
Ca (mg/L)	30	30
Mg (mg/L)	9	11
Na (mg/L)	16	21
K (mg/L)	7	9.8
SO ₄ (mg/L)	10	7.4
Cl (mg/L)	2	5.5
CO ₃ (mg/L)	<6	8.4
HCO ₃ (mg/L)	176	169
Alkalinity (mg/L CaCO ₃)	152	152
pH	8.5	8.7

Note. TDP = total dissolved phosphorus, NO₂₊₃ = nitrate and nitrite, NH₄ = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO₄ = sulfate, Cl = chloride, HCO₃ = bicarbonate, CO₃ = carbonate.

that the lake is more productive now than it was 60 years ago (Mitchell 1999).

Lac Ste Anne is well-protected from acidification: its pH of 8.7 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. Mineral ions such as calcium and sulfate are supplied by weathering in the watershed and from groundwater inflows. The lack of change in ion concentrations over time (Table 1) suggests that the relationship between Lac Ste Anne and its hydrology has not changed. Atmospheric deposition of acidifying pollutants from petroleum activities can often be seen in increasing sulfate concentrations. Because sulfate concentrations were not much different between 1984 and 2002, there is no evidence of pollution from atmospheric sources.

A brief introduction to Limnology

Indicators of water quality

Water samples are collected in Lakewatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in Lakewatch are sensitive to human activities in watersheds that can cause degraded 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 impacted (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 habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

Temperature and mixing

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. 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 often 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 near 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 $5 \text{ mg}\cdot\text{L}^{-1}$ and should not average less than $6.5 \text{ mg}\cdot\text{L}^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above $9.5 \text{ mg}\cdot\text{L}^{-1}$ 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. Some highly productive lakes are dominated by larger aquatic plants rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be 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 Transparency

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. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. 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 low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain 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 insects, depend on aquatic plants for food and shelter.

Trophic state

Trophic state is classification of lakes into four categories of fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are; **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic**. A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

Trophic status classification based on lake water characteristics.

Trophic state	Total Phosphorus (µg•L ⁻¹)	Total Nitrogen (µg•L ⁻¹)	Chlorophyll a (µg•L ⁻¹)	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.