

2023 Water Quality Report

Lac La Biche Lake

East Basin

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Lac La Biche County
welcoming by nature.

Executive Summary

Lac La Biche Lake (“LLB Lake”) is a large and scenic lake located in Lac La Biche County, Alberta (“County”) and is valued for a variety of recreational activities. However, there is a concern that declining water quality in the lake is limiting the opportunities of recreational activities such as swimming, boating, and fishing. For the purpose of this report, Lac La Biche Lake has been split up into two Basins (East and West) due to the size and physical attributes of the lake.

The County follows a regular program to monitor the water quality of lakes located within its jurisdiction. The water sampling events were conducted during the early spring and summer of 2023. The data collected includes water temperature, pH, specific conductivity, and dissolved oxygen which was collected in-situ through a multi-probe and Kemmerer sampling device. Analytical data of nitrogenous compounds, heavy metals, and other inorganic parameters was provided from ALS laboratory. Water samples for microbial parameters were analyzed by PROVLAB of Alberta Health Services.

Collected water samples were analyzed by ALS laboratory. The laboratory results obtained were compared to the CCME’s Canadian Environmental Quality Guidelines for Protection of Aquatic Life and Protection of Agricultural Water, and Alberta Environment and Protected Areas Environmental Quality Guidelines for Alberta Surface Waters 2018.

Trophic State Index (TSI) is a classification system designed to rate lakes based on the amount of biological activity they sustain. The concentrations of nutrients (nitrogen and phosphorus) are the primary determinants of TSI. Increased concentrations of nutrients tend to result in increased plant growth, followed by an increase in subsequent trophic level. Nurnberg (1996) used parameters including Secchi depth, chlorophyll, total nitrogen, and total phosphorus concentrations in lake waters to determine the trophic state of the lakes, which is provided as Table 1 in Appendix A. TSI is a useful tool for evaluation and management of lake health and setting objectives including sport and recreational activities related to the lake. Trophic classification of East Basin of Lac La Biche Lake based on Secchi depth and nutrients is presented in Table 2.

There are four classes of trophic states which include: Oligotrophic which would be the highest quality of water with low productivity, nutrients, and algae; Mesotrophic which is fair quality water with some productivity, nutrients, and algae; Eutrophic which is relatively poor-quality water with high productivity, nutrients, and algae; and Hypereutrophic which is the poorest quality water with excessive productivity, nutrients, and algae.

The East Basin of Lac La Biche Lake would be considered Hypereutrophic based on the average of the four water parameters: Secchi depth, total nitrogen, total phosphorus, and total chlorophyll-a. The trophic status would be Eutrophic based on Secchi depth, Hypereutrophic based on total nitrogen, Hypereutrophic based on total phosphorus, and Hypereutrophic based on chlorophyll-a.

Results and Discussion

In 2023, Secchi depths in the East Basin of Lac La Biche Lake were measured on June 22, July 24, and August 17, 2023. The average seasonal Secchi depth was observed to be 1.0 m which is lower than historical results. The low average Secchi depth means that the East Basin has poor transparency due to suspended materials. Based on the Secchi depths and in accordance with the classification provided in Table 1 (Appendix A), the East Basin of Lac La Biche Lake is classified as Eutrophic (high productivity, nutrients, and algae growth).

Dissolved oxygen data collected in 2023 shows that the average dissolved oxygen levels ranged from 5.95 mg/L to 8.04 mg/L. These concentrations were in proximity to regulatory criteria for dissolved oxygen in cold water lakes for all other life stages (6.5 mg/L) but may be limiting for early life stages (9.5 mg/L).

Sampling events in 2023 showed an average summer water temperature of 18.82 °C. Uniform temperature profiles were observed during the summer as there was no significant variation in temperatures with depth. Based on the data provided, thermal stratification was not observed in any of the summer sampling events between June 22 and August 17, 2023.

In 2023, three types of lake water samples for analyses of nutrients were collected from East Basin of Lac La Biche Lake; composite samples, Kemmerer samples (obtained from different depths using a Kemmerer device), and inflow/outflow samples. These samples were analyzed for total nitrogen and total phosphorus.

Total nitrogen concentrations in the composite samples collected from the East Basin in 2023 had an average of 1.56 mg/L of total nitrogen, while the Kemmerer samples collected had an average of 1.06 mg/L of total nitrogen. The average total nitrogen concentrations from composite and Kemmerer sampling were 1.31 mg/L and classifies the East Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

Total phosphorus concentrations in the composite samples collected during the summer of 2023 had an average of 0.183 mg/L of total phosphorus, while the Kemmerer samples collected had an average of 0.165 mg/L. Both the composite and Kemmerer samples of total phosphorus exceeded the applicable regulatory guidelines of 0.05 mg/L and were similar to historical results. The average total phosphorus concentrations from composite and Kemmerer sampling classify the East Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

The average N:P ratios for composite and Kemmerer sampling events were 9:1 and 6:1. which is lower than the Redfield Ratio of 16:1. Therefore, total phosphorus concentrations may not be considered a limiting nutrient and may be occurring in excess in the East Basin of Lac La Biche Lake.

Total chlorophyll-a concentrations in the composite samples collected during the summer of 2023 had an average of 96.97 µg/L of total chlorophyll-a, exceeding the standard of 3.5 µg/L for Oligotrophic lakes. This concentration classifies the East Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

Routine water chemistry showed that East Basin of Lac La Biche Lake has an average pH of 7.46 in 2023 which is similar to historical results.

Concentrations of metals analyzed from the composite and Kemmerer samples were generally below detection limits and/or below the applicable regulatory guidelines.

In the East Basin of Lac La Biche Lake, the beaches at Golden Sands and McArthur Place were tested for Enterococcus from May 24 to August 23, 2023. Beaches at McArthur Place were also tested for cyanobacteria during this time frame; however, the results were not released by Alberta Health

Services (AHS). McArthur Place data regarding Enterococcus shows that four samples collected on July 25, August 2, August 15, and August 23, 2023, exceeded the regulatory guidelines with counts of 11394 CCE/100 mL, 4854 CCE/100 mL, 1571 CCE/100 mL, and 26091 CCE/100 mL respectively. Golden Sands data regarding Enterococcus shows that four samples collected on June 6, July 25, August 15, and August 23, 2023, exceeded the regulatory guidelines with counts of 1954 CCE/100 mL, 12630 CCE/100 mL, 3969 CCE/100 mL, and 3288 CCE/100 mL respectively. Additional sampling for Enterococcus at these locations resulted in concentrations which were within the applicable guidelines.

The East Basin of Lac La Biche Lake would be considered Hypereutrophic based on the average of the four water parameters: Secchi depth, total nitrogen, total phosphorus, and total chlorophyll-a. The trophic status would be Eutrophic based on Secchi depth, Hypereutrophic based on total nitrogen, Hypereutrophic based on total phosphorus, and Hypereutrophic based on chlorophyll-a.

Recommendations:

It is recommended that Lac La Biche County continues to monitor the water quality of the East Basin of Lac La Biche Lake. Continuous monitoring will help the County to determine how the lake management strategies and policies such as the Watershed Management Plan and Riparian Setback Matrix Model are impacting the lake water quality, and what the net effect is on human and environmental health.

Monitoring and sampling should continue to be conducted under a strategic plan and in a uniform manner to ensure that results produced are meaningful and are useful for establishing a correlation with the past results. This may include sampling at same period of the year each time, recording the same parameters critical to lake health, obtaining samples from the same depths, and implementing a quality assurance program for reliability of analytical results.

Nutrient loading is the main source of eutrophication in Beaver Lake which is degrading the water quality, leading to algae growth, foul smells, and a reduction in water recreation. Therefore, action must be taken to slow down the eutrophication process and improve water quality. Best management practices would include education of the public on appropriate land use including restoration and protection of riparian areas (water buffers); and strengthening laws and regulations governing land use such as municipal sewer hookups and protection of environmental reserves.

Lac La Biche County recently updated the Lac La Biche Watershed Management Plan, which was adopted by Council in May 2021. This plan includes specific action items based on the recommendations that were formulated while drafting the plan.

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List of Abbreviations Used

- CCME: Canadian Council of Ministers of the Environment
- County: Lac La Biche County
- EQGASW-AGW: Environmental Quality Guidelines for Alberta Surface Waters 2018 for protection of Agricultural Water
- EQGASW-FAL: Environmental Quality Guidelines for Alberta Surface Waters 2018 for protection of Fresh Water Aquatic Life
- EQGASW-RA: Environmental Quality Guidelines for Alberta Surface Waters 2018 for Recreation and Aesthetics
- LLB Lake: Lac La Biche Lake
- QA/QC: Quality Assurance and Quality Control
- Total N: Total Nitrogen
- Total P: Total Phosphorus TSI: Trophic State Index

1. INTRODUCTION

Lac La Biche Lake is a large recreational lake popular for many recreational activities. It is approximately 215 km northeast of the city of Edmonton and shares its name with the hamlet of Lac La Biche which is on the southeast shore. A location map of the lake is presented in Figure 1.

LLB Lake has always been popular for a vast variety of recreational activities such as swimming, boating, and fishing. However, there is a concern that declining water quality in the lake is limiting the opportunities for these activities. LLB Lake covers an area of 234 km² with a watershed of 4040 km² within the Athabasca River drainage Basin and comprises of two large Basins (East Basin and West Basin) divided by a peninsula and two large islands. The mean depth of Lac La Biche Lake is 8.4 m, with a maximum of 21.3 m.

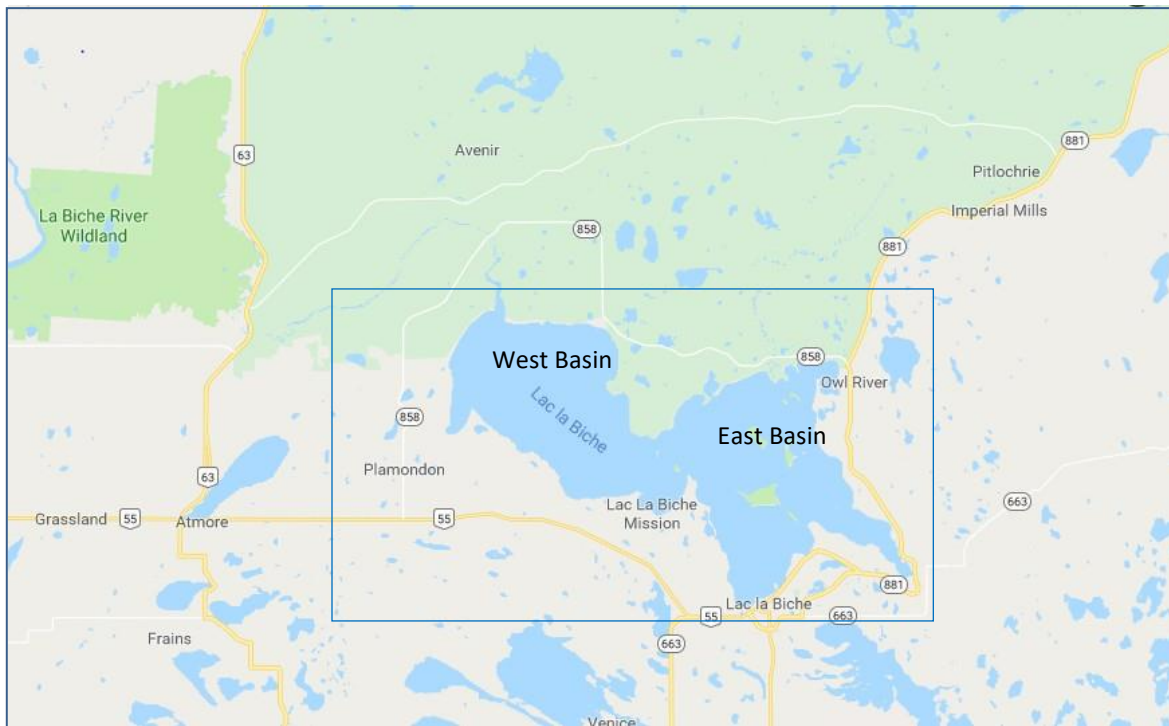


Figure 1: Location map of Lac La Biche Lake

There are several small unnamed creeks located around the lake that flow into the East and West Basins. The main inflows into LLB Lake are Owl River, Red Deer Brook, Plamondon Creek and one unnamed creek which flows into the bay near the Lac La Biche Mission. All of these major inflows are located in the East Basin except for Plamondon Creek which is located in the West Basin. The only outflow for the lake is the La Biche River, which is located on the northwest shore of the West Basin.

Agriculture in the Lac La Biche Lake watershed began in the late 19th century, while the hamlet of Lac La Biche began to grow in mid-20th century. Sewage from the hamlet began to be discharged into LLB Lake in 1951 with the first waste treatment plant. However, in 1983 the sewage was diverted to Field Lake which is upstream of Lac la Biche. Subsequent studies show that much of the sewage still drained back to Lac la Biche Lake via Red Deer Brook. Therefore, the treatment plant was upgraded in 1989 but continued to discharge into Field Lake. Residents of the area increasingly complained about water quality, particularly the surface algal blooms which decreased the water clarity (Schindler et al, 2008). Due to these concerns, a Biological Nutrient Removal (BNR) Facility was opened in 2014. The facility has proved effective in decreasing phosphorus and fecal bacteria in the effluent discharge.

Lac La Biche Lake has been historically exploited for fisheries. Some species have already collapsed and now the Lake is under stringent regulations. As of August 1, 2014, all lakes in Alberta are closed to commercial fishing. The main sport fish species found in the lake include Walleye (*Sander vitreus*), Yellow Perch (*Perca flavescens*), Northern Pike (*Esox lucius*) and Lake Whitefish (*Coregonus clupeaformis*).

2. WATER QUALITY SAMPLING PROGRAM

Lac La Biche Lake has been sampled by Lac La Biche County consistently every year since 2006. Due to the differences in water quality, shoreline morphology and depth, LLB Lake is sampled as two separate Basins and results are reported separately. LLB Lake East Basin sampling program for 2023 was completed as follows:

- a) Secchi Depths were measured on June 30, July 27, and August 17, 2023.
- b) Lake profiles of the East Basin were recorded to a maximum depth of 10 m using a multi-probe on February 7, June 30, July 27, and August 17, 2023.
- c) Composite samples from the East Basin were collected on June 22, July 24, and August 17, 2023. These samples were analyzed for nutrients, metals, and basic water chemistry parameters by ALS laboratories. Lake water samples were also analyzed for chlorophyll-a by InnoTech Alberta Laboratories.
- d) Kemmerer samples were collected on February 7, 2023, and August 17, 2023, from depths of 0 m, 3 m, 6 m, and 9 m on February 7, 2023, and depths of 3 m, 6 m, and 9 m on August 17, 2023. Samples were analyzed for nutrients, metals, and basic water chemistry parameters by ALS laboratories.
- e) Inflow and outflow samples were collected on May 29, June 21, July 19, and August 22, 2023; and were analyzed for nutrients, metals, and basic water chemistry parameters.
- f) Alberta Health Services (AHS) coordinates the monitoring of recreational beaches throughout the province. Lac La Biche County partnered with AHS to monitor cyanobacteria at McArthur Beach in the East Basin only; however, these results were not released by AHS. The beach locations sampled during 2023 for Enterococcus in the East Basin were Golden Sands Beach and McArthur Park Beach. These beaches were sampled on May 24, May 30, June 6, June 12, June 20, June 27, July 5, July 11, July 18, July 25, August 2, August 15, and August 23, 2023.

2.1 Water Quality Parameters

Water samples collected for each of the sampling locations were analyzed for a variety of parameters used to characterize the chemical composition of the lake and further identify any potential concerns. The water quality parameters measured and analyzed during the 2020 program along with a brief description of each parameter and reason for monitoring are provided in the table below:

Parameters Affecting Lake Water Quality

Water Quality Parameter	Description and Reason for Measuring
Secchi Depth	Secchi depth is a measure of the transparency of water and trophic state of a lake. A Secchi disk is generally a disk of 20 cm diameter with alternating black and white quadrants. It is lowered into the lake water until it can no longer be seen. This depth of disappearance is called the Secchi depth. A low Secchi depth (<4 m) is characteristic of a mesotrophic to hypereutrophic lake with turbid water. Whereas a high Secchi depth (>4 m) is characteristic of an oligotrophic lake with clear water.
Dissolved Oxygen	Dissolved oxygen is required by aquatic plants and animals for respiration. Survival of aquatic life such as fish, generally depends on an adequate amount of dissolved oxygen for respiration. As dissolved oxygen levels in the water drop below 5.0 mg/L, aquatic life is subjected to stress. Oxygen levels that consistently remain below 1-2 mg/L can result in the loss of large populations of fish.
Temperature	Temperature of water affects different physical, biological, and chemical characteristics of a lake and determines the behavior of many parameters responsible for water quality. The solubility of oxygen and other gases decrease as temperature increases. An increase in water temperature decreases the concentration of dissolved oxygen required for the survival of aquatic organisms.
Nutrients	Total nitrogen (N) and phosphorus (P) are principal nutrients in lake water and are representative of all forms of N and P present in the water. There are various sources of N and P both natural and anthropogenic. These nutrients are a major cause of eutrophication, decreasing dissolved oxygen concentrations and are detrimental to lake water quality.
Chlorophyll-a	Chlorophyll-a is a green pigment present in all green plants and is responsible for the absorption of light to provide energy for photosynthesis. It is associated with algae growth in a waterbody and affects the trophic status of a lake.
Metals	Metals enter the lake waters through natural (geological) and anthropogenic point and non-point sources. Certain metals such as lead and mercury, are toxic to aquatic life and can bio-accumulate in the tissues and organs of aquatic organisms, becoming a part of the food chain. This may lead to loss of aquatic life and further affect human health.
<i>Enterococcus</i>	<i>Enterococcus</i> bacteria is an indicator for the sanitary quality of water. The presence of these microbes indicate contamination from excreta of warm-blooded animals including humans and may pose serious and immediate health risks.

3. REGULATORY FRAMEWORK

The protection of water quality in Canadian lakes is a federal, provincial, and territorial responsibility. Therefore, lake waters in Alberta are regulated by federal and provincial guidelines and fall under the jurisdiction of Canadian Council of Ministers of the Environment (CCME), Alberta Environment and Protected Areas (EPA), and Health Canada.

The regulatory criteria selection for lake waters in Alberta are subjected to CCME’s Canadian Environmental Quality Guidelines (CEQG) and EPA’s Environmental Quality Guidelines for Alberta Surface Waters 2018 (EQGASW). Protection of lake water is covered under CCME’s CEQG and EPA’s EQGASW chapters of water quality guidelines for Protection of Aquatic Life, Protection of Agricultural Water, and protection of Recreation and Aesthetics. In addition, Health Canada’s Guidelines for Canadian Recreational Water Quality for protection of lake waters have also been considered.

The analytical and monitoring results obtained for this report were compared to the above-mentioned regulations and are hereinafter referred to as regulatory guidelines or regulatory criteria.

4. SAMPLING ANALYSIS AND MONITORING RESULTS

4.1 Secchi Depth

The Secchi disk is a common method used to measure water clarity. Water clarity of a lake can be influenced by the amount of suspended materials such as phytoplankton, zooplankton, pollen, sediments and dissolved compounds. The Secchi depth multiplied by 2 provides us with the euphotic depth of the lake. The euphotic depth is the maximum depth to which light can penetrate within a lake to facilitate growth.

During 2023, Secchi depths in the East Basin of Lac La Biche Lake were measured on June 30, July 27, and August 17, 2023. The measured Secchi depth increased from 0.8 m on June 30 to 1.5 m on July 27, then declined to 0.7 on August 17, 2023. Secchi depths are plotted in Figure 2.

The low average Secchi depth of 1.0 m means that the lake water has poor transparency due to suspended materials. Based on the average Secchi depth of 1.0 m, East Basin is classified as Eutrophic in accordance with Table 1 provided in Appendix A. If the average Secchi depth continues to decrease in subsequent years, the East Basin may be classified as Hypereutrophic based on Secchi depth.

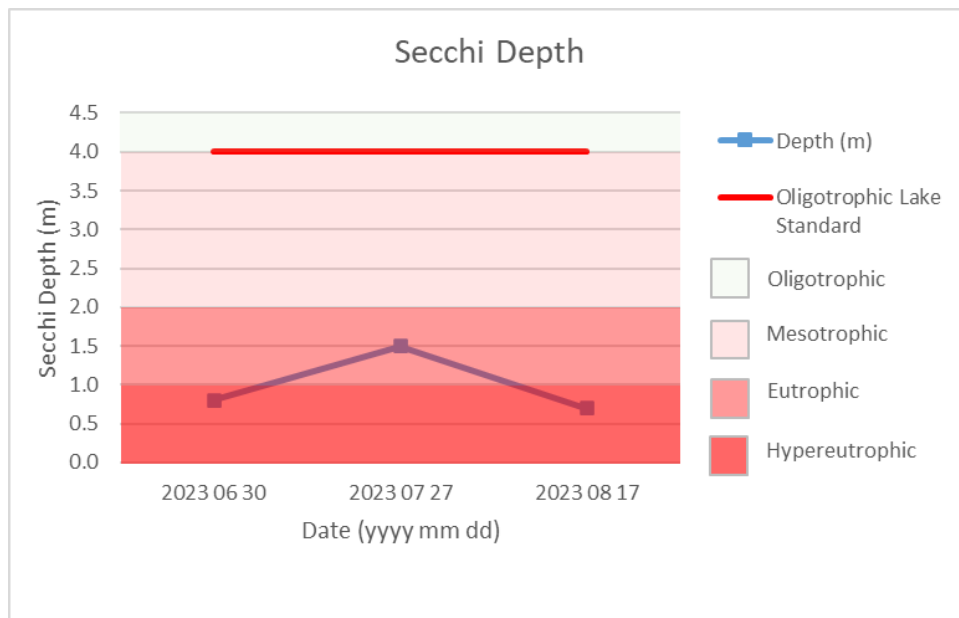


Figure 2: Secchi depths measured in East Basin of Lac La Biche Lake – 2023

4.2 Dissolved Oxygen

Dissolved oxygen is the amount of gaseous oxygen dissolved in the water and is necessary for respiration and survival of aquatic life (e.g., fish, invertebrates, bacteria, and underwater plants). Dissolved oxygen is also needed for the decomposition of organic matter in the lakes. Oxygen enters the lake water by direct absorption from the atmosphere through rapid movement of water or as a product of plant photosynthesis. Therefore, the epilimnion zone (shallow layer of water) is relatively richer in oxygen than the hypolimnion zone (deeper layer of water) which is low in oxygen due to consumption by respiration.

There are several conditions necessary for fish survival in a lake including adequate water temperatures and available dissolved oxygen for respiration. The regulatory guidelines for dissolved oxygen in cold water lakes are 9.5 mg/L for early life stages and 6.5 mg/L for all other life stages (CCME, 1999). If dissolved oxygen levels are too low, fish will move to other depths in the water column, often where temperatures are conducive to sustain aquatic life.

The amount of dissolved oxygen in lakes usually decreases under winter ice-cover primarily due to respiration by organisms (particularly bacteria) and decomposition of organic matter. In shallow lakes, oxygen depletion can proceed rapidly under ice during the winter. If dissolved oxygen drops below 3.0 mg/L during the winter, many fish and invertebrate species will not survive.

Dissolved oxygen levels in the East Basin of Lac La Biche Lake were recorded to a maximum depth of 10 m using the multi-probe on February 7, June 30, July 27, and August 17, 2023. A maximum dissolved oxygen concentration of 16.97 mg/L was recorded on July 30, 2023, at a depth of 1 m. This declined to 0 mg/L at the lakebed (Figure 3). The average dissolved oxygen over the sampling period was 6.82 mg/L.

In 2023, the dissolved oxygen data from East Basin indicated that the average dissolved oxygen levels for all sampling events ranged from 5.95 mg/L to 8.04 mg/L. These concentrations are in proximity to regulatory criteria for dissolved oxygen in cold water lakes for all other life stages (6.5 mg/L) but may be limiting for early life stages (9.5 mg/L).

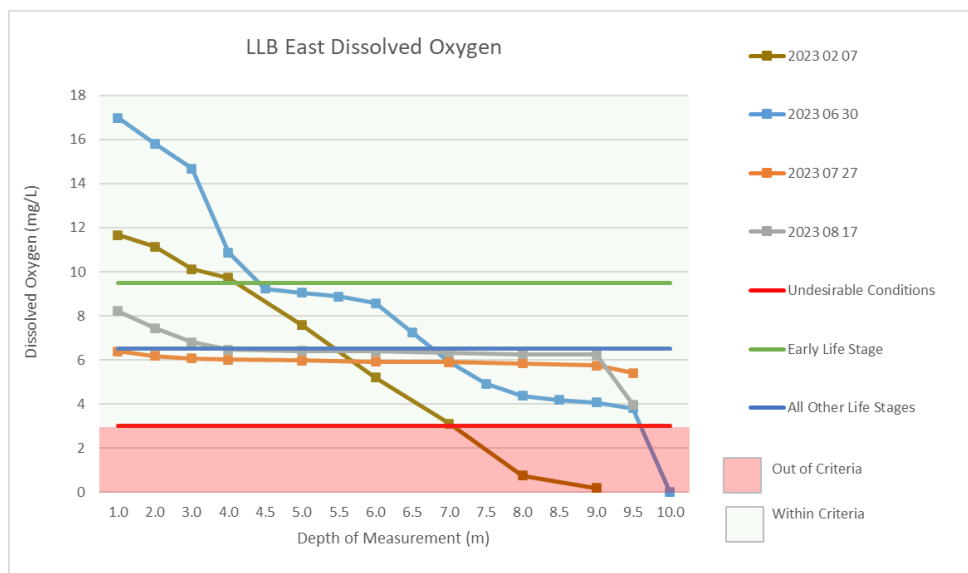


Figure 3: Dissolved oxygen in East Basin of Lac La Biche Lake – 2023

4.3 Temperature

Water temperature in a lake determines the behavior of many parameters responsible for water quality. Thermal stratification occurs within a lake with a distinct difference in temperature between the surface water (epilimnion layer) and the deeper water (hypolimnion layer) separated by a thermocline. The thermocline is identified when the water changes by more than one degree Celsius per meter. Under winter conditions, ice covers the surface water, and a thermocline is formed with the colder water at the surface and the warmer water at the bottom of the lake. Lakes without thermal stratification mix from top to bottom and this mixing allows oxygen to distribute throughout the water column preventing hypolimnetic anoxia (lack of oxygen). In the summertime, warmer surface water can facilitate Cyanobacteria blooms at the lake surface (Wetzel, R. 2001).

The East Basin temperatures were recorded to a maximum depth of 10 m on February 7, June 30, July 27, and August 17, 2023. Results of temperatures observed on different dates and depths are illustrated in Figure 4. A minimum temperature of 0.35 °C was observed on February 7, at a 1 m depth and a maximum temperature of 21.90 was noted on June 30, 2023, at a 1 m depth.

Sampling events in the summer of 2023 showed an average summer water temperature of 18.82°C in the East Basin of LLB Lake. Uniform temperature profiles were observed as temperatures over depth did not vary significantly.

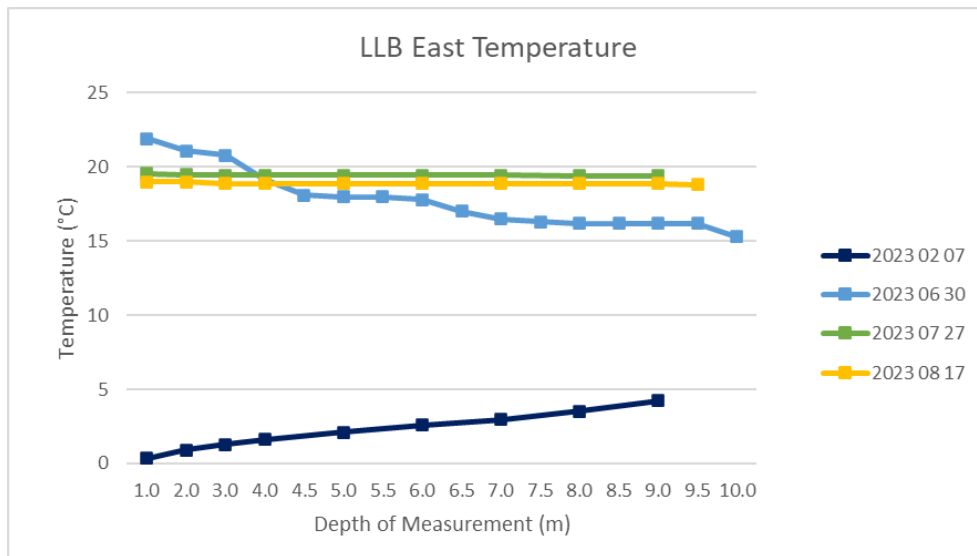


Figure 4: Temperature profile for East Basin of Lac La Biche Lake – 2023

4.4 Nutrients

Excessive levels of nitrogen and phosphorus are found in many lakes across Alberta leading to excessive growth of algae and aquatic plants. Decay of aquatic vegetation causes oxygen depletion in the water column and contributes to eutrophication. Consequently, the decreased levels of oxygen can suffocate fish and other aquatic organisms. High nutrient conditions foster algal blooms and can result in the proliferation of toxin-producing blue-green algae (e.g., Cyanobacteria). The input of nutrients into aquatic systems can occur naturally, but large amounts of nutrients typically originate from indirect, non-point anthropogenic sources, including improperly treated sewage, residential use of fertilizers and agricultural operations.

In 2023, three types of lake water samples for analysis of nutrients were collected from the East Basin of Lac La Biche Lake; composite samples; Kemmerer Samples (obtained from different depths using a Kemmerer device); and inflow and outflow samples from various streams in the East Basin.

Total Nitrogen

Total nitrogen is an essential nutrient for plants and animals; however, excessive amounts of nitrogen in lake water may lead to low levels of dissolved oxygen and negatively affect water quality and health of aquatic life within the lake. Nitrogen concentrations in the water are typically measured in three forms: ammonia, nitrates, and nitrites. Total nitrogen is the sum of total Kjeldahl nitrogen (ammonia, organic and reduced nitrogen), nitrate and nitrite. Nitrogen levels in lakes are also affected by atmospheric deposition, which refers to nitrogen in the air being deposited into the water system. Nitrogen oxides (NOx) are added to atmosphere due to the burning of fossil fuels, so emissions from motor vehicles and industrial facilities can also affect nitrogen levels in aquatic environments.

Composite Samples

Composite lake water samples for analyses of total nitrogen were collected on June 22, July 24, and August 17, 2023. The analytical results of these samples are presented in Figure 5 below. Total nitrogen concentration increased throughout the summer months, with a minimum concentration of 0.83 mg/L recorded on June 22 and a maximum concentration of 2.52 mg/L recorded on August 17, 2023. Nitrogen concentrations in the composite samples collected from the lake in 2023 had an average of 1.56 mg/L of total nitrogen which exceeds the applicable regulatory guidelines.

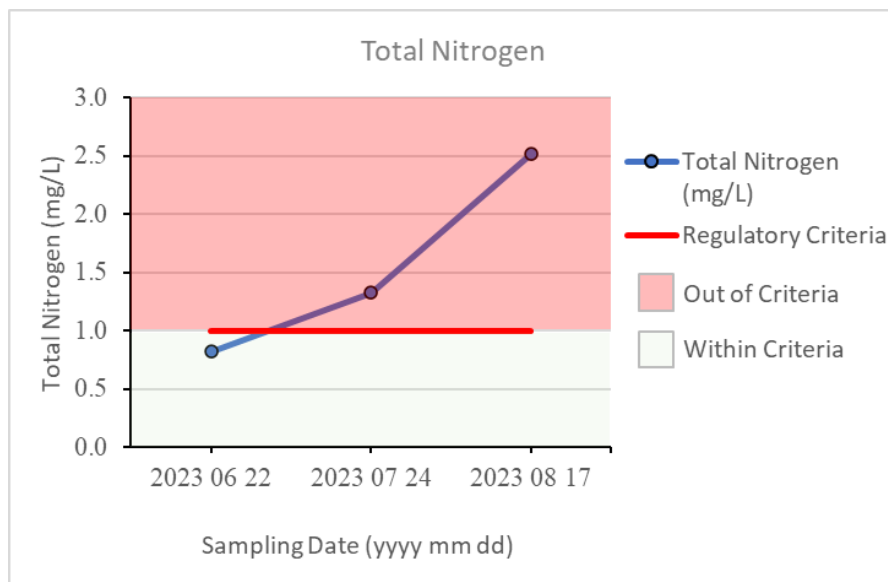


Figure 5: Total nitrogen from composite samples in East Basin of LLB Lake – 2023

Kemmerer Sampling

Kemmerer water samples are collected from different depths of the lake by using a Kemmerer device which makes it possible to obtain a sample of water from specific depths. Kemmerer samples were collected from the East Basin of Lac La Biche Lake on February 7, 2023, and August 17, 2023, from depths of 0 m, 3 m, 6 m, and 9 m on February 7 and 3 m, 6 m, and 9 m on August 17. These samples were analyzed for total nitrogen by ALS laboratories. The analytical results of total nitrogen are

presented in Figure 6.

Total nitrogen concentrations did not exceed the regulatory guideline of 1.0 mg/L on February 7, 2023. Two samples exceeded the guidelines on August 17, 2023, at 3 m and 6 m. The average total nitrogen from the Kemmerer samples is 1.06 mg/L. The average total nitrogen concentration from both the composite and Kemmerer sampling is 1.31 mg/L which results in a trophic classification of Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total nitrogen.

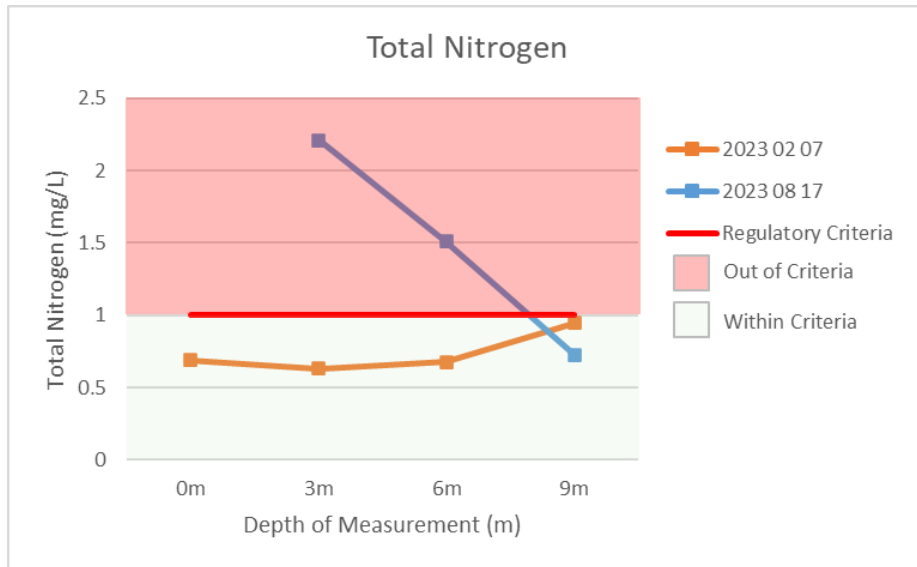


Figure 6: Total nitrogen from Kemmerer samples in East Basin of LLB Lake - 2023

Total Phosphorus

Increased phosphorus concentrations are the largest cause of degradation in water quality within lakes, causing ‘dead zones’, toxic algal blooms, a loss of biodiversity and increased health risks for plants, animals and humans that encounter polluted lake waters. Run-off from agriculture, human sewage and industrial practices results in increased phosphorus concentrations in lake water and lakebed sediments (Wetzel, 2001). Long-term monitoring activities following the control of phosphorus sources to lakes indicates that plants and animals do not recover from the effects of excessive phosphorus for several years.

Composite Sampling

Composite lake water samples for total phosphorus analysis were collected on June 22, July 24, and August 17, 2023, from the East Basin in Lac La Biche Lake. The analytical results are presented in Figure 7. Total phosphorus concentrations increased throughout the summer months. A minimum concentration of 0.10 mg/L was recorded on June 22, increasing to a maximum of 0.290 mg/L on August 17, 2023. The total phosphorus concentrations of all composite samples collected during 2023 exceeded the applicable regulatory guidelines of 0.050 mg/L with an average of 0.183 mg/L total phosphorus. This average total phosphorus concentration classifies the East Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total phosphorus from composite samples.

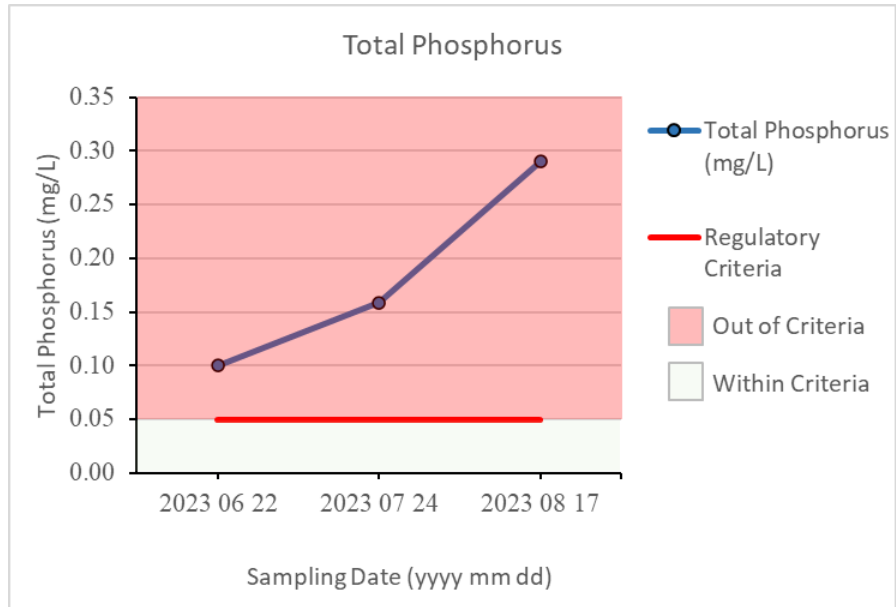


Figure 7: Total phosphorus from composite samples in East Basin of LLB Lake – 2023

Kemmerer Sampling

Kemmerer samples were collected from the East Basin of Lac La Biche Lake on February 7, 2023, and August 17, 2023, from depths of 0 m, 3 m, 6 m, and 9 m on February 7 and 3 m, 6 m, and 9 m on August 17. These were analyzed for total phosphorus by ALS laboratories. The laboratory results are presented in Figure 8.

All lake water samples collected during Kemmerer sampling on February 7 and August 17, 2023 exceeded the regulatory guideline. The average total phosphorus from Kemmerer sampling is 0.165 mg/L which is higher than the applicable regulatory guideline. The average total phosphorus concentration from both the composite and Kemmerer sampling is 0.174 mg/L which results in a trophic classification of Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total phosphorus.

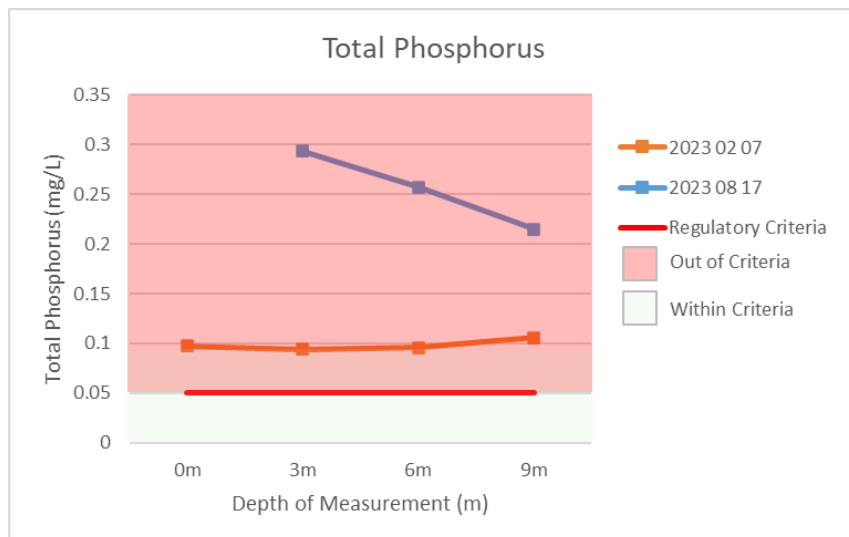


Figure 8: Total phosphorus from Kemmerer samples in East Basin of LLB Lake - 2023

N:P Ratio

The Redfield Ratio describes the optimal balance of total nitrogen to total phosphorus for aquatic plant growth, which is an optimal value of 16:1 (Teubner and Dokulil 2002). If the ratio is lower than 16:1, phosphorus is no longer considered a limiting nutrient and aquatic vegetation and Cyanobacteria can use the dissolved and atmospheric nitrogen for growth by using the high amounts of phosphorus available in lake waters. If the ratio is higher than 16:1, it indicates that the phosphorus concentrations are occurring at levels much less than nitrogen and hence limits the growth within lakes.

The average N:P ratios for composite and Kemmerer sampling events in the East Basin of Lac La Biche Lake were 9:1 and 6:1, with the average of both being 8:1. As the ratio is lower than the Redfield ratio, total phosphorus can no longer be considered a limiting nutrient and may be occurring in excess.

4.5 Tributary Sampling

Sampling Results

The inflows and outflow for Lac La Biche Lake were collected on May 29, June 21, July 19, and August 22, 2023. Data regarding total nitrogen and phosphorus concentrations is illustrated in Figure 9 and 10 below.

It is important to note that the samples obtained from the inflows and outflows do not account for the flow rate or volume of the water; therefore, this is not a true representation of concentrations found in the water.

A map showing the location of these samples is illustrated in Figure 17.

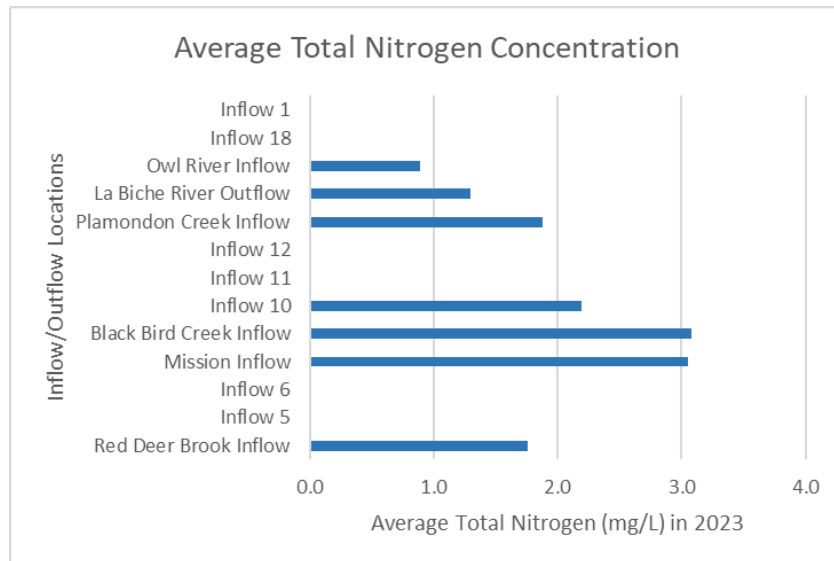


Figure 9: Inflow and outflow total nitrogen concentration for Lac La Biche Lake - 2023

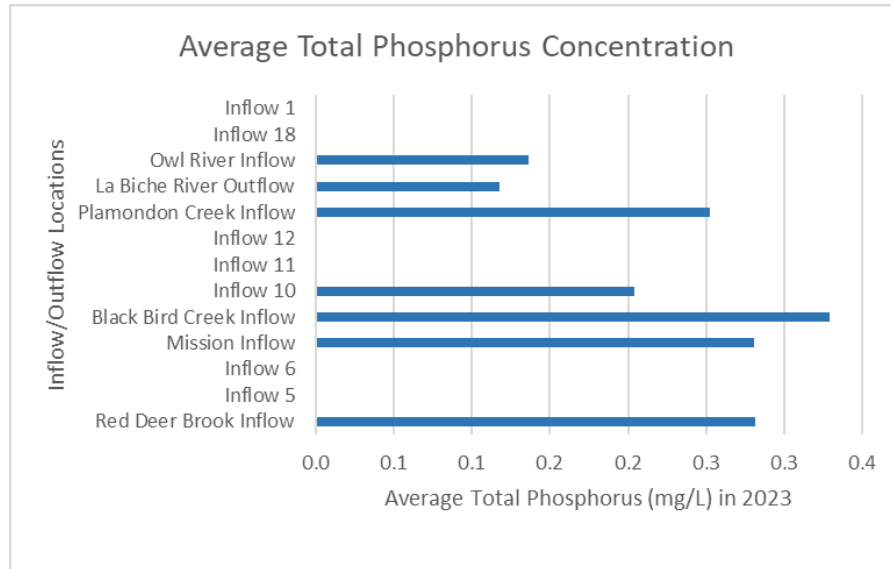


Figure 10: Inflow and outflow total phosphorus concentration for Lac La Biche Lake – 2023

Hydrometric Monitoring

In 2022, Lac La Biche County had 2 hydrometric data loggers installed in Plamondon Creek and Red Deer Brook. The loggers record water level and temperature data every 15 minutes throughout the sampling season. The County also purchased equipment and began to conduct hydrometric monitoring on each of the tributaries included in sampling events. The hydrometric data includes volume and water velocity, which will allow for a flow rate to be calculated for each tributary. This will go towards creating a water and nutrient budget. A water budget will provide a breakdown of sources and losses of water to the lake. A nutrient budget will focus on the external and internal sources and losses of phosphorus within the Lac La Biche Lake watershed. These budgets will provide an accurate representation of water and nutrient movements and will aid in lake management to reduce algal blooms and improve lake water quality.

4.6 Chlorophyll-a

Chlorophyll-a is used as a measurement of algal biomass present in lake water. It is a green pigment found in plants, algae, and cyanobacteria, which allows these organisms to photosynthesize. All algae and cyanobacteria produce chlorophyll-a, hence its usage as a proxy for algal biomass. High concentrations of chlorophyll-a indicate an elevated number of algae in the lake water. Due to the presence of chlorophyll-a in cyanobacteria, the measurement can be an underestimate of algae biomass when blue green algae are present in the lake water.

Composite lake water samples for filtering and analyses of chlorophyll-a were collected on June 22, July 22, and August 17, 2023. The analytical results of these samples are presented in Figure 11 below. Chlorophyll-a concentrations increased throughout the summer months, with a minimum concentration of 49.3 µg/L recorded on June 22 and a maximum concentration of 159 µg/L recorded on August 17, 2023. All 3 measurements fall in the chlorophyll-a range for a hypereutrophic classification. Total chlorophyll-a concentrations in the samples collected during the summer of 2023 had an average of 96.8 µg/L of total chlorophyll-a, which classifies the East Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

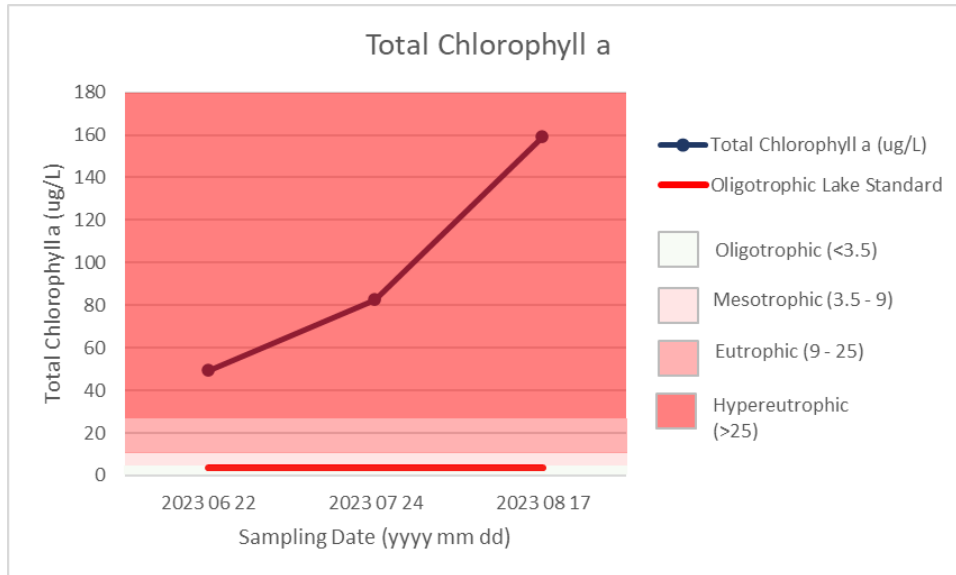


Figure 11: Total Chlorophyll-a from Composite samples in East Basin of LLB Lake - 2023

4.7 Routine Water Chemistry

Results of routine water chemistry of composite, Kemmerer, and inflow/outflow water samples collected from the East Basin of Lac La Biche Lake are presented in Table 5 in Appendix A.

The average measured pH for East Basin was 7.46 which was slightly higher than in past years. The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. The ability of a lake to neutralize these hydrogen ions is referred to as a buffering capacity. Any lake with a total alkalinity of more than 100 mg/L is considered to have high buffering capacity (Mitchell and Prepas 1990). The pH in Lac La Biche Lake is likely buffered against change by its high alkalinity. The high alkalinity in Alberta lakes is derived from the rich calcareous glacial till over which the lakes have formed.

4.8 Metals

Metals enter the water naturally through the weathering of rocks and soil. These metals are generally non-toxic and in low concentrations. However, metals can also come from a wide variety of anthropogenic and non-point pollution sources including runoff from urban areas, wastewater discharge, improperly managed sewage treatment, industrial activities, and agricultural runoff.

The total dissolved metals from the composite, Kemmerer and inflow/outflow samples collected from the East Basin of Lac La Biche Lake in 2023 were generally below detection limits and did not exceed the applicable regulatory guidelines (Table 6, Appendix A).

4.9 Bacteriological Beach Sampling

Previously in Alberta, the water quality of recreational beaches had been evaluated using fecal indicator bacteria, such as fecal (thermotolerant) coliforms, *Escherichia coli*. A monitoring program was developed in 2012 that allowed visual detection of algal blooms, along with the ability to sample for species composition and total Cyanobacterial cell count. This program also allowed for sampling of concentrations of the most common Cyanobacterial toxin, microcystin. Health Canada’s Guidelines for

Canadian Recreational Water Quality (Health Canada 2012) were used to set the water quality targets.

It has been determined that *Enterococcus* species is a stronger health indicator than the previously tested fecal indicator, *E. coli* and coliforms. Based on the research (Wade et al., 2008) and the published work by the United States Environmental Protection Agency (US EPA 2014), *Enterococcus* was determined to be the best indicator organism for monitoring fecal contamination in swimming areas and other recreational water.

This sampling is done through a partnership between Lac La Biche County and Alberta Health Services. The County is responsible for obtaining the samples which are then delivered to Alberta Health Services. Alberta Health Services then ensures that the analysis is completed, and they are responsible for any subsequent beach closures.

In the East Basin of Lac La Biche Lake, the beaches at Golden Sands and McArthur Place were tested from May 24 to August 23, 2023. Golden Sands beach water was tested for *Enterococcus*, while McArthur Place beach water was tested for *Enterococcus* and cyanobacteria (blue green algae).

McArthur Place data regarding *Enterococcus* shows that four samples collected on July 25, August 2, August 15, and August 23, 2023, exceeded the regulatory guidelines with counts of 11394 CCE/100 mL, 4854 CCE/100 mL, 1571 CCE/100 mL, and 26091 CCE/100 mL respectively.

Golden Sands data regarding *Enterococcus* shows that four samples collected on June 6, July 25, August 2, and August 23, 2023, exceeded the regulatory guidelines with counts of 1954 CCE/100 mL, 12630 CCE/100 mL, 3969 CCE/100 mL, and 3288 CCE/100 mL respectively. Additional sampling for *Enterococcus* at these locations resulted in concentrations which were within the applicable guidelines.

Where there is exceedance of *Enterococcus*, Alberta Health Services issues a water quality advisory. Advisory signs are posted on site until samples show a concentration within criteria.

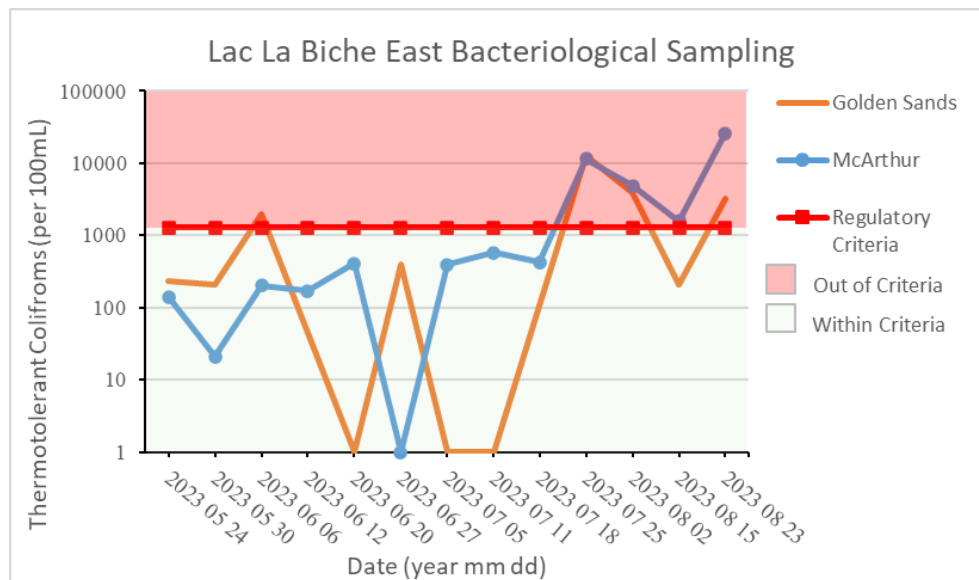


Figure 12: *Enterococcus* counts from beaches in East Basin of LLB Lake – 2023

5. HISTORICAL TREND ANALYSIS

The objective of the historical trend analysis is to provide an overview of water quality conditions in a lake with time and to evaluate the impact of watershed management practices on lake water quality.

Three parameters are significant in trend analyses for lake water quality: Secchi depth, total nitrogen, and total phosphorus; all of which are also used for trophic classification of lakes.

5.1 Secchi Depth

Historical data indicates that the Secchi depth in the East Basin of Lac La Biche Lake has historically been Mesotrophic (some productivity, nutrients, and algae growth) to Eutrophic (high productivity, nutrients, and algae growth) based on Secchi depth with little variation through the years. The Secchi depth ranges from 1.0 m to 2.9 m and has been less than the standard Oligotrophic Secchi depth of 4 m ever since the monitoring began in 2006 (Figure 13). The recorded Secchi depth for 2023 represents the lowest value in the recorded history of the data. The overall trend shows that Secchi depth is not improving with time. The low average Secchi depth means that the lake water has poor transparency due to suspended materials. However, the Secchi depth readings may not provide an exact measure of the water transparency due to various errors such as time of the day, sun's glare on the water, and eyesight of the observer.

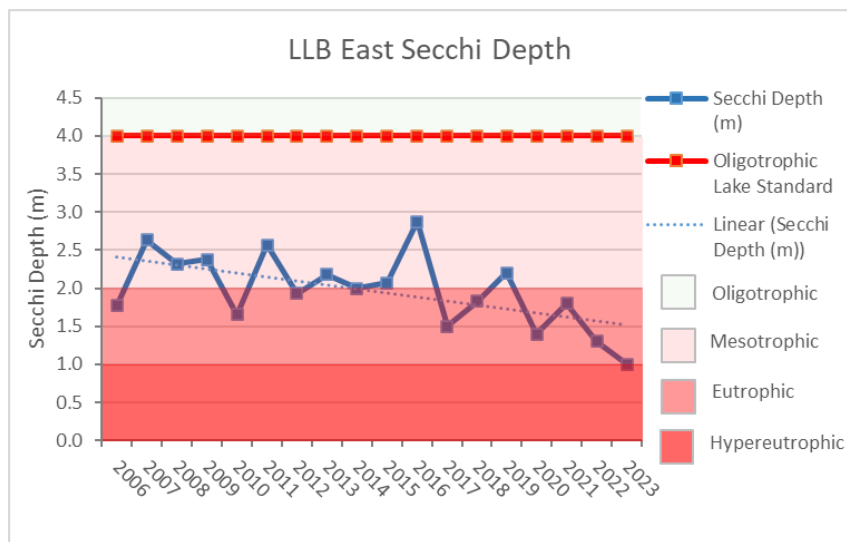


Figure 13: Historical trend for Secchi Depth in East Basin of Lac La Biche Lake

5.2 Total Nitrogen

Historical data indicates that the East Basin of Lac La Biche Lake has been classified as Eutrophic (high productivity, nutrients, and algae growth) to Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total nitrogen. Total nitrogen concentrations for the East Basin have been over the regulatory guidelines of 1.0 mg/L since 2017. Before this, concentrations were only over the guideline in 2006, 2007, and 2015. The maximum total nitrogen (3.15 mg/L) in the East Basin was recorded in 2019; however, there was a drastic drop in total nitrogen concentration in 2020 which may be due to the high-water levels during that year. The overall trend shows that total nitrogen in the East Basin of Lac La Biche Lake is increasing over time.

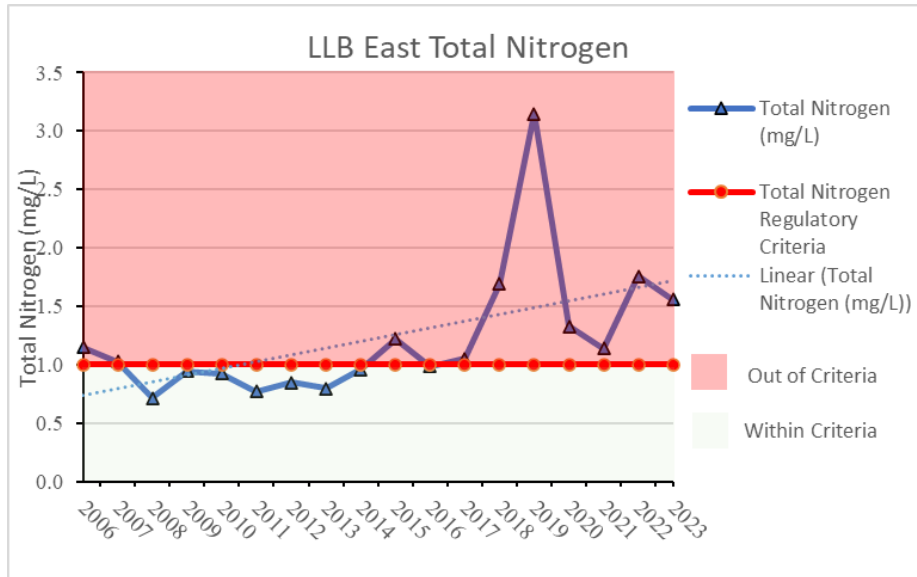


Figure 14: Historical trend of total nitrogen in East Basin of Lac La Biche Lake

5.3 Total Phosphorus

Historical data shows that total phosphorus concentration in the East Basin of Lac La Biche Lake has ranged from 0.05 mg/L to 0.24 mg/L and has exceeded the regulatory criteria of 0.05 mg/L since 2006 as shown in Figure 15. Historical data shows that the East Basin of LLB Lake has been classified as Eutrophic (high productivity, nutrients, and algae growth) to Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total phosphorus. A temporal increasing trend in total phosphorus concentration has been observed. The continuous increase of total phosphorus concentration in this lake clearly shows that phosphorus loading in this lake is increasing over time. There was a drastic decrease in total phosphorus concentration observed in 2020 which may be due to the high-water-levels experienced that year.

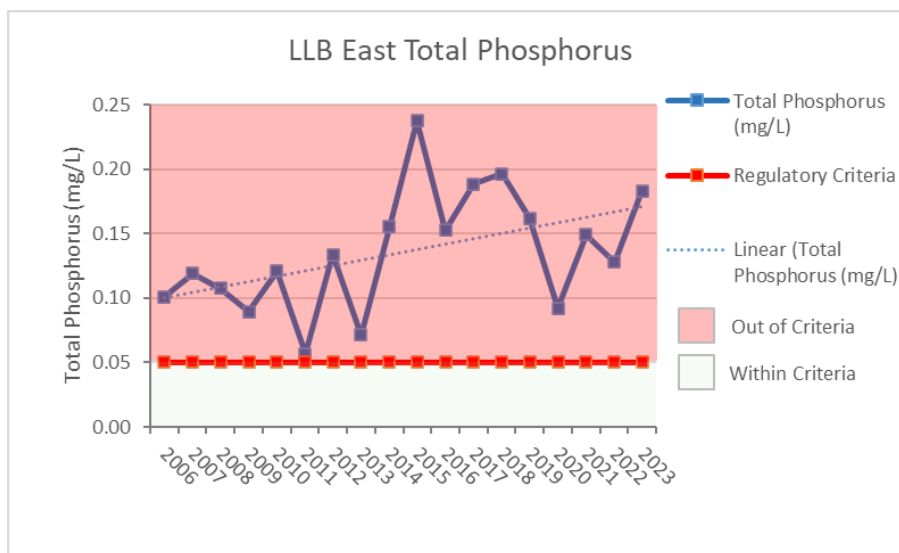


Figure 15: Historical trend of total phosphorus in East Basin of Lac La Biche Lake

5.4 Lac La Biche Lake Water Levels

Lac La Biche Lake water levels have been monitored by Environment Canada every year since 1930. There are large fluctuations seen in the water levels recorded as seen in Figure 16 below.

During the spring of 2020, Lac La Biche experienced high levels of precipitation. The precipitation combined with other unknown variables, resulted in extremely high-water levels. Flooding occurred throughout the watershed in early June 2020. The high-water levels remained for the duration of the summer and resulted in a significant improvement in water quality. Nutrient levels were much lower (demonstrated in Figure 14 and Figure 15 showing historical results of nutrients) and Cyanobacteria (blue-green algae) blooms were delayed until August (opposed to June/July).

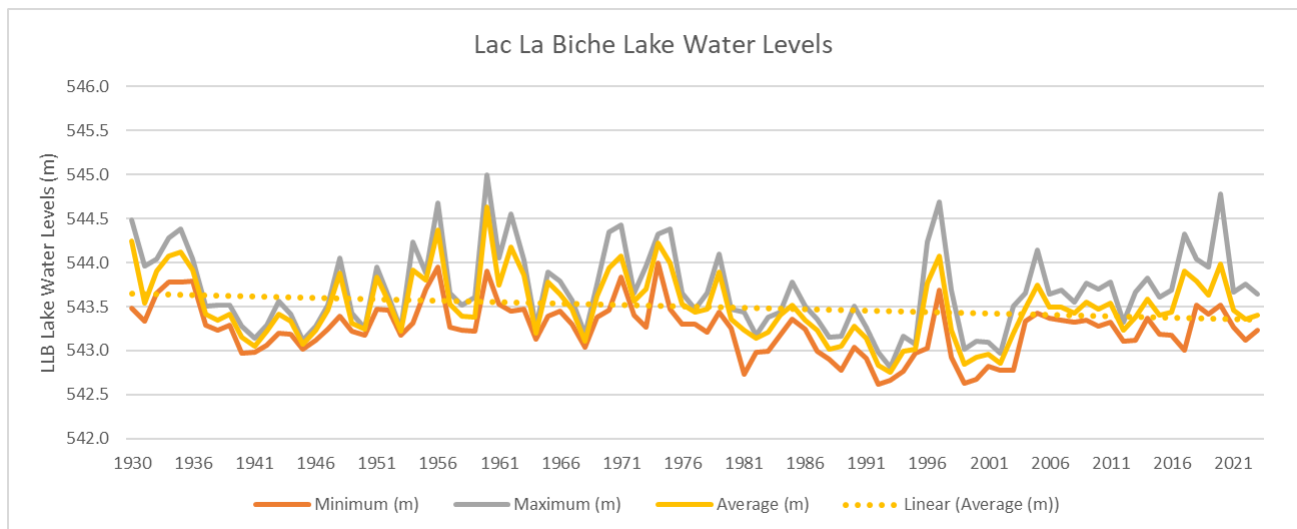


Figure 16: Historical water levels of Lac La Biche Lake

6. DISCUSSION

Trophic State Index (TSI) is a classification system designed to rate lakes based on the amount of biological activity they sustain. The concentrations of nutrients (nitrogen and phosphorus) are the primary determinants of TSI. Increased concentrations of nutrients tend to result in increased plant growth, followed by an increase in subsequent trophic level. Nurnberg (1996) used parameters including Secchi depth, chlorophyll, total nitrogen, and total phosphorus concentrations in lake waters to determine the trophic state of the lakes, which is provided as Table 1 in Appendix A. TSI is a useful tool for evaluation and management of lake health and setting objectives including sport and recreational activities related to the lake. Trophic classification of the East Basin of Lac La Biche Lake based on Secchi depth and nutrients is presented in Table 2.

There are four classes of trophic states which include: Oligotrophic which would be the highest quality of water with low productivity, nutrients and algae; Mesotrophic which is fair quality water with some productivity, nutrients and algae; Eutrophic which is relatively poor-quality water with high productivity, nutrients and algae; and Hypereutrophic which is the poorest quality water with excessive productivity, nutrients, and algae.

The East Basin of Lac La Biche Lake would be considered Hypereutrophic based on the average of the four water parameters: Secchi depth, total nitrogen, total phosphorus, and total chlorophyll-a. The trophic status would be Eutrophic based on Secchi depth, Hypereutrophic based on total nitrogen,

Hypereutrophic based on total phosphorus, and Hypereutrophic based on total chlorophyll-a.

7. RECOMMENDATIONS

It is recommended that Lac La Biche County continues to monitor the water quality of the East Basin of Lac La Biche Lake. Continuous monitoring will help the County to determine how the lake management strategies and policies such as the Watershed Management Plan and Riparian Setback Matrix Model are impacting the lake water quality, and what the net effect is on human and environmental health.

Monitoring and sampling should continue to be conducted under a strategic plan and in a uniform manner to ensure that results produced are meaningful and are useful for establishing a correlation with the past results. This may include sampling at same period of the year each time, recording the same parameters critical to lake health, obtaining samples from the same depths, and implementing a quality assurance program for reliability of analytical results.

Nutrient loading is the main source of eutrophication in Beaver Lake which is degrading the water quality, leading to algae growth, foul smells, and a reduction in water recreation. Therefore, action must be taken to slow down the eutrophication process and improve water quality. Best management practices would include education of the public on appropriate land use including restoration and protection of riparian areas (water buffers); and strengthening laws and regulations governing land use such as municipal sewer hookups and protection.

Lac La Biche County updated the Lac La Biche Watershed Management Plan, which was adopted by Council in May 2021. This plan includes specific action items based on the recommendations that were formulated while drafting the plan.

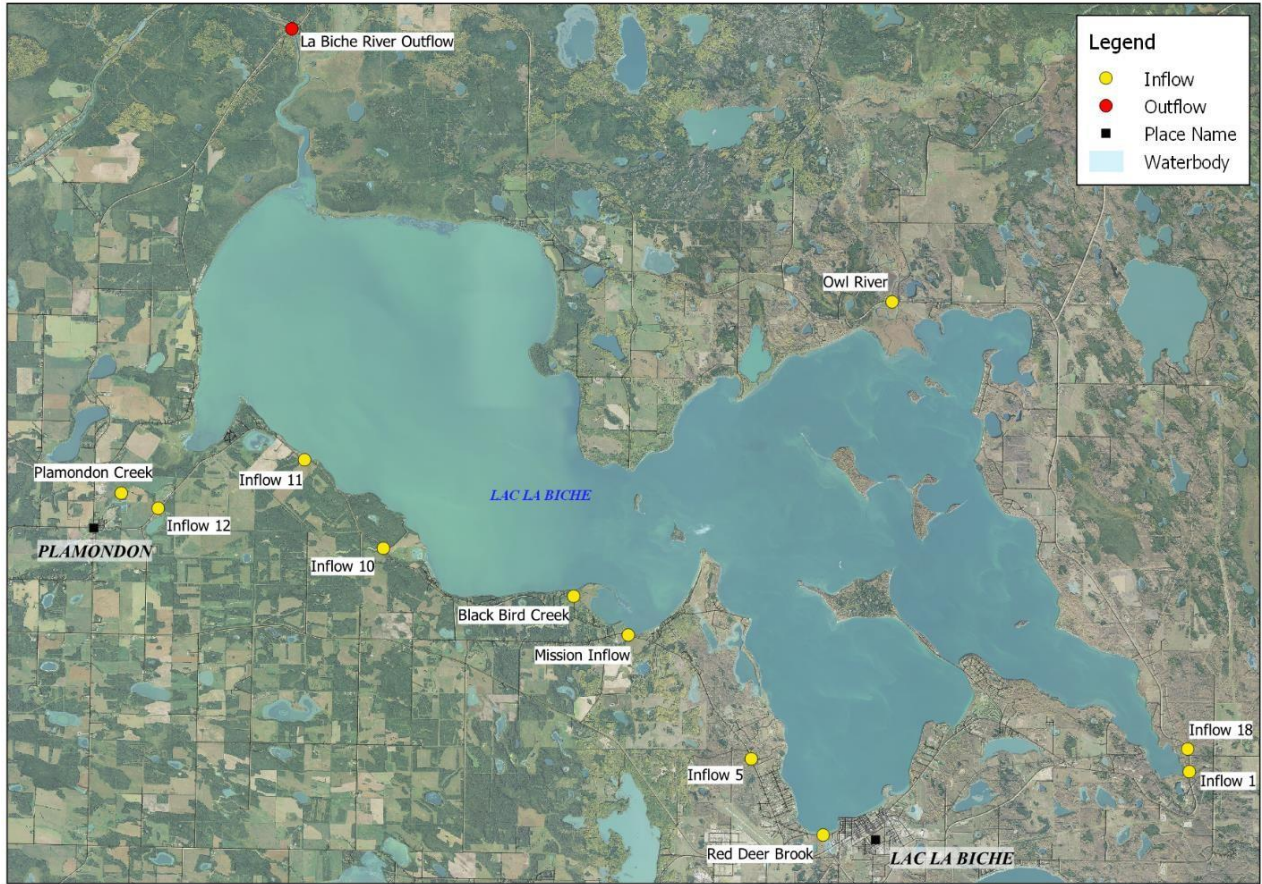


Figure 17: Map of Lac La Biche Lake with inflow/outflow locations

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APPENDIX A

Table 1: Trophic status classification based on lake water parameters (Nurnberg 1996)

Trophic State	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Secchi Depth (m)	Total Chlorophyll-a (µg/L)
Oligotrophic	<0.01	<0.35	>4	<3.5
Mesotrophic	0.01 – 0.03	0.35 – 0.65	4 - 2	3.5 - 9
Eutrophic	0.03 – 0.10	0.65 – 1.20	2 - 1	9 - 25
Hypereutrophic	>0.10	>1.20	<1	>25

Table 2: Trophic status of East Basin based on lake water parameters 2023

Trophic State	Secchi Depth	Total Nitrogen	Total Phosphorus	Total Chlorophyll-a
	(m)	(mg/L)		(µg/L)
Oligotrophic	>4	<0.35	<0.01	<3.5
Mesotrophic	4 – 2	0.35 – 0.65	0.01 – 0.03	3.5 – 9
Eutrophic	2 – 1	0.65 – 1.20	0.03 – 0.1	9 – 25
Hypereutrophic	<1	>1.2	>0.1	>25
LLB East Basin 2023	1.0	1.56	0.183	96.9
Trophic State of LLB East Basin 2023	Eutrophic	Hypereutrophic	Hypereutrophic	Hypereutrophic

Table 3: Average lake water N:P ratios for composite and Kemmerer samples from East Basin - 2023

Sampling Event	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	N:P
Composite Sampling	1.56	0.183	9:1
Kemmerer Sampling	1.05	0.165	6:1

Table 4: Routine water chemistry analysis from composite samples in East Basin of LLB Lake - 2023

Date of Sampling	June 30, 2023	July 27, 2023	August 17, 2023
	mg/L		
pH	8.30	5.95	8.13
Temperature (°C)	18.09	19.45	18.91
Ammonia, Total (as N)	0.0122	0.0239	0.0380
Nitrate (as N)	<0.020	<0.020	0.025
Nitrite (as N)	<0.010	<0.010	<0.010
Nitrate and Nitrite (as N)	<0.0300	<0.0300	<0.0300

* Based on average pH and temperature of 7.46 and 18.82 ° C of Lac La Biche East Basin in 2023

1: CCME C Guidelines, de-minimis criteria for Protection of Aquatic Life and Protection of Agricultural Water

2: Environmental Quality Guidelines for Alberta Surface Waters 2018

a: CCME Canadian Environmental Quality Guidelines for water for the Protection of Aquatic Life

b: CCME Canadian Environmental Guidelines for the Protection of Agricultural Water

Table 5: Total recoverable metals from Kemmerer samples in East Basin of LLB Lake – 2023

Date of Sampling	Kemmerer Sampling (6 m depth) February 7, 2023	Kemmerer Sampling (6 m depth) August 17, 2023	Criteria ¹	Criteria ²
Parameters	------(mg/L)-----			
Aluminum (Al)-Total	0.0036	0.0074	0.1 ^a	0.1
Arsenic (As)-Total	0.00136	0.00219	0.005 ^a	0.005
Barium (Ba)-Total	0.0549	0.0431	NS	NS
Beryllium (Be)-Total	<0.000020	<0.000020	100 ^b	NS
Boron (B)-Total	0.042	0.034	1.5 ^a	1.5
Cadmium (Cd)-Total	<0.0000050	<0.0000050	0.00009 ^a	0.00033
Chromium (Cr)-Total	<0.00050	<0.00050	NS	NS
Cobalt (Co)-Total	<0.00010	<0.00010	0.05 ^a	0.0012
Copper (Cu)-Total	0.0008	<0.00050	0.0040 ^a	0.022
Iron (Fe)-Total	0.014	0.076	0.3 ^a	0.3
Lead (Pb)-Total	0.00049	0.00006	0.007 ^a	0.007
Lithium (Li)-Total	0.0115	0.0099	2.5 ^b	NS
Manganese (Mn)-Total	0.221	0.189	0.2 ^b	NS
Mercury (Hg)-Total	<0.0000050	<0.0000050	0.000026 ^a	NS
Molybdenum (Mo)-Total	0.000401	0.000463	0.073 ^a	0.073
Nickel (Ni)-Total	<0.00050	0.00086	0.150 ^a	0.11
Selenium (Se)-Total	<0.000050	<0.000050	0.001 ^a	NS
Silver (Ag)-Total	<0.000010	<0.000010	0.00025 ^a	0.00025
Thallium (Tl)-Total	<0.000010	<0.000010	0.0008 ^a	0.0008
Tin (Sn)-Total	<0.00010	<0.00010	NS	NS
Titanium (Ti)-Total	<0.00030	<0.00030	NS	NS
Uranium (U)-Total	0.000065	0.00005	0.01 ^b	0.015
Vanadium (V)-Total	<0.00050	<0.00050	0.1 ^b	NS
Zinc (Zn)-Total	<0.0030	<0.0030	0.007 ^a	0.03

1: CCME Canadian Environmental Quality Guidelines, de-minimis criteria for Protection of Aquatic Life and Protection of Agricultural Water

2 - Environmental Quality Guidelines for Alberta Surface Waters 2018

a: CCME Canadian Environmental Quality Guidelines for water for the Protection of Aquatic Life

b: CCME Canadian Environmental Quality Guidelines for Protection of Agricultural Water

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Table 6: Historical data of routine chemistry and other parameters for East Basin of Lac La Biche Lake

Parameter	Year																	
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
pH	8.62	8.60	8.60	8.47	8.48	8.39	8.86	8.39	8.30	8.90	8.30	8.72	8.36	8.13	7.75	7.76	8.11	7.46
Secchi Depth (m)	1.77	2.63	2.32	2.38	1.65	2.57	1.93	2.18	2.00	2.07	2.88	1.50	1.83	2.20	1.4	1.8	1.3	1
Total Nitrogen (mg/L)	1.15	1.03	0.72	0.95	0.93	0.77	0.85	0.80	0.96	1.22	0.99	1.05	1.69	3.15	1.33	1.14	1.76	1.56
Total Phosphorus (mg/L)	0.101	0.119	0.108	0.089	0.121	0.057	0.134	0.071	0.155	0.238	0.153	0.188	0.197	0.162	0.092	0.149	0.128	0.183
Nitrate/Nitrite (mg/L)	0.00	0.01	0.06	0.18	0.02	0.12	0.03	<0.071	0.09	0.07	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.0300	<0.0300
Ammonia (mg/L)	0.11	0.02	0.04	0.13	0.05	0.08	0.08	<0.050	0.05	0.05	0.05	0.11	<0.050	<0.050	<0.050	0.011	0.0506	0.0247
Specific Conductivity (µS/cm)	271	284	298	289	278	258	281	281	284	243	287	248	384	255	423	348	808	274.9

Table 7: Historical trend of total metals in East Basin of Lac La Biche Lake

Dissolved Metals	2019	2020	2021	2022	2023	Criteria ¹	Criteria ²
	------(mg/L)-----						
Aluminum (Al)	0.0035	<0.00895	0.004	0.0041	0.0055	0.1a	0.1
Arsenic (As)	0.00179	0.00116	0.00146	0.001145	0.001775	0.005a	0.005
Barium (Ba)	0.0455	0.04645	0.0433	0.04875	0.049	NS	NS
Boron (B)	0.039	0.041	<0.00010	0.0385	<0.000020	1.5a	1.5
Cadmium (Cd)	<0.000010	<0.000010	0.039	<0.0000050	0.038	0.00009a	0.00019
Chromium (Cr)	<0.00020	<0.00020	<0.0000050	<0.00050	<0.0000050	NS	NS
Copper (Cu)	0.0016	<0.00155	<0.00010	0.002185	<0.00050	0.0032a	0.02
Iron (Fe)	0.045	0.0265	<0.00010	<0.010	<0.00010	0.3a	0.3
Lead (Pb)	<0.00010	<0.000061	<0.00050	<0.000050	0.0008	0.005a	0.0042
Lithium (Li)-Total	0.0099		0.04	0.0116	0.045		
Manganese (Mn)	0.0782	0.1938	<0.000050	0.0275	0.000275	0.2b	NS
Mercury (Hg)	<0.0000050	<0.0000050	0.0108	<0.0000050	0.0107	0.000026a	NS
Molybdenum (Mo)-Total	0.000314		0.089	0.000417	0.205		
Nickel (Ni)	<0.0010	<0.0010	<0.000005	<0.00050	<0.0000050	0.125a	0.063
Selenium (Se)	<0.00010	<0.00010	0.000414	0.000053	0.000432	0.001a	NS
Silver (Ag)	<0.000020	<0.000020	<0.00050	<0.000010	0.00086	0.00025a	0.00025
Thallium (Tl)-Total	<0.000010		0.000051	<0.000010	<0.000050		
Tin (Sn)-Total	<0.00010		<0.000010	<0.00010	<0.000010		
Titanium (Ti)-Total	<0.00030		<0.000010	<0.00030	<0.000010		
Uranium (U)	0.000063	0.0000595	<0.00010	0.0000725	<0.00010	0.01b	0.015
Zinc (Zn)	<0.0060	0.0177	<0.00030	0.00735	<0.00030	0.007a	0.03

1: CCME Canadian Environmental Quality Guidelines, de-minimis criteria for Protection of Aquatic Life and Protection of Agricultural Water

2 - Environmental Quality Guidelines for Alberta Surface Waters 2018

a: CCME Canadian Environmental Quality Guidelines for water for the Protection of Aquatic Life

b: CCME Canadian Environmental Quality Guidelines for Protection of Agricultural Water