Lac La Biche County
welcoming by nature.

2020 Lac La Biche Lake East Basin Water Quality Report Lac La Biche County Alberta

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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 water quality of lakes located within its jurisdiction. The water sampling events were conducted during the early spring and summer of 2020. 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 Parks' 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 phosphorous) 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.

For the purpose of this report, the parameters used to determine the trophic state will only include Secchi depth, total nitrogen and total phosphorus. Chlorophyll will not be used to determine the trophic state. Chlorophyll 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. Chlorophyll concentration is measured as part of the County's monitoring program. However, the measurement can be an underestimate of algae biomass when blue-green algae are present. It is also difficult to have consistent measurements of Chlorophyll as there can be large variances in concentrations due to anomalies such as temperature and weather conditions such as precipitation and wind. Therefore, it is difficult to report Chlorophyll concentrations and make recommendations based on the results. Based on this, Chlorophyll is not reported in this document.

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 Eutrophic based on the average of the three water parameters Secchi depth, total nitrogen and total phosphorus. The trophic status would be Eutrophic based on Secchi depth, Eutrophic based on total nitrogen, and Eutrophic based on total phosphorus.

Results and Discussion

In 2020, Secchi depths in the East Basin of Lac La Biche Lake were measured on May 28, June 24, and August 18, 2020. The average seasonal Secchi depth was observed to be 1.4 m which is consistent with 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 2020 shows that the average dissolved oxygen levels ranged from 7.11 mg/L to 10.19 mg/L. These concentrations were in proximity to the regulatory criteria for dissolved oxygen in cold water lakes for early life stages (9.5 mg/L) and for all other life stages (6.5 mg/L).

Sampling events in 2020 showed an average summer water temperature of 14.95 $^{\circ}$C. Uniform temperature profiles were observed during the summer as there were 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 March 17 and August 18, 2020.

In 2020, 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 phosphorous.

Total nitrogen concentrations in the composite samples collected from the East Basin in 2020 had an average of 1.33 mg/L of total nitrogen, while the Kemmerer samples collected had an average of 0.87 mg/L of total nitrogen. The inflow/outflow samples ranged from 0.92 mg/L to 3.99 mg/L of total nitrogen. The average total nitrogen concentrations from composite and Kemmerer sampling is 1.10 mg/L and classifies the East Basin of Lac La Biche Lake as Eutrophic (high productivity, nutrients, and algae growth).

Total phosphorus concentrations in the composite samples collected during the summer of 2020 had an average of 0.09 mg/L of total phosphorus, while the Kemmerer samples collected had an average of 0.05 mg/L; and the inflow/outflow samples ranged from 0.012 mg/L to 1.46 mg/L total phosphorus. Both the composite and Kemmerer samples of total phosphorus exceeded the applicable regulatory guidelines of 0.05 mg/L and were slightly lower than historical results. The average total phosphorus concentrations from composite and Kemmerer sampling classify the East Basin of Lac La Biche Lake as Eutrophic (high productivity, nutrients, and algae growth).

The average N:P ratios for composite and Kemmerer sampling events were 15:1 and 18:1 which is very close to the Redfield Ratio of 16:1. Therefore, the total phosphorus may not be considered a limiting nutrient in the East Basin of Lac La Biche Lake.

Routine water chemistry showed that East Basin of Lac La Biche Lake has an average pH of 7.75 in 2020 which is slightly lower than historical results.

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

During the summer of 2020, the beach monitoring program was put on hold by Alberta Health Services due to Covid-19. However, in the beginning of July 2020, Alberta health Services confirmed that McArthur Beach would be sampled to determine total Cyanobacteria (blue-green algae) counts. McArthur Beach was tested for Cyanobacteria on July 20, July 27, August 3, August 10, August 17, August 23, and August 31, 2020. All samples collected in 2020 did not exceed the regulatory guidelines of 100,000 cells/100mL. However, towards the end of August 2020, Cyanobacteria blooms were

visible, and samples contained counts that began to reach the regulatory criteria; therefore, Alberta Health Services issued a water quality advisory. Alberta Health Services stopped the beach monitoring program effective September 4, 2020; therefore, no further samples were taken.

In 2020, Alberta Lake Management Society (ALMS) worked with Lac La Biche County to complete three types of sampling: satellite imagery to track Cyanobacteria (blue-green algae) blooms, watermilfoil sampling (aquatic invasive species), and bacteriological sampling (Cyanobacteria and Enterococcus). The results of the satellite imagery and bacteriological beach sampling are not yet available for review. However, the watermilfoil sampling was confirmed to be native Northern Watermilfoil (*Myriophyllum sibiricum*) and was not the invasive Eurasian Watermilfoil (*Myriophyllum spicatum*).

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 13 and Figure 14 showing historical results of nutrients) and Cyanobacteria (blue-green algae) blooms were delayed until August (opposed to June/July).

The East Basin of Lac La Biche Lake would be considered Eutrophic based on the average of the three water parameters Secchi depth, total nitrogen and total phosphorus. The trophic status would be Eutrophic based on Secchi depth, Eutrophic based on total nitrogen, and Eutrophic based on total phosphorus. This is an improvement from historical results and may be the impact

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 watershed protection and waste and recycling management; 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 is currently in the process of updating the Lac La Biche Watershed Management Plan (WMP). This plan will include specific action items based on the recommendations that are formulated while drafting the plan. The WMP will be completed in early 2021; therefore, next year there will be further recommendations and action items for the lake monitoring program that will arise based on the WMP.

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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 Phosphorous
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 km^2 with a watershed of 4040 km^2 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 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). 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.

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 2020 was completed as follows:

a) Secchi Depths were measured on May 28, June 24, and August 18, 2020;
b) Lake profiles of the East Basin were recorded to a maximum depth of 9.5 m using multi-probe on March 17, May 28, June 24, and August 18, 2020;
c) Composite samples from the East Basin were collected on May 2, June 24, and August 18, 2020. These samples were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories;
d) Kemmerer water samples were collected March 14 and August 18, 2020 from depths of 3, 6, and 9 m, and were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories.
e) Inflow and outflow samples were collected on May 25, June 1, June 15, July 2, and August 13, 2020; and were analyzed for nutrients, metals and basic water chemistry parameters.
f) Monitoring of cyanobacteria was conducted at McArthur Beach only. This beach was sampled on July 20, July 27, August 3, August 10, August 17, August 24, and August 31, 2020.

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.
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.
Enterococcus	*Enterococcus* 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 Parks (AEP), and Health Canada.

The regulatory criteria selection for lake waters in Alberta are subjected to CCME's Canadian Environmental Quality Guidelines (CEQG) and AEP's Environmental Quality Guidelines for Alberta Surface Waters 2018 (EQGASW). Protection of lake water is covered under CCME's CEQG and AEP'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 2020, Secchi depths in the East Basin of Lac La Biche Lake were measured on May 28, June 24, and August 18, 2020. The measured Secchi depth declined from 2.0 m on May 28, 2020 to 0.75 m on August 18, 2020. Secchi depths are plotted in Figure 2. A declining trend in Secchi depth was observed in 2019 (Figure 2).

The low average Secchi depth of 1.4 m means that the lake water has poor transparency due to suspended materials. Based on the average Secchi depth of 1.4 m, East Basin is classified as Eutrophic in accordance to the Table 1 provided in Appendix A.

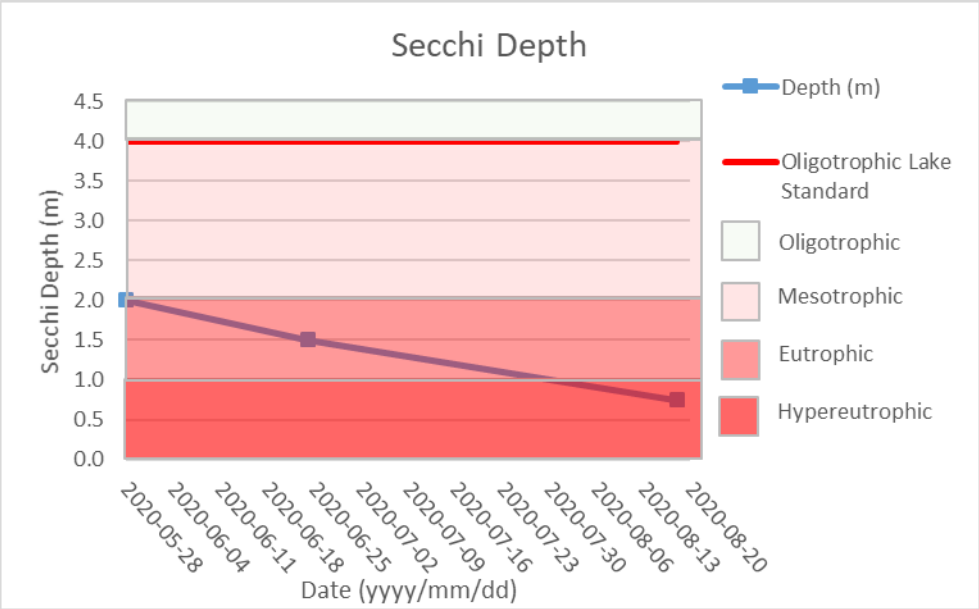

Figure 2: Secchi depths measured in East Basin of Lac La Biche Lake – 2020

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 11 m using multi-probe on March 17, May 28, June 24, and August 18, 2020. A maximum dissolved oxygen concentration of 13.11 and 13.10 mg/L was observed on March 17 and August 18, 2020 at a depth of 1 m depth which declined to 0.25 mg/L on March 17 and 7.51 mg/L on August 18 at the lakebed (Figure 4). Average dissolved oxygen measurements over the sampling period was 8.40 mg/L.

In 2020, the dissolved oxygen data from East Basin indicated that the average dissolved oxygen levels for all sampling events ranged from 7.11 mg/L to 10.19 mg/L and within proximity to the regulatory criteria for dissolved oxygen in cold water lakes (9.5 mg/L for early life stages and 6.5 mg/L for all other life stages).

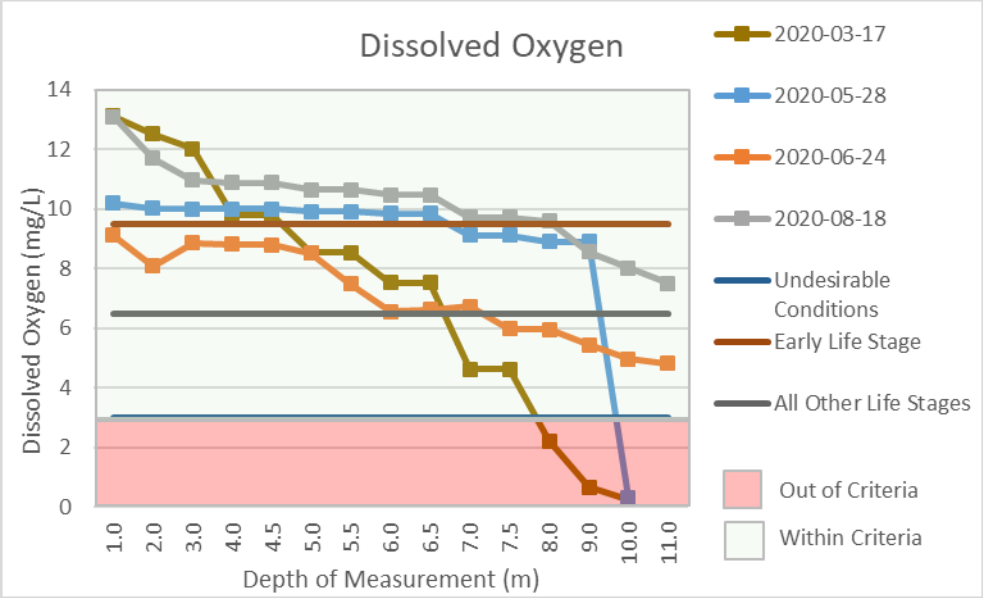

Figure 3: Dissolved oxygen in East Basin of Lac La Biche Lake - 2020

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 11 m on March 17, May 28, June 24, and August 18, 2020. Results of temperatures observed on different dates and depths are illustrated in Figure 4. A minimum temperature of 0.666 ˚C was observed on March 17, 2020 at a 1 m depth, which increased to a temperature of 4.313 ˚C at a 10 m depth.

Sampling events in the summer of 2020 showed an average summer water temperature of 14.95 ˚C in the East Basin of LLB Lake. Uniform temperature profiles were observed as temperatures over depth did not vary significantly.

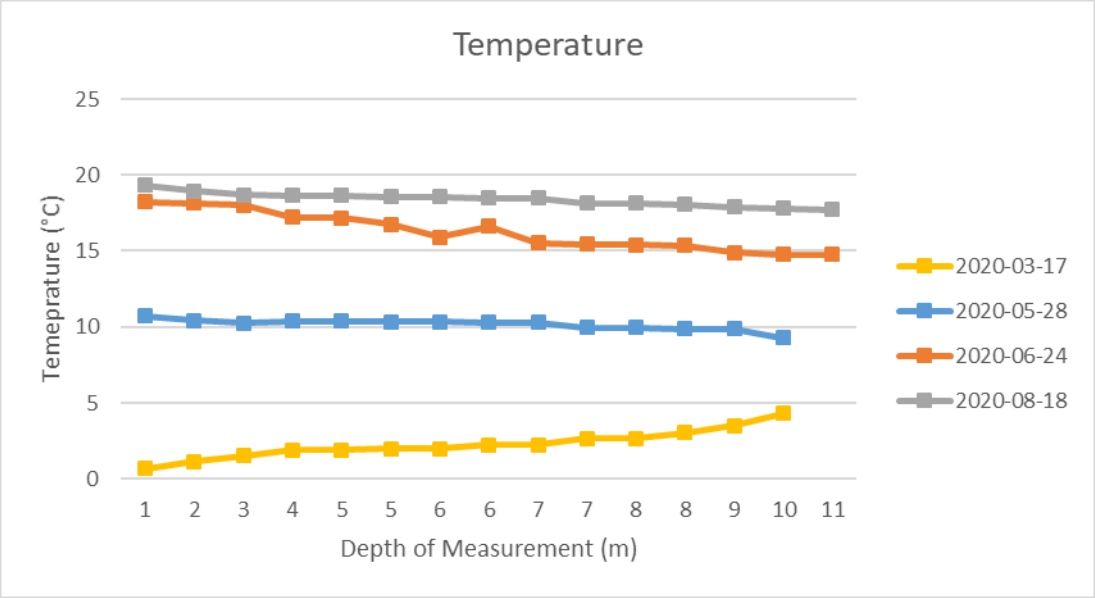

Figure 4: Temperature profile for East Basin of Lac La Biche Lake - 2020

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 2020, 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 May 28, June 24, and August 18, 2020. The analytical results of these samples are presented in Figure 5 below. As indicated, the minimum total nitrogen concentration of 0.70 mg/L was noted in sample collected on May 28, 2020 and the maximum concentration of 2.13 mg/L was observed in a sample collected on August 18, 2020. Nitrogen concentrations in the composite samples collected from the lake in 2020 had an average of 1.33 mg/L of total nitrogen which exceeded the applicable regulatory guidelines.

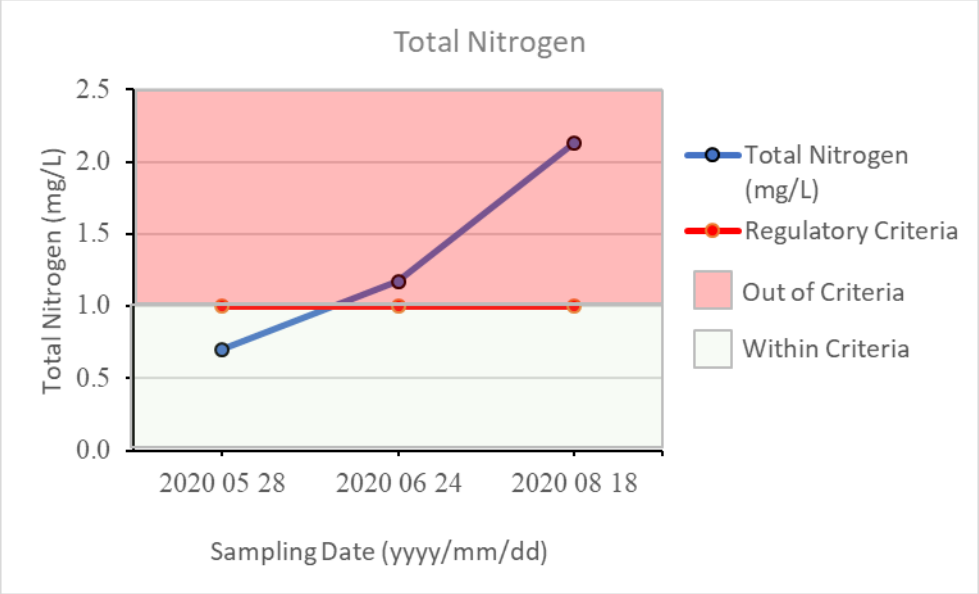

Figure 5: Total nitrogen from composite samples in East Basin of LLB Lake – 2020

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 March 17 from depths of 3 m, 6 m, 9 m, and 12 m and August 18, 2020 from depths of 3 m, 6 m, and 9 m. These samples were analyzed for total nitrogen by ALS laboratories. The analytical results of these samples presented in Figure 6.

Total nitrogen concentrations in the samples collected only exceeded the regulatory guidelines on March 17, 2020 at a 12 m depth and on August 18, 2020 at 3 m and 6 m depths, all other samples collected did not exceed the regulatory guidelines. The average total nitrogen from all Kemmerer samples is 0.87 mg/L. The average total nitrogen concentration from composite and Kemmerer sampling is 1.10 mg/L which results from the Kemmerer sampling resulted in a trophic classification of Eutrophic (high productivity, nutrients, and algae growth) based on total nitrogen.

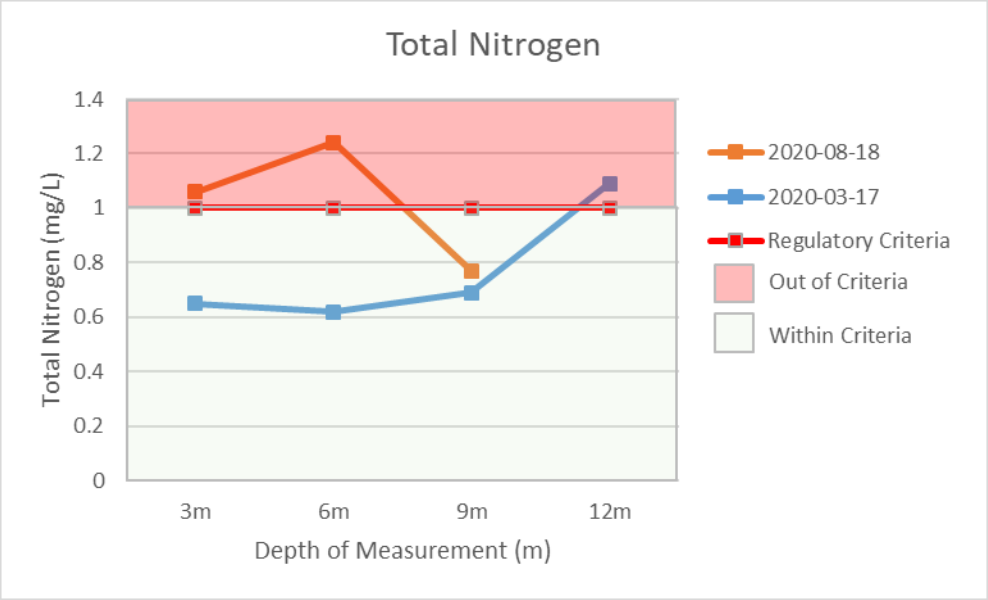

Figure 6: Total nitrogen from Kemmerer samples in East Basin of LLB Lake - 2020

Inflow and Outflow Sampling

The inflows and outflow for Lac La Biche Lake had samples collected on May 25, June 1, June 15, July 2, and August 13, 2020. The results of total nitrogen in these samples are illustrated in Figure 7. Inflow 12 was not sampled due to low volume and flow. As indicated below (Figure 7) the total nitrogen concentrations in all inflow samples, except Owl River, exceeded the applicable regulatory guidelines (1.0 mg/L). A map showing the location of these samples is found on Figure 16.

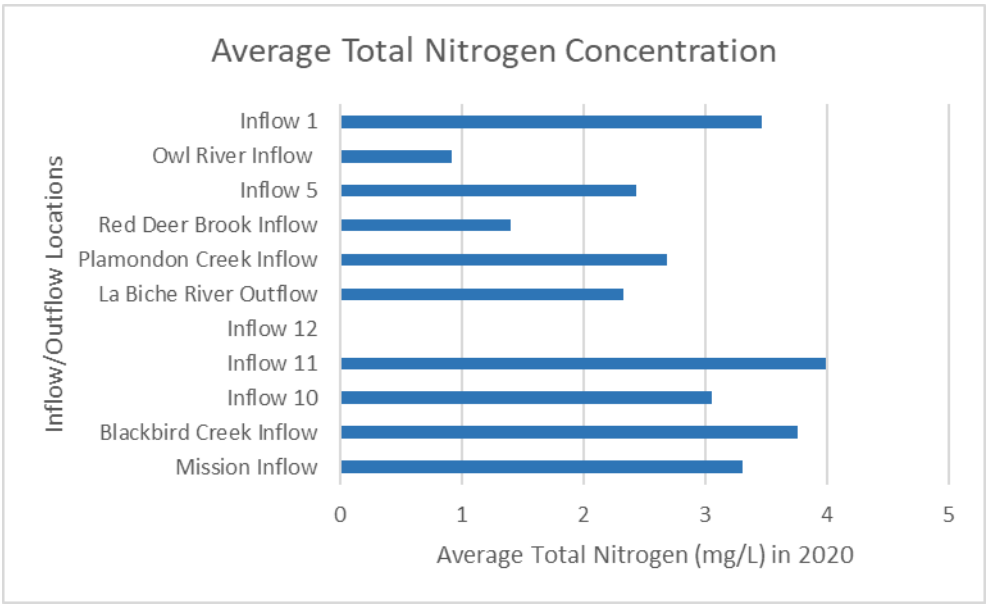

Figure 7: Inflow and outflow total nitrogen concentration for Lac La Biche Lake - 2020

Total Phosphorous

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 phosphorous for several years.

Composite Sampling

Composite lake water samples for total phosphorous analysis were collected on May 28, June 24, and August 18, 2020 from the East Basin in Lac La Biche Lake. The analytical results are presented in Figure 8.

A minimum total phosphorous concentration of 0.053 mg/L was found in a sample collected on May 28, 2020 which increased to 0.159 mg/L on August 18, 2020. Total phosphorous concentrations of all composite samples collected during 2020 exceeded the applicable regulatory guidelines (0.050 mg/L) with an average of 0.092 mg/L total phosphorus. This average total phosphorus concentration classifies the East Basin of Lac La Biche Lake as Eutrophic (high productivity, nutrients, and algae growth) based on total phosphorus from composite samples.

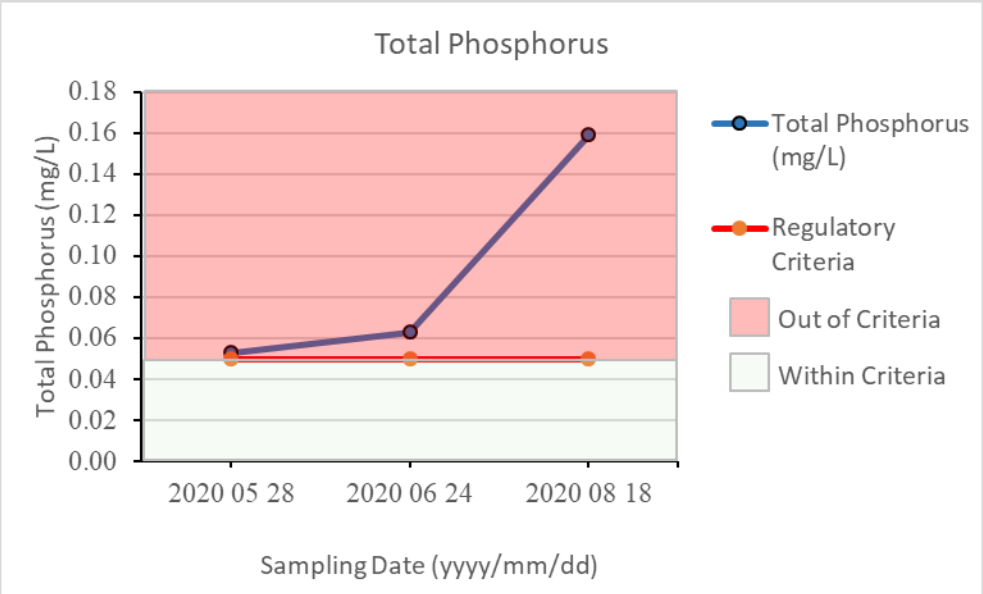

Figure 8: Total phosphorus from composite samples in East Basin of LLB Lake – 2020

Kemmerer Sampling

Kemmerer water samples using Kemmerer sampling device were collected on March 17 from 3 m, 6 m, 9 m, and 12 m depths and on August 18, 2020 from depths of 3 m, 6 m, and 9 m and were analyzed for total phosphorous by ALS laboratories. The laboratory results are presented in Figure 9.

The total phosphorus concentration in lake water samples collected on August 18, 2019 exceeded the regulatory guideline of 0.05 mg/L, while samples collected on March 17, 2020 only exceeded the

guideline at the 12 m depth. Total phosphorous concentrations in the samples collected on March 17, 2020 increased with lake depth. The average total phosphorus from Kemmerer sampling is 0.05 mg/L which is in close proximity to the applicable regulatory guideline. The results from the Kemmerer sampling resulted in the same trophic state classification as the composite samples which is Eutrophic (high productivity, nutrients, and algae growth) based on total phosphorus.

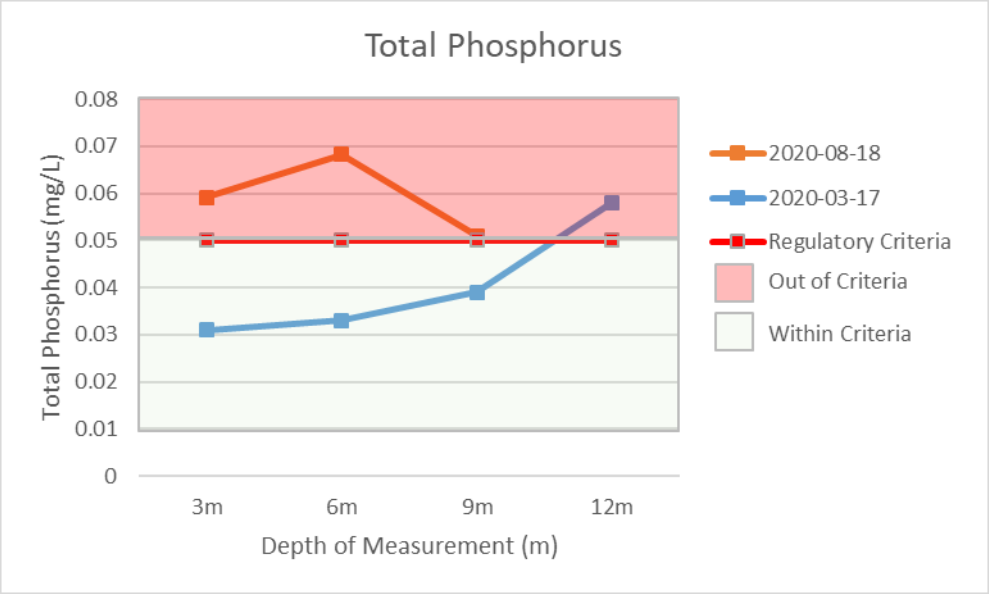

Figure 9: Total phosphorus from Kemmerer samples in East Basin of LLB Lake - 2020

Inflow and Outflow Sampling

The inflows and outflow for Lac La Biche Lake were collected on May 25, June 1, June 15, July 2, and August 13, 2020. Data regarding inflow total phosphorus concentrations is illustrated in Figure 10 below. Inflow 12 was not sampled due to low volume and flow.

Total phosphorus concentrations in more than half of the inflow and outflow samples exceeded the applicable regulatory guideline 0.05 mg/L for total phosphorus concentration. However, Owl River, La Biche River, and Inflow 10 were within the regulatory guideline of 0.05 mg/L. A map showing the location of these samples is found on Figure 16.

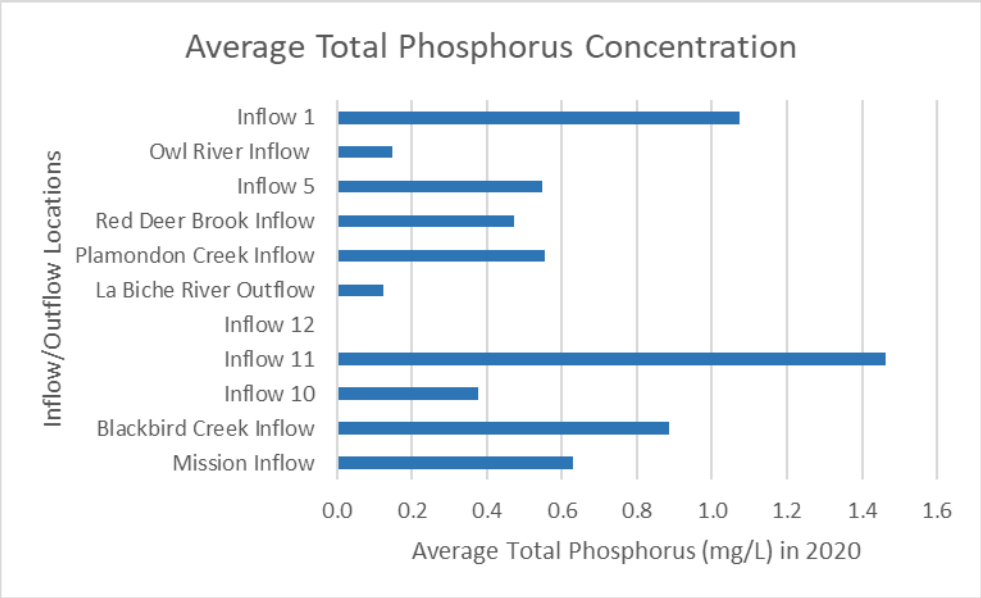

Figure 10: Inflow and outflow total phosphorous concentration for Lac La Biche Lake - 2020

N:P Ratio

The Redfield Ratio describes the optimal balance of total nitrogen to total phosphorous 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 15:1 to 18:1, which very close to the Redfield Ratio of 16:1. Therefore, the total phosphorus may not be considered a limiting nutrient.

4.5 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 7.75 which was slightly lower than 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.

4.6 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 2020, were generally below detection limits and did not exceed the applicable regulatory guidelines (Table 6, Appendix A).

4.7 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 a visual detection of algal blooms, along with the ability to sample for species composition and total Cyanobacterial cell count. This program also allowed to sample for the concentrations of the most common Cyanobacterial toxic, 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.

During the summer of 2020, the beach monitoring program was put on hold by Alberta Health Services due to Covid-19. However, in the beginning of July 2020, Alberta health Services confirmed that McArthur Beach would be sampled to determine total Cyanobacteria (blue-green algae) counts only and would not be sampled for Enterococcus. Therefore, Lac La Biche County collected samples from McArthur Beach for Cyanobacteria on July 20, July 27, August 3, August 10, August 17, August 23, and August 31, 2020.

All samples collected in 2020 did not exceed the regulatory guidelines of 100,000 cells/100mL. However, towards the end of August 2020, Cyanobacteria blooms were visible, and samples contained counts that began to reach the regulatory criteria; therefore, Alberta Health Services issued a water quality advisory. Alberta Health Services stopped the beach monitoring program effective September 4, 2020; therefore, no further samples were taken.

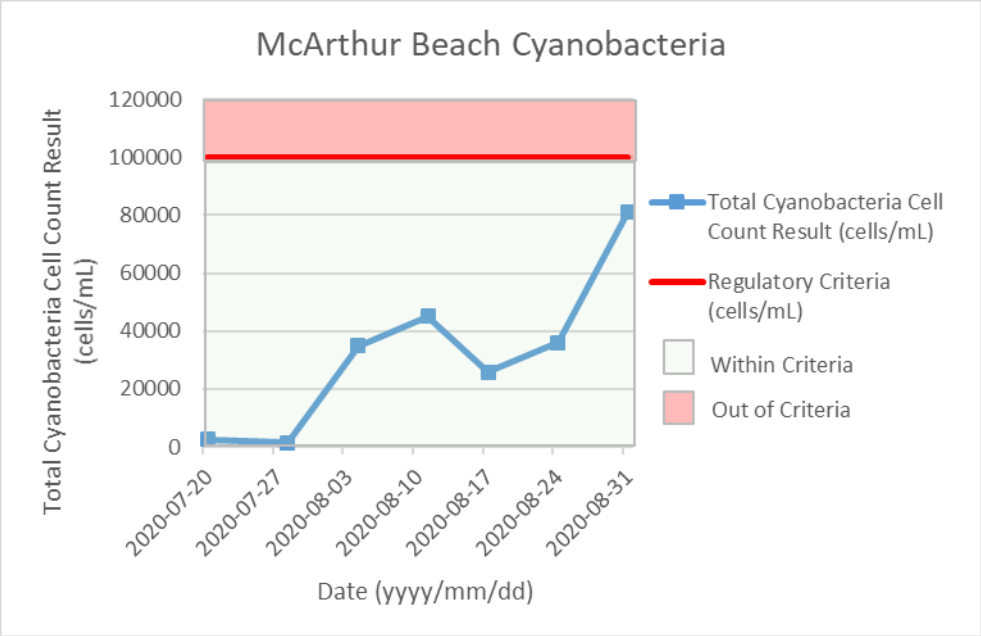

Figure 11: *Enterococcus* counts from beaches in East Basin of LLB Lake - 2020

4.8 Alberta Lake Management Society Sampling

During the summer of 2020, Alberta Lake Management Society (ALMS) worked with Lac La Biche County to complete three types of sampling: satellite imagery to track Cyanobacteria (blue-green algae) blooms, watermilfoil sampling (aquatic invasive species), and bacteriological beach sampling (Cyanobacteria and Enterococcus).

On August 18, 2020 an ALMS representative joined Lac La Biche County to complete the satellite imagery sampling on Lac La Biche Lake. The imagery is used as part of a larger project to map algal and Cyanobacteria abundance and track bloom development, severity, and spread in lakes throughout Alberta. The satellite imagery is validated through surface water samples to build a monitoring model to track Cyanobacteria blooms in Alberta's lakes. The results of this sampling have not been analyzed yet and the results have not been confirmed to be reportable at this time. ALMS will notify Lac La Biche County on any further progress with results.

During the last week of August, Lac La Biche County collected a watermilfoil sample from Lac La Biche Lake. The sample was sent to Alberta Plant Health Laboratory and was analyzed to determine if the specimen was native Northern Watermilfoil (*Myriophyllum sibiricum*) or the invasive Eurasian Watermilfoil (*Myriophyllum spicatum*). The sample from Lac La Biche Lake was determined to be native Northern Watermilfoil.

Lac La Biche County also worked with ALMS on a beach monitoring program at popular recreational beaches on Lac La Biche Lake. The County collected samples from McArthur Beach for Cyanobacteria and Enterococcus, while Plamondon White Sands, Golden Sands, Mission Beach, and Campers Beach at Sir Winston Churchill Park were all sampled for Enterococcus. ALMS completed this sampling through collaboration with the University of Alberta and Alberta Health Services. The results of this sampling will be compiled within a report by the University of Alberta and will be available for interested parties such as Lac La Biche County in 2021.

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 1.5 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 12). 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.

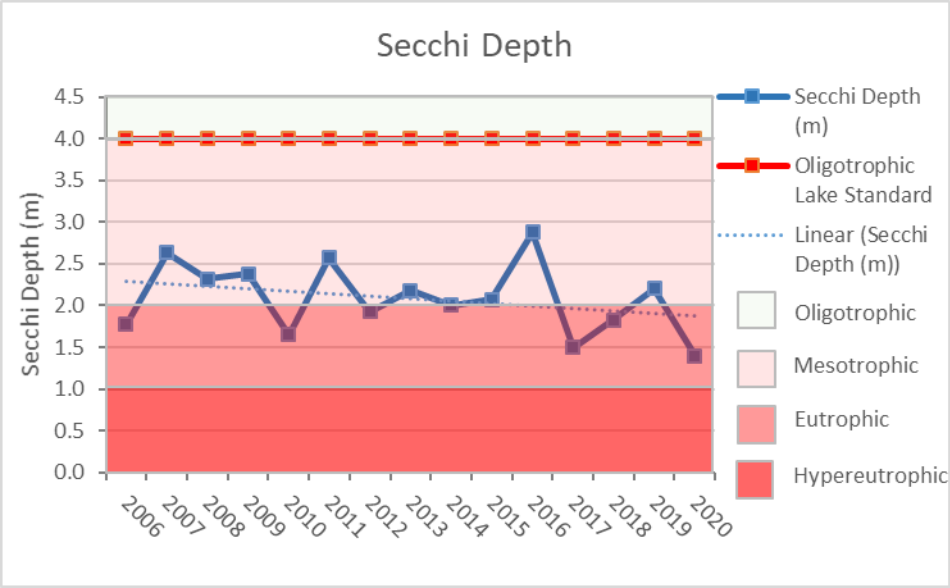

Figure 12: Historical trend for Secchi Depth in East Basin of Lac La Biche Lake

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) based on total nitrogen. The East Basin has been less than the regulatory guidelines of 1.0 mg/L of total nitrogen except during 2006, 2015, and 2017 to 2019. The maximum total nitrogen (3.15 mg/L) in 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.

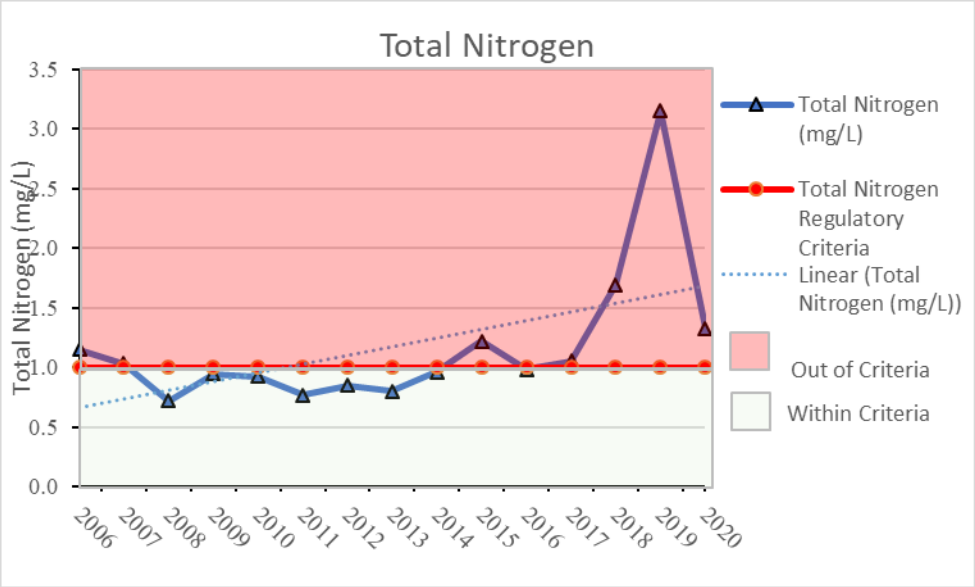

Figure 13: Historical trend of total nitrogen in East Basin of Lac La Biche Lake

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 14. 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.

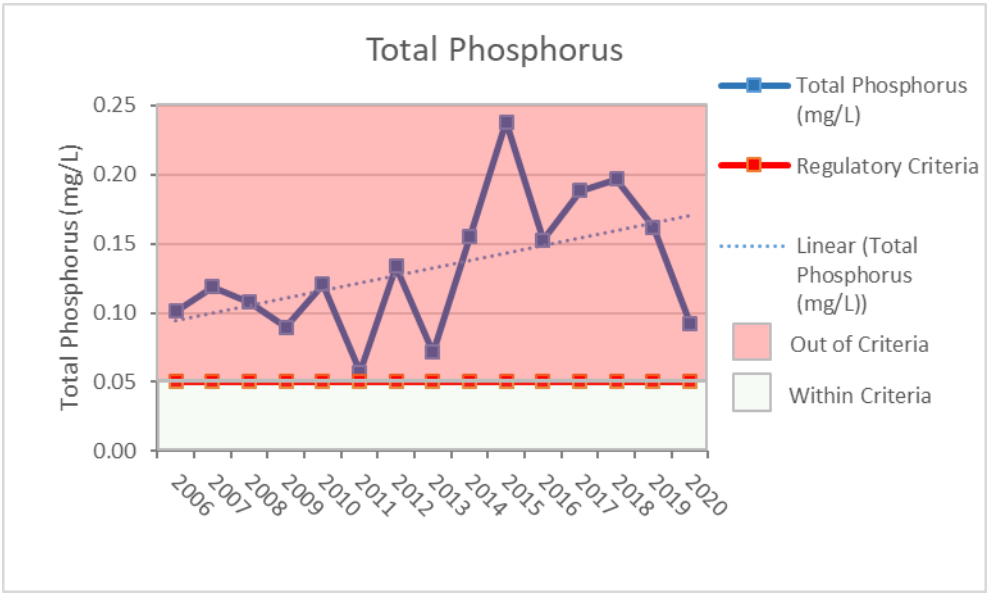

Figure 14: Historical trend of total phosphorus in East Basin of Lac La Biche Lake

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 15 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 13 and Figure 14 showing historical results of nutrients) and Cyanobacteria (blue-green algae) blooms were delayed until August (opposed to June/July).

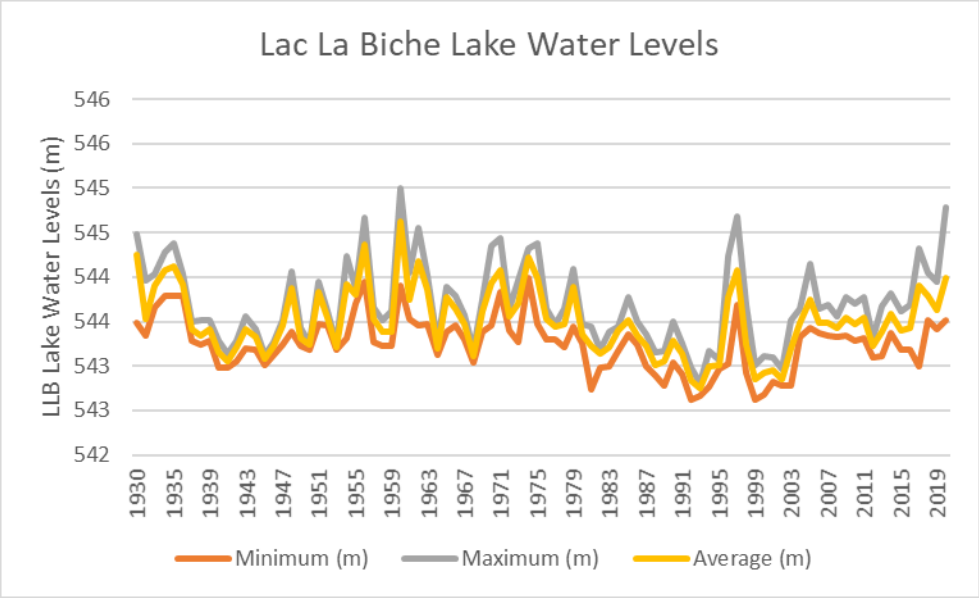

Figure 15: Historical water levels of Lac La Biche Lake

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 phosphorous) 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.

For the purpose of this report, the parameters used to determine the trophic state will only include Secchi depth, total nitrogen and total phosphorus. Chlorophyll will not be used to determine the trophic state. Chlorophyll 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. Chlorophyll concentration is measured as part of the County's monitoring program. However, the measurement can be an underestimate of algae biomass when blue-green algae are present. It is also difficult to have consistent measurements of Chlorophyll as there can be large

variances in concentrations due to anomalies such as temperature and weather conditions such as precipitation and wind. Therefore, it is difficult to report Chlorophyll concentrations and make recommendations based on the results. Based on this information, Chlorophyll is not reported in this document.

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 Eutrophic based on the average of the three water parameters Secchi depth, total nitrogen and total phosphorus. The trophic status would be Eutrophic based on Secchi depth, Eutrophic based on total nitrogen, and Eutrophic based on total phosphorus.

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 watershed protection and waste and recycling management; 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 is currently in the process of updating the Lac La Biche Watershed Management Plan (WMP). This plan will include specific action items based on the recommendations that are formulated while drafting the plan. The WMP will be completed in early 2021; therefore, next year there will be further recommendations and action items for the lake monitoring program that will arise based on the WMP.

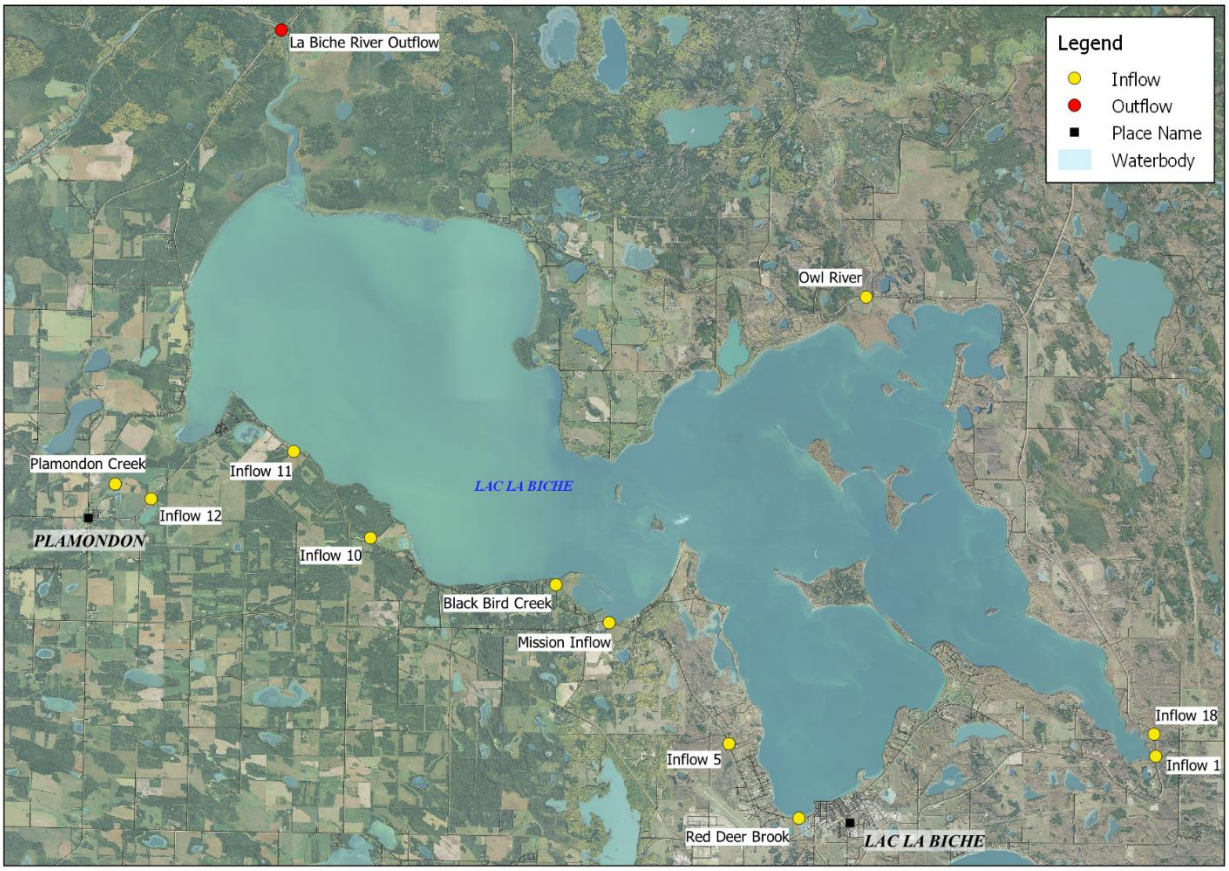

Figure 16: Map of Lac La Biche Lake with inflow/outflow locations

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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)
Oligotrophic	<0.01	<0.35	>4
Mesotrophic	0.01 – 0.03	0.35 – 0.65	4 - 2
Eutrophic	0.03 – 0.10	0.65 – 1.20	2 - 1
Hypereutrophic	>0.10	>1.20	<1

Table 2: Trophic status of East Basin based on lake water parameters 2020

Trophic State	**Secchi Depth**	**Total Nitrogen**	**Total Phosphorus**
	(m)	(mg/L)	
Oligotrophic	>4	<0.35	<0.01
Mesotrophic	4 – 2	0.35 – 0.65	0.01 – 0.03
Eutrophic	2 – 1	0.65 – 1.20	0.03 – 0.1
Hypereutrophic	<1	>1.2	>0.1
LLB East Basin 2020	1.4	1.08	0.07
Trophic State of LLB East Basin 2019	Mesotrophic	Hypereutrophic	Hypereutrophic
Trophic State of LLB East Basin 2020	Eutrophic	Eutrophic	Eutrophic

Table 3: Average lake water N:P ratios for composite and Kemmerer samples from East Basin - 2020

Sampling Event	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**N:P**
Composite Sampling	1.33	0.092	15:1
Kemmerer Sampling	0.84	0.047	18:1

Table 4: Routine water chemistry analysis from composite samples in East Basin of LLB Lake - 2020

Date of Sampling	**May 28, 2020**	**June 24, 2020**	**August 18, 2020**
	mg/L		
pH	7.81	6.51	8.14
Temperature (°C)	10.17	16.28	18.41
Ammonia, Total (as N)	<0.05	<0.05	0.087
Nitrate (as N)	<0.020	<0.020	<0.020
Nitrite (as N)	<0.010	<0.010	<0.010
Nitrate and Nitrite (as N)	<0.022	<0.022	<0.022

* Based on average pH and temperature of 7.75 and 14.95 °C of Lac La Biche East Basin in 2020

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 – 2020

Date of Sampling	**Kemmerer Sampling (9 m depth) March 17, 2020**	**Kemmerer Sampling (6 m depth) August 18, 2020**	**Criteria[1]**	**Criteria[2]**
Parameters	----------(mg/L)----------			
Aluminum (Al)-Total	<0.0030	0.0149	0.1[a]	0.1
Arsenic (As)-Total	0.0009	0.00142	0.005[a]	0.005
Barium (Ba)-Total	0.0549	0.038	NS	NS
Beryllium (Be)-Total	<0.00010	<0.00010	100[b]	NS
Boron (B)-Total	0.039	0.042	1.5[a]	1.5
Cadmium (Cd)-Total	<0.0000050	<0.0000050	0.00009[a]	0.00033
Chromium (Cr)-Total	<0.00010	<0.00010	NS	NS
Cobalt (Co)-Total	<0.00010	<0.00010	0.05[a]	0.0012
Copper (Cu)-Total	<0.00050	0.0026	0.0040[a]	0.022
Iron (Fe)-Total	0.013	0.04	0.3[a]	0.3
Lead (Pb)-Total	<0.000050	0.000072	0.007[a]	0.007
Lithium (Li)-Total	0.0116	0.0098	2.5[b]	NS
Manganese (Mn)-Total	0.359	0.0286	0.2[b]	NS
Mercury (Hg)-Total	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	0.000406	0.000384	0.073[a]	0.073
Nickel (Ni)-Total	<0.00050	<0.00050	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	0.000072	0.000047	0.01[b]	0.015
Vanadium (V)-Total	<0.00050	<0.00050	0.1[b]	NS
Zinc (Zn)-Total	0.017	0.0064	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

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

	Year														
Parameter	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
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
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
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
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
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
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
Specific Conductivity (µS/cm)	271	284	298	289	278	258	281	281	284	243	287	248	384	255	423

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

Dissolved Metals	**2017**	**2018**	**2019**	**2020**	**Criteria[1]**	**Criteria [2]**
	----------(mg/L)----------					
Aluminum (Al)	0.0062	0.0041	0.0035	<0.00895	0.1a	0.1
Arsenic (As)	0.00166	0.00187	0.00179	0.00116	0.005a	0.005
Barium (Ba)	0.0423	0.0484	0.0455	0.04645	NS	NS
Boron (B)	0.04	0.038	0.039	0.041	1.5a	1.5
Cadmium (Cd)	0.0000055	<0.0000050	<0.000010	<0.000010	0.00009a	0.00019
Chromium (Cr)	0.00012	<0.00010	<0.00020	<0.00020	NS	NS
Copper (Cu)	0.00172	<0.00050	0.0016	<0.00155	0.0032a	0.02
Iron (Fe)	0.072	0.141	0.045	0.0265	0.3a	0.3
Lead (Pb)	0.000057	0.000064	<0.00010	<0.000061	0.005a	0.0042
Lithium (Li)-Total	0.0111	0.0096	0.0099			
Manganese (Mn)	0.17	0.27	0.0782	0.1938	0.2b	NS
Mercury (Hg)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.000026a	NS
Molybdenum (Mo)-Total	0.000334	0.000320	0.000314			
Nickel (Ni)	<0.00050	<0.00060	<0.0010	<0.0010	0.125a	0.063
Selenium (Se)	<0.000050	<0.000050	<0.00010	<0.00010	0.001a	NS
Silver (Ag)	<0.000010	<0.000010	<0.000020	<0.000020	0.00025a	0.00025
Thallium (Tl)-Total	<0.000010	<0.000010	<0.000010			
Tin (Sn)-Total	<0.00010	<0.00010	<0.00010			
Titanium (Ti)-Total	0.00045	<0.00030	<0.00030			
Uranium (U)	0.000047	0.000054	0.000063	0.0000595	0.01b	0.015
Zinc (Zn)	0.0069	0.0096	<0.0060	0.0177	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