2020 Lac La Biche Lake West 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 2019. 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 West 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 West 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 West Basin of Lac La Biche Lake were measured on June 16, June 24, July 6, and August 19, 2020. The average seasonal Secchi depth was observed to be 1.9 m which is consistent with historical results. Based on the Secchi depths and in accordance with the classification provided in Table 1 (Appendix A), the West 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 6.80 mg/L to 14.38 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 15.8 ˚C. Uniform temperature profiles were generally observed during the summer as there were no significant variation in temperatures with depth, except for sampling events on June 24 and July 6, 2020 which showed a thermocline with thermal stratification in the water column.

In 2020, three types of lake water samples for analyses of nutrients were collected from West 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 West Basin in 2020 had an average of 0.87 mg/L of total nitrogen, while the Kemmerer samples collected had an average of 0.724 mg/L of total nitrogen; and the inflow/outflow samples ranged from 0.92 mg/L to 3.99 mg/L of total nitrogen. Both the composite and Kemmerer samples total nitrogen concentrations did not exceed the applicable regulatory guidelines of 1.0 mg/L and were improved from historical results. The average total nitrogen concentrations from composite and Kemmerer sampling classify the West 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 0.05 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 were equal to the applicable regulatory guidelines of 0.05 mg/L. The average total phosphorus concentrations from composite and Kemmerer sampling classify the West 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 17:1 and 15:1 which is close to the Redfield Ratio of 16:1. Therefore, the total phosphorus may not be considered a limiting nutrient in the West Basin of Lac La Biche Lake.

Routine water chemistry showed that West Basin of Lac La Biche Lake has an average pH of 7.98 in 2020 which is consistent with 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 West 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.

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 depth of 21.3 m.

Figure 1: Location map of Lake 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 which are reported separately. LLB Lake West Basin sampling program for 2020 was completed as follows:

a) Secchi Depths were measured on June 16, June 24, July 6, and August 19, 2020;
b) Composite samples from the West Basin were collected on June 16, June 24, July 6, and August 19, 2020. Lake water samples were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories;
c) Kemmerer water samples were collected on March 17, 2020 from depths of 3, 6, 9, 12, 15, and 18 m; and on August 19, 2020 from depths of 3, 6, 9, and 12 m. These samples were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories;
d) 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;
e) Lake profiles were recorded to a maximum depth of 20 m using a multi-probe March 17, June 16, June 24, July 6, and August 19, 2020;
f) Monitoring of cyanobacteria was conducted at McArthur Beach in the East Basin 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.

In 2020, Secchi depths in the West Basin were measured on June 16, June 24, July 6, and August 19, 2020. An overall a decreasing temporal trend was observed (Figure 2), with an average Secchi depth of 1.94 m.

The low average Secchi depth of 1.94 m means that the lake water has poor transparency due to suspended materials. Based on the Secchi depths, West Basin is classified as Mesotrophic in accordance to the Table 1 provided in Appendix A.

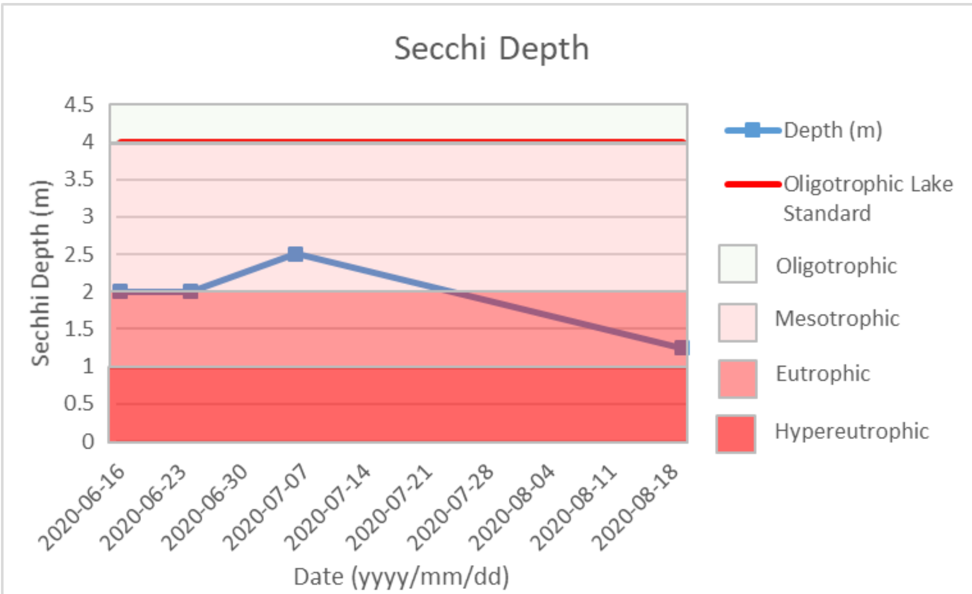

Figure 2: Secchi depths measured in West Basin of LLB Lake – 2020

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 West Basin of Lac La Biche Lake were recorded to a maximum depth of 20 m using a multi-probe on March 17, June 16, June 24, July 6, and August 19, 2020. A maximum dissolved oxygen concentration of 18.79 mg/L was observed on June 24, 2020 at a depth of 1 m which declined gradually to a concentration of 11.50 mg/L at the lakebed (Figure 3).

Dissolved oxygen data collected in 2020 shows that the average dissolved oxygen levels ranged from 6.80 mg/L to 14.38 mg/L and were within proximity to regulatory guidelines 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).

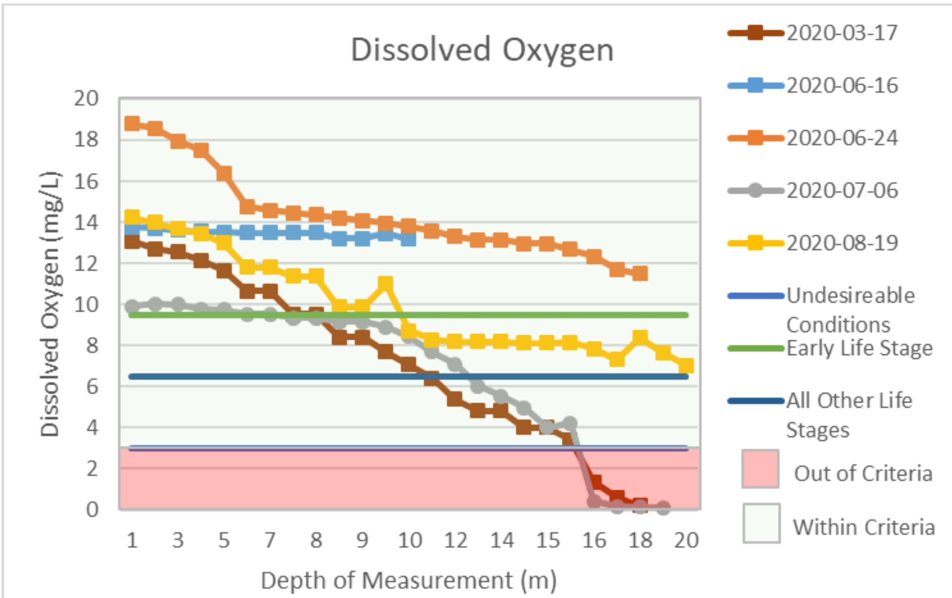

Figure 3: Dissolved oxygen in West Basin of LLB Lake - 2020

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 West Basin temperatures were recorded to a maximum depth of 20 m on March 17, June 16, June 24, July 6, and August 19, 2020. A minimum temperature of 0.162 ˚C was observed on March 17, 2020 at a depth of 1 m. While a maximum temperature of 19.874 ˚C was observed on August 19, 2020 at a 1 m depth. Results of temperatures observed on different dates and depth are illustrated in Figure 4.

Sampling events in the summer of 2020 showed an average summer water temperature of 15.8 ˚C in the West Basin of LLB Lake. Uniform temperature profiles were generally observed during the summer and winter as there were no significant variation in temperatures with depth, except for sampling events on June 24 and July 6, 2020 which showed a thermocline with thermal stratification in the water column. On

June 24, 2020 the thermocline was found around 5-7 m depth, while on July 6, 2020 the thermocline was found around the 11-13 m depth.

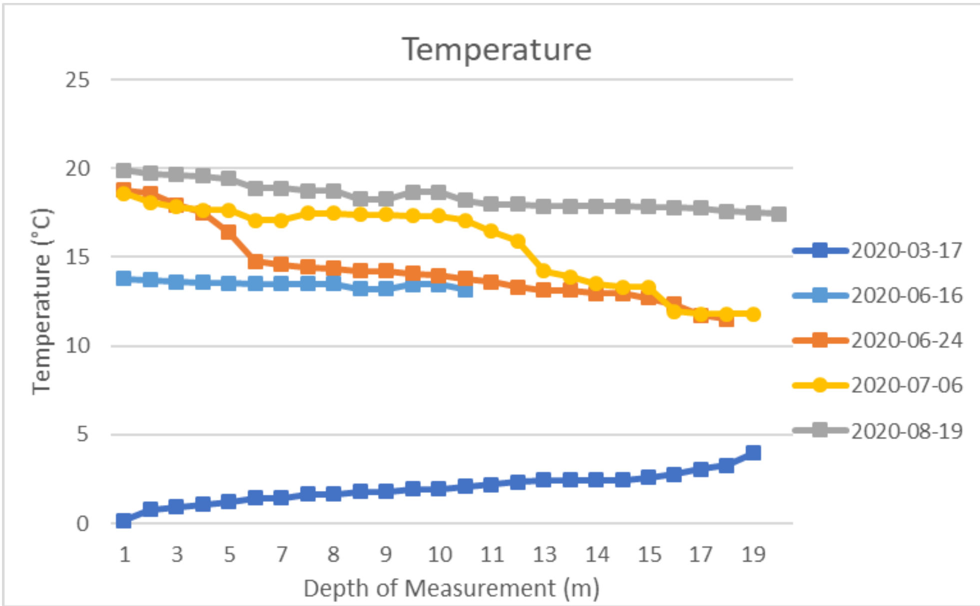

Figure 4: Temperature profile in West Basin of LLB Lake - 2020

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 West 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 West 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 16, June 24, July 6, and August 19, 2020. The analytical results are presented in Figure 5. The results indicated that the minimum total nitrogen concentration of 0.55 mg/L was found in sample collected on June 24, 2020 and the maximum total nitrogen concentration of 1.44 mg/L was found in sample collected on August 19, 2020.

Nitrogen concentrations in the composite samples collected from the lake in 2020 had an average of 0.87 mg/L of total nitrogen which does not exceed the applicable regulatory guidelines. The average total nitrogen indicates that the West Basin of Lac La Biche Lake is Eutrophic (high productivity, nutrients, and algae growth) based on total nitrogen from composite samples.

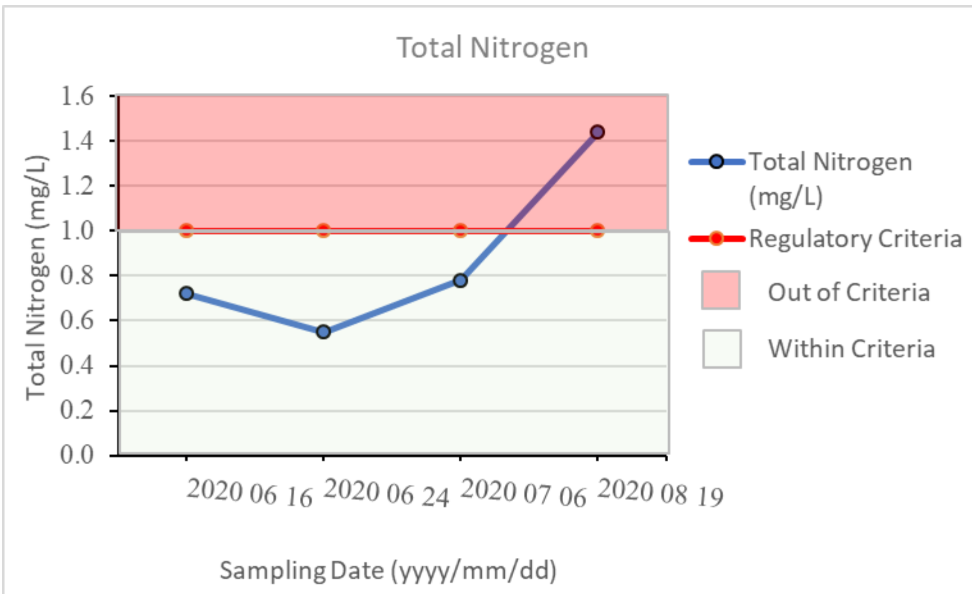

Figure 5: Total nitrogen from composite samples in West Basin of LLB Lake - 2020

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 water samples were collected from the West Basin of Lac La Biche Lake on March 17, 2020 from depths of 3 m, 6 m, 9 m, 12 m, 15 m, and 18 m and August 19, 2020 from depths of 3 m, 6 m, 9 m, and 12 m. The average total nitrogen concentration from Kemmerer sampling is 0.77 mg/L. The analytical results of total nitrogen in these samples are presented in Figure 6.

The average total nitrogen the same different trophic state classification as the composite samples which is Eutrophic (high productivity, nutrients, and algae growth) based on total nitrogen. Therefore, the average between both composite and Kemmerer sampling results in a trophic status of Hypereutrophic based on the average total nitrogen concentration of 0.82 mg/L.

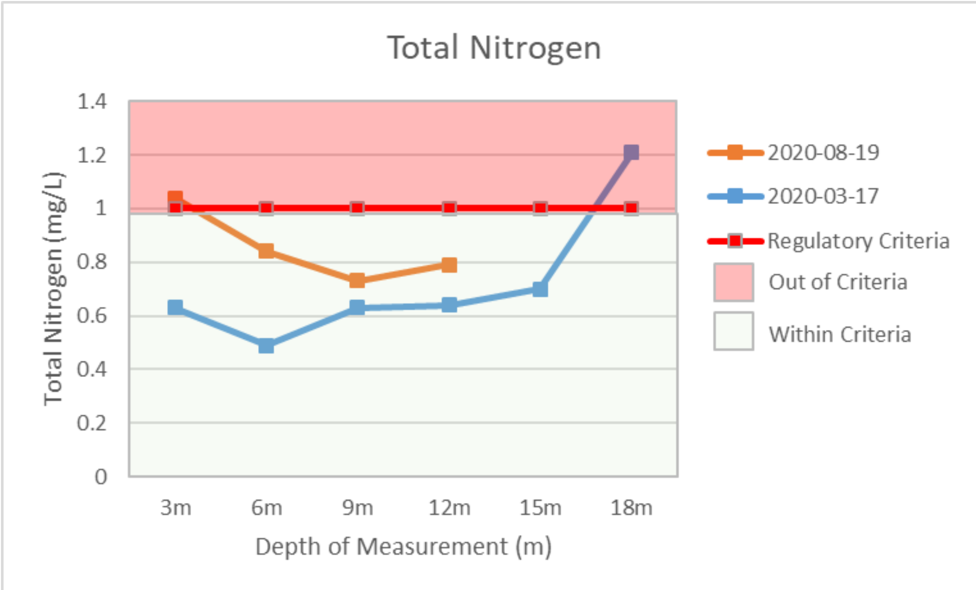

Figure 6: Total nitrogen from Kemmerer samples in West Basin of LLB Lake - 2020

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.

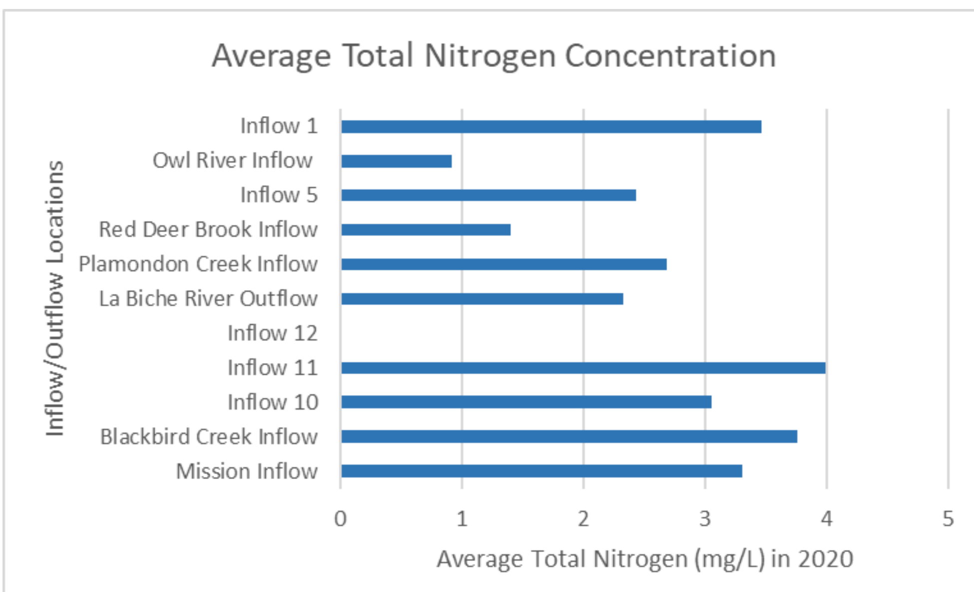

Figure 7: Inflow and outflow total nitrogen concentration for Lac La Biche Lake - 2020

Total 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 phosphorous for several years.

Composite Sampling

Composite lake water samples for analyses of total phosphorus were collected on June 16, June 24, July 6, and August 19, 2020 from the West Basin of Lac La Biche Lake. The analytical results are presented in Figure 8.

Total phosphorus concentrations of composite samples collected during 2020 exceeded the applicable regulatory guidelines (0.050 mg/L) only on August 19, 2020. The average total phosphorus from composite samples in 2020 was 0.05 mg/L. This average total phosphorus concentration classifies the West Basin of Lac La Biche Lake as Eutrophic (high productivity, nutrients, and algae growth) based on total phosphorus from composite samples.

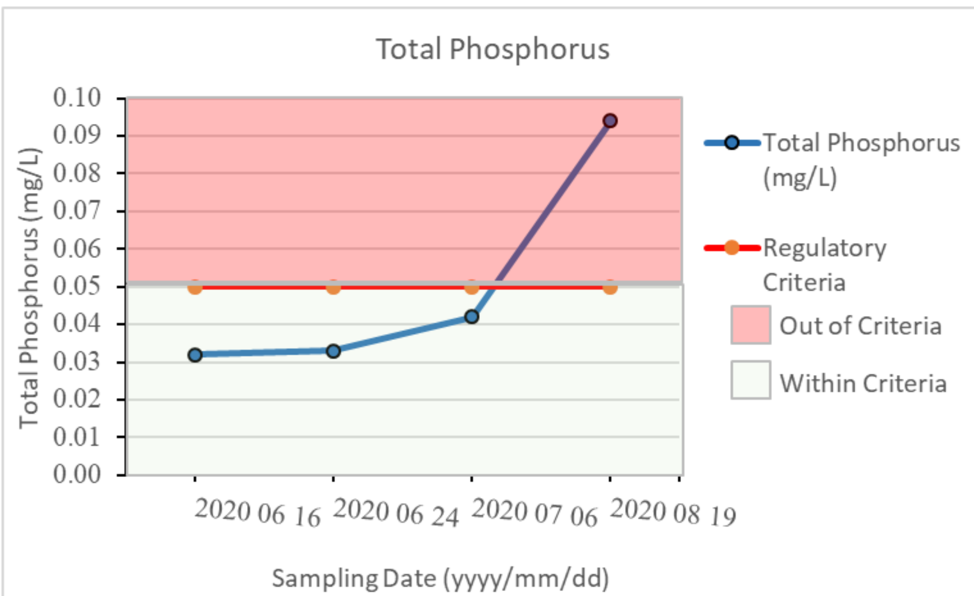

Figure 8: Total phosphorus from composite samples in West Basin of LLB Lake - 2020

Kemmerer Sampling

Kemmerer water samples using a Kemmerer device were collected on March 17, 2020 from depths of 3 m, 6 m, 9 m, 12 m, 15 m, and 18 m and August 19, 2020 from depths of 3 m, 6 m, 9 m, and 12 m. These samples were analyzed for total phosphorus and their results are presented in Figure 9.

Total phosphorus concentrations were almost constant throughout the lake depth for both sampling dates, aside from the 18 m depth on March 17, 2020 which spiked. Higher concentrations are expected towards the lakebed, as this is where nutrients settle. The average total phosphorus concentrations in the Kemmerer samples, exceeded the applicable regulatory guideline for freshwater aquatic life of 0.05

mg/L with an average total phosphorus concentration of 0.053 mg/L. 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.

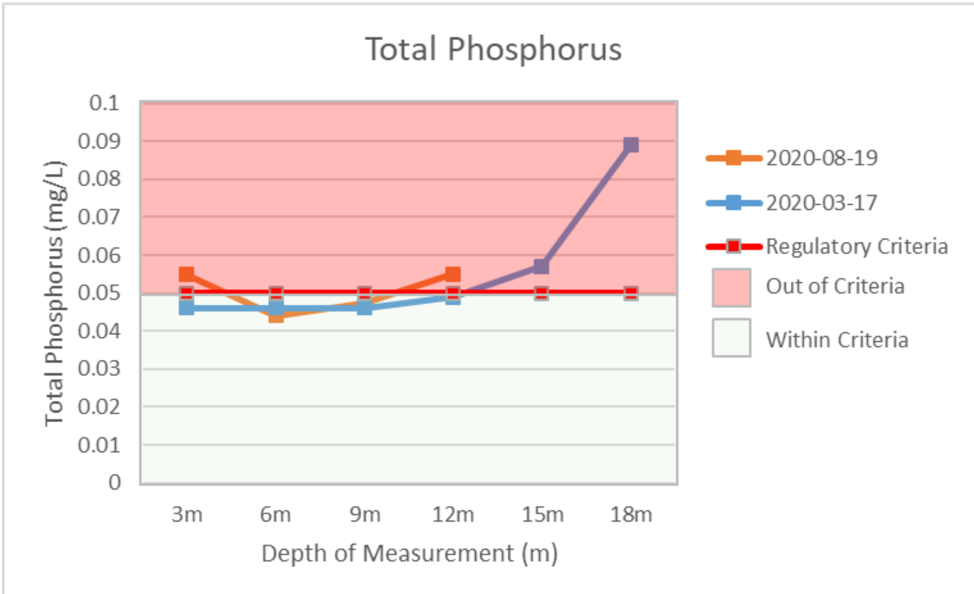

Figure 9: Total phosphorus from Kemmerer samples in West Basin of LLB Lake – 2020

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 10were within the regulatory guideline of 0.05 mg/L. A map showing the location of these samples is found on Figure 16.

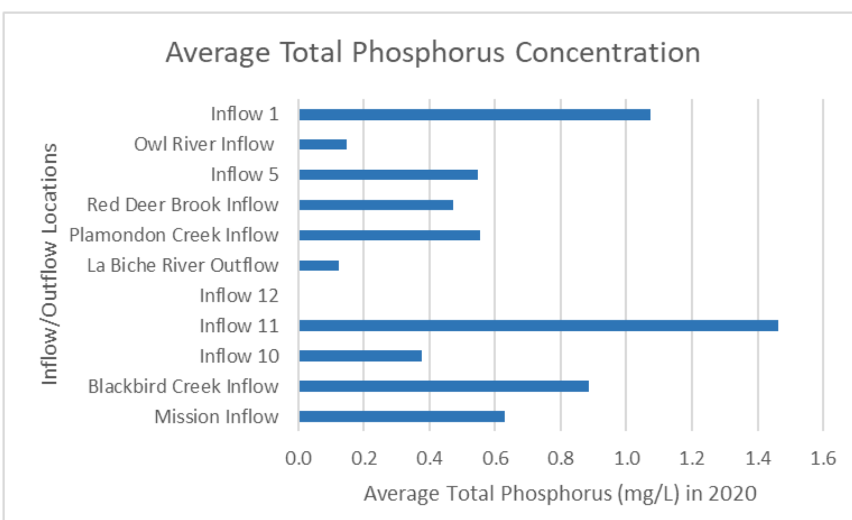

Figure 10: Inflow and outflow total phosphorous concentration for Lac La Biche Lake – 20120

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 West Basin of Lac La Biche Lake were 17:1 to 15:1, which are 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 West Basin of Lac La Biche Lake are presented in Table 4 of Appendix A.

The average measured pH value of 7.98 in West Basin was consistent with the average of 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 West Basin of Lac La Biche Lake in 2020, were generally below detection limits and did not exceed the applicable regulatory guidelines Table 5; 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. McArthur Beach is not located in the West Basin; however, for the purpose of this report, this beach monitoring will be included.

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.

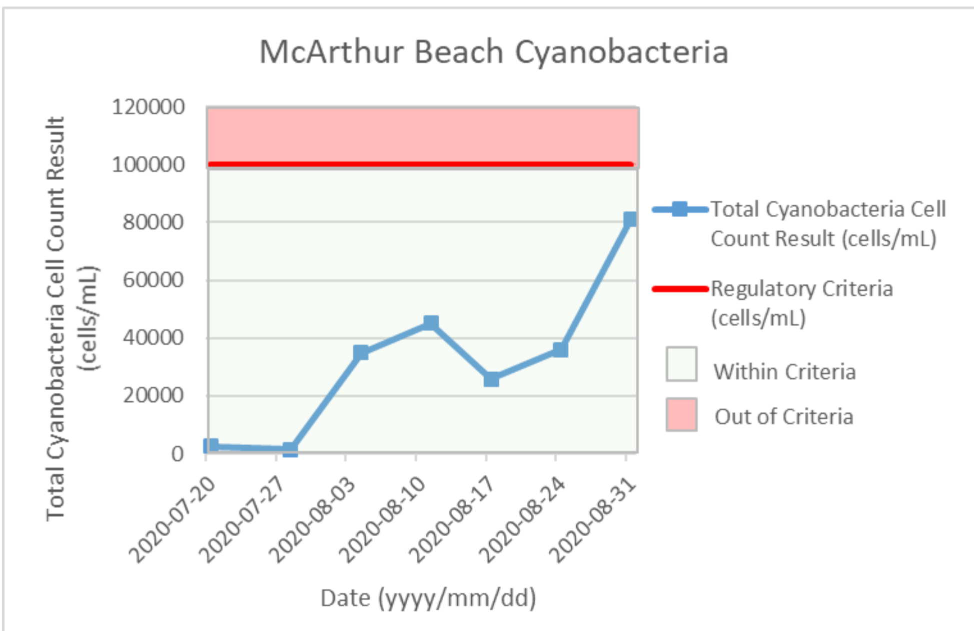

Figure 11: Cyanobacteria counts from McArthur Beach – 2020

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 West Basin of Lac La Biche Lake has always been less than the standard Oligotrophic Secchi Depth of 4 m except in 2009 as shown in Figure 12. The trophic state based on Secchi depth has been between Mesotrophic (some productivity, nutrients, and algae growth) and Eutrophic (high productivity, nutrients, and algae growth). 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.

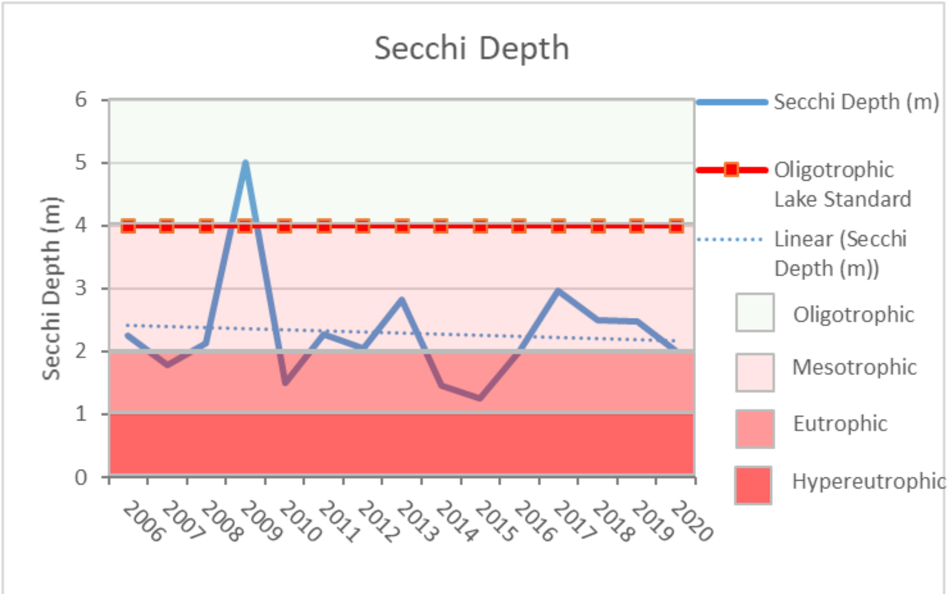

Figure 12: Historical trend of Secchi depth in West Basin of LLB Lake

5.2 Total Nitrogen

Historical data indicates that total nitrogen in West Basin of Lac La Biche Lake has been classified as Eutrophic (high productivity, nutrients, and algae growth) based on total nitrogen and did not exceed regulatory guideline of 1.0 mg/L except in 2006 and 2014 to current (Figure 13). The maximum total nitrogen concentration (3.12 mg/L) was recorded in in 2019; however, there was a drastic drop in total nitrogen concentration in 2020 which may be due to the high-water levels and thermal stratification.

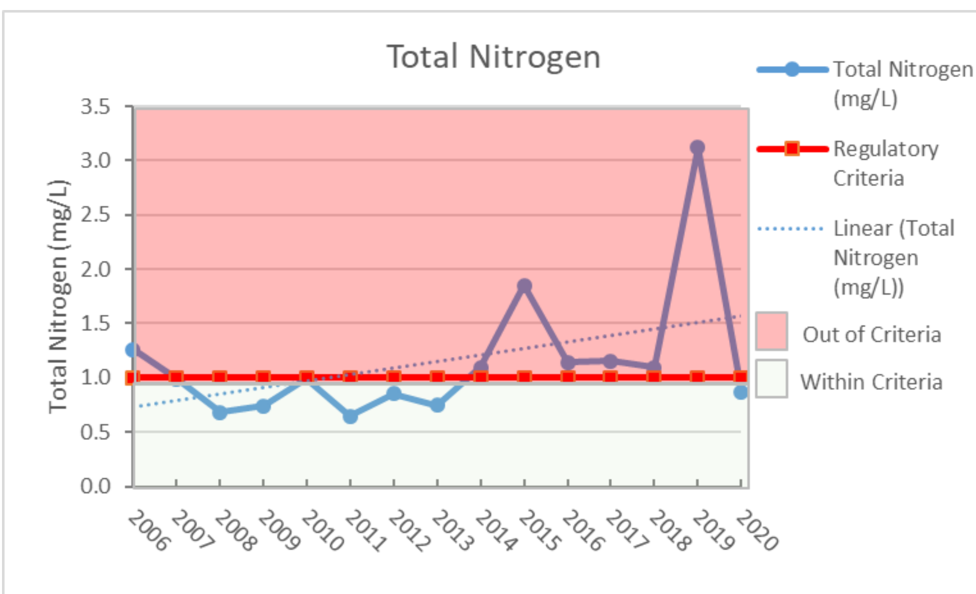

Figure 13: Historical trend of total nitrogen in West Basin of LLB Lake

5.3 Total Phosphorus

Historical data shows that total phosphorus concentration in the West Basin of Lac La Biche Lake has always exceeded the applicable regulatory guideline of 0.05 mg/L except in 2009 and 2011 (Figure 14). Since 2011, the total phosphorus concentration in the lake has been higher than the applicable guideline and a temporal increasing trend in concentration has been observed. The continuous increase of total phosphorus concentration in this lake is alarming and 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 and thermal stratification.

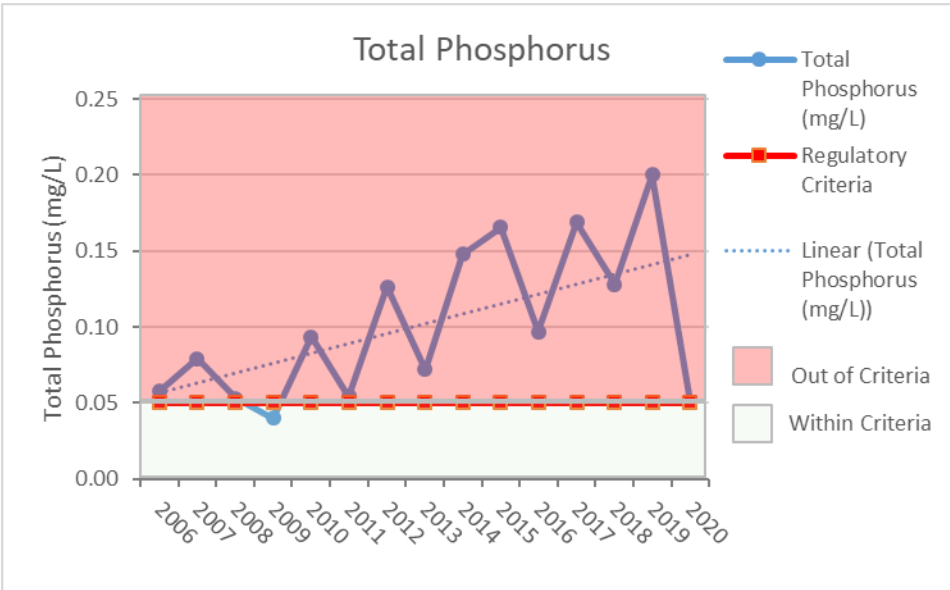

Figure 14: Historical trend of total phosphorus in West Basin of LLB Lake

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).

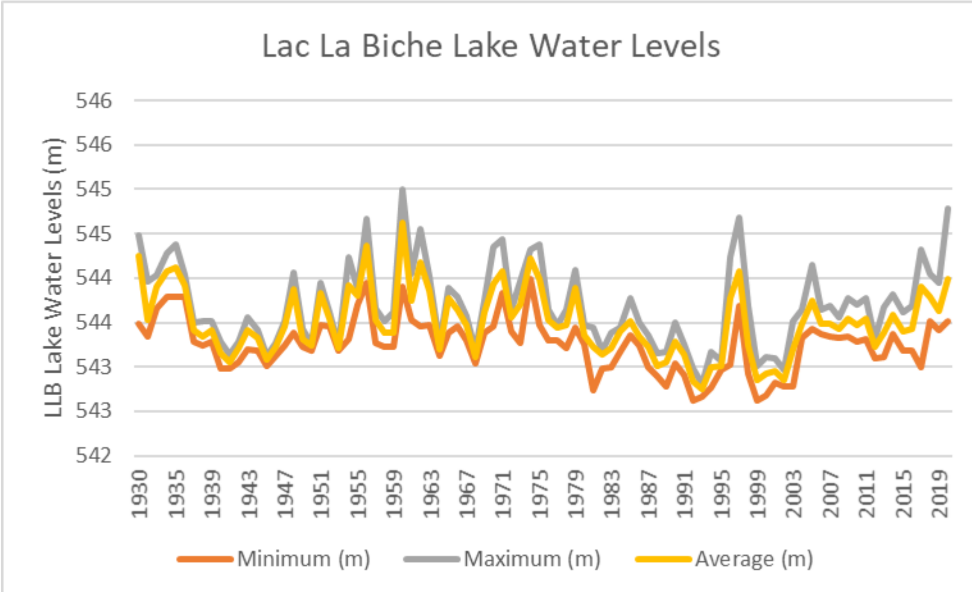

Figure 15: Historical water levels of Lac La Biche Lake

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 West 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 West 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.

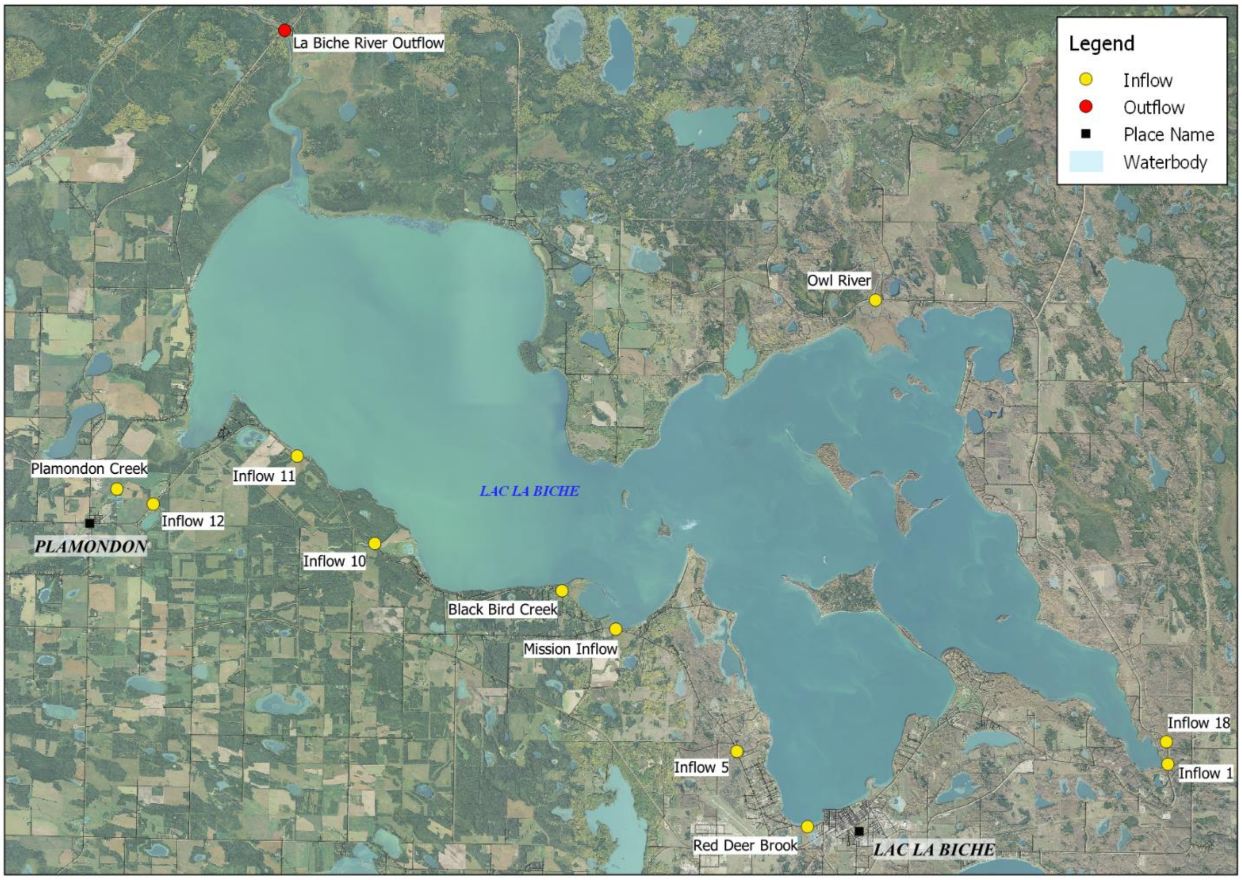

Figure 16: Map of Lac La Biche Lake with inflow/outflow locations

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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 West 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 – 1.2	0.03 – 0.1
Hypereutrophic	<1	>1.2	>0.1
West Basin Data 2020	1.94	0.82	0.05
West Basin Trophic State 2019	Mesotrophic	Hypereutrophic	Hypereutrophic
West Basin Trophic State 2020	Eutrophic	Eutrophic	Eutrophic

Table 3: Average N:P ratios in West Basin of LLB Lake in 2020

Sampling Event	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**N:P**
Composite Sampling	0.87	0.05	17:1
Kemmerer Sampling	0.77	0.05	14:1

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

Date of Sampling	June 16, 2020	June 24, 2020	July 6, 2020	August 18, 2020
	mg/L			
pH	8.35	7.33	7.28	8.20
Temperature (°C)	13.48	14.38	15.74	18.42
Ammonia, Total (as N)	<0.050	<0.050	<0.050	0.072
Nitrate (as N)	<0.020	<0.020	<0.020	<0.020
Nitrite (as N)	<0.010	<0.010	<0.010	<0.010
Nitrate and Nitrite (as N)	<0.022	<0.022	<0.022	<0.022

* Based on average pH and temperature of 7.98 and 15.8 °C of LLB West Basin in 2020
1: CCME C Guidelines, de-minimis criteria for Protection of Aquatic Life and 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 Guidelines for Protection of Agricultural Water Uses (Irrigation and Livestock pathways included)

Table 5: Total recoverable metals from Kemmerer samples in West Basin samples 2020

Date of Sampling	**Kemmerer Sampling (12 m depth) March 17, 2020**	**Kemmerer Sampling (9 m depth) August 20, 2020**	**Criteria[1]**	**Criteria[2]**
Parameters	-------------(mg/L)--------------			
Aluminum (Al)-Total	<0.0030	0.0072	0.1[a]	0.1
Arsenic (As)-Total	0.001	0.00129	0.005[a]	0.005
Barium (Ba)-Total	0.0498	0.0415	NS	NS
Beryllium (Be)-Total	<0.00010	<0.00010	100[b]	NS
Boron (B)-Total	0.039	0.044	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	0.00298	0.0040[a]	0.022
Iron (Fe)-Total	<0.010	0.023	0.3[a]	0.3
Lead (Pb)-Total	<0.000050	0.000051	0.007[a]	0.007
Lithium (Li)-Total	0.011	0.0101	2.5[b]	NS
Manganese (Mn)-Total	0.00928	0.047	0.2[b]	NS
Mercury (Hg)-Total	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	0.000312	0.000399	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	0.00005	0.000051	0.01[b]	0.015
Vanadium (V)-Total	<0.00050	<0.00050	0.1[b]	NS
Zinc (Zn)-Total	<0.0030	0.0036	0.007[a]	0.03

1: CCME C Guidelines, de-minimis criteria for Protection of Aquatic Life and 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 Guidelines for Protection of Agricultural Water Uses (Irrigation and Livestock pathways included)

Table 6: Historical trend of routine water variables for LLB West Basin

	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	8.30	8.04	7.77	7.99
Secchi Depth (m)	2.26	1.78	2.13	5.00	1.50	2.27	2.04	2.81	1.45	1.25	2.00	2.96	2.50	2.47	2.00
Total Nitrogen (mg/L)	1.26	0.99	0.68	0.74	1.00	0.65	0.86	0.75	1.09	1.85	1.14	1.15	1.10	3.12	0.87
Total Phosphorus (mg/L)	0.06	0.08	0.05	0.04	0.09	0.05	0.13	0.07	0.15	0.17	0.10	0.17	0.13	0.20	0.05
Nitrate/Nitrite (mg/L)	0.01	0.00	0.00	0.21	0.05	0.11	<0.071	<0.071	0.07	0.06	<0.022	<0.05	<0.022	<0.022	<0.022
Ammonia (mg/L)	0.15	0.07	0.11	0.05	0.17	0.03	0.07	<0.050	0.18	0.05	0.10	0.20	<0.050	<0.050	<0.050
Specific Conductivity (µS/cm)	277	292	296	294	284	286	287	288	296	243	289	250	385	255	362

Table 7: Historical trend of total metals in West Basin of LLB Lake

Dissolved Metals	2017	2018	2019	2020	Criteria[1]	Criteria [2]
		------------------(mg/L) --------------------				
Aluminum (Al)	0.0064	<0.0030	0.007	<0.0051	0.1[a]	0.1
Arsenic (As)	0.00201	0.00147	0.00163	0.001145		0.005
Barium (Ba)	0.0498	0.0414	0.0493	0.0457		NS
Beryllium (Be)-Total	<0.00010	<0.00010	<0.00010	<0.00010	100[b]	NS
Boron (B)	0.031	0.036	0.038	0.0415	1.5[a]	1.5
Cadmium (Cd)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.00009[a]	0.00019
Chromium (Cr)	0.00055	<0.00010	0.00023	<0.00010	NS	NS
Cobalt (Co)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.05[a]	0.0012
Copper (Cu)	<0.00050	<0.00050	<0.00050	<0.00050	0.0032[a]	0.02
Iron (Fe)	0.037	0.014	0.168	<0.0165	0.3[a]	0.3
Lead (Pb)	<0.000050	0.000060	0.000076	<0.000051	0.005[a]	0.0042
Lithium (Li)-Total	0.0111	0.0096	0.0099	0.01055	2.5[b]	NS
Manganese (Mn)	0.171	0.127	0.167	0.028	0.2[b]	NS
Mercury (Hg)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	0.000334	0.000320	0.000314	0.000356	0.073[a]	0.073
Nickel (Ni)	<0.00050	<0.00050	<0.00050	<0.00050	0.125[a]	0.063
Selenium (Se)	<0.000050	<0.000050	<0.000050	<0.000050	0.001[a]	NS
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	0.00025[a]	0.00025
Thallium (Tl)-Total	<0.000010	<0.000010	<0.000010	<0.000010	0.0008[a]	0.0008
Tin (Sn)-Total	<0.00010	<0.00010	<0.00010	<0.00010	0.0[a]	NS
Titanium (Ti)-Total	0.00045	<0.00030	<0.00030	<0.00030	0.0[a]	NS
Uranium (U)	0.000047	0.000046	0.000051	0.0000505	0.01[b]	0.015
Vanadium (V)-Total	<0.00050	<0.00050	0.00092	<0.00050	0.1[b]	NS
Zinc (Zn)	<0.0030	0.0044	0.0110	<0.0033	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 Guidelines for Protection of Agricultural Water Uses (Irrigation and Livestock pathways included)