Lac La Biche County
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2017
Water Quality Report
Lac La Biche Lake West Basin
Lac La Biche County, Alberta

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October 15, 2018

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W W W .E N V I R O L E A D.C A

Executive Summary

Lac La Biche Lake ("LLB Lake") is a large and a 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. As part of this program, Envirolead Canada ("Envirolead") has completed this 2017 Water Quality Report for the West Basin of LLB Lake under the authorization of the County. The data to complete this report was collected and provided to Envirolead by the County.

The water sampling events were conducted during the early spring and summer of 2017. 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 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 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. Mesotrophic based on Secchi depth, Eutrophic based on total nitrogen, and Hypereutrophic based on total phosphorus.

Results and Discussion

In 2017, Secchi depths in the West Basin of Lac La Biche Lake were measured on March 7, June 30, July 13, August 1, and August 21, 2017. The average seasonal Secchi depth was observed to be 3.4 m and is lower than 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 Mesotrophic (some productivity, nutrients, and algae growth).

Dissolved oxygen data collected in 2017 shows that the average dissolved oxygen levels ranged from 10.01 mg/L to 6.07 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 2017 showed an average water temperature of 16.2 ^{O}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 7 and August 21, 2017.

In 2017, 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 2017 had an average of 1.03 mg/L of total nitrogen, while the Kemmerer samples collected had an average of 0.77 mg/L of total nitrogen; and the inflow/outflow samples ranged from 0.5 mg/L to 3.4 mg/L of total nitrogen. Both the composite and Kemmerer samples total nitrogen concentrations exceeded the applicable regulatory guidelines of 1.0 mg/L and were consistent with 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 2017 had an average of 0.18 mg/L of total phosphorus, while the Kemmerer samples collected had an average of 0.19 mg/L; and the inflow/outflow samples ranged from 0.08 mg/L to 2.13 mg/L total phosphorus. Both the composite and Kemmerer samples of total phosphorus exceeded the applicable regulatory guidelines of 0.05 mg/L and have been consistently increasing from historical results. The average total phosphorus concentrations from composite and Kemmerer sampling classify the West Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

The average N:P ratios for composite and Kemmerer sampling events were 2:1 and 8:1 which is lower than the Redfield Ratio of 16:1. Therefore, the total phosphorus is no longer 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 8.32 in 2017 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.

In the West Basin of Lac La Biche Lake, the beaches at Bayview Beach, Plamondon White Sands, and McGrane Beach were tested for thermotolerant coliforms on June 21 and June 27, 2017. McGrane

Beach data regarding thermotolerant coliforms shows that one sample collected on August 17, 2017 exceeded the regulatory guidelines with a count of 600 CFU/100 mL. Plamondon White Sands data regarding thermotolerant coliforms shows that one sample collected on June 27, 2017 exceeded the regulatory guidelines with a count of 230 CFU/100 mL. Additional sampling for thermotolerant coliform at these locations resulted in concentrations which were within the applicable guidelines.

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. Mesotrophic based on Secchi depth, Eutrophic based on total nitrogen, and Hypereutrophic based on total phosphorus.

Recommendations

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

Due to the largescale oil and gas development and exploration operations across the County and in its surrounding, the likelihood of petroleum hydrocarbons entering the lake water through various means cannot be ignored. Envirolead recommends that analyses of petroleum hydrocarbons dissolved in the lake water should also be included in the monitoring program.

A strategic monitoring plan should be developed by the County to ensure that sampling is carried out in a consistent manner for all lakes that are sampled each year. This would include sampling each lake the same number of times per year with a uniform sampling procedure; and implementing a quality assurance program for both the multi-probe and water chemistry analysis to ensure that data used to evaluate the lake water quality are accurate and reliable. By maintaining consistency in sampling programs, the County will be able to monitor changes occurring in lake water quality, and hence assist the County in developing policies and management practices to ensure the optimum health of the lake.

Nutrient loading is the main source of eutrophication in Lac La Biche 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.

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List of Abbreviations Used

CCME: Canadian Council of Ministers of the Environment
County: Lac La Biche County
Envirolead: Envirolead Canada Ltd.
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 Control and Quality Assurance
Total N: Total Nitrogen
Total P: Total Phosphorous
TSI: Trophic State Index

1. INTRODUCTION

Under the authorization of Lac La Biche County, Alberta ("County"), Envirolead Canada Ltd. ("Envirolead") completed this annual 2017 Water Quality Report for West Basin of Lac La Biche Lake (LLB Lake) based on the data provided by the County. The completion of this report is part of the ongoing water quality monitoring program of lakes present in the County.

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 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, windsurfing, waterskiing, boating and fishing. There is a concern however, that declining water quality in the lake is limiting the opportunities for these activities, particularly fishing and swimming. 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 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 Albert 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 2017 was completed as follows:

a) Secchi Depths were measured on March 7, June 30, July 13, August 01, and August 21, 2017;
b) Composite samples from the West Basin were collected on June 30, July 13, August 1, and August 21, 2017. Lake water samples were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories;
c) Kemmerer water samples were collected on July 3, 2017 from depths of 3, 6, 9, 12, 15, and 18 m; and on August 28, 2017 from depths of 3, 6, 9, 12, 15, 18, and 21 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 30, June 30, July 24, and August 17, 2017; and were analyzed for nutrients, metals and basic water chemistry parameters;
e) Lake profiles were recorded to a maximum depth of 19.5 m using a multi-probe on March 7, June 30, July 13, August 01, and August 21, 2017;
f) Monitoring of fecal coliform and Escherichia coliform (E. coli) bacteria was conducted at popular swimming locations through partnership of County and Alberta Health Services. The beach locations sampled during 2017 in the West Basin were Bayview Beach, Plamondon White Sands Beach, and McGrane Beach. Microbiological samples were submitted to PROVLAB of Alberta Health.

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 waterbody and further identify any potential concerns. The water quality parameters measured and analyzed during the 2017 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.
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.
Thermotolerant coliforms	Thermotolerant coliforms is the group of coliform bacteria also referred to as "fecal coliforms" and is an indicator for the sanitary quality of water. The term "thermotolerant coliforms" is gaining acceptance over fecal coliform. 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 2017, Secchi depths in the West Basin were measured on March 7, June 30, July 13, August 1, and August 21, 2017. A maximum Secchi depth of 5.3 m was recorded on March 7, 2017; while a minimum Secchi depth of 2.6 m was recorded on August 1, 2017. Overall a decreasing temporal trend was observed (Figure 2), with an average Secchi depth of 3.4 m.

Based on the Secchi depths, Lac La Biche West Basin is classified as Mesotrophic in accordance to the Table 1 provided in Appendix A.

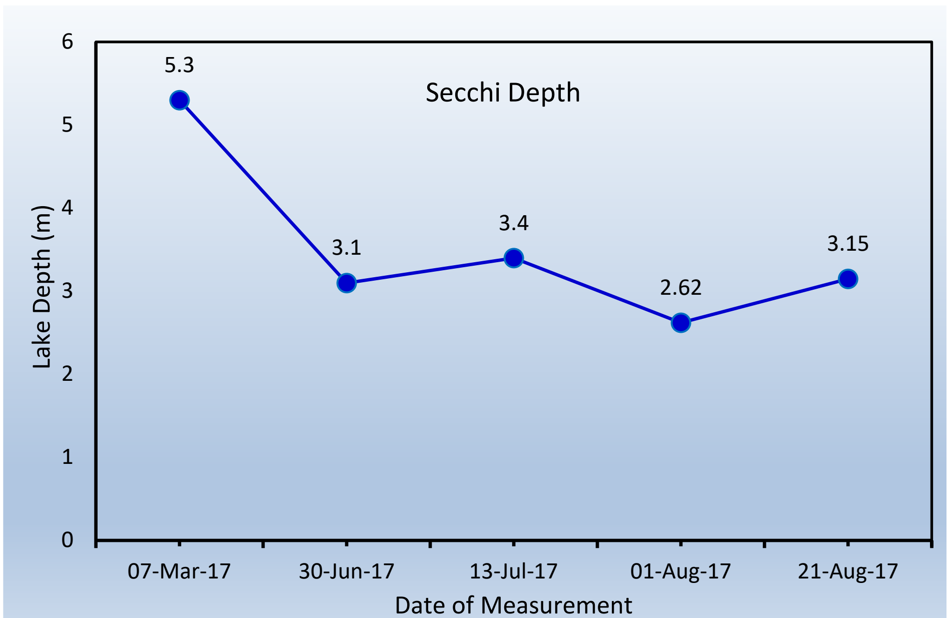

Figure 2: Secchi depths measured in West Basin of LLB Lake - 2017

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. 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 19.5 m using a multi-probe on March 7, June 30, July 13, August 1, and August 21, 2017. A maximum dissolved oxygen concentration of 13.35 mg/L was observed on March 7, 2017 at a depth of 1 m, which declined gradually to a concentration of 3.05 mg/L at the lake bed (Figure 4).

Dissolved oxygen data collected in 2017 shows that the average dissolved oxygen levels ranged from 10.01 mg/L to 6.07 mg/L and were within proximity to the 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).

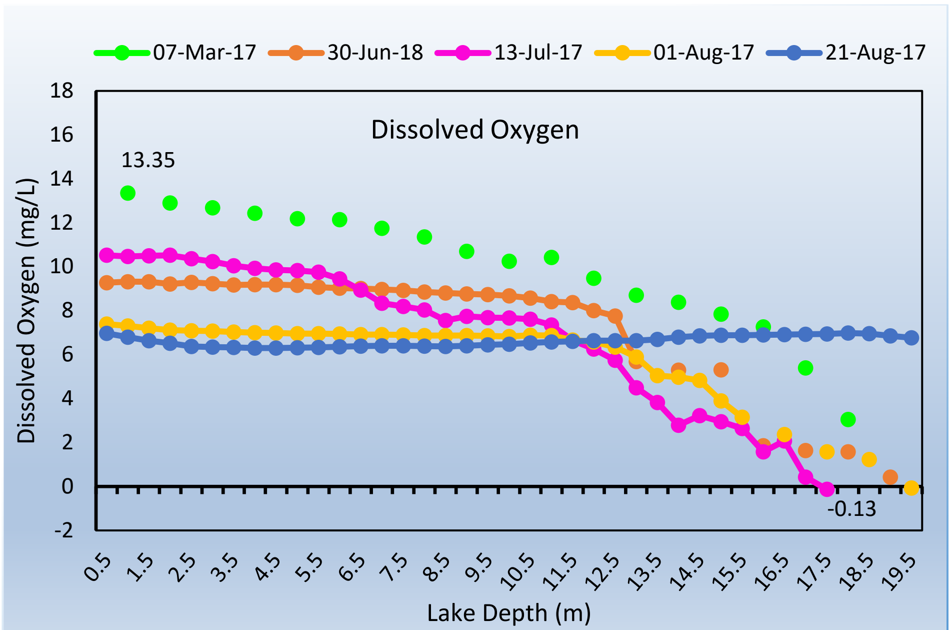

Figure 3: Dissolved oxygen in West Basin of LLB Lake - 2017

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 summer time, 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 19.5 m on March 7, June 30, July 13, August 1 and August 21, 2017. Results of temperatures observed on different dates and depths are illustrated in Figure 4. A minimum temperature of 0.02 ^{O}C was observed on March 7, 2017 at a 1 m depth, while a maximum temperature of 20.8 ^{O}C was recorded at a 1 m depth on July 13, 2017.

Sampling events in the summer of 2017 showed an average temperature of 16.2 ^{O}C in the West Basin of Lac La Biche Lake. Uniform temperature profiles were observed during the summer, as temperatures over depth did not vary significantly. Thermal stratification was not observed during any of the summer sampling events between June 30 and August 21, 2017. Results of temperatures observed on different dates and depth are illustrated in Figure 4.

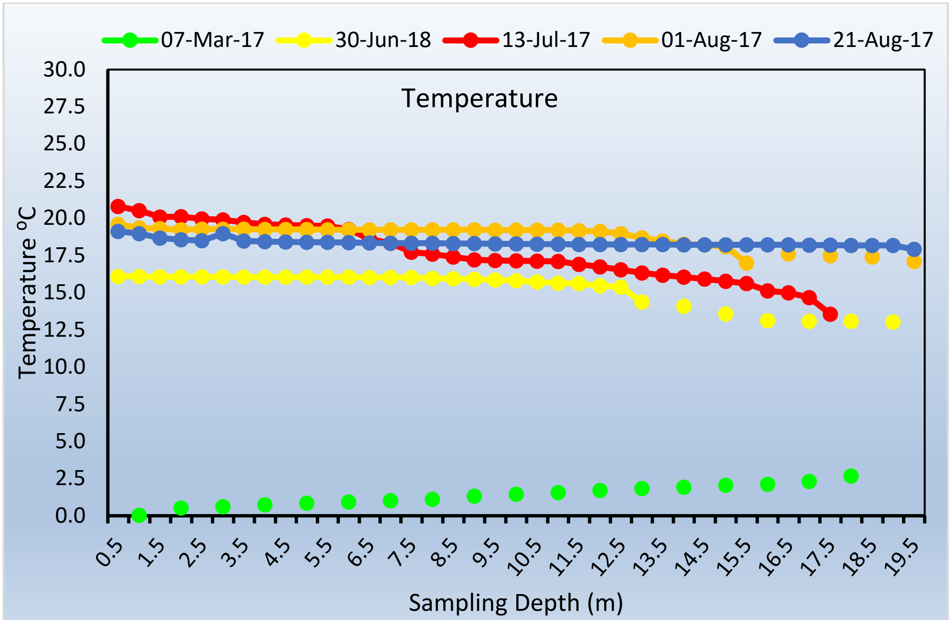

Figure 4: Temperature profile in West Basin of LLB Lake - 2017

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 2017, 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 30, July 13, August 1, and August 21, 2017. The analytical results are presented in Figure 5. The results indicated that the minimum total nitrogen concentration of 0.82 mg/L was found in sample collected on June 30, 2017 and the maximum total nitrogen concentration of 1.30 mg/L was found in sample collected on August 1, 2017.

Nitrogen concentrations in the composite samples collected from the lake in 2017 had an average of 1.03 mg/L of total nitrogen which exceeded 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.

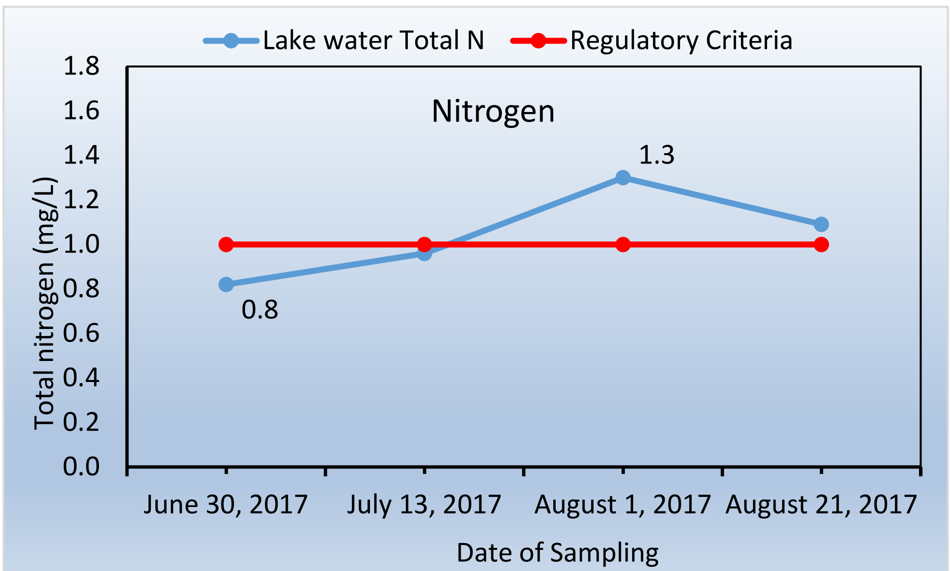

Figure 5: Total nitrogen concentration from composite samples in West Basin of LLB Lake - 2017

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 West Basin of Lac La Biche Lake on July 3, 2017 from depths of 3 m, 6 m, 9 m, 12 m, 15 m, and 18 m; and on August 28, 2017 from depths of 3 m, 6 m, 9 m, 12 m, 15 m, 18 m and 21 m. The analytical results of total nitrogen in these samples are presented in Figure 6. The results indicated that total nitrogen in West Basin did not exceed the regulatory guidelines with the exception of samples obtained from 3 m and 6 m on August 28.

The average total nitrogen from all Kemmerer samples is 0.77 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 nitrogen.

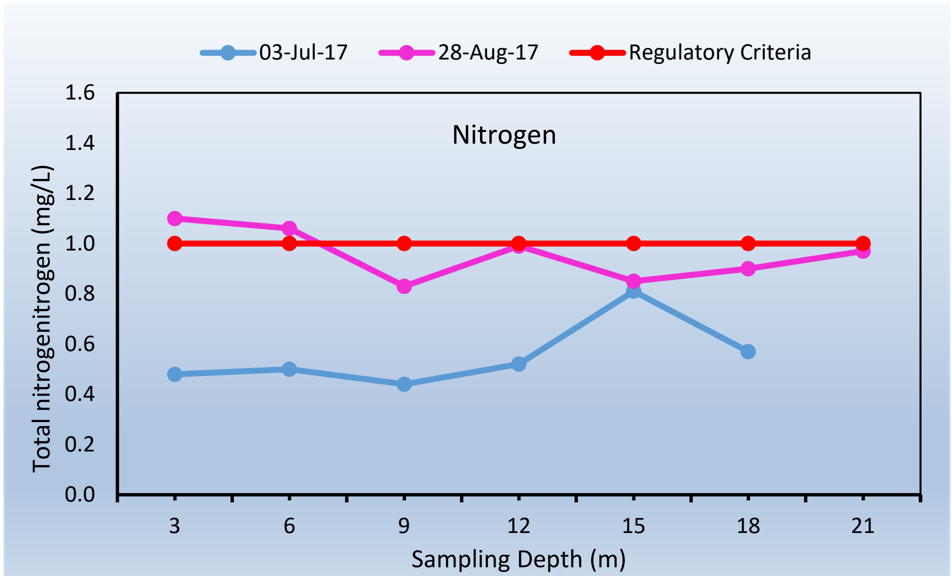

Figure 6: Total nitrogen concentration from Kemmerer samples in West Basin of LLB Lake – 2017

Inflow and Outflow Sampling

The inflows from Plamondon Creek and outflows from Lac La Biche River were monitored and sampled on May 30, June 30, July 24, and August 17, 2017. The analytical results of total nitrogen from these samples are presented in Figure 7. As indicated, the total nitrogen in the samples collected from Plamondon Creek Inflow were higher than the La Biche River outflow.

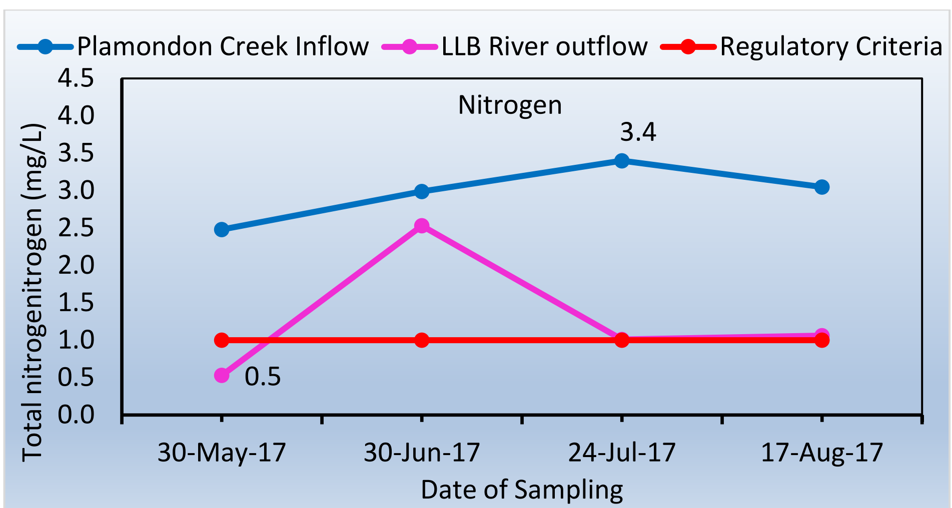

Figure 7: Total nitrogen from Plamondon Creek inflow and La Biche River outflow - 2017

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 lake bed 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 30, July 13, August 1, and August 21, 2017 from the West Basin of Lac La Biche Lake. The analytical results are presented in Figure 8.

Total phosphorus concentrations of all composite samples collected during 2017 exceeded the applicable regulatory guidelines (0.050 mg/L) with an average of 0.18 mg/L total phosphorus. This average total phosphorus concentration classifies the West Basin of Lac La Biche Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total phosphorus from composite samples.

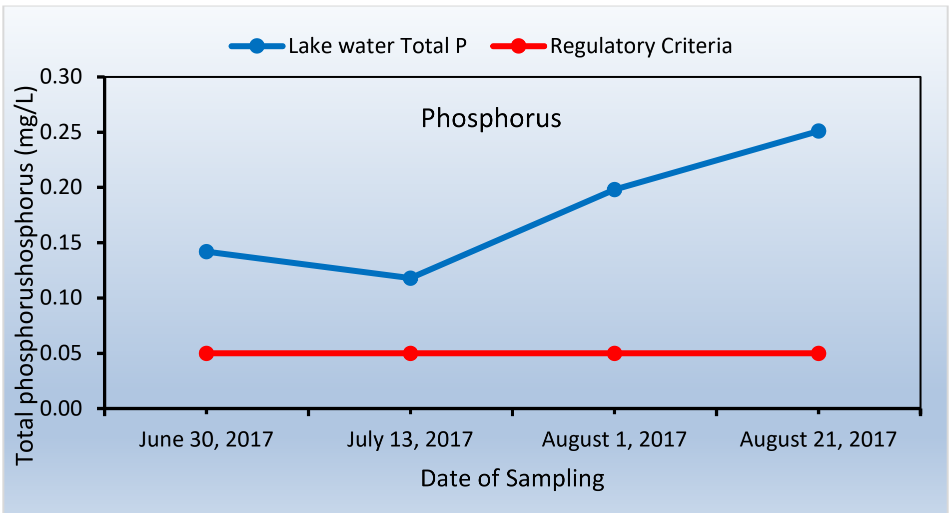

Figure 8: Total phosphorus from composite samples in West Basin of LLB Lake - 2017

Kemmerer Sampling

Kemmerer water samples using Kemmerer device were collected on July 3, 2017 from depths of 3 m, 6 m, 9 m, 12 m, 15 m, and 18 m; and then on August 28, 2017 from 3 m, 6 m, 9 m, 12 m, 15 m, 18 m, and 21 m. These samples were analyzed for total phosphorus and their results are presented in Figure 9.

As indicated in Figure 9, the total phosphorus concentration in samples collected in July 3, 2017 were lower than the samples collected on August 28, 2017. Total phosphorus concentrations were almost constant throughout the lake depth for both sampling dates except the sample collected from 15 m on July 3, showing a total phosphorus concentration of 0.29 mg/L. Total phosphorus concentrations in all samples collected from different depths in July and August 2017, exceeded the applicable regulatory guideline for fresh water aquatic life of 0.05 mg/L with an average total phosphorus concentration of 0.19 mg/L. The results from the Kemmerer sampling resulted in the same trophic state classification as the composite samples which is Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total phosphorus.

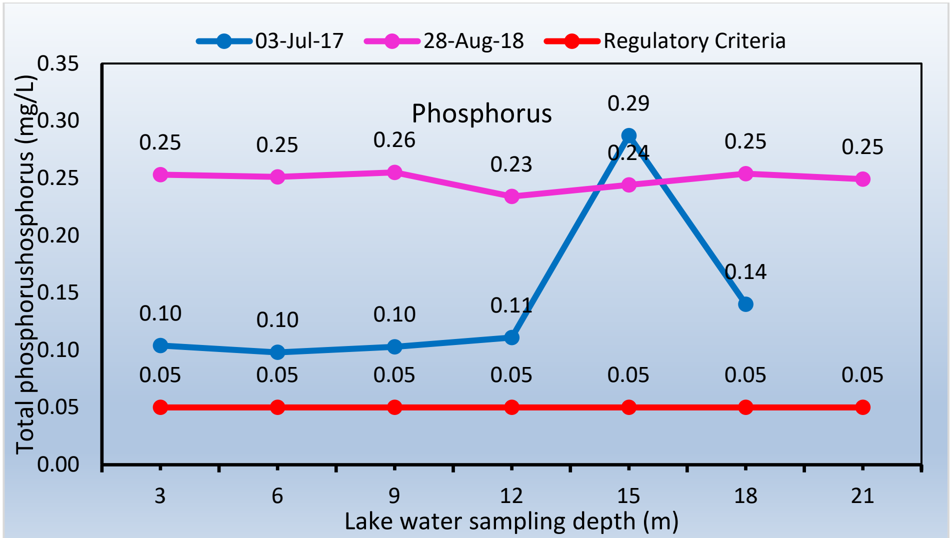

Figure 9: Total phosphorus from Kemmerer samples in West Basin of LLB Lake - 2017

Inflow and Outflow Sampling

The inflow from Plamondon Creek and outflow from the La Biche River were monitored and sampled on May 30, June 30, July 24, and August 17, 2017. Analytical results of these samples are presented in Figure 10.

Total phosphorus in Plamondon Creek Inflow samples were significantly higher than the La Biche River outflow samples. Both inflow and outflow samples exceeded the regulatory guideline of 0.05 mg/L for total phosphorus.

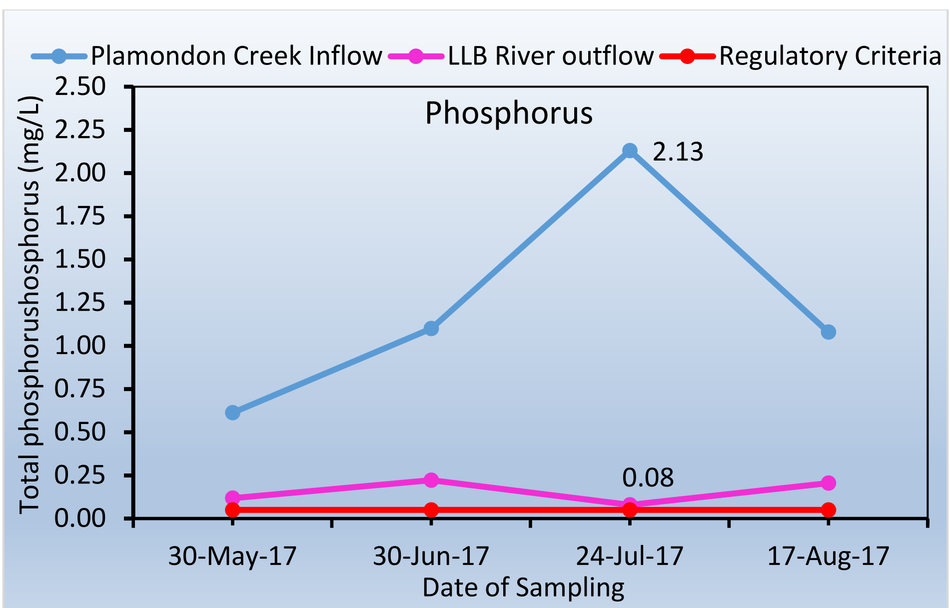

Figure 10: Total phosphorus from Plamondon Creek inflow and La Biche River outflow - 2017

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 2:1 to 8:1 , which are lower than the Redfield Ratio of 16:1. Therefore, the total phosphorus is no longer 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 8.32 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 2017, were generally below detection limits and did not exceed the applicable regulatory guidelines Table 5; Appendix A.

4.7 Coliforms

Coliform bacteria are indicators for sanitary conditions of water. They are members of Enterobacteriaceae family that includes *Escherichia coliform* (E. coli) which are capable of growth at 37° C (total coliforms) or 44°C - 45° C (thermotolerant coliforms). The term thermotolerant is now preferred over disease causing fecal coliform. Higher concentrations of coliform bacteria in lake water can cause gastrointestinal and upper respiratory illness on direct contact with recreational users. Coliforms enter the lake water through various means, including: sewage discharge, non-point agriculture and urban storm water runoff, wildlife (birds, muskrats) and domestic animals.

The current guidelines for E. coli and fecal coliforms advise that the geometric mean of bacteriological counts from not fewer than 5 samples of water taken over a 30 day period does not exceed 200 fecal coliforms per 100 mL of water; and no 2 consecutive samples of water have a bacteriological count in excess of 400 fecal coliforms per 100 mL of water. If any samples exceed these guidelines, the public will be notified, warning signs will be posted, and possible water quality control actions should be implemented (Health Canada 2012).

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

In the West Basin of Lac La Biche Lake, the beaches located at Bayview Beach, Plamondon White Sands, and McGrane Beach were tested for thermotolerant coliforms. Results of these samples are presented in Figure 11.

Bayview Beach data regarding thermotolerant coliforms shows that two samples collected on June 21 and June 27, 2017 exceeded the regulatory guidelines with counts of 220 CFU/100 mL and 600 CFU/100 mL. McGrane Beach data regarding thermotolerant coliforms shows that one sample collected on August 17, 2017 exceeded the regulatory guidelines with a count of 600 CFU/100 mL. Plamondon White Sands data regarding thermotolerant coliforms shows that one sample collected on June 27, 2017 exceeded the regulatory guidelines with a count of 230 CFU/100 mL. All other samples met the regulatory guidelines for Thermotolerant coliform.

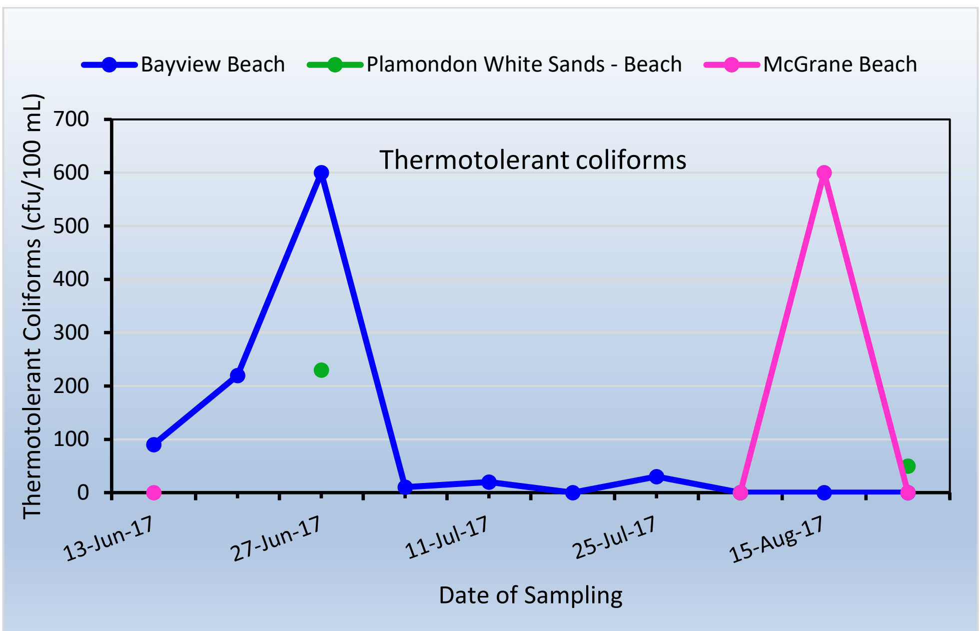

Figure 11: Thermotolerant coliform counts from beaches in West Basin of LLB Lake - 2017

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 Secchi depth measurement of 5.3 m in 2017 indicates a significant improvement from 2009. The Secchi depth readings however, 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.

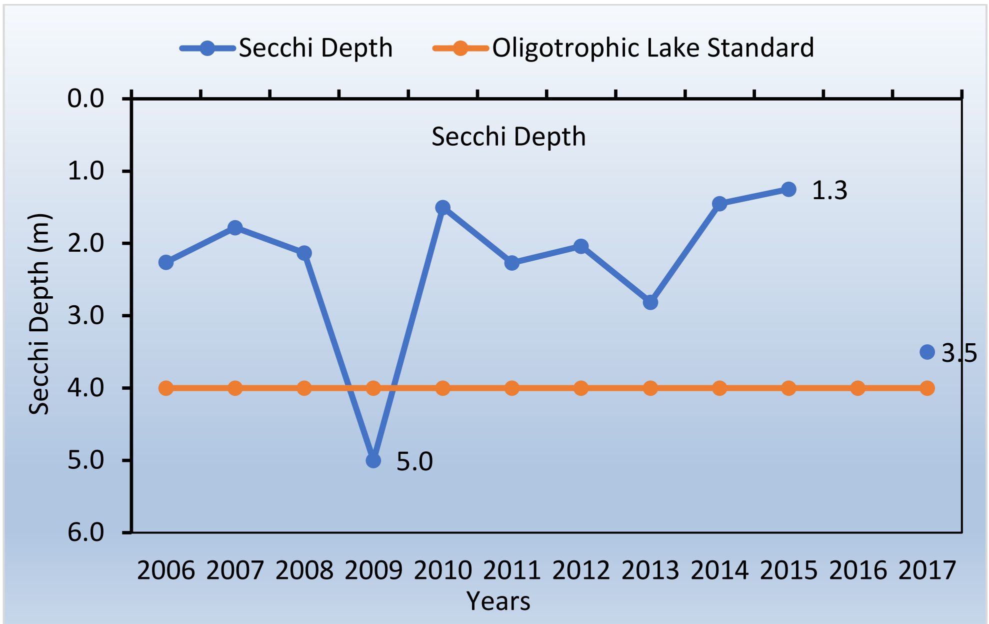

Figure 12: Historical trend of Secchi depth in West Basin of LLB Lake

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, 2014, 2105, and 2016 (Figure 13). The maximum total nitrogen concentration (1.85 mg/L) was recorded in in 2015; however, a declining trend in total nitrogen concentration was observed in the past two years which dropped below the regulatory guidelines in 2017.

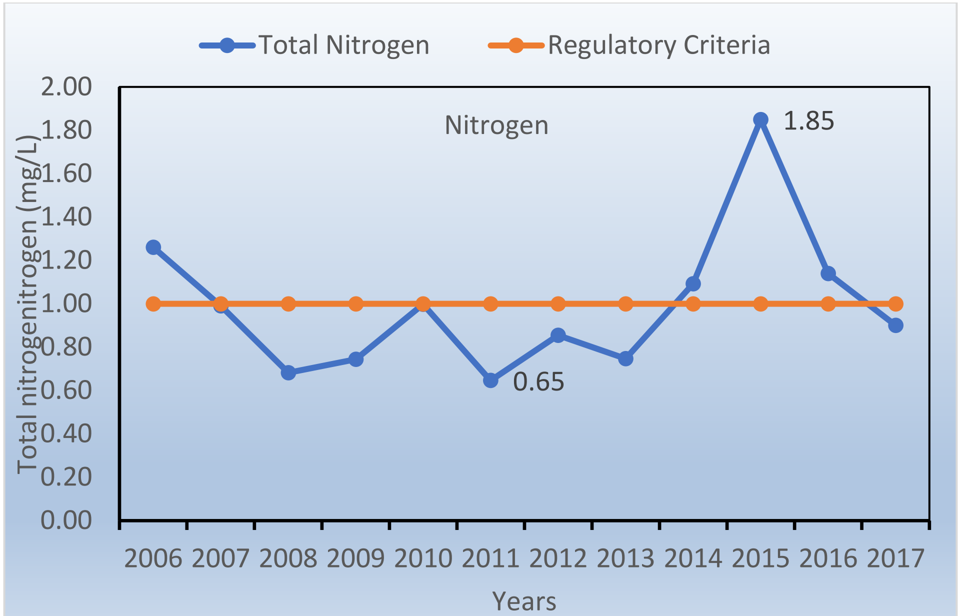

Figure 13: Historical trend of total nitrogen in West Basin of LLB Lake

5.3 Total Phosphorus

Historical data shows that total phosphorus concentration in the West Basin of Lac La Biche Lake has 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.

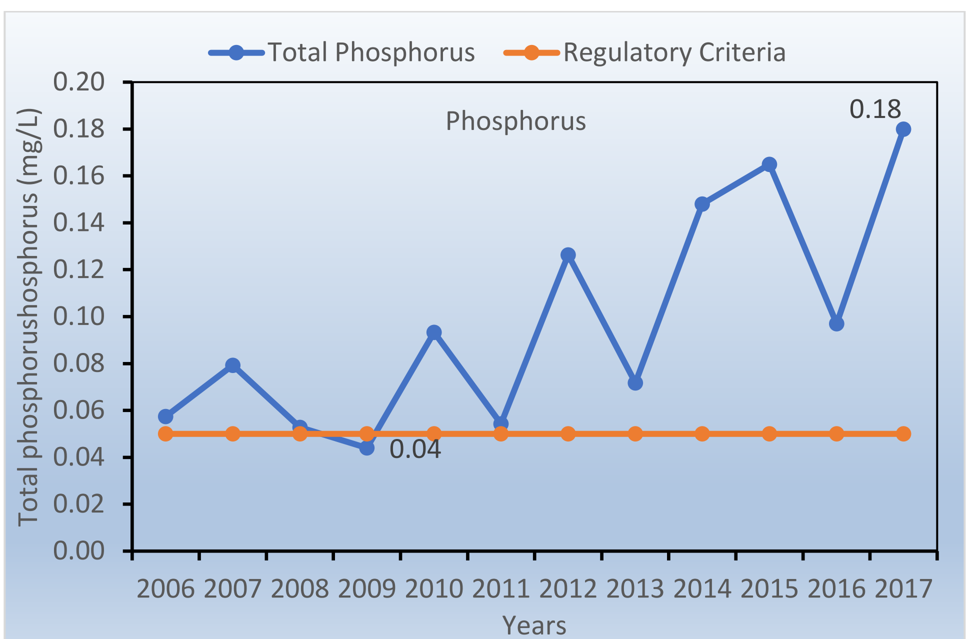

Figure 14: Historical trend of total phosphorus in West Basin of LLB Lake

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. Mesotrophic based on Secchi depth, Eutrophic based on total nitrogen, and Hypereutrophic based on total phosphorus.

7. RECOMMENDATIONS

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

Due to the largescale oil and gas development and exploration operations across the County and in its surrounding, the likelihood of petroleum hydrocarbons entering the lake water through various means cannot be ignored. Envirolead recommends that analyses of petroleum hydrocarbons dissolved in the lake water should also be included in the monitoring program.

A strategic monitoring plan should be developed by the County to ensure that sampling is carried out in a consistent manner for all lakes that are sampled each year. This would include sampling each lake the same number of times per year with a uniform sampling procedure; and implementing a quality assurance program for both the multi-probe and water chemistry analysis to ensure that data used to evaluate the lake water quality is accurate and reliable. By maintaining consistency in sampling programs, the County will be able to monitor changes occurring in lake water quality, and hence assist the County in developing policies and management practices to ensure the optimum health of the lake.

Nutrient loading is the main source of eutrophication in Lac La Biche 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 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.

Figure 15: Map of Lac La Biche Lake with inflow/outflow locations

8. REFERENCES

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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 2017

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 – 1.00	0.0310 – 0.1
Hypereutrophic	<1	>1.2	>0.1
West Basin Data	3.5	0.90	0.18
West Basin Trophic State 2017	Mesotrophic	Eutrophic	Hypereutrophic
West Basin Trophic State 2016		Eutrophic	Eutrophic

Table 3: Average N:P ratios in West Basin of LLB Lake in 2017

Sampling Event	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**N:P**
Composite Sampling	1.04	0.18	6:1
Kemmerer Sampling	0.77	0.19	4:1
Inflow Sampling	2.98	1.23	2:1
Outflow Sampling	1.28	0.16	8:1

Table 4: Routine water chemistry analysis of composite samples – West Basin of LLB Lake 2017

Sampling Date	**June 30, 2017**	**July 13, 2017**	**August 1, 2017**	**August 21, 2017**	**Criteria[1]**	**Criteria[2]**
-------------------------(mg/L)--------------------------						
pH	8.32	8.32	8.32	8.32		
Temperature ^{O}C	14.32	14.32	14.32	14.32		
Ammonia-N	<0.050	0.059	0.184	0.369	0.196*	0.325*
Nitrate-N	<0.020	<0.020	<0.020	0.03	3[a]	3
Nitrite-N	<0.010	<0.010	<0.010	<0.010	0.2[2]	0.2
Nitrate & Nitrite-N	<0.022	<0.022	<0.022	<0.050	100[b]	NS

* Based on average pH and temperature of 8.32 and 14.32 oC of LLB West Basin in 2017
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 of LLB Lake - 2017

Sampling Date	**30-06-2017**	**21-08-2017**	**Kemmerer Sampling at 12 m**	**Plamondon Creek Inflow**	**Criteria[1]**	**Criteria [2]**
	--------------------------(mg/L)------------------------					
pH	8.32	-	-	-		
Hardness (as $CaCO_3$)	128	-	-	-		
Aluminum (Al)-Total	<0.0030	0.0064	<0.0030	0.0846	0.1[a]	0.1
Antimony (Sb)-Total	<0.00010	<0.00010	<0.00010	0.00022	NS	NS
Arsenic (As)-Total	0.00149	0.00201	0.00169	0.00209	0.005[a]	0.005
Barium (Ba)-Total	0.0461	0.0498	0.0537	0.0539	NS	NS
Beryllium (Be)-Total	<0.00010	<0.00010	<0.00010	<0.00010	100[b]	NS
Boron (B)-Total	0.036	0.031	0.045	0.076	1.5[a]	1.5
Cadmium (Cd)-Total	<0.0000050	<0.0000050	<0.0000050	0.0000061	0.00009[a]	0.00019
Chromium (Cr)-Total	0.00035	0.00055	<0.00010	0.00039	NS	NS
Cobalt (Co)-Total	<0.00010	<0.00010	<0.00010	0.00056	0.05[a]	0.0012
Copper (Cu)-Total	<0.00050	<0.00050	<0.00050	0.00082	0.0032[a]	0.02
Iron (Fe)-Total	0.034	0.037	0.022	**1.11**	0.3[a]	0.3
Lead (Pb)-Total	<0.000050	<0.000050	0.000066	0.000159	0.005[a]	0.0042
Lithium (Li)-Total	0.0116	0.0111	0.0117	0.0172	2.5[b]	NS
Manganese (Mn)-Total	**0.203**	0.171	**0.382**	**0.295**	0.2[b]	NS
Mercury (Hg)-Total	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	0.000184	0.000334	0.00032	0.000525	0.073[a]	0.073
Nickel (Ni)-Total	<0.00050	<0.00050	<0.00050	0.00263	0.125[a]	0.063
Selenium (Se)-Total	<0.000050	<0.000050	<0.000050	0.000172	0.001[a]	NS
Silver (Ag)-Total	<0.000010	<0.000010	<0.000010	0.000028	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	<0.00030	0.00045	<0.00030	0.00241	0.0[a]	NS
Uranium (U)-Total	0.00003	0.000047	0.000057	0.000745	0.01[b]	0.015
Vanadium (V)-Total	<0.00050	<0.00050	<0.00050	0.00087	0.1[b]	NS
Zinc (Zn)-Total	<0.0030	<0.0030	0.0041	<0.0030	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 data of routine chemistry and other parameters for West Basin of LLB Lake

Parameters	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
pH	8.5	8.1	8.52	8.38	8.38	8.23	8.61	8.21	8.5	8.9	8.28	8.32
Conductivity (µS/cm)	277.3	292	295.9	293.6	283.5	285.6	286.9	288.1	295.9	242.9	289	202
Secchi Depth (m)	2.26	1.78	2.13	5	1.5	2.27	2.04	2.813	1.45	1.25	n/a	3.5
Total N (mg/L)	1.26	0.99	0.682	0.744	0.998	0.646	0.855	0.747	1.09	1.84	1.14	0.9
Total P (mg/L)	0.06	0.08	0.05	0.04	0.09	0.05	0.13	0.07	0.15	0.17	0.10	0.18
Ammonia (mg/L)	0.146	0.065	0.113	0.05	0.169	0.031	0.074	<0.050	0.183	0.05	0.1	0.204
Nitrate/Nitrite (mg/L)	0.012	0.004	0.0043	0.207	0.047	0.111	<0.071	<0.071	0.068	0.061	<0.022	<0.05
Total Dissolved Solids (mg/L)	177.5	185.8	n/a	n/a	180	182.2	186	184.4	n/a	184.8	153	239

Table 7: Historical trend of total metals for LLB West Basin

Dissolved Metals	**2015**	**2016**	**2017**	**Criteria[1]**	**Criteria [2]**
	------------------(mg/L) --------------------				
pH	-	-	8.32		
Hardness (as $CaCO_3$)	-	-	128		
Aluminum (Al)	0.0118	0.0051	0.0064	0.1[a]	0.1
Antimony (Sb)	<0.0005	<0.0001	<0.00010	NS	NS
Arsenic (As)	0.00161	0.00144	0.00201	0.005[a]	0.005
Barium (Ba)	0.055	0.0479	0.0498	NS	NS
Beryllium (Be)-Total			<0.00010	100[b]	NS
Boron (B)	0.043	0.043	0.031	1.5[a]	1.5
Cadmium (Cd)	<0.000025	<0.000005	<0.0000050	0.00009[a]	0.00019
Chromium (Cr)	<0.0005	<0.00010	0.00055	NS	NS
Cobalt (Co)-Total			<0.00010	0.05[a]	0.0012
Copper (Cu)	<0.0025	<0.00093	<0.00050	0.0032[a]	0.02
Iron (Fe)	<0.050	0.02	0.037	0.3[a]	0.3
Lead (Pb)	<0.00025	<0.00005	<0.000050	0.005[a]	0.0042
Lithium (Li)-Total			0.0111	2.5[b]	NS
Manganese (Mn)	0.0855	0.0479	0.171	0.2[b]	NS
Mercury (Hg)	<0.000005	<0.000005	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total			0.000334	0.073[a]	0.073
Nickel (Ni)	<0.000025	<0.000005	<0.00050	0.125[a]	0.063
Selenium (Se)	<0.00025	<0.00005	<0.000050	0.001[a]	NS
Silver (Ag)	<0.00005	<0.00001	<0.000010	0.00025[a]	0.00025
Thallium (Tl)-Total			<0.000010	0.0008[a]	0.0008
Tin (Sn)-Total			<0.00010	0.0[a]	NS
Titanium (Ti)-Total			0.00045	0.0[a]	NS
Uranium (U)	0.000042	0.000053	0.000047	0.01[b]	0.015
Vanadium (V)-Total			<0.00050	0.1[b]	NS
Zinc (Zn)	<0.015	<0.003	<0.0030	0.007[a]	0.03

*Analysis for total dissolved metals began in 2016
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)