2018
Elinor Lake Water Quality Report
Lac La Biche County, Alberta

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Adapted From:

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

Executive Summary

Elinor Lake is relatively small, but scenic lake located within Lac La Biche County, Alberta ("County"), and is known for a variety of recreational activities such as swimming and boating. However, there is a concern that declining water quality in the lake is limiting the opportunities of recreational activities. Therefore, it is important that the lake water quality be monitored.

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 2018. 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.

The water sampling events were conducted during spring and summer of 2018. Collected water samples were analyzed by ALS laboratory. The laboratory results obtained were compared to the CCME 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 Elinor 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.

Elinor Lake would be considered Mesotrophic based on the average of the three water parameters Secchi depth, total nitrogen and total phosphorus. Oligotrophic based on Secchi depth, Hypereutrophic based on total nitrogen, and Mesotrophic based on total phosphorus.

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Results and Discussion

In 2018, Secchi depths in Elinor Lake were measured on April 5, August 2, and August 16, 2018. The average seasonal Secchi depth was observed to be 4.3 m which is slightly higher than historical results. Based on the Secchi depths and in accordance with the classification provided in Table 1 (Appendix A), Elinor Lake is classified as Oligotrophic (some productivity, nutrients, and algae growth).

Dissolved oxygen data collected in 2018 shows that the average dissolved oxygen levels ranged from 7.25 mg/L to 3.09 mg/L. These concentrations slightly lower than the regulatory guidelines of 9.5 mg/L for early life and 6.5 mg/L for all other life stages in cold water lakes.

A temporal decrease in temperature was observed with an average temperature of 10.5 ^{O}C. Stratified temperature profiles were observed during the summer as there was significant variation in temperatures with depth. Based on the data provided, thermal stratification was observed in the sampling events between July 4 and August 24, 2018.

In 2018, two types of lake water samples for analyses of nutrients were collected from Elinor Lake; composite samples and Kemmerer samples (obtained from different depths using a Kemmerer device). These samples were analyzed for total nitrogen and total phosphorous.

Total nitrogen concentrations in the composite samples collected from the lake in 2018 had an average of 1.20 mg/L of total nitrogen, while the Kemmerer samples collected had an average of 1.58 mg/L of total nitrogen; both of which exceeded the applicable regulatory guidelines and were consistent with historical results. Total nitrogen concentrations from both sampling methods classify Elinor Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

Total phosphorus concentrations in the composite samples collected during the summer of 2018 had an average of 0.02 mg/L of total phosphorus, while the Kemmerer samples collected had an average of 0.04 mg/L. The average of both sampling methods is 0.03 mg/L of total phosphorus which does not exceed the applicable regulatory guidelines of 0.05 mg/L and were consistent with historical results. Total phosphorus concentrations from both sampling methods classify Elinor Lake as Mesotrophic (high productivity, nutrients, and algae growth).

The average N:P ratios for composite and Kemmerer sampling events were 60:1 and 37:1 which is higher than the Redfield Ratio of 16:1. Therefore, the total phosphorus concentrations are considered low enough for phosphorus to be considered the main nutrient limiting growth in Elinor Lake.

Routine water chemistry showed that Elinor Lake has an average pH of 7.79 in 2018 which is consistent with historical results.

Concentrations of metals analyzed from the composite and Kemmerer samples taken at a depth of 9 m were generally below detection limits and/or below the applicable regulatory guidelines.

Elinor Lake would be considered Mesotrophic based on the average of the three water parameters Secchi depth, total nitrogen and total phosphorus. Oligotrophic based on Secchi depth, Hypereutrophic based on total nitrogen, and Mesotrophic based on total phosphorus.

Recommendations:

It is recommended that County continues to monitor the water quality of Elinor Lake to achieve to continue to long term representation of the average water quality in the lake. Continuous monitoring will help in evaluating if the existing lake management policies need to be changed to ensure the lake's health. To ensure that data received is consistent and comparable year to year, consistency in spatial and temporal data collection needs to be maintained in a consistent manner.

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

Monitoring and sampling should 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 Elinor 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: Lake 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

Elinor Lake is located in east central Alberta, approximately 35 km southeast of the town of Lac La Biche within the Beaver River drainage basin in the County (Figure 1). The lake covers a surface area of 9.33 km^2 with a mean depth of 5.2 m and a maximum depth of 17.2 m. The lake is one of the two main lakes that flows directly into Beaver Lake. The popular game fish of this lake are Yellow Perch (*Perca flavescens*), Northern Pike (*Esox lucius*), Walleye (*Sander vitreus*), and Lake Whitefish (*Coregonus clupeaformis*).

Figure 1: Location map of Elinor Lake

2. WATER QUALITY SAMPLING PROGRAM

Elinor Lake has been sampled by the County consistently every year from 2005 – 2018. Elinor Lake is sampled for various parameters using different techniques. Vertical profiles were taken using a multi-probe testing different depths (zones) of the lake for dissolved oxygen, pH, conductivity, and temperature. Composite samples are taken from 10 different locations throughout the lake, while Kemmerer sampling is used for discrete depth sampling; both the composite and Kemmerer samples are tested for nutrients such as, phosphorus, nitrogen, ammonia, nitrates, nitrites, and metals. Elinor Lake sampling program for 2018 was completed as follows:

a) Secchi and Euphotic Depths were measured on April 5, August 2, and August 16, 2018 using Secchi Disc;
b) Composite samples from the lake April 5, August 2, and August 16, 2018 and were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories;
c) Kemmerer water samples were collected on April 5, and August 15, at 3 m depth intervals (3 m, 6 m, 9 m, 12 m and 15 m), and were analyzed for nutrients, metals and basic water chemistry parameters by ALS laboratories;
d) Lake profiles were recorded to a maximum depth of 18 m using a multi-probe on April 5, August 2, and August 16, 2018.

2.1 Water Quality Parameters

Water samples collected during 2018 sampling events of Elinor Lake were analyzed for several parameters to characterize the lake water and identify potential issues associated with lake water quality. The water quality parameters measured/analyzed during 2018 are provided in the table below with a brief description.

Lake Water Quality Parameters

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.

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 2018, Secchi depths were measured on April 5, August 2, and August 16, 2018. The maximum Secchi depth of 6.0 m was recorded on April 5, 2018, while a minimum Secchi depth of 3.25 m was recorded on August 15, 2018. Overall a decreasing temporal trend was observed for Secchi depth as presented in Figure 2. The average Secchi depth of 4.3 m in the Elinor Lake is indicative of Oligotrophic (low productivity, nutrients, and algae growth) in accordance with trophic status of lake water parameters (Nurnberg 1996), provided in Table 1 of Appendix A.

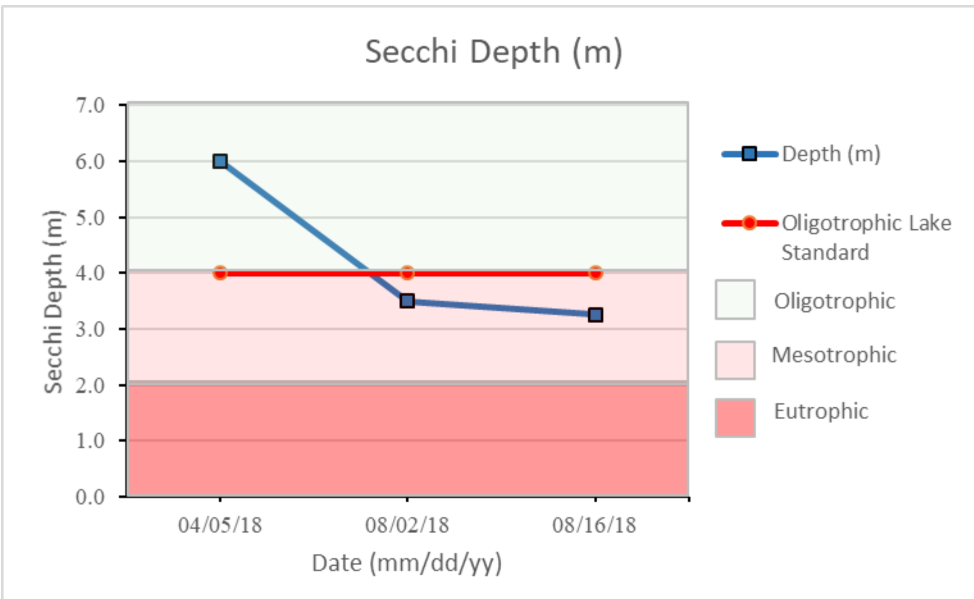

Figure 2: Secchi depth measurements in Elinor Lake - 2018

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.

In 2018, dissolved oxygen levels in Elinor Lake were recorded to a maximum depth of 18 m using a multi-probe on April 5, August 2, and August 16, 2018. Depths 9 m to 15 m were exempted due to anomalies in the data collected. Maximum recorded dissolved oxygen was 8.8 mg/L observed on August 2, 2018 at 2 m and 3 m depths which declined gradually to 2.95 mg/L at 8 m (Figure 3) depth. Average dissolved oxygen concentrations ranged from 7.25 mg/L to 3.09 mg/L and were slightly lower than the regulatory guidelines of 9.5 mg/L for early life and 6.5 mg/L for all other life stages in cold water lakes.

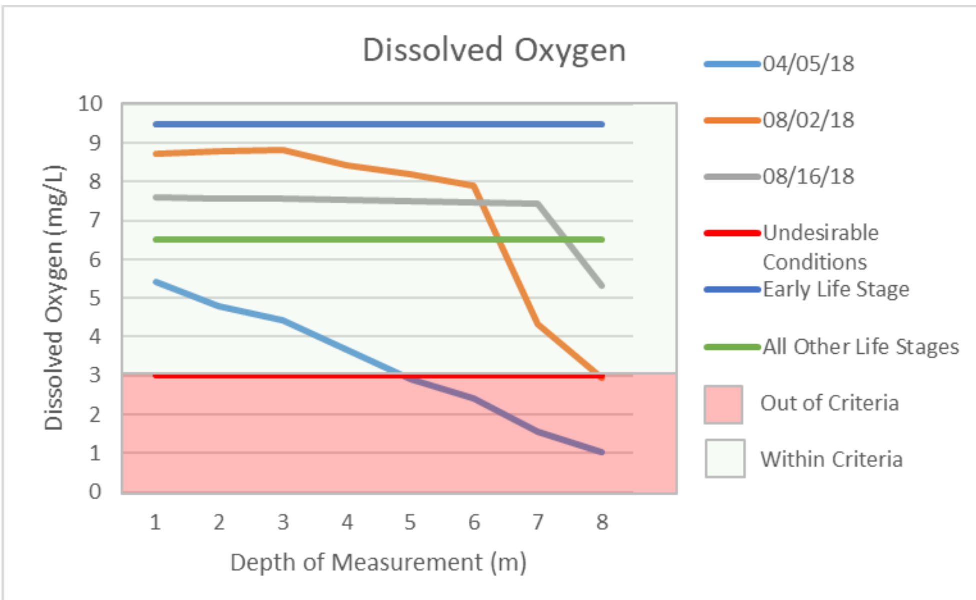

Figure 3: Dissolved oxygen in in Elinor Lake - 2018

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 summer time, warmer surface water can facilitate cyanobacteria blooms at the lake surface (Wetzel, R. 2001).

Elinor Lake temperatures were recorded to a maximum depth of 18 m. The minimum temperature of 0.14 ^{o}C was recorded on April 5 at 1 m depth, and the maximum temperature of 22 ^{o}C was observed on July 2, 2018 at a 1 m depth. An average temperature of 10.5 ^{O}C was observed during the sampling period. Results of temperatures observed on different dates and depth are illustrated in Figure 4. Elinor Lake temperature sampling data showed a fairly stratified temperature profile during the summer sampling events.

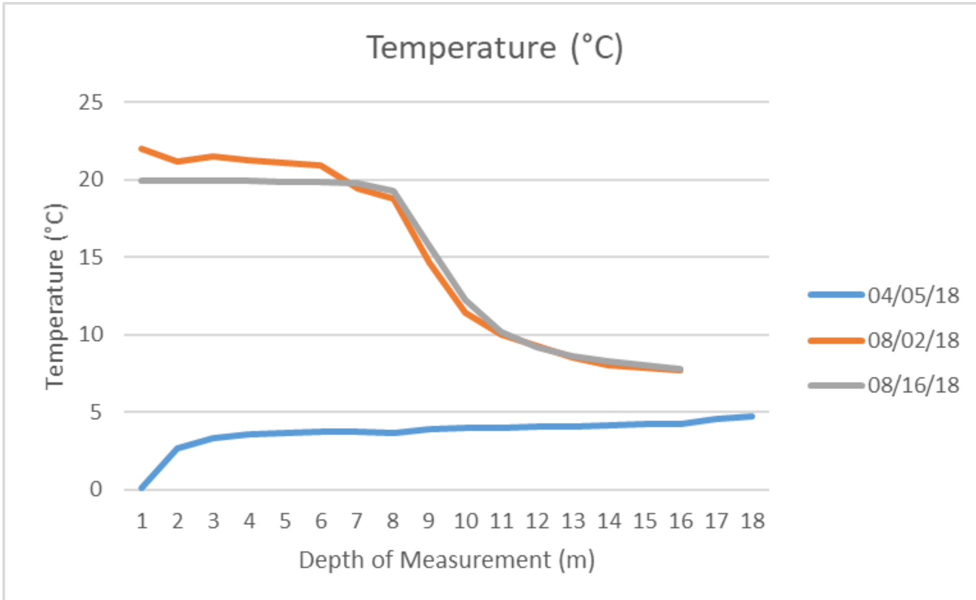

Figure 4: Elinor Lake temporal and spatial temperature measurements – 2018

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 2018, two types of lake water samples for analyses of nutrients were collected from Elinor Lake; composite samples and Kemmerer samples (obtained from different depths using a Kemmerer device). These samples were analyzed for total nitrogen and total phosphorous.

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 and this 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 Sampling

Composite lake water samples for total Nitrogen analysis were collected on July 25, August 2, and August 16, 2018.

The minimum total nitrogen concentration of 0.85 mg/L was analyzed in sample collected on July 25, and maximum total nitrogen concentration of 1.57 mg/L was analyzed in a sample collected on August 16, 2018 (Figure 5). An increase in total nitrogen concentration was observed during the sampling period. The average total nitrogen concentration in the composite sampling was 1.20 mg/L of total nitrogen.

Lake water composite samples collected on August 2 and August 16, 2018 exceeded the regulatory guideline of 1.0 mg/L for total nitrogen. However, total nitrogen concentrations in the sample collected on July 25, 2018 met the applicable regulatory guidelines. . The average total nitrogen indicates that Elinor Lake is Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total nitrogen from composite samples.

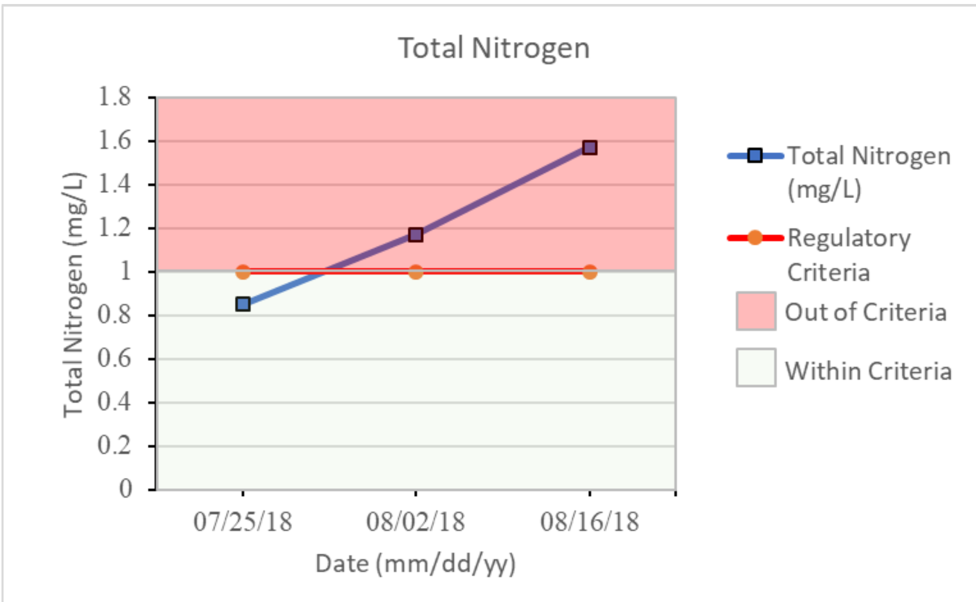

Figure 5: Total nitrogen from composite samples of Elinor Lake – 2018

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 on April 5, 2018, and August 15, 2018 from depths of 3 m, 6 m, 9 m, 12 m, and 15 m. These samples were analyzed for total nitrogen by ALS laboratories. Data regarding total nitrogen of Elinor Lake is illustrated in Figure 6.

A minimum total nitrogen concentration of 1.37 mg/L was found at a 3 m depth on April 5, 2018 and a maximum total nitrogen concentration of 2.52 mg/L was found at a 12 m depth on August 15, 2018. An overall average of 1.58 mg/L of total nitrogen was found in the Kemmerer samples. A spatial increasing trend was observed in total nitrogen concentrations in Elinor Lake with depth. The total nitrogen concentrations in all samples exceeded the regulatory guideline of 1.0 mg/L. The results from the Kemmerer sampling resulted in the same trophic state classification as the composite samples for total nitrogen which is Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total nitrogen.

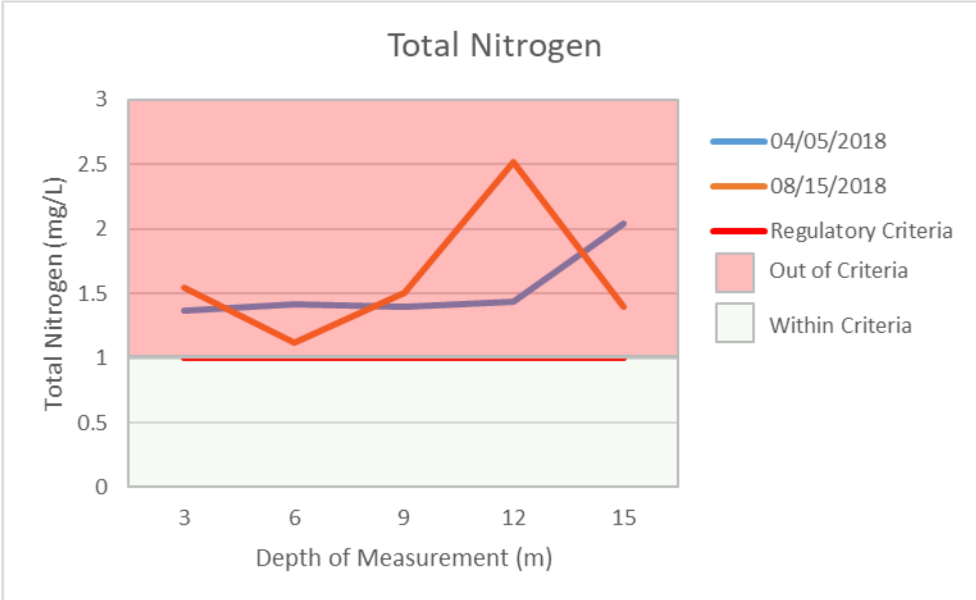

Figure 6: Total nitrogen from Kemmerer samples of Elinor Lake – 2018

Total Phosphorous

Increased phosphorus concentrations are the largest cause of degradation in water quality within lakes, causing 'dead zones', toxic algal blooms, a loss of biodiversity and increased health risks for plants, animals and humans that encounter polluted lake waters. Run-off from agriculture, human sewage and industrial practices results in increased phosphorus concentrations in lake water and 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 total phosphorous analysis were collected on July 25, August 2, and August 16, 2018 and the total phosphorus concentrations were all 0.02 mg/L of total phosphorus. The analytical results are illustrated in Figure 7.

Total phosphorus concentrations in the composite samples had an average of 0.02 mg/L of total phosphorus which is below the applicable regulatory guideline of 0.05 mg/L. This average total phosphorus concentration classifies Elinor Lake as Mesotrophic (some productivity, nutrients, and algae growth) based on total phosphorus from composite samples.

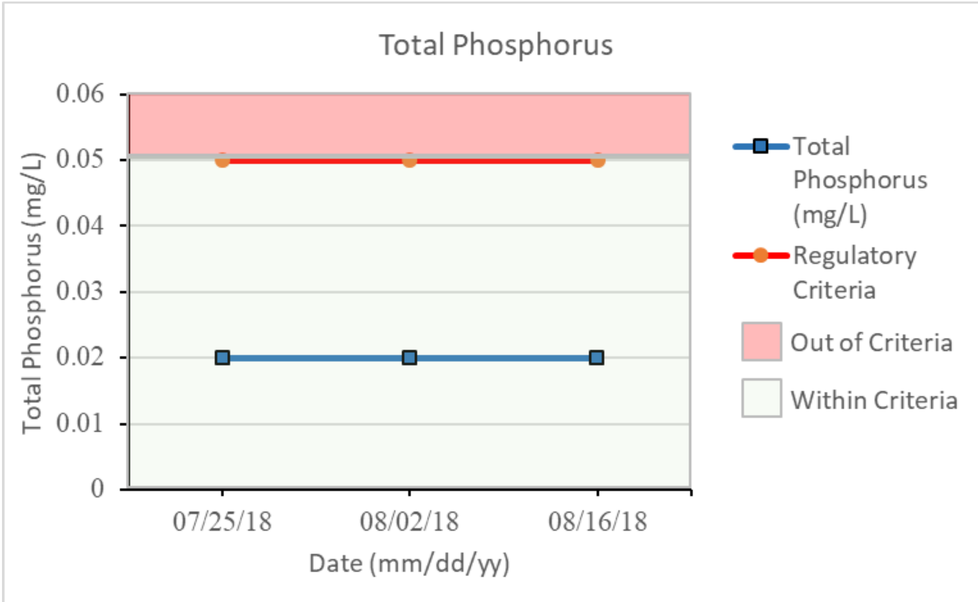

Figure 7: Total phosphorus from composite samples of Elinor Lake - 2018

Kemmerer Sampling

Kemmerer water samples from Elinor Lake were collected on April 5 and August 15, 2018 from 3 m, 6 m, 9 m, 12 m, and 15 m depths. They were analyzed for total phosphorus by ALS laboratories. Analytical results are presented in Figure 8.

Total phosphorus concentrations were almost constant throughout the lake depth for both all sampling dates except in the samples collected between 12 m and 15 m depth, which had maximum total phosphorus concentration of 0.14 mg/L. The average total phosphorus concentration was 0.04 mg/L from the Kemmerer samples. The average total phosphorus did not exceed the regulatory guideline of 0.05 mg/L.

The results from the Kemmerer sampling resulted in a poorer trophic state classification as the composite samples for total phosphorus. The composite sampling average of 0.02 mg/L total phosphorus resulted in a trophic status of Mesotrophic (some productivity, nutrients, and algae growth). However, the Kemmerer sampling average of 0.04 mg/L of total phosphorus which resulted in a trophic status of Eutrophic (high productivity, nutrients, and algae growth) based on total phosphorus. Therefore, the average of both results in 0.03 mg/L of total phosphorus which is a trophic status of Mesotrophic (some productivity, nutrients, and algae growth) based on total phosphorus.

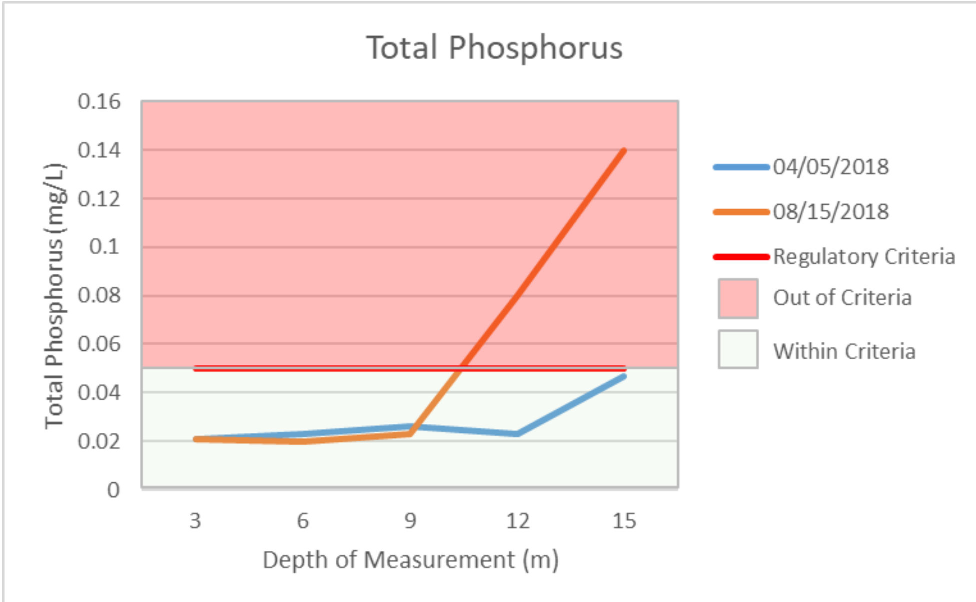

Figure 8: Total phosphorus from Kemmerer samples of Elinor Lake – 2018

N:P Ratio

The Redfield Ratio describes the optimal balance of total nitrogen to total phosphorous for aquatic plant growth and has 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 total nitrogen to total phosphorus ratios (N:P ratio) were 60:1 and 37:1 for composite and Kemmerer samples, respectively, which are higher than the Redfield Ratio of 16:1 indicating that phosphorus is a limiting factor for growth in this lake.

4.5 Routine Water Chemistry

Results of routine water chemistry of composite and Kemmerer samples are presented in Table 4 in Appendix A.

The average measured pH for Elinor Lake was 7.79 which 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 Elinor 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 and 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 analytical results of total dissolved metals in the Kemmerer and composite water samples collected from Elinor Lake are presented in Table 5.

Concentrations of all metals analyzed from the composite and Kemmerer samples taken at a depth of 9 m were generally below detection limits and/or below the applicable regulatory guidelines.

5. HISTORICAL TREND ANALYSIS

The objective of the historical trend analysis is to provide 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 used for trophic classification of lakes.

5.1 Secchi Depth

Historical data shows that Secchi Depth in Elinor Lake ranged from 2.5 m – 4.25 m and has been less than the standard Oligotrophic Secchi Depth of 4 m except in 2009 and 2018, as illustrated in Figure 9. Historical data for Secchi depth shows that it did not significantly change over time from 2005 (3.25 m) to 2017 (3.21 m) but now appears to be on the rise in 2018 (4.25 m). The historical Secchi depth shows that the clarity of Elinor Lake is relatively good. However, the Secchi depth readings may not provide an exact measure of the water transparency, as there can be errors because of the sun's glare on the water, and eyesight of the observer.

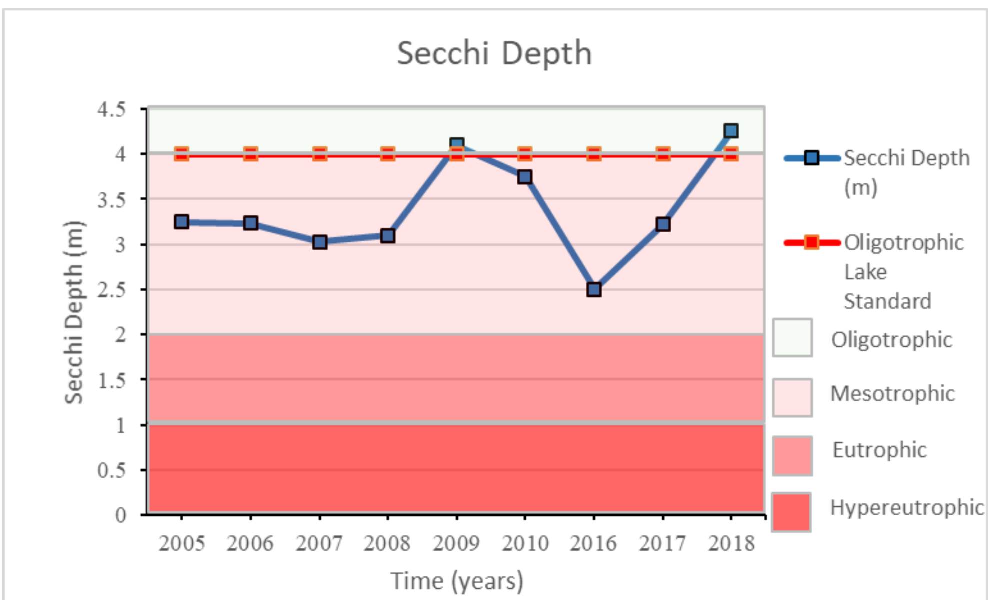

Figure 9: Historical trend for Secchi Depth in Elinor Lake

5.2 Total Nitrogen

Historical data shows that total nitrogen concentration in Elinor Lake ranged from 1.07 mg/L to 1.54 mg/L of total nitrogen and consistently exceeded the regulatory guideline of 1.0 mg/L. A maximum total nitrogen concentration of 1.54 mg/L was measured in 2007; however, a temporal decreasing trend in total nitrogen concentration has been observed since 2007. Total nitrogen concentrations have historically been classified as Hypereutrophic (excessive productivity, nutrients, and algae growth).

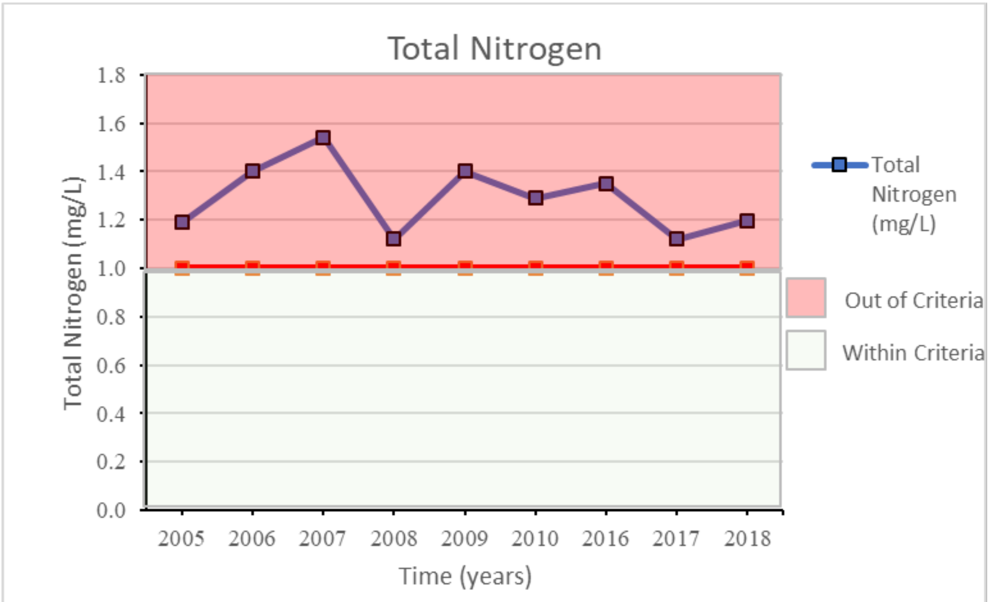

Figure 10: Historical trend of total nitrogen concentrations in Elinor Lake

5.3 Total Phosphorus

Historical data shows that the total phosphorus concentration have been without significant variation since 2005. Overall variation of total phosphorous concentrations ranged from 0.014 mg/L in 2005 to 0.02 mg/L in 2018. Total phosphorus concentrations in Elinor lake did not exceed the regulatory guideline of 0.05 (Figure 11) since monitoring began in 2005. Total phosphorus concentrations have historically been classified as Mesotrophic (some productivity, nutrient, and algae growth).

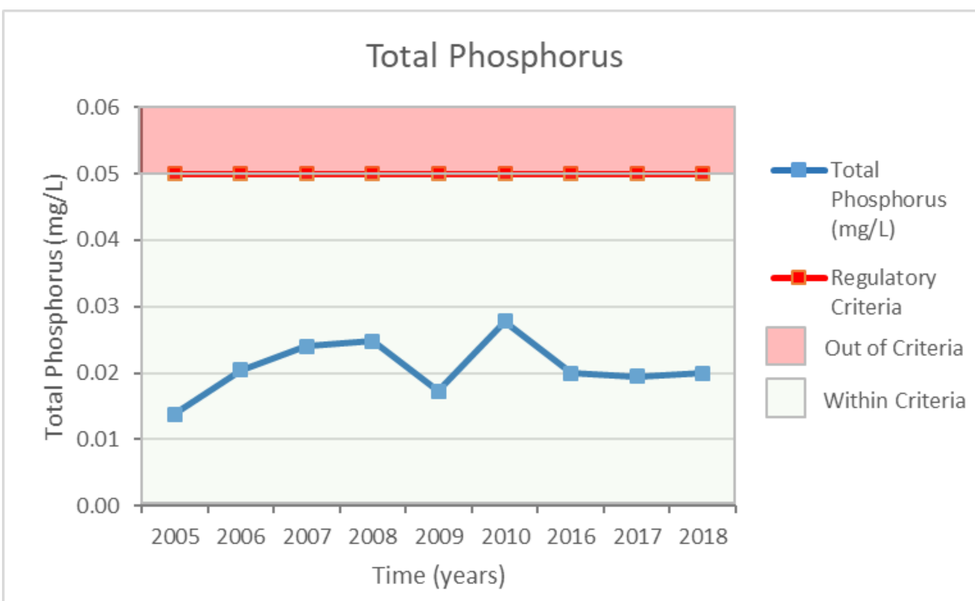

Figure 11: Historical trend of total phosphorus concentrations in Elinor Lake

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 Elinor 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.

Elinor Lake would be considered Mesotrophic based on the average of the three water parameters Secchi depth, total nitrogen and total phosphorus. Oligotrophic based on Secchi depth, Hypereutrophic based on total nitrogen, and Mesotrophic based on total phosphorus.

7. RECOMMENDATIONS

It is recommended that County continues to monitor the water quality of Elinor Lake to achieve to continue to long term representation of the average water quality in the lake. Continuous monitoring will help in evaluating if the existing lake management policies need to be changed to ensure the lake’s health. To ensure that data received is consistent and comparable year to year, consistency in spatial and temporal data collection needs to be maintained in a consistent manner.

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

Monitoring and sampling should 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 Elinor 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.

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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 Elinor Lake based on lake water parameters 2018

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
Elinor Lake	3.21	1.12	0.019
Trophic State of Elinor Lake in 2018	Oligotrophic	Hypereutrophic	Mesotrophic
Trophic State of Elinor Lake in 2017	Mesotrophic	Hypereutrophic	Mesotrophic

Table 3: Average lake water N:P ratios for composite and Kemmerer samples from Elinor Lake

Sampling Event	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**N:P**
Composite Sampling	1.20	0.02	60:1
Kemmerer Sampling	1.58	0.04	37:1

Table 4: Routine water chemistry analysis from Elinor Lake – 2018

Parameters	April 5, 2018	July 25, 2018	August 16, 2018	Criteria [1]	Criteria [2]
	---------------------------(mg/L)----------------------------				
pH	7.50	8.03	8.01		
Temperature ^{O}C	3.7	15.2	14.9		
Ammonia, Total (as N)	0.165	<0.050	<0.050	0.141[a]*	0.122
Nitrate (as N)	0.243	<0.020	<0.020	3.00[a]	3
Nitrite (as N)	<0.010	<0.010	<0.010	0.20[2]	0.2
Nitrate and Nitrite (as N)	0.243	<0.022	<0.022	100[b]	NS

* Based on average pH and temperature of 8.01 and 11.3 ^{o}C of Elinor Lake in 2018

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Table 5: Dissolved metals in Elinor Lake – 2018

Sampling Event	Kemmerer		Criteria1	Criteria2
Date of Sampling	April 5, 2018	August 16, 2018		
Parameters	------------------------------------(mg/L)---------------------------------			
pH	7.50	8.01		
Hardness (as CaCO3)	211			
Aluminum (Al)-Total	<0.0030	0.0042	0.1[a]	0.1
Antimony (Sb)-Total	<0.00010	<0.00010	NS	NS
Arsenic (As)-Total	0.00092	0.00086	0.005[a]	0.005
Barium (Ba)-Total	0.0505	0.0549	NS	NS
Beryllium (Be)-Total	<0.00010	<0.00010	100[b]	NS
Boron (B)-Total	0.071	0.063	1.5[a]	1.5
Cadmium (Cd)-Total	<0.0000050	<0.0000050	0.0037[a]	0.00025
Chromium (Cr)-Total	<0.00010	0.00436	-	NS
Cobalt (Co)-Total	<0.00010	<0.00010	0.05[a]	0.0012
Copper (Cu)-Total	<0.00050	<0.00050	0.0038[a]	0.028
Iron (Fe)-Total	<0.010	0.025	0.3[a]	0.3
Lead (Pb)-Total	<0.000050	<0.000050	0.0065[a]	0.0065
Lithium (Li)-Total	0.0294	0.0268	2.5[b]	NS
Manganese (Mn)-Total	0.0729	0.694	0.2[b]	NS
Mercury (Hg)-Total	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	<0.000050	<0.000050	0.073[a]	0.073
Nickel (Ni)-Total	<0.00050	0.00080	0.147[a]	0.084
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	0.000066	0.000048	0.01[b]	0.015
Vanadium (V)-Total	0.00054	<0.00050	0.1[b]	NS
Zinc (Zn)-Total	<0.0030	<0.0030	0.007[a]	0.03

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Table 6: Historical trend of water chemistry parameters from the Elinor Lake

	Year								
Parameter	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2016**	**2017**	**2018**
pH	8.36	8.26	8.26	8.13	8.60	8.33	8.15	8.35	7.79
Secchi Depth (m)	3.25	3.23	3.03	3.10	4.10	3.75	2.50	3.22	4.25
Total Nitrogen (mg/L)	1.19	1.40	1.54	1.12	1.40	1.29	1.35	1.12	1.20
Total Phosphorus (mg/L)	0.014	0.020	0.024	0.025	0.017	0.028	0.020	0.020	0.020
Specific Conductivity (µS/cm)	347	359	380	392	402	379	407	331	572

Table 7. Historical trend of dissolved metals from the Elinor Lake

Dissolved Metals	2017	2018	Criteria[1]	Criteria[2]
	-------------------(mg/L) -----------------			
pH	8.36	7.79		
Hardness (as $CaCO_3$)	176	211		
Aluminum (Al)	<0.015	0.0036	0.1[a]	0.1
Antimony (Sb)	<0.00050	<0.00010	NS	NS
Arsenic (As)	0.00076	0.00089	0.005[a]	0.005
Barium (Ba)	0.0434	0.0527	NS	NS
Beryllium (Be)-Total	<0.00050	<0.00010	100[b]	NS
Boron (B)	0.054	0.067	1.5[a]	1.5
Cadmium (Cd)	<0.000025	<0.0000050	0.0037[a]	0.00025
Chromium (Cr)	<0.00050	0.00223	-	NS
Cobalt (Co)-Total	<0.00050	<0.00010	0.05[a]	0.0012
Copper (Cu)	<0.0025	<0.00050	0.0038[a]	0.028
Iron (Fe)	<0.050	0.0175	0.3[a]	0.3
Lead (Pb)	<0.00025	<0.000050	0.0065[a]	0.0065
Lithium (Li)-Total	0.0225	0.0281	2.5[b]	NS
Manganese (Mn)	0.0235	0.3835	0.2[b]	NS
Mercury (Hg)	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	<0.00025	<0.000050	0.073[a]	0.073
Nickel (Ni)	<0.0025	0.00065	0.147[a]	0.084
Selenium (Se)	<0.00025	<0.000050	0.001[a]	NS
Silver (Ag)	<0.000050	<0.000010	0.00025[a]	0.00025
Thallium (Tl)-Total	<0.000050	<0.000010	0.0008[a]	0.0008
Tin (Sn)-Total	<0.00050	<0.00010	NS	NS
Titanium (Ti)-Total	<0.0015	<0.00030	NS	NS
Uranium (U)	0.000061	0.000057	0.01[b]	0.015
Vanadium (V)-Total	<0.0025	0.00052	0.1[b]	NS
Zinc (Zn)	<0.015	<0.0030	0.007[a]	0.03

*Analysis for total dissolved metals began in 2016
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