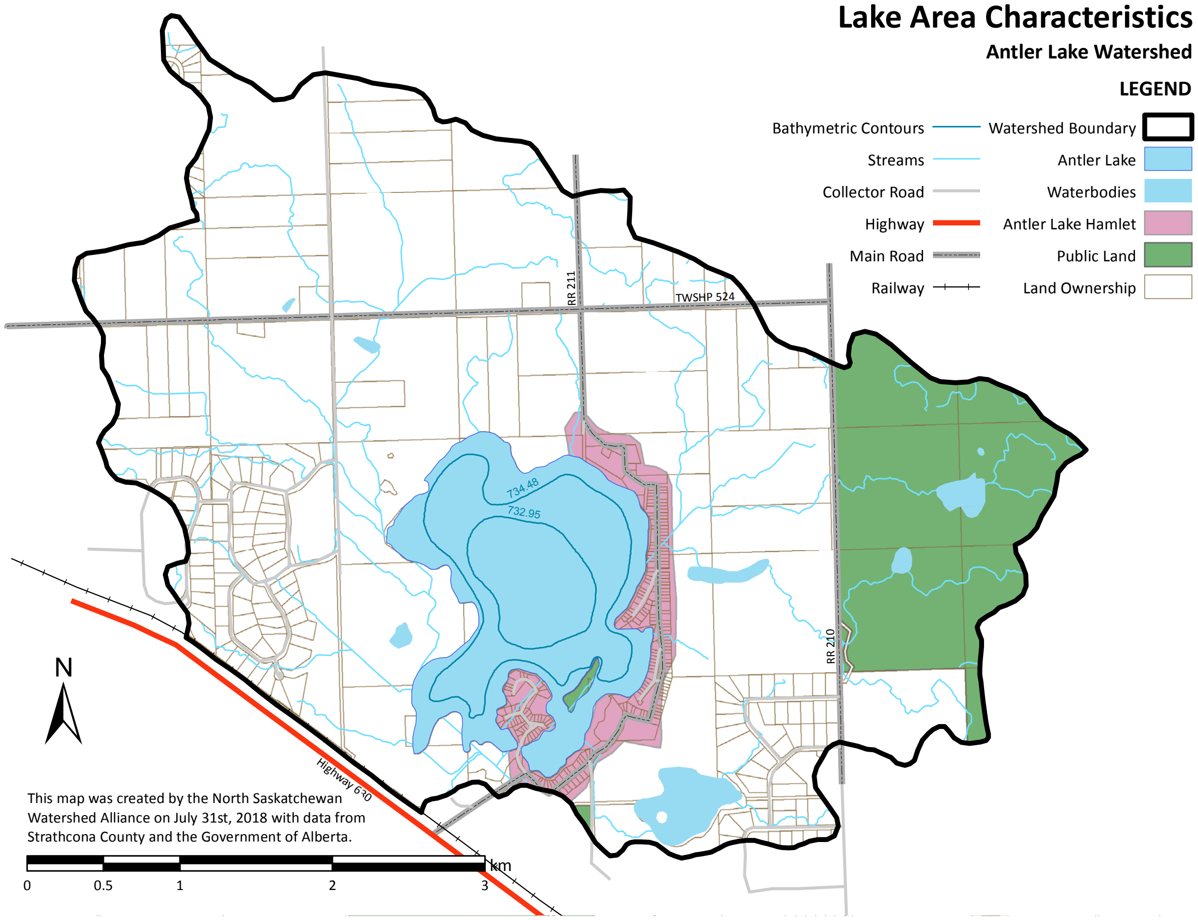
4.0 Lake Characteristics

4.1 General Description

Antler Lake is a small, shallow, and highly productive lake, located 35 km east of the City of Edmonton in the Beaverhill sub-watershed. It is comprised of a shallow, main basin with two islands located in the southern end of the lake: Antler Lake Island and Hazelnut Island. Hazelnut Island is connected by road access to the main shore and has several lakeshore properties (**Figure 40**). Antler is a polymictic lake, meaning, the lake mixes most days throughout the open water season because it is relatively shallow and exposed. Currently, Antler Lake is classified as hypereutrophic, with very high biological productivity (**Table 5**; AEP, 2018b).



This map was created by the North Saskatchewan Watershed Alliance on July 31st, 2018 with data from Strathcona County and the Government of Alberta.

Figure 40. **Bathymetry and Lake Area Characteristics of the Antler Lake Watershed** (data from Strathcona County GIS Services, 2018; AltaLis, 2016)

Table 5. General Lake Characteristics for Antler Lake (AEP, 2018b; Figliuzzi, 2018).

General Lake Characteristics		Antler Lake
Physical Characteristics	**Lake Surface Area (km^2)** (at mean elevation of 738.278 m)	2.38
	Watershed-to-Lake Ratio	8.87:1
	Max Depth (m)	4.69
	Mean Depth (m)	1.76
	Shoreline Length (km)	10.9
	Dam, Weir	No
Recreational Characteristics	**Campground**	No
	Boat Launch	No
	Sport Fish	None
Water Quality Characteristics *(Averages based on available data).*	**Trophic Status**	Hypereutrophic
	Total Phosphorus (µg/L)	380
	Chlorophyll-α (µg/L)	121
	Total Dissolved Solids (mg/L)	320

4.2 Lake Hydrology

A water balance is a tool used by hydrologists to describe how water flows through a watershed. Based on the fundamental concepts of the water cycle, water inputs (i.e. precipitation, surface runoff, and groundwater) and water outputs (i.e. surface outflow, groundwater, diversions) are calculated along with measurements of water volume in the lake (**Figure 41**). Based on these core principles, it should be possible to both decipher changes of input or output from sources over time and generate a “budget” for future management plans. The relationship between water and the watershed is dynamic, in that the shape (and other properties) of the land can alter the runoff of water. This means that measurements of runoff can be quite variable from year-to-year and for each precipitation event. Ideally, a water balance would be carried out for each storage and depression area to identify the actual quantity of runoff reaching the primary water body. However, as this level of analysis is impractical, or impossible in most instances, the concept of “gross” and “effective” drainage areas has come into common use to account for this variability in the contributing drainage area.

Antler Lake, as well as other upland lakes, including Cooking, McFadden, Halfmoon, Bennett, and Wanisan, occupy internal drainage basins during periods of low lake levels. During wet, climatic cycles, several of these lakes (McFadden, Cooking, Halfmoon, and Antler) spill over via Cooking Lake Creek into Hastings Lake. The most recent recorded occurrence of water flowing from Cooking Lake is the 1952-1955 period. During these events, water flows east into Beaverhill Lake, then northwestward into the North Saskatchewan River via Beaverhill Creek (**Figures 42-43**; Geowest, 1997).

Water enters Antler Lake through surface runoff during precipitation events. Surface outflow from Antler Lake is controlled by a culvert, located at the southeast end of the lake, where water flows intermittently southward under Antler Lake Road towards Cooking Lake through small creeks (Figliuzzi and Associates, Ltd., 2018). Water flows into Little Antler Lake (locally named), located between Antler Lake and North Cooking Lake, outside of the Antler Lake watershed boundary (**Appendix 2: Figure 1**).

WATER BALANCE EQUATION

CHANGE IN LAKE WATER STORAGE

WATER

WATER

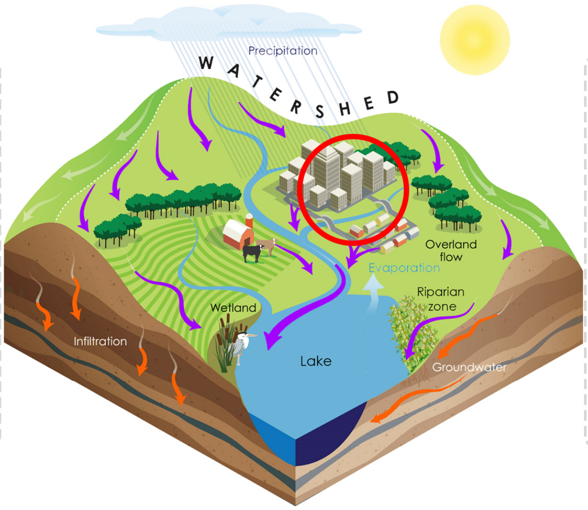
$$\Delta S = \text{INPUTS} - \text{OUTPUTS}$$

WATER INPUTS

Precipitation Input
Rain & snow falling directly on the lake

Surface Inflow
Inflow of water on the ground surface from the catchment or drainage area

Groundwater Inflow
Water entering the lake by buried channels and connections to underground aquifers



WATER OUTPUTS

Evaporation Losses
Evaporation directly from the lake surface area

Surface Outflow
Water leaving the lake through a defined outlet

Groundwater Outflow
Water leaving the lake through infiltrating directly into the groundwater system

Diversions
Water diverted into (+) or out of (-) the lake due to human activity

Figure 41. How a water balance equation is calculated.

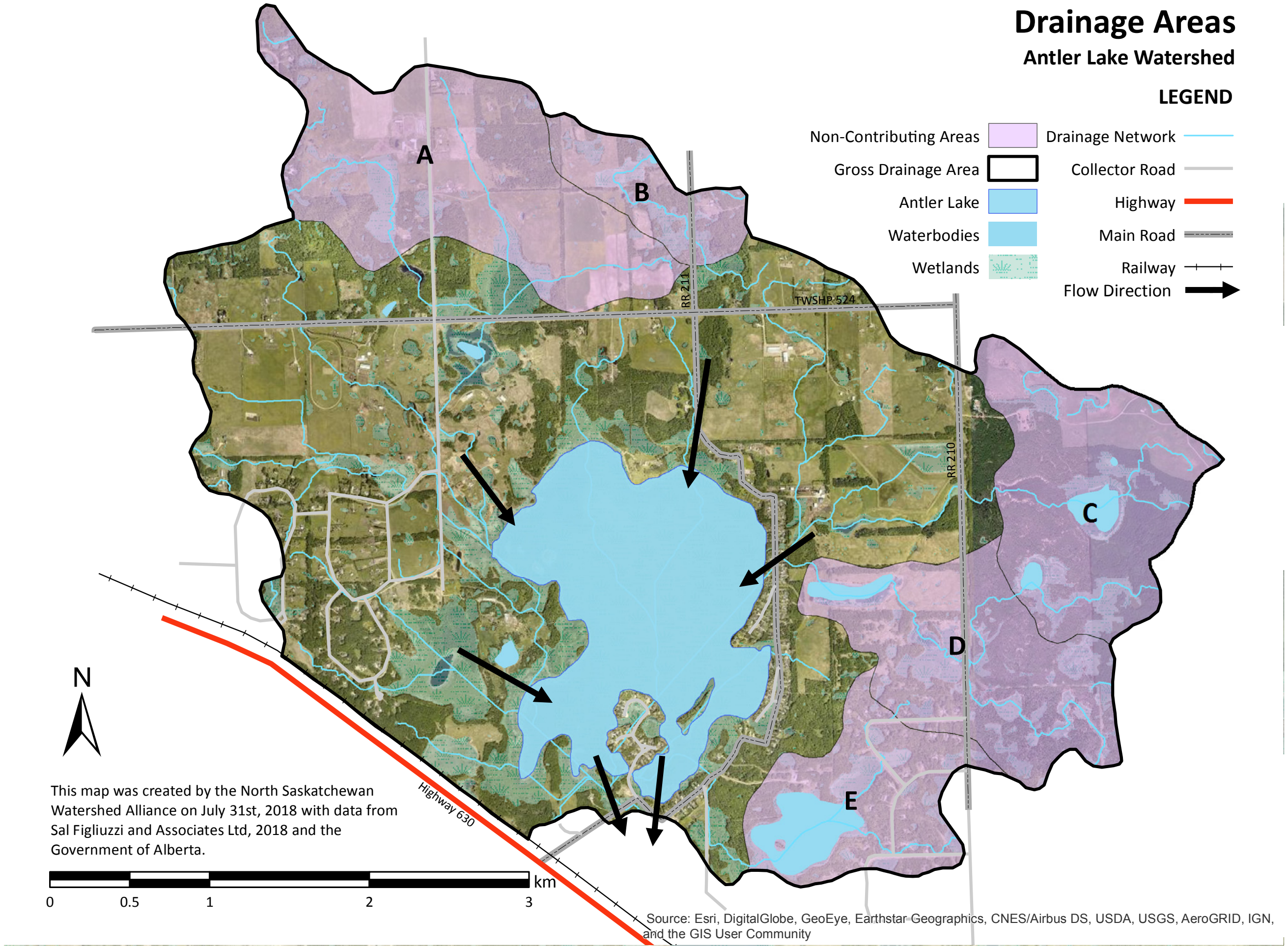
A water balance was developed for Antler Lake using the gross and effective drainage areas (**Figure 42**; **Appendix 2**), and long-term hydrology and climate data for the period 1980 to 2016 (Figliuzzi and Associates, Ltd., 2018). Detailed methods and data sources can be found in **Appendix 2**. The updated physical and hydrologic parameters estimated from the water balance for Antler Lake are presented in **Table 6**. The water balance analysis was calculated as the long-term annual mean (Figliuzzi and Associates, Ltd., 2018).

The water balance for Antler Lake and the estimation of hydrologic parameters has been carried out with the assumption that there is no reverse flow from Little Antler Lake into Antler Lake. There are no current water allocation and consumption permits at Antler Lake, and therefore, water diversion was set at zero in the water balance calculation. The resulting water balance showed slightly higher evaporative losses compared to precipitation inputs and surface outflow, with minimal groundwater inflow (**Figure 44**). A hydraulic residence time (the time required to fully replace the lake volume) was estimated to be 18.7 years (Sal Figliuzzi and Associates Ltd., 2018). The lake has a relatively short filling time and a rapid flushing rate (5.35% of lake volume per year) relative to other lakes in Alberta; the nearby Cooking and Hastings lakes have residence times that exceed 100 years (Mitchell and Prepas, 1990).

Table 6. Summary of Water Balance Parameters for the Antler Lake Watershed (Figliuzzi and Associates, Ltd., 2018).

	Sal Figliuzzi and Associates Ltd, 2018
PHYSICAL PARAMETERS	(long-term annual mean: 1980 – 2016)
Gross drainage area (includes lake surface area) *	21.10 km^2
Effective drainage area (excludes lake surface area) *	11.25 km^2
Non-contributing drainage area	7.47 km^2
Lake surface area at mean elevation	2.38 km^2
Lake storage volume at mean elevation	4,190,250 m^3
HYDROLOGICAL PARAMETERS	
Mean water level (GSC)	738.28 m
Total surface inflow	538,660 m^3
Surface outflow	224,000 m^3
Net groundwater inflow	40,425 m^3
Mean annual precipitation	504.3 mm
Precipitation input	1,170,000 m^3
Mean annual gross evaporation	666 mm
Evaporation losses	1,545,000 m^3
Mean residence time	18.7 years

*Determined by Sal Figliuzzi and Associates Ltd. (2018). The gross and effective drainage area is calculated based on the local drainage basin.



Drainage Areas

Antler Lake Watershed

This map was created by the North Saskatchewan Watershed Alliance on July 31st, 2018 with data from Sal Figliuzzi and Associates Ltd, 2018 and the Government of Alberta.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 42. Gross and Non-Contributing Drainage Areas and Surface Water Features for the Antler Lake Watershed.

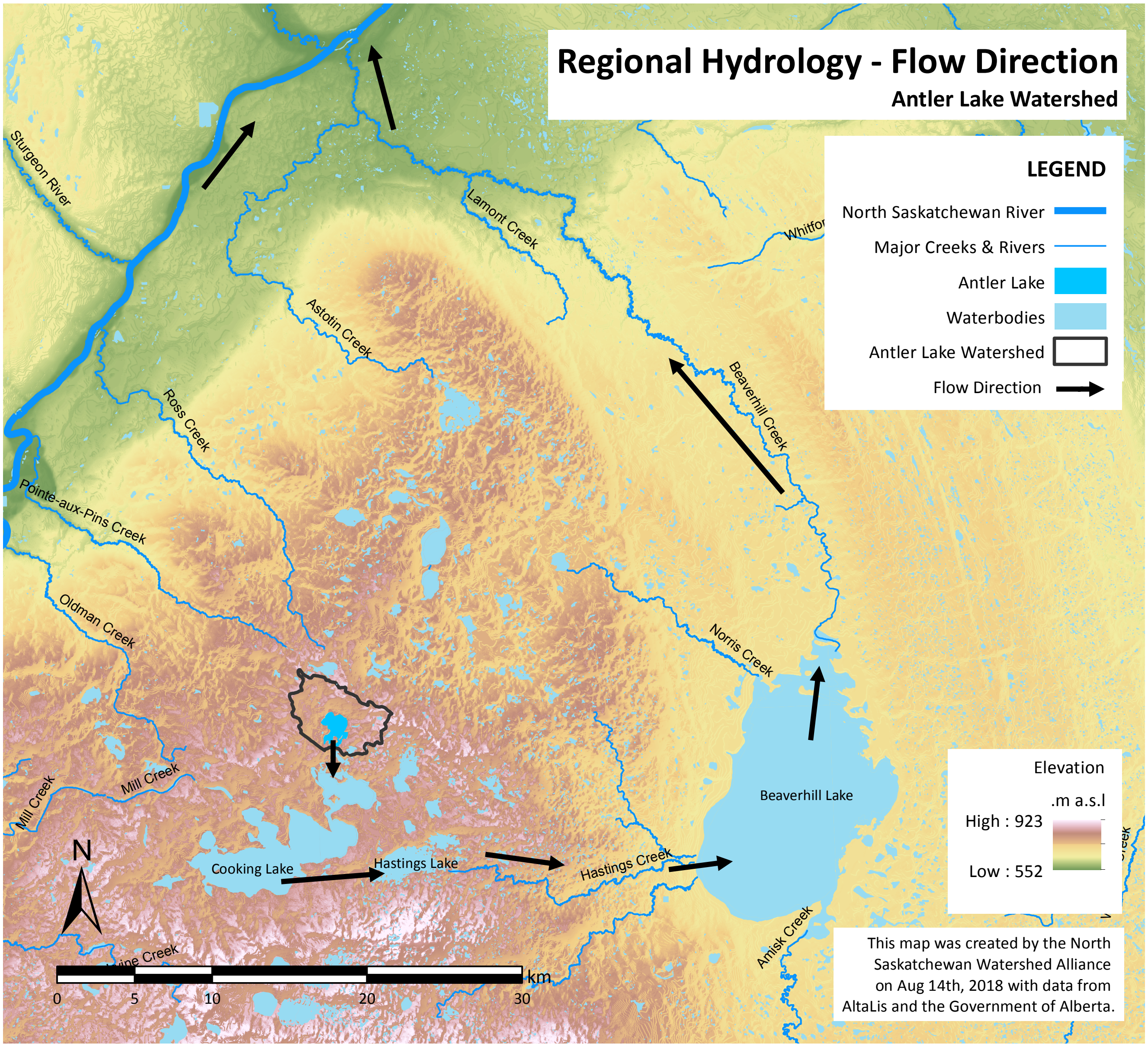


Figure 43. Regional Hydrological Flow from the Antler Lake Watershed (AltaLis, 2016).

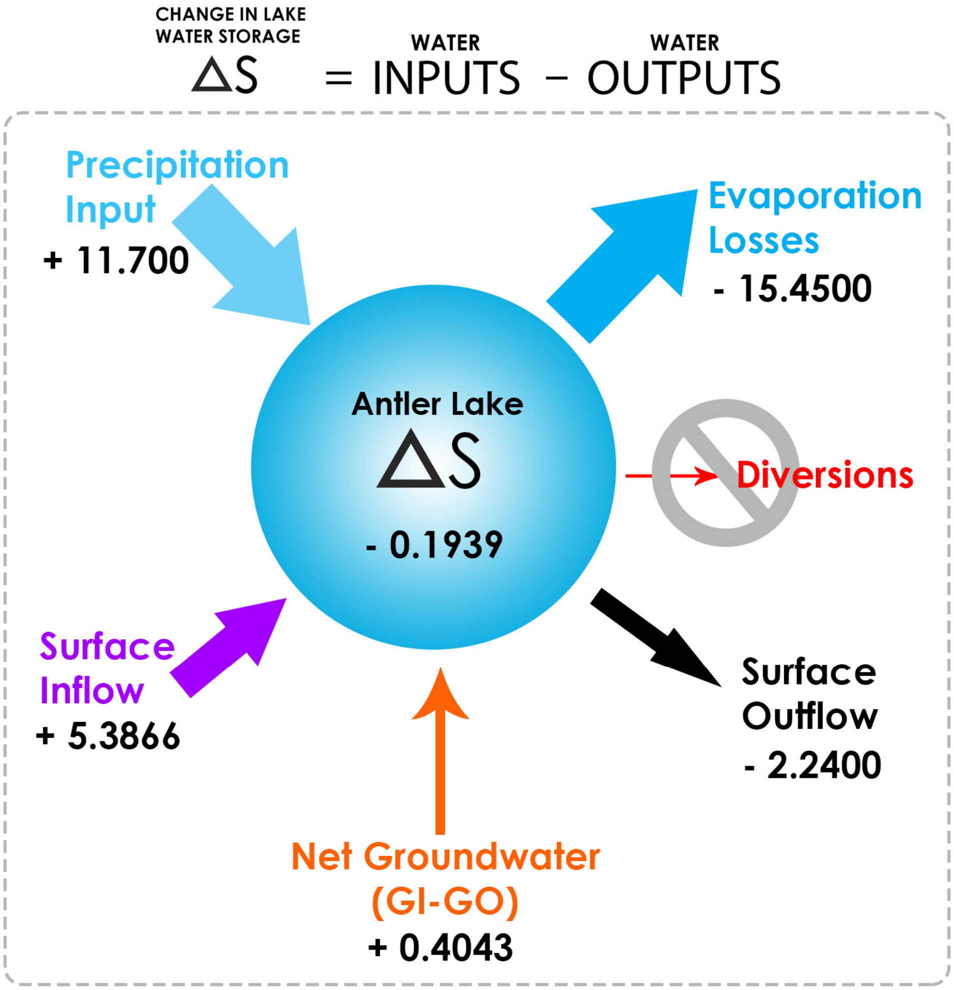


Figure 44. Water Balance Summary for the Antler Lake Watershed (Figliuzzi & Associates, Ltd., 2018).

4.3 Lake Levels

Water levels at Antler Lake fluctuated over a range of 0.425 m between 1959 to 2018 (**Figure 45**). Historically, lake levels were highest in July 1974 and lowest in September 2010 (**Table 7**). The largest, annual reduction in water level occurred from 2007-08 (0.6 m decline), and the largest increase occurred from 2010-11 (0.7 m increase). Despite annual fluctuations, a general decline in water levels has been observed at Antler Lake during the period of record (**Figure 45**). Over the past twenty years, the pattern of fluctuation of lake levels has shown a significant decrease from 1997 to 2010 (1.8 m decrease), and since 2010, lake levels have been on the rise, almost reaching the historic water level average.

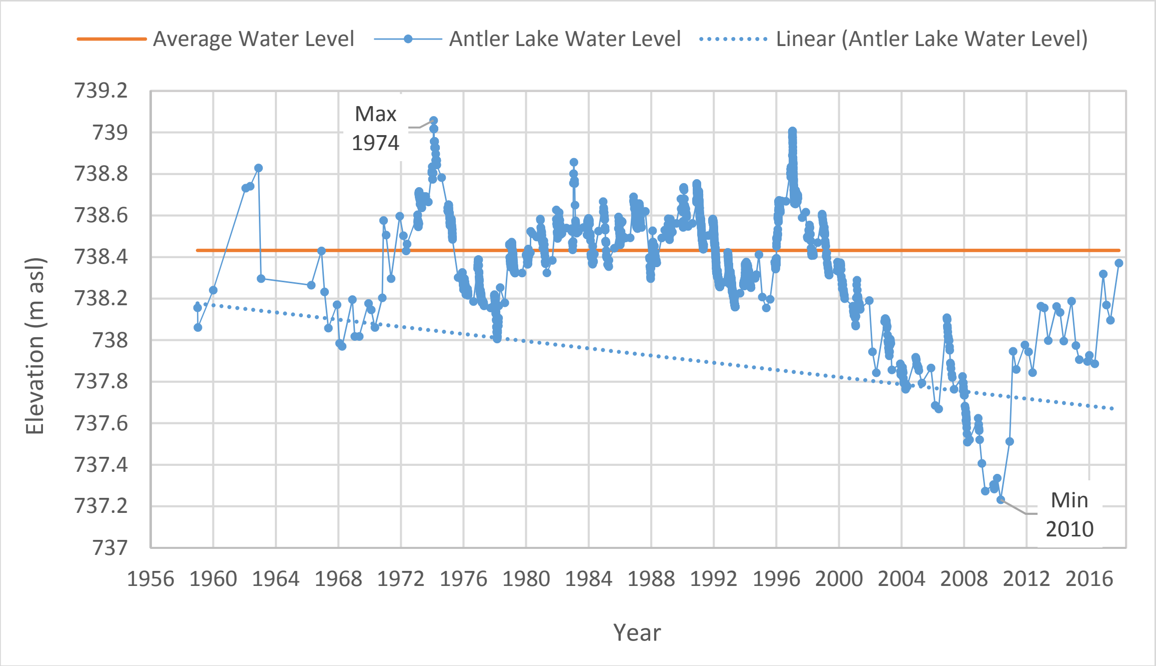


Figure 45. Water Levels for Antler Lake Near Tofield (Station no. 05EB904) from 1959 – 2017. Measured in meters above sea level (m asl) (ECCC, 2017a; 2017b).

Antler Lake water levels appeared to loosely follow rainfall patterns until the turn of the 21st century. From this point on, there is a steeper decline and dampened response to precipitation variations, likely due to warmer temperatures in the current climate cycle (**Figure 46**). In addition, the introduction of roads and other infrastructure that isolates some areas and prevents flow from reaching the lake may also play a role in the decline (Figliuzzi and Associates, Ltd., 2018). However, the same pattern of decline has been observed regionally for other lakes in the Beaver Hills Moraine, suggesting the greater cause may be climate.

For instance, in the 2018 *Water Balance* report (Figliuzzi and Associates, Ltd., 2018; **Appendix 2**), the computed hydrologic parameters indicate that, on average, Antler Lake loses approximately 1,545,000 m^3/yr., or about 37% of its volume, to evaporation, a volume which must be replaced primarily by precipitation and surface inflow. Antler Lake was also found to have lost 711,000 m^3 of storage (ΔS) or

19,250 m^3/yr. from January 1980 to December 2016. The annual evaporation does not generally vary significantly; therefore, it can be concluded that the lake elevation and surface area is very sensitive to climatic conditions and can drop significantly during years of below average precipitation. This is further supported by the fact that there are no water-use licenses from Antler Lake and its watershed. Therefore, the change in storage would appear to reflect natural variation.

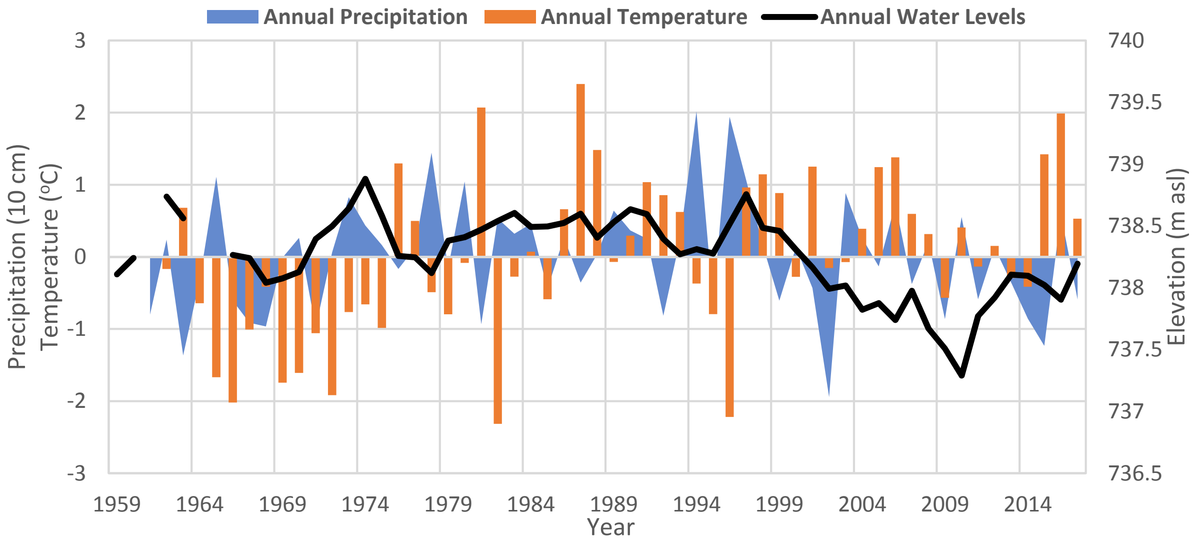


Figure 46. Antler Lake Water Levels at Antler Lake Near Tofield (Station no. 05EB904) from 1959 – 2017 Compared to Annual Temperature and Precipitation Data Averaged from Four Environment Canada Weather Monitoring Stations Nearest to Antler Lake (AAF, 2018; ECCC, 2017a; ECCC, 2017b).

In 1973, *The Cooking Lake Area Study* was initiated by Alberta Environment in response to concerns about water levels and that of other nearby lakes including Antler (Alberta Environment, 1977). This study also concluded that precipitation levels had the greatest effect on the elevations of lakes in the moraine, and that changes in evaporation and runoff were also important (Stanley Assoc. Eng. Ltd. 1976; Alberta Environment, 1977). In 1900, long-term, precipitation records indicated that area lakes were filled to their greatest recorded capacities when seasonal precipitation reached the level of a 1-in-100-year return period, an event that is expected to occur once every 100 years, or 1% of the time. In 1953, seasonal precipitation levels were the highest recorded since 1901, followed by three consecutive years of higher than average rainfall. This event reached the level of a 1-in-50-year return period (expected to occur 2% of the time), resulting in most lake levels in the area reaching a peak water level. After the study, in 1974, lake levels rose again in another year of high precipitation (Mitchell and Prepas, 1990). *The Cooking Lake Area Study* recommended that water-level, augmentation plans and lake-level, control structures be considered on an as-needed basis for each of the study lakes (Alberta Environment, 1977). Water-level augmentation has not been implemented, and therefore, no control structure has been necessary for Antler Lake, as it rarely overflows (Mitchell and Prepas, 1990).

Table 7. Estimated Historical Changes to Mean Depth and Volume in Antler Lake (ECCC, 2017a; 2017b).

	Elevation (m a.s.l.)	**Volume**[1] ($m^3 \times 10^6$)	**Area**[1] (km^2)	**Mean Depth** (m)	**Volume** (% change from average)
Historical Max (1974)	739.06	6.387	3.247	**1.967**	52%
Historical Average	738.28	4.190	2.377	**1.763**	0%
Historical Min (2010)	737.23	2.196	1.424	**1.542**	-48%

Changing lake levels and chemistry in response to drought are often reflective of a lake's landscape position and connection to groundwater (Kratz, et al., 1997). Lakes with small watersheds that are isolated from groundwater inputs are extremely dependent on precipitation to maintain water levels and will respond quickly to drought. Lakes with larger watersheds will show less of a decline during drought conditions because of the additional surface runoff received by the lake (Kerkhoven, 2012). Due to Antler Lake's relatively small watershed area, the lake elevation and surface area are overly sensitive to climatic conditions (Figliuzzi and Associates, Ltd., 2018). In the last eight years, levels in Antler Lake have shown a gradual rise, while Cooking and Hasting Lakes have continued to see a decline in lake levels (**Figure 47**).

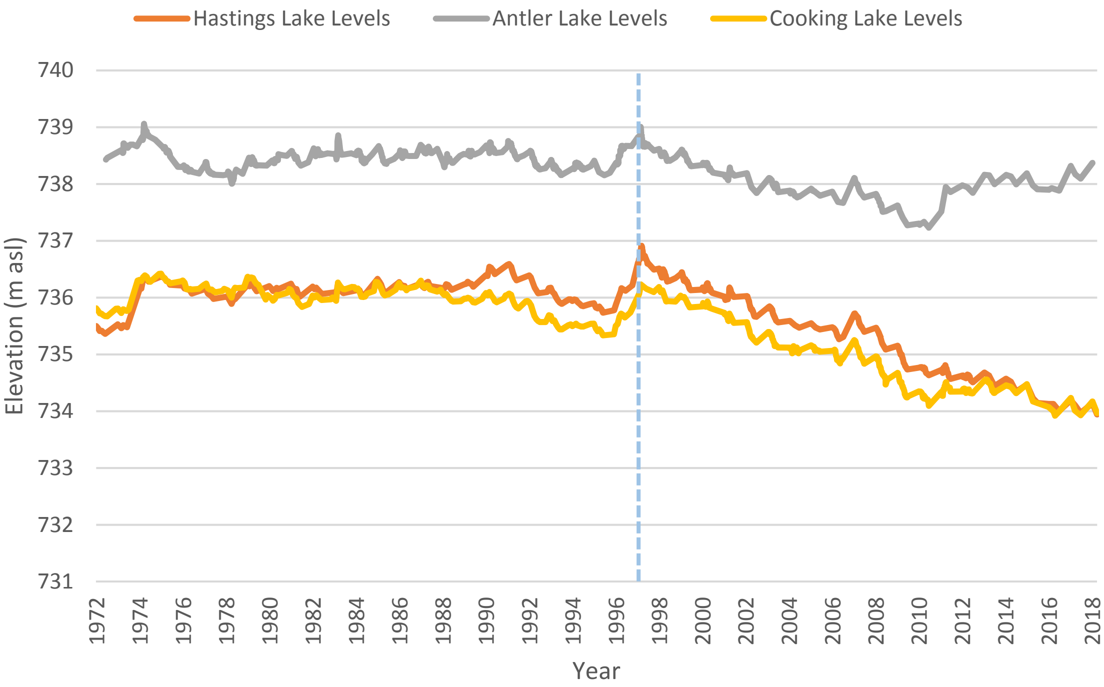


Figure 47. Regional Comparison of Lake Levels in the Beaver Hills Moraine. Latest available water level reported on July 27, 2018. Monthly Mean Water Levels 1972-1995 and Daily Water Levels 1996-Present (AEP, 2018b). Blue dashed line represents the 1997 baseline.

Key Messages:

- Antler Lake has a relatively fast residence time of 18.7 years.
- Precipitation and evaporation have the largest effects on lake levels, regionally; these effects were confirmed by local studies and the water balance.
- Regionally, lake levels have been in a general decline since the late 1990s.
- Water levels have gradually been rising at Antler Laker in recent years, opposing the downward trend of other lakes in the region.
- Antler Lake's small watershed makes it sensitive to changes in climate, being precipitation and temperature.

4.4 Surface Water Quality

Changes in water quality can be indicative of changes to the watershed in both signs of deterioration or improvement. There are many commonly measured indicators of water quality, some of which will be discussed below. Antler Lake is categorized as a nutrient-rich lake with frequent algal blooms and productive shoreline vegetation. Composite, integrated, euphotic zone (layer closest to the surface) samples were taken during the open water season by Alberta Environment in 1987 and by the Alberta Lake Management Society (ALMS) LakeWatch Program in 2016 and 2017. The amount, frequency, and range of sampling dates vary between these sampling years (1987 & 2016-2017), making comparisons difficult. Samples were analyzed for temperature, oxygen levels, ion concentrations, metals, nutrient concentrations, water clarity, microcystins, fecal contamination, and invasive species. Specific, water quality parameters are discussed in greater detail below.

4.4.1 Temperature and Dissolved Oxygen

Water temperature and dissolved oxygen profiles in the water column are important indicators for water quality. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed into the underlying layers. Antler Lake is very shallow, and as a result, mixes frequently during the ice-free period, resulting in uniform temperatures throughout the water column. From June to August, water temperatures remain consistently above 20^{o} C through the water column until September, when they decrease to approximately 10^{o} C (**Figure 48**). Antler Lake can be classified as polymictic, because the entire water column mixes fully, multiple times, throughout the summer. Therefore, thermal stratification has not been observed in Antler Lake (ALMS, 2016; 2017).

Antler Lake remains well-oxygenated at the surface, throughout the summer, measuring above the Canadian Council for Ministers of the Environment guidelines of 6.5 mg/L for the Protection of Aquatic Life (**Figure 49**; ALMS, 2016). However, progressive oxygen depletion may occur with depth as the lake warms between mid-to-late summer. Due to the lack of thermal stratification within Antler, the lake was not observed to have reached anoxia because of the frequent mixing of the water column during the sampling period (ALMS, 2016; 2017). In nutrient-rich lakes, anoxia can occur under ice when respiration processes exceed under-ice photosynthesis, and air entrainment of oxygen is limited. This can prevent fish populations from establishing in shallow lakes. During the open water season, the lake is well-oxygenated to the bottom; however, due to Antler's shallow nature, the lake most likely becomes anoxic soon after ice formation. Unfortunately, data has not been collected during the winter months at Antler Lake to confirm this suspicion.

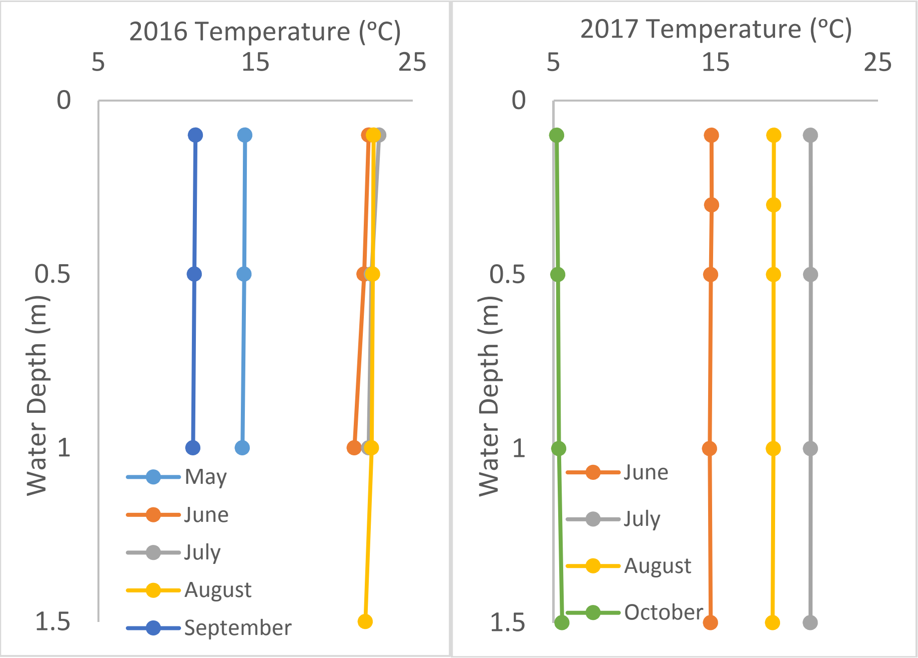


Figure 48. Temperature (°C) Profiles for Antler Lake Measured Five Times Over the Course of the Summer of 2016 and 2017 (ALMS, 2016;2017).

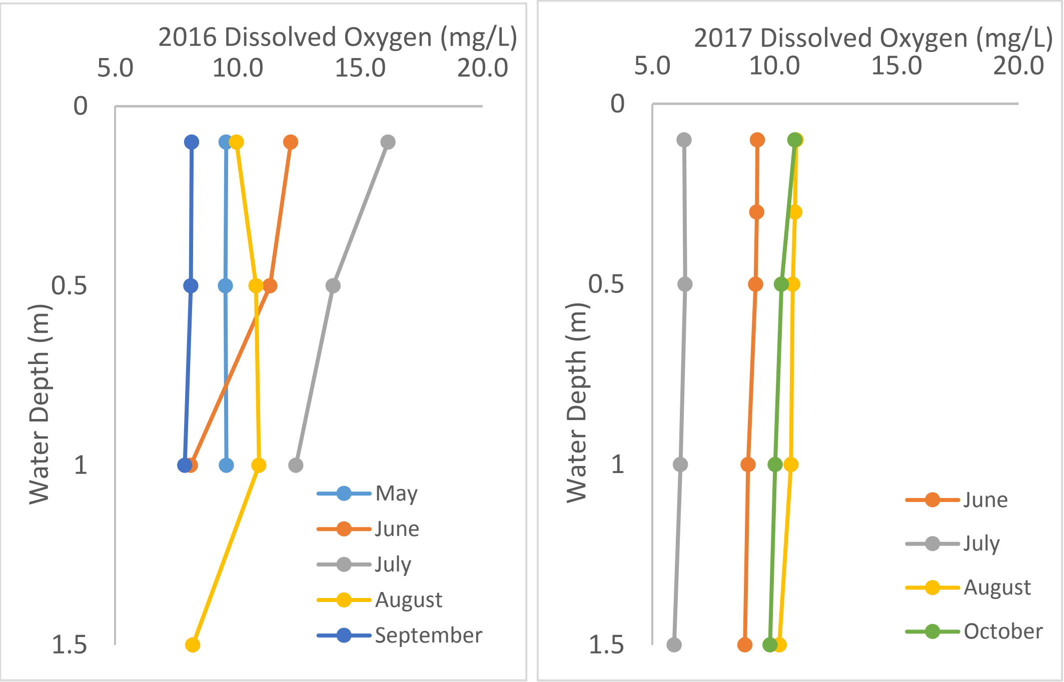


Figure 49. Dissolved Oxygen Profiles (mg/L) for Antler Lake 2016-2017 (ALMS, 2016; 2017).

4.4.2 Ions and Related Variables

Several water quality indicators are chemical in nature. These naturally occurring chemicals tell us about the condition of the lake and the suitability of the environment for supporting aquatic life. For instance, dissolved ions are types of salts, measured to determine the salinity or conductivity of the water. Aquatic organisms have specific salt tolerances and pH sensitivities for survivability. While dissolved ions can be quite variable, a pH of 6.5-9 is recommended for the protection of aquatic life (CCME, 2008).

Antler Lake is a freshwater lake with moderately alkaline water. Moderate alkalinity and bicarbonate concentrations help to buffer the lake against changes in pH (**Figure 50**). Dominant ions in the lake are bicarbonate (HCO_3), calcium (Ca), and sodium (Na), contributing to a relatively moderate conductivity measure of 534 µS/cm (**Figure 51**). Average, annual, ion chemistry values in Antler Lake are presented in **Table 8**, along with the percent change between sampling years.

Table 8. Average Annual Ions and Related Parameter Concentrations in Antler Lake (1987, 2016-17) from May to September (AEP, 2018e).

Parameter (mg/L)	1987	2016	% Change 1987-2016	2017	% Change 2016-2017
Calcium	27.6	39.6	-4.29%	36	+0.13%
Magnesium	9.4	18.8	+1.60%	16.5	-0.40%
Sodium	14.4	37.8	+4.91%	35.75	+0.72%
Potassium	12.6	32.6	+2.40%	29.75	+0.08%
Sulphate	22.8	33	-1.43%	25	-1.01%
Chloride	7	35	+5.85%	31.5	-0.03%
Carbonate*	5	21.78		12.83	
Bicarbonate	144	196	-9.04%	180	+0.51%
Hardness	107.6	176		157.5	
Total Dissolved Solids (TDS)	166.8	320		280	
Total Alkalinity	121.6	196		170	

*Lowest detectable limit substituted for non-detects based on recommendations in Mitchell, 2006.

The concentrations of most ions (salts/electrolytes) in Antler Lake, though naturally variable, have increased from 1987 to 2016 (**Table 8**). Total dissolved solids (TDS) and specific conductivity have also increased by 92% and 77%, respectively. As lake levels decline, ions may become more concentrated, although this response is limited by solubility and chemical equilibria (Anderson, 2000). In other words, this increase is likely tied to changes in water quantity as evaporation will increase the concentration of most water quality variables (ALMS, 2016). The water in Antler Lake is moderately alkaline, with pH measurements above 8.0, consistently, for the past 30 years. As is most evident from 2016 and 2017 data, the pH can fluctuate seasonally, with highest peaks occurring in July (**Figure 50**). The highest pH value recorded at Antler Lake was 9.54 in July 2016 (AEP, 2019). These high values may be associated with algal blooms and higher rates of biological productivity, and therefore, photosynthesis. An important, potential outcome from increases in pH, is the effect of drawing phosphorus from lake sediments, which can contribute to internal loading (James and Barko, 1991). Generally, Antler Lake is within guidelines, but should be monitored closely.

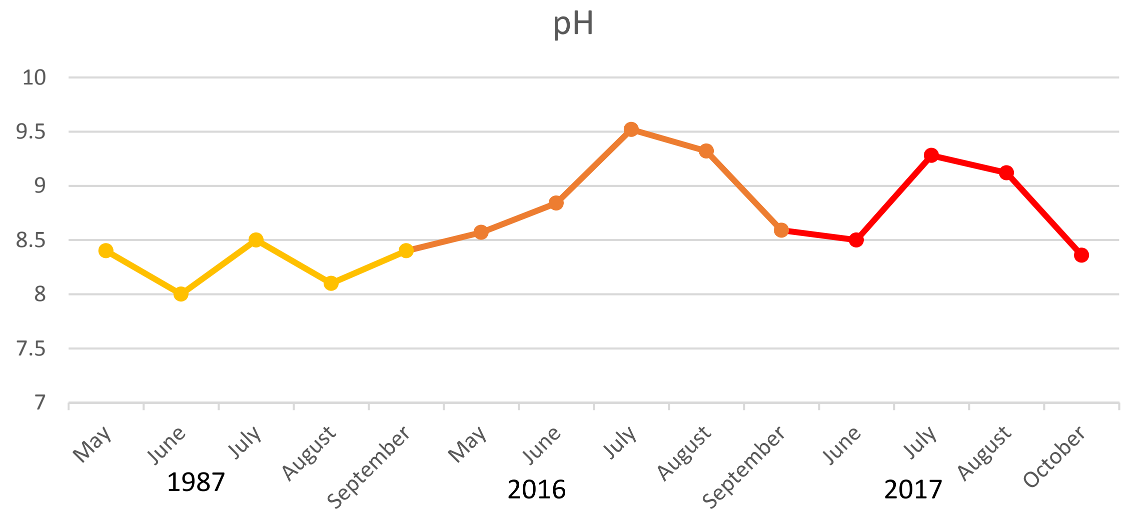


Figure 50. pH profiles for Antler Lake (1987, 2016-17).

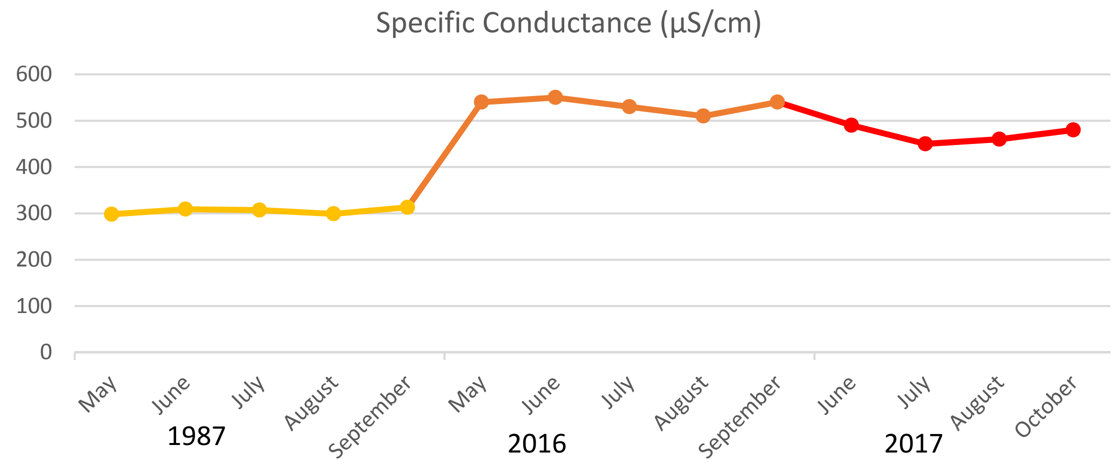


Figure 51. Specific Conductance (µS/cm).

4.4.3 Metals

Metals are naturally occurring elements that exist in the ground. The types of metals found in a lake are dependent upon the surrounding geology and soils. Some metals are harmless, unless in large concentrations or altered forms, like silver. Some metals are essential nutrients required in our diet, like iron and zinc. Other metals can be very poisonous in small concentrations, like lead or mercury.

In 2016 and 2017, metals in Antler Lake were measured by ALMS (**Table 9**). In 2016, Aluminum measured at a concentration of 165 µg/L, which is above the recommended guideline of 100 µg/L, but in 2017, fell below the guideline at 89.2 µg/L (ALMS, 2016; 2017). Iron levels resulted in the opposite trend, measuring below guidelines in 2016 at 229 µg/L, but exactly at the guideline in 2017 at 300 µg/L. High levels of aluminum and iron are indicative of sediment contamination of the water samples, which is common in shallow lakes (ALMS, 2016). All other metals reported were below CCME guidelines for the Protection of Freshwater Aquatic Life.

Table 9. Concentration of Metals Measured in Antler Lake. The CCME Heavy Metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented (ALMS, 2016; 2017; CCME, 1999).

Metals (Total Recoverable) (µg/L)	2016	2017	Guidelines
Aluminum	165	89.2	100[a]
Antimony	0.154	0.127	6[d]
Arsenic	1.87	1.81	5
Barium	57.9	65.9	1000[d]
Beryllium	0.015	0.013	100[c,e]
Bismuth	0.002	0.0015	/
Boron	98.7	65.2	1500
Cadmium	0.012	0.005	0.26[b]
Chromium	0.29	0.2	/
Cobalt	0.339	0.439	1000[e]
Copper	0.91	0.62	4[b]
Iron	229	300	300
Lead	0.356	0.276	7[b]
Lithium	37.6	26.4	2500[f]
Manganese	80.6	30.3	200[f]
Molybdenum	0.761	0.763	73[c]
Nickel	0.979	1.39	150[b]
Selenium	0.24	0.2	1
Silver	0.003	0.002	0.25
Strontium	198	196	/
Thallium	0.0024	0.003	0.8
Thorium	0.0186	0.011	/
Tin	0.033	0.03	/
Titanium	4.96	3.2	/
Uranium	0.577	0.524	15
Vanadium	1.53	1.13	100[e,f]
Zinc	2.8	3.1	30

Values represent means of total recoverable metal concentrations; A forward slash (/) indicates an absence of data or guidelines.

[a] *Based-on pH ≥ 6.5*

[b] *Based on water hardness > 180mg/L (as $CaCO_3$)*

[c] *CCME interim value.*

[d] *Based on Canadian Drinking Water Quality guideline values.*

[e] *Based on CCME Guidelines for Agricultural use (Livestock Watering).*

[f] *Based on CCME Guidelines for Agricultural Use (Irrigation).*

Red indicates exceedance of guidelines;
Orange indicates nearing guideline.

4.4.4 Nutrients and Related Variables

Nutrient levels are indicated by the presence of Phosphorus (TP), Nitrogen (TN), and Chlorophyll-*a*. Phosphorus and Nitrogen are the primary nutrients required by plants, algae, and cyanobacteria for growth. Chlorophyll is an essential pigment used by plants, algae, and cyanobacteria for photosynthesis. In Alberta lakes, phosphorus is the primary nutrient driving algal growth (ALMS, 2016). Total nitrogen (TN) also contributes to algal productivity but is not the limiting nutrient. Measurements of these nutrients help us understand the amount of biological productivity that is occurring in the lake, how it changes over time, and helps us determine the trophic state of the lake. Other factors, such as salinity, turbidity, temperature, and physical mixing patterns, are important determinants of the quantity and types of algae that develop (Bierhuizen and Prepas, 1985). Algal blooms are a major feature of summer water quality in Alberta lakes, affecting water transparency and aesthetics directly, and other lake features, such as oxygen concentrations and blue-green algae (cyanobacteria) growth. The control of excessive summer algal blooms is therefore an important goal of lake management in Alberta.

Table 10. Chemical and physical parameters used by ALMS to characterize the trophic status of lakes (ALMS, 2017).

TROPHIC STATE	TOTAL PHOSPHORUS (µg•L^{-1})	TOTAL NITROGEN (µg•L^{-1})	CHLOROPHYLL A (µg•L^{-1})	SECCHI DEPTH (m)
Oligotrophic	< 10	< 350	< 3.5	> 4
Mesotrophic	10 – 30	350 - 650	3.5 - 9	4 - 2
Eutrophic	30 – 100	650 - 1200	9 - 25	2 - 1
Hypereutrophic	> 100	> 1200	> 25	< 1

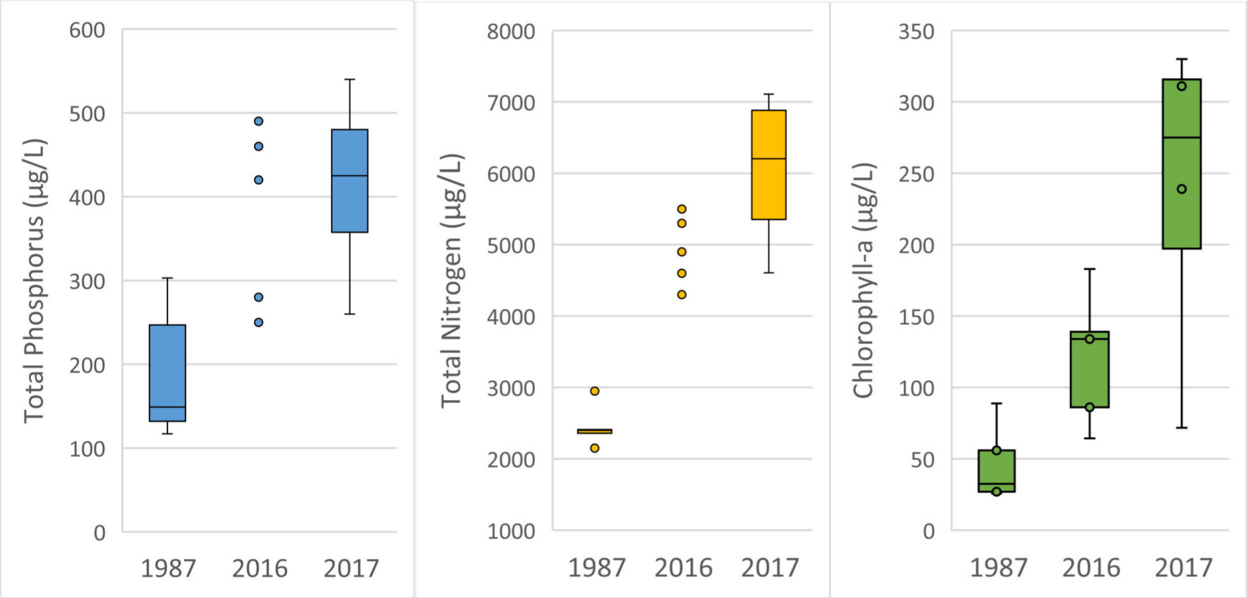


Figure 52. Measurements of common nutrients in Antler Lake (1987-2017). A) Total Phosphorus, B) Total Nitrogen, C) Chlorophyll-a.

In Antler Lake, phosphorus concentrations are extremely high, with an average, annual total phosphorus (TP) concentration of 410 µg/L in 2017 (**Table 10**; **Figure 52A**; ALMS, 2017). Phosphorus concentrations have been above 100 µg/L since their first measurement in 1987, but the amount has increased by 117% over a 30-year period. High phosphorus concentrations may be a result of phosphorus loading from external sources in the watershed, such as agricultural land and livestock, and from internal sources like the lake sediment (Mitchell and Prepas, 1990).

Total Nitrogen (TN) in Antler Lake is also exceedingly high, with an average concentration of 6030 µg/L in 2017 (**Figure 52B**). High TP, TN and Chl-*a* concentrations, along with a decrease in annual, average, secchi depth (**Figure 53**) (a measure of water clarity using a secchi disk), suggests a reduction in overall water quality and clarity over time. Increased nutrient concentrations may be a result of multiple factors: declining lake volumes, increased internal loading, altered land use, and/or a changing regional climate. Nutrients may become more concentrated as lake volumes decline (Anderson, 2000). Internal loading (from sediments) in a lake is higher with anoxic conditions and increased lake temperatures, which may occur more frequently in a shallow lake such as Antler (Mitchell and Prepas, 1990).

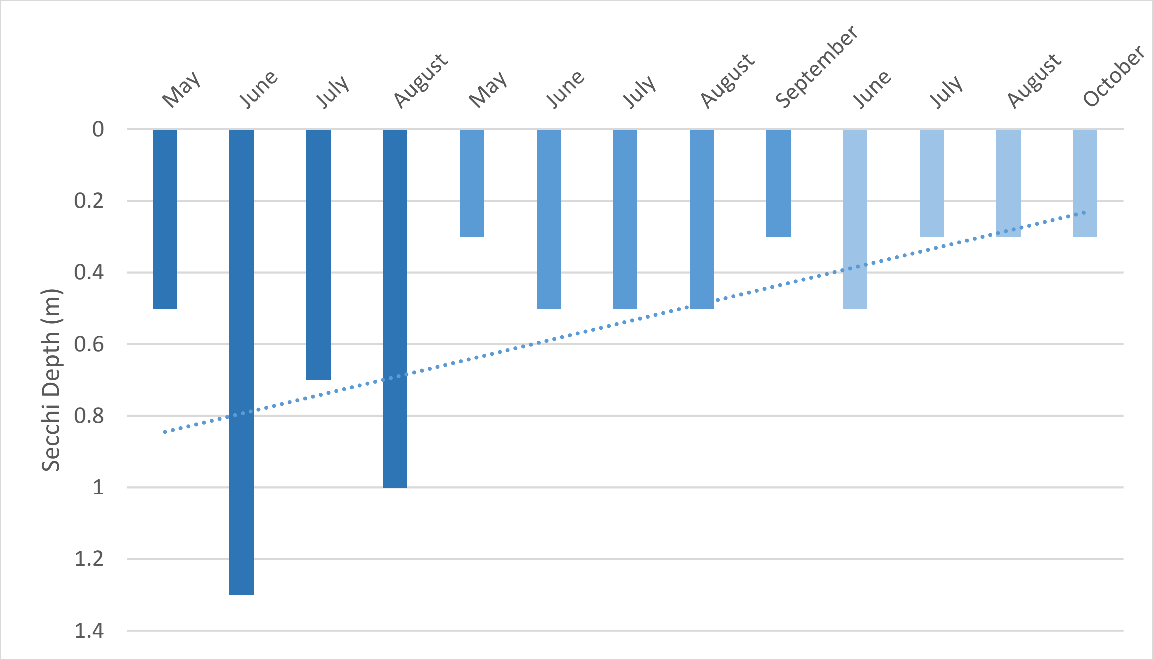


Figure 53. Secchi Depth Measurements for Antler Lake (1987, 2016-17).

According to the measurements of nutrients and secchi depth, Antler Lake is classified as hypereutrophic (**Table 10**). In its current state, Antler Lake has similar rates of productivity to Driedmeat Lake (in the Battle River watershed) and slightly lower Cooking Lake, a much larger lake located directly downstream of the Antler Lake watershed (**Figure 54**).

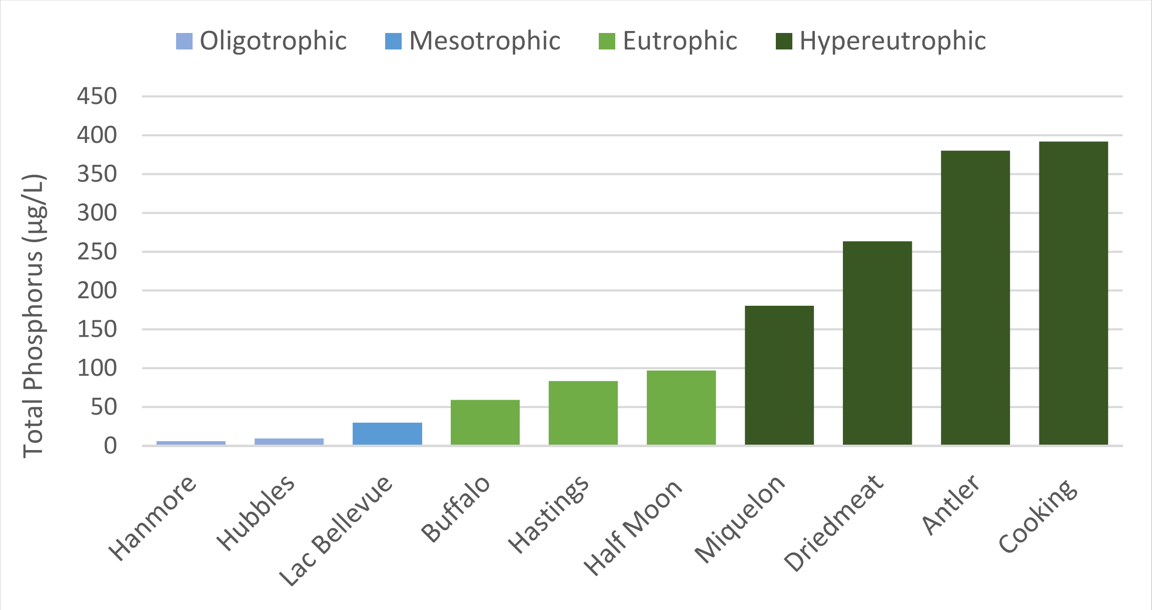


Figure 54. Trophic status of lakes sampled in nearby Counties, classified using average total phosphorus concentrations. The number of years used to calculate average total phosphorus varied by lake (AEP, 2018f).

4.4.4.1 Phosphorus Budget

Phosphorus is considered the most common, limiting, chemical factor for algal growth in freshwater lakes (Schindler, et al., 2008). The development of phosphorus budgets and models have become commonplace in the lake research and management disciplines, and they are used as diagnostic tools to quantify pollution sources (**Figure 55**) and evaluate long-term, management options for lakes (OECD, 1981; Rast, et al., 1989). The refinement and application of eutrophication models has been an ongoing focus in limnology since the first watershed/lake nutrient relationships were developed in the 1960s (Vollenweider, 1968).

No historical phosphorus budgets exist for Antler Lake or any surrounding lakes in the region. For this report, the NSWA has completed a high-level analysis of potential phosphorus sources and modeled scenarios based on available data (**Appendix 3**). Two scenarios were modeled: whole watershed contribution in above average precipitation conditions (EDA + NCA), and the effective drainage area (EDA-only) contribution in average precipitation conditions. These models consider different contributions of phosphorus from runoff across different land use categories, contributions from atmospheric deposition, sewage, and potential for phosphorus recycling, otherwise referred to as internal loading.

Considering the recent climate trends, depth of the lake, and that water has not been flowing out of Antler Lake in recent years, it is most likely that the best scenario to describe Antler Lake's phosphorus condition would be the EDA-only model. Likewise, although sewage may have been a major contributor to phosphorus in the lake in the past, the installment of a sewer system has likely eliminated sewage as a source since the 1980's. In both modelling scenarios, phosphorus concentration was greatly underpredicted, as was that of nitrogen, chlorophyll-a, and Secchi depth. Calibrated models (adjusting predicted to observed values) revealed that the incorporation of internal loading was an important factor to balance the model, and accounted for approximately 95% of the phosphorus contribution, or 7 mg/m^2/day on average. Overall, surface runoff contributed very little phosphorus to the system, in comparison, within these models.

This preliminary phosphorus budget only provides a high-level estimate of phosphorus concentration. Our prediction is that internal loading is the key contributor to phosphorus in Antler Lake, and that past land use practices were a likely culprit to the current state. Further study would be necessary to determine if changes to current land use practices could make improvements to phosphorus loading in the lake. Without further assessment, it is best to assume that drainage into the lake is likely to pick up nutrients from the surrounding land and that best management practices should always be used to eliminate the threat of further loading of the system. The detailed phosphorus budget can be found in Appendix 4.

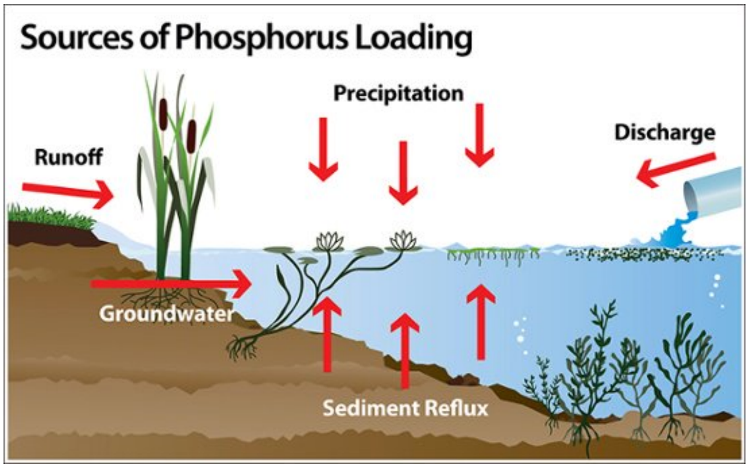


Figure 55. Generalized Diagram of the Sources of Phosphorus Loading (SOLitude, 2017).

4.4.5 Microcystins

Microcystins are a type of liver toxin produced by certain species of cyanobacteria that are prevalent in Alberta lakes (ALMS, 2016). Microcystins have been measured as an indicator for blue-green algae in Alberta lakes because they are believed to be the most common toxin produced by cyanobacteria species in the province (ALMS, 2016).

Microcystins are not always produced by cyanobacteria, and when they are, can be released in concentrations that fluctuate greatly over time. Typically, multiple measurements of microcystin concentrations are required throughout the summer to understand the relative risk associated with algal blooms during different periods.

On average, annual microcystin concentrations from composite sampling across Antler Lake have not exceeded the Alberta recreational guideline of 20 µg/L (**Table 11**; ALMS, 2016; 2017). Likewise, there have been no recorded blue-green algae health advisories issued for Antler Lake by Alberta Health Services. However, in August of 2017, measured microcystin concentrations were well above the recommended guideline at 41.03 µg/L (**Table 11**; ALMS, 2017). Considering that microcystin levels dropped down by October, this indicates there was a bloom that occurred in late July or early August in 2017.

Table 11. Microcystin Concentrations Measured Five Times at Antler Lake in 2016 (ALMS, 2016; 2017)

Year	Date	Microcystin Concentration (µg/L)
2016	May-31	0.31
	Jun-28	0.4
	Jul-27	0.34
	Aug-15	0.94
	Sep-12	1.11
2017	Jun-23	1.15
	Jul-31	7.87
	Aug-23	41.03
	Oct-04	13.47

* Microcystin guideline for Canadian recreational water quality is set at ≤ 20 µg/L

1.1.1 Bacterial Source Tracking

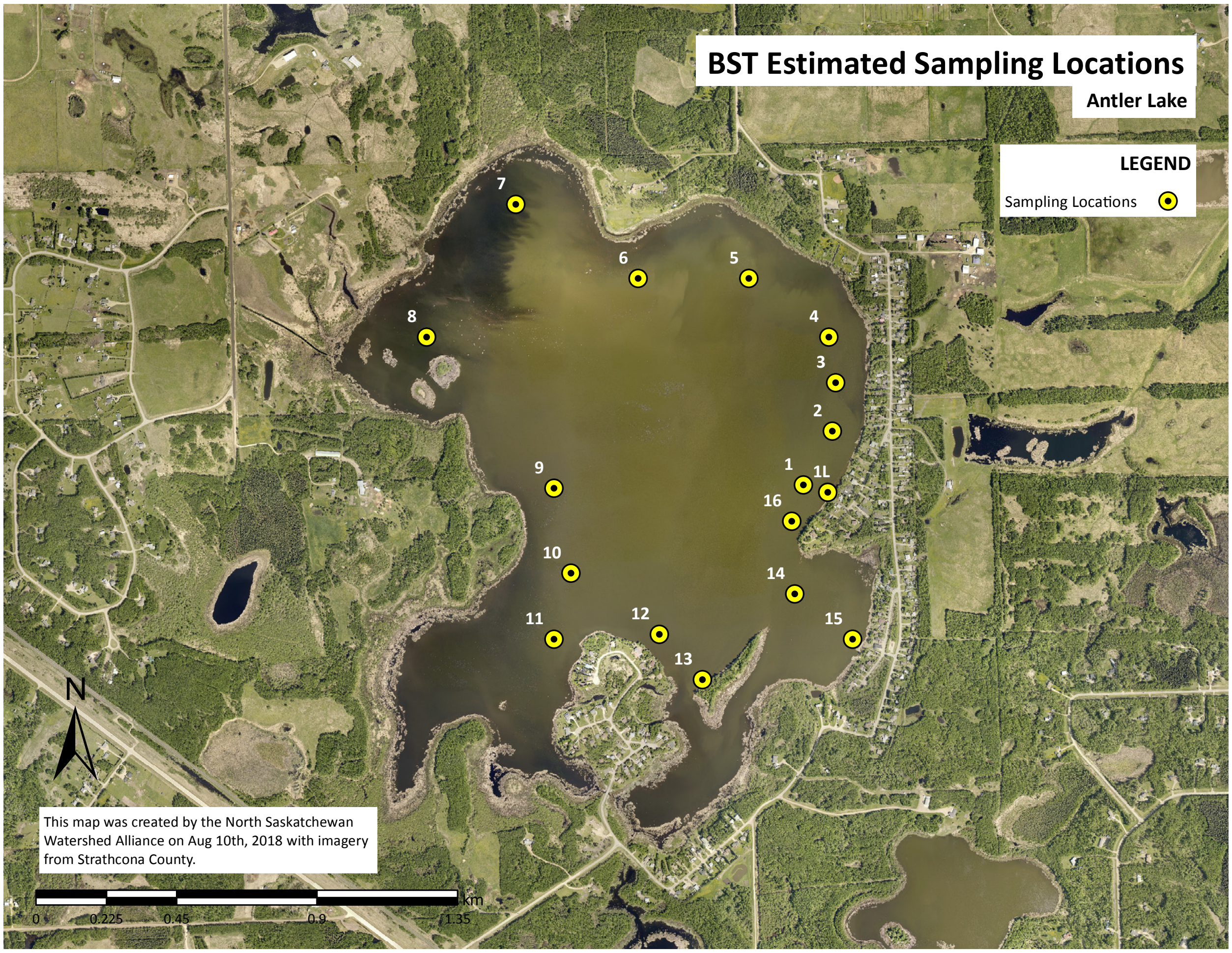
Fecal contamination of aquatic environments impacts a wide range of regions, both urban and rural, and may carry risks to human health. This includes the potential spread of dangerous bacterial and viral pathogens, such as hepatitis, along with other human pathogens, such as *Cryptosporidium parvum*, *Giardia lamblia*, *Salmonella spp.*, and *E. coli* O157:H7, which are associated with animal fecal pollution (SWCSMH, 2017). This contamination can result in beach closures that suspend recreational activities.

Microbial indicators can be useful tools for risk assessment, especially when used with testing methods and analysis techniques that can define specific sources of these organisms. Bacterial Source Tracking (BST) also known as Microbiological Source Tracking (MST), fecal source tracking, or fecal typing is a relatively new methodology that is being used to determine the sources of fecal pathogen contamination in the environment (e.g. from human, livestock, or wildlife origins) (U.S.EPA, 2002). The fecal *Bacteroides-Prevotella* detection methodology developed by Prof. Katherine Field Ph.D., of the Dept. of Microbiology, at Oregon State University, in Corvallis, Oregon, has been described as the most economic and reliable method for BST (SWCSMH, 2017).

There are a wide range of possible sources of fecal contamination and of fecal indicator bacteria (FIB), including human waste through leaking sewer lines and septic systems, wild animals, animal husbandry, and pets. There are also environmental reservoirs of fecal bacteria, including sand, soil, sediments, aquatic vegetation, decaying algae, and shoreline wrack (Yates, et al., 2016). Within the Antler Lake watershed, the most probable contributors to contamination include human waste from the Hamlet of Antler Lake, livestock, and wildlife sources.

Pollution that is linked to human sources, for example, leaking sewers, can be resolved by infrastructure improvements. Pollution by non-human sources may be indicated by lack of detection of genes (markers) from human-associated microorganisms, and/or by detection of markers associated with specific animal sources, for example, cattle, poultry, or dogs. Mitigation of animal pollution sources can be relatively simple, such as fencing cattle away from a river, moving feedlot operations, or educating pet owners about waste disposal. In other cases, remedial steps may require greater investment, for example, changing disposal practices for land-applied manure (Yates, et al., 2016).

Antler Lake was sampled on August 5th, 2018 by David Trew and Leah Hammonic, where 17 water samples were taken around the lake in open water areas (**Figure 56**). Samples were processed by Sydney Rudko, B.Sc., at the University of Alberta, utilizing published methods for BST via qPCR (DNA detection method) (Rudko, et al., 2017; Green, et al., 2014). All samples from Antler Lake were found to be negative for fecal contamination.



This map was created by the North Saskatchewan Watershed Alliance on Aug 10th, 2018 with imagery from Strathcona County.

Figure 56. Bacterial Source Tracking Estimated Sampling Locations Around Antler Lake.

4.4.6 Invasive Species

Dreissenid mussels, including Zebra (*Dreissena polymorpha*) and Quagga (*Dreissena bugensis*) mussels are invasive species that pose a significant concern for Alberta (**Figure 57**), due to their ability to impair the function of water transportation infrastructure and adversely impact the aquatic environment. These invasive mussels have caused millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities in other parts of North America (ALMS, 2016). Invasive mussels can also act to filter large amounts of phytoplankton from the water column, taking away this needed food source from fish and other native species. In 2016, LakeWatch undertook invasive species monitoring for zebra and quagga mussels and their juvenile offspring (veligers) in Antler Lake. No zebra, quagga mussels, or their juvenile offspring were observed in the lake (ALMS, 2016; 2017).

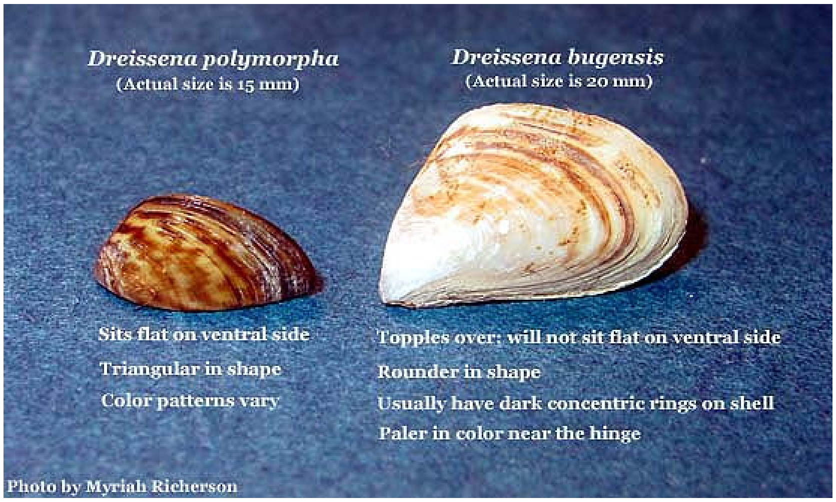


Figure 57. How to Identify Invasive Mussel Species. (left) Zebra Mussel; (right) Quagga Mussel. OFAH/OMNRF Invading Species Awareness Program. (2012). Zebra and Quagga Mussels. Retrieved from: www.invadingspecies.com.

Currently, no other assessments of invasive species have been conducted in the Antler Lake watershed.

4.5 Recreation

Antler Lake is within the Beaver Hills Moraine, an important regional, recreation area located within an hour of the City of Edmonton. Many people from the city and surrounding communities use the moraine's forests and lakes for a wide variety of consumptive (hunting, fishing, trapping, snowmobiling, ATV riding) and non-consumptive (hiking, cross-country skiing, camping, horseback riding, boating, mountain biking, canoeing/kayaking, geocaching, birding, wildlife viewing) activities (RC & EIDOS, 2012). There are also many winter activities including: cross-country skiing, dog sledding/skijoring, fat-tire biking, skating, snowmobiling, and snowshoeing. The Beaver Hills Moraine is home to more than 200 species of birds, including two pairs of nesting trumpeter swans, the largest and rarest swan species in the world making this area a popular, birding destination.

Antler Lake is adjacent to the Beaver Hills Dark-Sky Preserve. The 300 km^2 preserve, established in 2006, encompasses the entirety of Elk Island National Park, Cooking Lake-Blackfoot Provincial Recreation Area, Miquelon Lake Provincial Park, Strathcona Wilderness Centre, and the Ukrainian Cultural Heritage Village. A sanctuary from artificial light, the dark-sky preserve is an area that maintains a pristine, nocturnal environment, supporting a healthy habitat for nocturnal wildlife. This area is also a popular destination for stargazing. Royal Astronomical Society of Canada (RASC) Edmonton Centre members have conducted dark sky observing sessions at Elk Island and Blackfoot for over 20 years. The Beaver Hills Dark Sky Preserve raises public awareness on light pollution abatement, and supports astronomical, environmental, and cultural interests (RASC, 2018).

Despite the lake's location within the Beaver Hills, Antler Lake is difficult to access, very much limiting the ability for use as a recreational area. There are public lands adjacent to the lake, but no public walking paths or entrances to the water. Talking to residents around the lake about this has revealed two major concerns: 1) residents living further from the lakeshore have no way of utilizing the lake for recreation, as there are no boardwalks or other ways to interact with the lake and surrounding natural area, and 2) without designated access points, winter recreationists will often use off-road vehicles on private property and sensitive areas to access the lake (personal communication). Considering the popularity of this lake and its proximity to large urban areas, it may be an important point for future discussion among the community and Strathcona County.

Key Messages:

- Antler Lake is a shallow waterbody, with an average depth of 1.76 m, with no variation in temperature with depth.
- The lake experiences good dissolved oxygen during the summer months, but likely becomes anoxic during the winter.
- Dissolved ions (salts) are becoming more concentrated over time, as are the metals aluminum and iron.
- The lake is hypereutrophic with high levels of nutrients and low clarity. Internal loading of phosphorus, from lake bottom sediments, is likely the greatest current contributor to cyanobacteria blooms in the summer.
- High levels of Microcystins from cyanobacteria blooms have been detected, though they vary throughout the summer.
- No fecal bacteria or invasive mussels were detected.

5.0 Screening and Assessing Lake Vulnerability

A wide range of land and water characteristics may be considered in the development of lake and watershed management plans. Several key limnological, hydrological, and anthropogenic factors have been discussed in this report. The challenge is to integrate the information contained in these various factors into an overall assessment.

Hutchinson Environmental Sciences Ltd. (HESL) prepared a summary of lake and watershed risk assessment approaches used in British Columbia, Ontario, and Minnesota (HESL, 2015). These jurisdictions used key lake and watershed factors to develop cumulative assessment approaches for assessing lake vulnerability to water quality degradation.

A similar screening and assessment tool was developed by the NSWA for Isle Lake and Lac Ste Anne (NSWA, 2017) and has been used to make a high-level assessment of the Antler Lake watershed. The metrics were derived from lake management literature and water science principles. A summary of 15 key factors is presented below and in **Table 12**. The potential to influence or impact lake water quality is used as the end point for the screening criteria. The condition of the lake and its watershed, with respect to each factor, is evaluated as low, medium, or high concern, and then an overall interpretation is presented.

Watershed Factors:

- *Watershed Land Cover*
- *Tributary Water Quality*
- *Watershed Area to Lake Surface Area Ratio*

Shoreline Factors:

- *Proportion of Developed Shoreline*
- *Riparian Area Health*
- *Soil Suitability for Septic Fields*
- *Shoreline Complexity*

Lake Water Quality Factors:

- *Trophic Status*
- *Fisheries Summerkill Risk*
- *Fisheries Winterkill Risk*
- *Internal Phosphorus Loading Rate*

Hydrologic and Morphometric Factors:

- *Hydrologic Flushing Rate*
- *Groundwater Inflow*
- *Licensed Water Withdrawals*
- *Littoral Zone Extent*

Data are currently available to assess 10 out of the 15 metrics for Antler Lake. Four (4) metrics indicate high concern, three (3) indicate moderate concern and three (3) indicate low concern (**Table 12**). *Based on this assessment, the overall condition of Antler Lake is assessed at a moderate-to-high concern level*.

This assessment is preliminary. Further assessment requires additional monitoring and information to fill in data gaps to address the five metrics for which complete information was unavailable: tributary water quality, riparian health, soil suitability for septic, internal phosphorus loading, and groundwater inflow to lake. The sensitivity of the lakes may be assessed at a higher level of concern (or lower) once information is obtained on riparian health and groundwater hydrology. In the absence of this data, it is recommended that a ***conservative approach is applied*** in protecting this lake until additional information is obtained. A conservative approach considers that the remaining five metrics are rated at high concern, thereby elevating the overall rating for the lake to a high concern level.

METRICS	LOW CONCERN	MODERATE CONCERN	HIGH CONCERN
WATERSHED FACTORS			
Watershed Land Cover	Natural State	0 – 25% disturbance from Natural	**25 – 75% disturbance from Natural**
Tributary Water Quality*	Good [TP] < 100 µg/L	Fair [TP] 100 – 250 µg/L	Poor [TP] > 250 µg/L
Watershed Area: Lake Surface Area Ratio (surrogate factor for water supply)	High Ratio > 10	**Medium Ratio** **5 – 10**	Low Ratio < 5
SHORELINE FACTORS			
Proportion of Shoreline Developed	Natural State	Moderate Development 0 – 25%	**High Development** **25 – 75%**
Riparian Area Health*	Healthy	Moderately Impaired	Highly Impaired
Soil suitability for septic (depth to groundwater)*	Depth to GW > 3.0 m	Depth to GW 1.0 – 3.0 m	Depth to GW < 1.0 m
Shoreline Complexity (shoreline development factor)[3]	**SDF 1 – 2**	SDF 2 – 3	SDF > 3

Table 12. Summary of Lake and Watershed Features for Antler lake.

[3] The shoreline development factor (SDF) is the ratio of the lake shoreline length to the circumference of a circle of the same area. It is often used by fisheries biologists with a high SDF resulting in more abundant fish habitat. In this case, a high SDF is of high concern because it means there is a greater length of shoreline that could potentially be impacted by development.

METRICS	LOW CONCERN	MODERATE CONCERN	HIGH CONCERN
WATER QUALITY CONDITIONS			
Trophic Status	Oligo-Mesotrophic	Meso-Eutrophic	**Eutrophic-Hypereutrophic**
Summerkill Risk	**Well mixed – high [DO]**	Moderate rate of hypolimnetic [DO] depletion, spring/fall mixing	Extended hypolimnetic [DO] depletion; no mixing
Winterkill Risk	**Mean depth > 3.0 m**	Mean depth 2.0 – 3.0 m	**Mean depth < 2.0 m**
Internal Phosphorus Loading*	< 1 mg/m^2/day	1 – 5 mg/m^2/day	> 5 mg/m^2/day
HYDROLOGIC AND MORPHOMETRIC FACTORS			
Flushing Rate (% of Lake Volume/yr)	> 10%/yr	**3 – 10%/yr**	< 3%/yr
Groundwater Inflow to Lake*	High Inflow	Medium Inflow	Low Inflow
Water Allocation Volume % of Inflow	**< 10%**	10 – 20%	> 20%
Littoral Zone (< 4m) as % of Lake Area	Low (< 25%)	Moderate (25 – 50%)	**High (> 50%)**