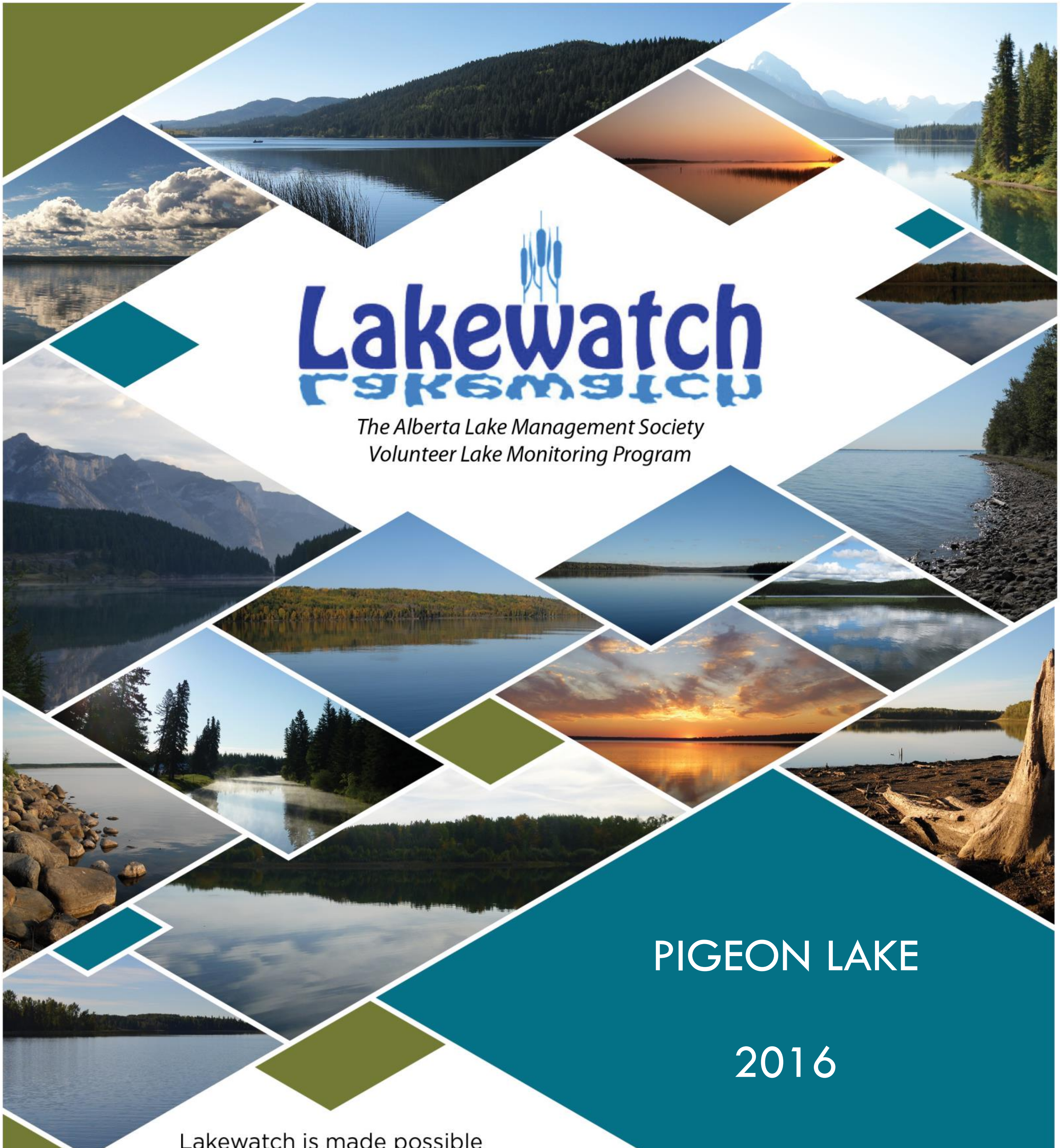

Lakewatch

The Alberta Lake Management Society
Volunteer Lake Monitoring Program

PIGEON LAKE

2016

Lakewatch is made possible
with support from:

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Environment and Climate Change Canada / Environnement et Changement climatique Canada
Pigeon Lake Watershed Association
Cargill
Alberta Environment and Parks
LICA Lakeland Industry & Community Association
Beaver River Watershed Alliance
Red Deer River Watershed Alliance
MD 61 Wainwright

ALBERTA LAKE MANAGEMENT SOCIETY'S LAKEWATCH PROGRAM

LakeWatch has several important objectives, one of which is to collect and interpret water quality data on Alberta Lakes. Equally important is educating lake users about their aquatic environment, encouraging public involvement in lake management, and facilitating cooperation and partnerships between government, industry, the scientific community and lake users. LakeWatch Reports are designed to summarize basic lake data in understandable terms for a lay audience and are not meant to be a complete synopsis of information about specific lakes. Additional information is available for many lakes that have been included in LakeWatch and readers requiring more information are encouraged to seek those sources.

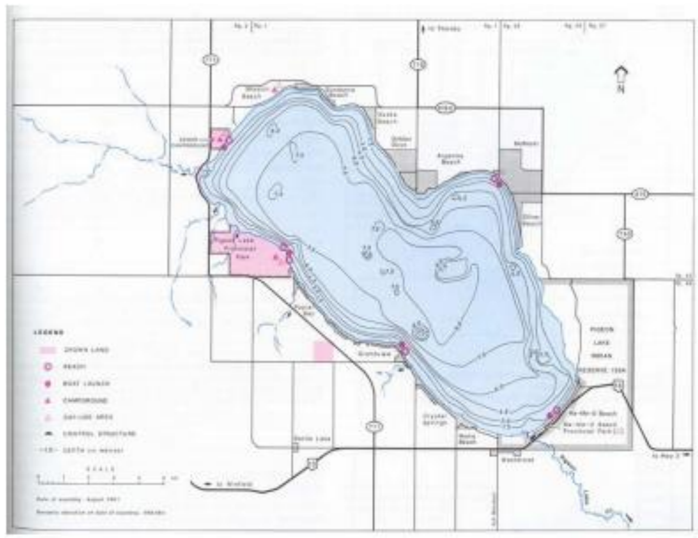
ALMS would like to thank all who express interest in Alberta's aquatic environments and particularly those who have participated in the LakeWatch program. These people prove that ecological apathy can be overcome and give us hope that our water resources will not be the limiting factor in the health of our environment.

ACKNOWLEDGEMENTS

The LakeWatch program is made possible through the dedication of its volunteers. We would like to extend a special thanks to all the volunteers who assisted with the sampling program in 2016. We would also like to thank the Pigeon Lake Watershed Association, its contributing members, and Summer Villages for their financial support and assistance with program coordination. We would also like to thank Alicia Kennedy, Ageleky Bouzetos, and Breda Muldoon who were summer technicians in 2016. Executive Director Bradley Peter was instrumental in planning and organizing the field program. Alicia Kennedy was instrumental in report design. This report was prepared by Laura Redmond and Bradley Peter. The Beaver River Watershed, the Lakeland Industry and Community Association, Environment Canada, and Alberta Environment and Parks are major sponsors of the LakeWatch program.

PIGEON LAKE

Pigeon Lake is a large (96.7 km^2), shallow (average depth = 6m) lake located in the counties of Wetaskiwin and Leduc. It is a very popular recreational lake within easy driving distance from the cities of Edmonton, Leduc, and Wetaskiwin. Pigeon Lake lies within the Battle River watershed. Water flows into the lake through intermittent streams draining the west and northwest portions of the watershed. The outlet, Pigeon Lake Creek, at the southeast margin of the lake, drains toward the Battle River.[1] The lake's drainage basin is small (187 km^2) but heavily developed with agriculture, oil and gas, and community developments throughout the watershed.



Bathymetric map of Pigeon Lake (Mitchell & Prepas 1990)

The lake name is a translation from the Cree Mehmew Sâkâhikan, which means 'Dove Lake', but by 1858 the name Pigeon Lake was in use.[2] It has been suggested that the name Pigeon Lake refers to the huge flocks of Passenger Pigeons that once ranged in the area.[1] The lake was also previously known as Woodpecker Lake, and the Stoney name is recorded as Ke-gemni-wap-ta.[2] The water quality of Pigeon Lake is typical of large, productive, shallow lakes in Alberta, with water remaining quite green for most of the summer. However, residents have recently expressed concern over perceptions of deteriorating water quality as a result of recurring toxic blue-green algal blooms, fish kills, and beach advisories[3]. Due to these concerns, there has been a demand to examine ways to reduce the frequency and intensity of cyanobacteria blooms. In 2013, data was collected to prepare a nutrient budget for Pigeon Lake - this report was later released in 2014 and it outlines areas of interest when considering watershed and in-lake management options[4]. In addition, the Pigeon Lake Watershed Alliance is due to finalize a Watershed Management Plan in late 2017.

The watershed area for Pigeon Lake is 176.62 km^2 and the lake area is 97.32 km^2. The lake to watershed ratio of Pigeon Lake is 1:2. A map of the Pigeon Lake watershed area can be found http://alms.ca/wp-content/uploads/2016/12/Pigeon.pdf.

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[1] Mitchell, P. and E. Prepas. 1990. Atlas of Alberta Lakes, University of Alberta Press. Retrieved from http://sunsite.ualberta.ca/projects/alberta-lakes/ Aubrey, M. K. 2006.

[2] Aubrey, M. K. 2006. Concise place names of Alberta. Retrieved from http://www.albertasource.ca/placenames/resources/searchcontent.php?book=1

[3] Aquality Environmental Consulting. 2008. Pigeon Lake State of Watershed Report. Prepared for Pigeon Lake Watershed Alliance. Retrieved from: www.plwa.ca.

[4] Teichreb, C.2014. Pigeon Lake Phosphorus Budget. Alberta Environment and Sustainable Resource Development. 28 pp.

WATER CHEMISTRY

ALMS measures a suite of water chemistry parameters. Phosphorus, nitrogen, and chlorophyll-a are important because they are indicators of eutrophication, or excess nutrients, which can lead to harmful algal/cyanobacteria blooms. One direct measure of harmful cyanobacteria blooms are Microcystins, a common group of toxins produced by cyanobacteria. See Table 2 for a complete list of parameters.

Total phosphorus (TP) in Pigeon Lake had an average concentration of 26 µg/L in 2016, putting it in the mesotrophic classification (Table 2). TP levels in Pigeon Lake in 2016 were historically low, though tend to fluctuate between mesotrophic and eutrophic classifications. TP increased throughout the summer, with a maximum concentration of 42 µg/L on September 7 (Figure 1). Pigeon Lake experiences wide fluctuations year to year in both its total phosphorus and chlorophyll-*a* concentrations. These two parameters appear closely related based on historical values (Figure 2).

Chlorophyll-*a* concentrations increased over the course of the summer, with an average concentration of 27.9 µg/L in 2016 (Table 2). This puts Pigeon Lake in the hypereutrophic trophic status class. A maximum concentration of 52.9 µg/L was reached on September 29 (Figure 1).

Pigeon Lake had an average TKN concentration of 0.85 mg/L over five sampling dates in 2016 (Table 2). On August 10, TKN concentrations peaked to a seasonal maximum of 1 mg/L and decreased throughout the rest of the sampling season (Figure 1).

Average pH measured as 8.6 in 2016, buffered by moderate alkalinity (160 mg/L $CaCO_3$) and bicarbonate (184 mg/L HCO_3). Calcium and sodium were the dominant ions contributing to a relatively low conductivity measure of 320 uS/cm (Table 2).

METALS

Samples were analyzed for metals once in the summer (Table 3). In total, 27 metals were sampled for. It should be noted that many metals are naturally present in aquatic environments due to the weathering of rocks and may only become toxic at higher levels.

Metals were measured once at Pigeon Lake and all measured values fell within their respective guidelines (Table 3).

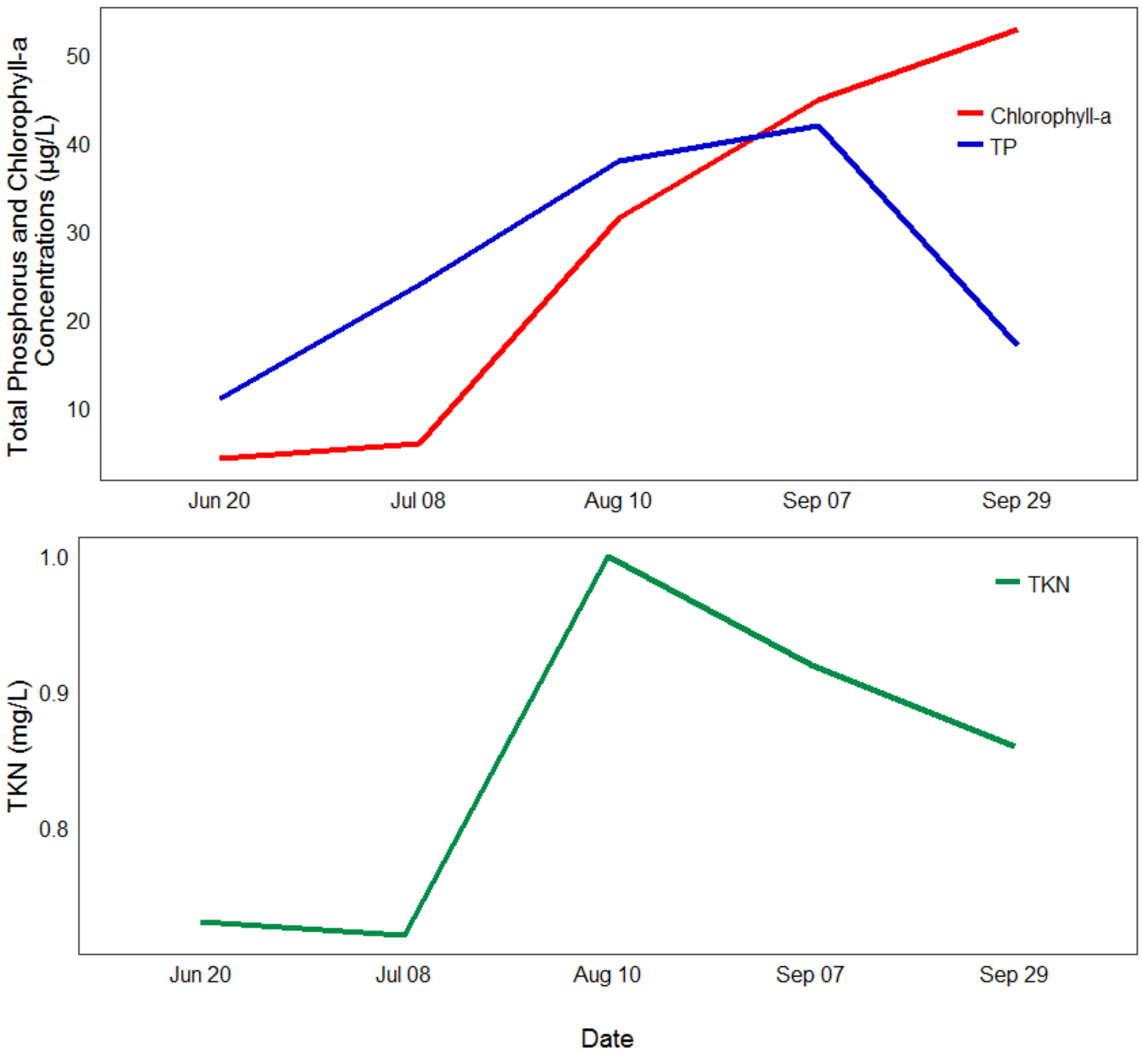

Figure 1- Total Phosphorus (TP), Total Kjeldahl Nitrogen (TKN), and Chlorophyll-*a* concentrations measured five times over the course of the summer at Pigeon Lake.

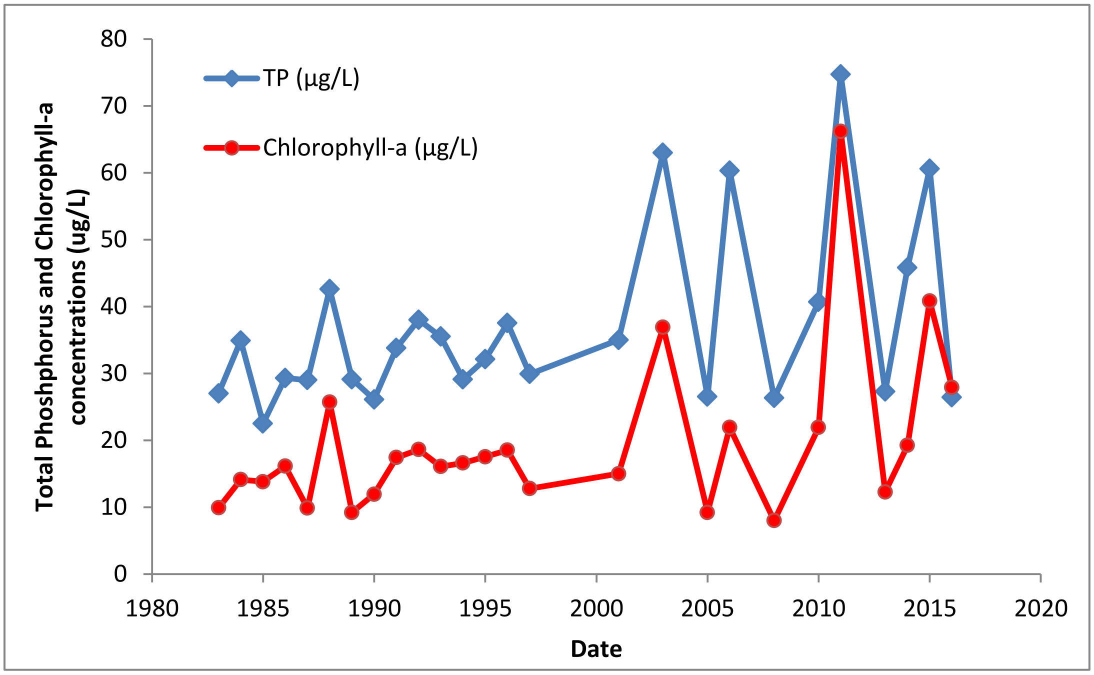

Figure 2- Historical total phosphorus (TP) and chlorophyll-*a* (ug/L) summer averages for Pigeon Lake. Lines have been connected across years when data was not collected at Pigeon Lake to highlight inter-annual variability. This graph is not intended to interpolate concentrations in years lacking data.

WATER CLARITY AND SECCHI DEPTH

Water clarity is influenced by suspended materials, both living and dead, as well as dissolved colored compounds in the water column. During the melting of snow and ice in spring, lake water can become turbid (cloudy) from silt transported into the lake. Lake water usually clears in late spring but then becomes more turbid with increased algal growth as the summer progresses. The easiest and most widely used measure of lake water clarity is the Secchi disk depth. Two times the Secchi disk depth equals the euphotic depth – the depth to which there is enough light for photosynthesis.

Average Secchi depth in 2016 was 3.36 m, classifying Pigeon Lake as mesotrophic, or moderately productive (Figure 3). Compared to historical measurements, an average value of 3.36 m is quite clear for Pigeon Lake. A maximum Secchi depth of 5.40 m was recorded on June 20, which decreased throughout the sampling season with warmer temperatures. Secchi depth was negatively correlated with chlorophyll-*a* (r= -0.97, df= 3, *p-value*= 0.007), implying that decreasing water clarity was associated with increasing algal bloom mass.

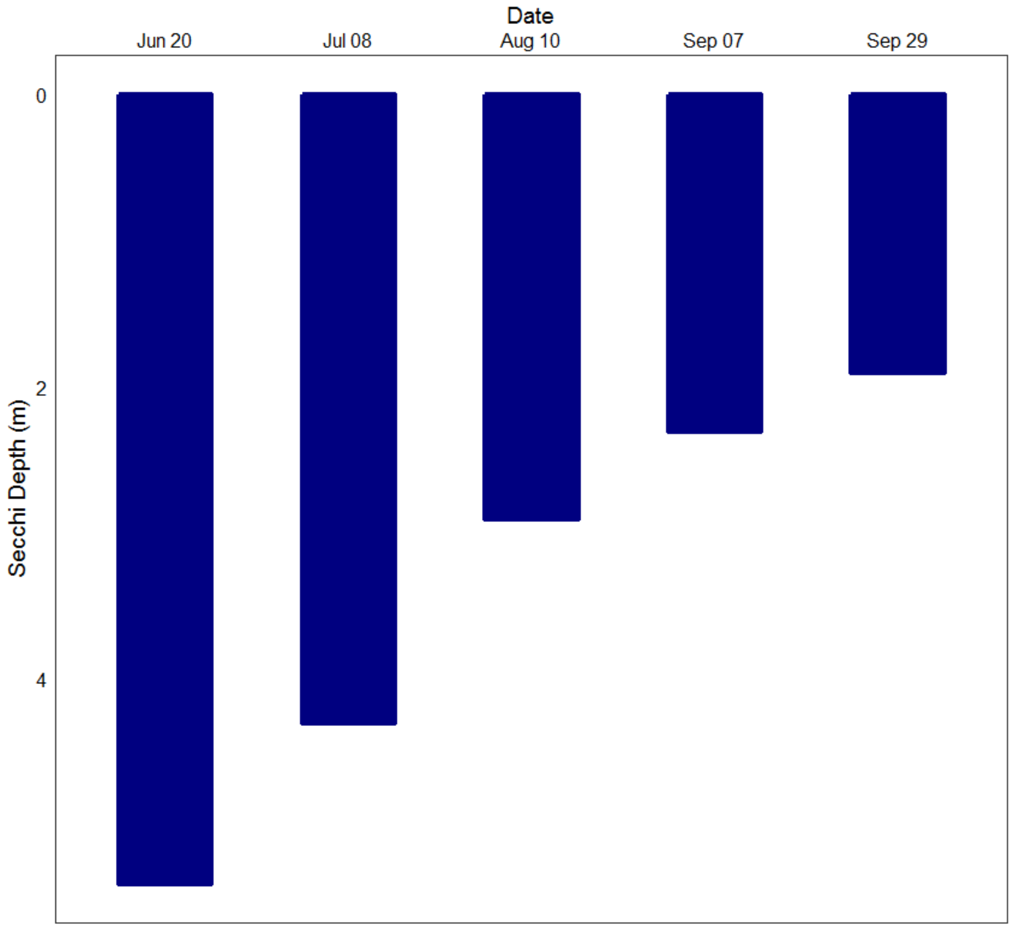

Figure 3 – Secchi depth values measured five times over the course of the summer at Pigeon Lake in 2016.

WATER TEMPERATURE AND DISSOLVED OXYGEN

Water temperature and dissolved oxygen profiles in the water column can provide information on water quality and fish habitat. The depth of the thermocline is important in determining the depth to which dissolved oxygen from the surface can be mixed. Please refer to the end of this report for descriptions of technical terms.

Pigeon Lake water temperatures varied throughout the summer (Figure 3a). A maximum temperature of 20.38 °C was observed on August 10, and by September 29, the entire water column was approximately 12°C. Given the shallow depth of Pigeon Lake, it never reached thermal stratification. Pigeon Lake can therefore be classified as polymictic, because it mixes fully multiple times over the course of the summer.

Pigeon Lake remained 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 3b). Since Pigeon Lake never thermally stratified, the entire water column remained well oxygenated throughout the entire sampling season.

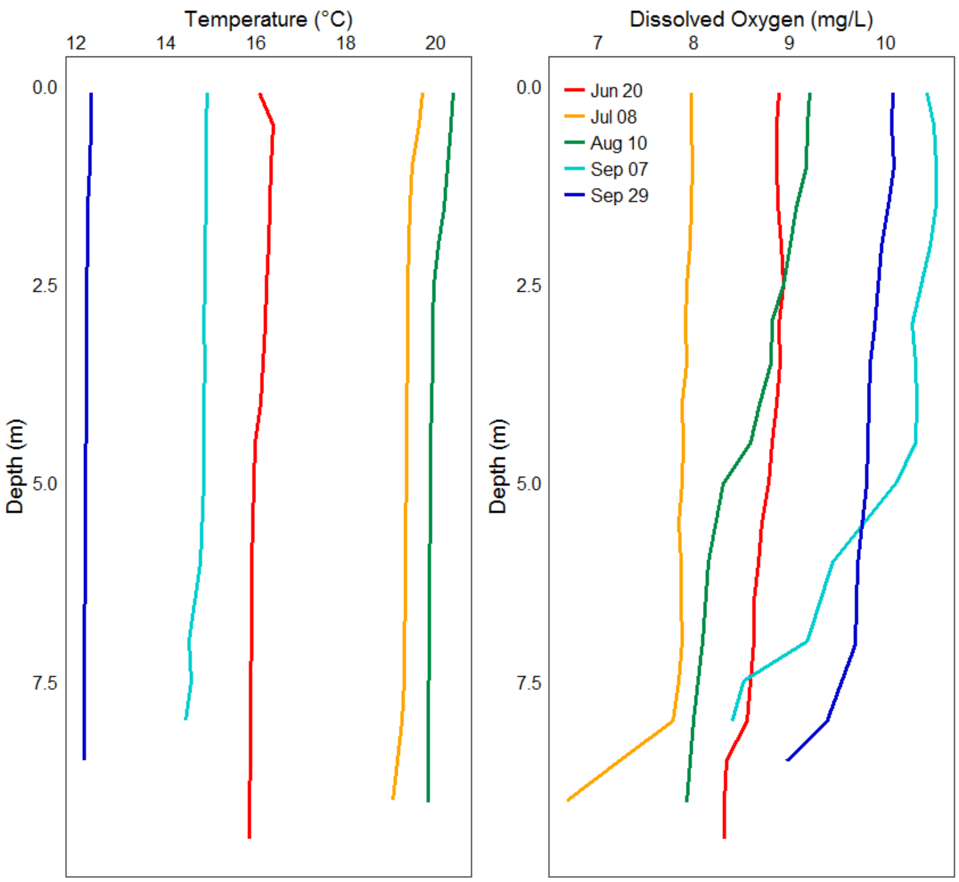

Figure 3 – a) Temperature (°C) and b) dissolved oxygen (mg/L) profiles for Pigeon Lake measured five times over the course of the summer of 2016.

MICROCYSTIN

Microcystins are toxins produced by cyanobacteria (blue-green algae) which, when ingested, can cause severe liver damage. Microcystins are produced by many species of cyanobacteria which are common to

Alberta's lakes, and are thought to be the one of the most common cyanobacteria toxins. In Alberta, recreational guidelines for microcystin are set at 20 µg/L.

Table 1 – Microcystin concentrations measured five times at Pigeon Lake in 2016. All measured concentrations remained below the recommended guidelines for recreational use in 2016.

Date	Microcystin Concentration (µg/L)
Jun 20	0.13
Jul 8	0.11
Aug 10	0.05
Sep 7	0.28
Sep 29	0.10
Average	0.13

Composited microcystin concentrations in Pigeon Lake in 2016 were low, falling well below the recommended guidelines (20 µg/L). Individual locations on Pigeon Lake may have higher concentrations of microcystin and recreation in cyanobacteria blooms should be avoided.

INVASIVE SPECIES MONITORING

Dreissenid mussels pose a significant concern for Alberta because they impair the function of water conveyance infrastructure and adversely impact the aquatic environment. These invasive mussels have been linked to creating toxic algae blooms, decreasing the amount of nutrients needed for fish and other native species, and causing millions of dollars in annual costs for repair and maintenance of water-operated infrastructure and facilities.

Monitoring involved two components: monitoring for juvenile mussel veligers using a plankton net and monitoring for attached adult mussels using substrates installed in each lake. In 2016, no invasive mussels were detected in Pigeon Lake.

WATER LEVELS

There are many factors influencing water quantity. Some of these factors include the size of the lakes drainage basin, precipitation, evaporation, water consumption, ground water influences, and the efficiency of the outlet channel structure at removing water from the lake. Requests for water quantity monitoring should go through Alberta Environment and Parks Monitoring and Science division.

Water levels in Pigeon Lake have remained relatively stable since Environment Canada began monitoring the lake in 1972 (Figure 4). Since 1972, Pigeon Lake water levels fluctuated between a maximum of 850.6 m asl and a minimum of 849.4 m asl. Data from Environment Canada was only available until 2015.

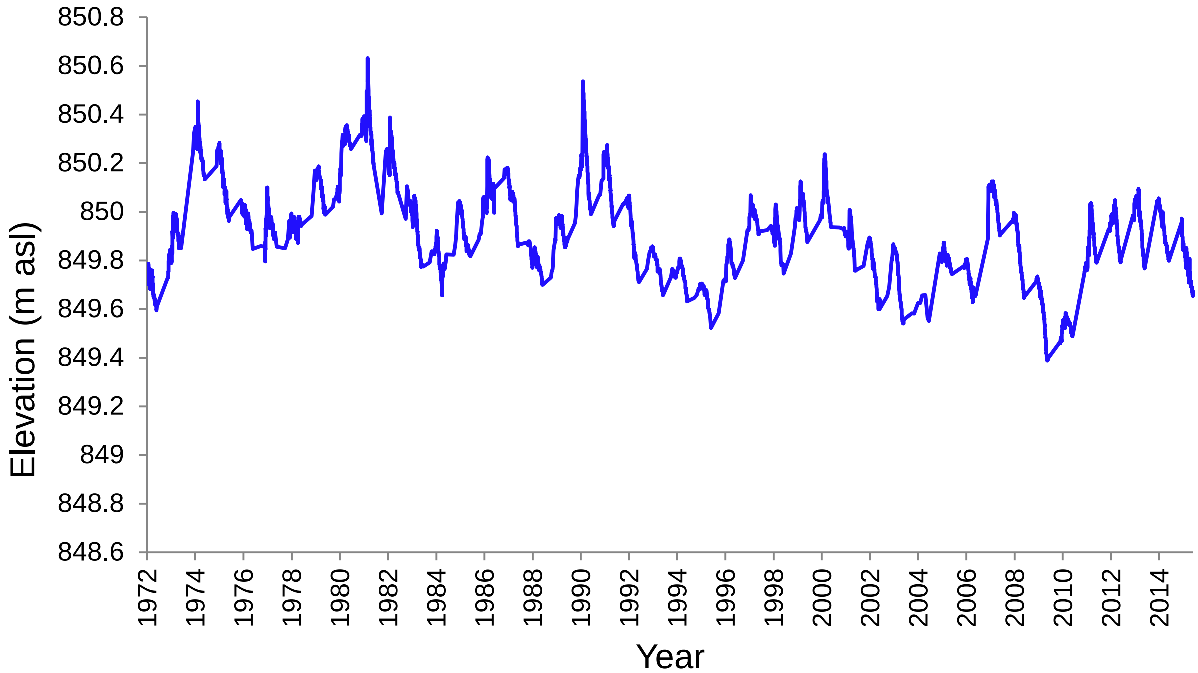

Figure 4- Water levels measured in meters above sea level (m asl) from 1972-2015. Data retrieved from Environment Canada.

Table 2: Average Secchi depth and water chemistry values for Pigeon Lake. Historical values are given for reference.

Parameter	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
TP (µg/L)	27	34.9	22.5	29.3	29	42.6	29.1	26.1	33.8	38	35.5	29.1
TDP (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Chlorophyll-*a* (µg/L)	9.91	14.1	13.8	16.13	9.85	25.7	9.2	11.94	17.4	18.6	16.08	16.6
Secchi depth (m)	3.19	1.94	2.19	3.08	2.25	1.63	2.35	2.32	2.14	1.72	1.98	2.13
TKN (mg/L)	0.945	/	640	/	/	/	/	/	/	/	/	/
NO_2 and NO_3 (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/
NH_3 (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/
DOC (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Ca (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Mg (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Na (mg/L)	15	15.3	16.3	15	15	17.1	16.12	14.33	14	17	17	17
K (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
SO_4^{2-} (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Cl^- (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
CO_3 (mg/L)	/	/	/	/	/	/	/	/	/	/	/	/
HCO_3 (mg/L)	180.5	178.2	184	168.62	176.15	170.52	187.3	175.3	176.7	174	174.7	176.5
pH	8.37	8.43	8.35	8.57	8.5	8.36	8.32	8.5	8.46	8.45	8.56	8.6
Conductivity (µS/cm)	283.25	288	292.25	280.3	293	279	302.2	293.7	292.7	285.7	286.7	290
Hardness (mg/L)	112.13	103.25	113	109.7	111	109.25	119.95	122	120.7	110.7	113.3	113.5
TDS (mg/L)	156.7	153.7	157.9	151.21	157.41	151.1	163	157.7	155.7	152.3	154	154.5
Microcystin (µg/L)	/	/	/	/	/	/	/	/	/	/	/	/
Total Alkalinity (mg/L $CaCO_3$)	151.75	152.95	152.58	147	153.5	144.9	155.8	152.7	150	146	148	149.5

Table 2: Continued- Average Secchi depth and water chemistry values for Pigeon Lake. Historical values are given for reference.

Parameter	1995	1996	1997	2001	2003	2005	2006	2008	2010	2011	2013	2014	2015	2016
TP (μg/L)	32.1	37.5	29.9	35	63	26.5	60.3	26.3	40.7	74.7	27.3	45.8	60.6	26
TDP (μg/L)	/	/	/	/	/	6	38	9	13	19.1	7.69	16.4	11.2	6
Chlorophyll-*a* (μg/L)	17.53	18.5	12.77	15	36.9	9.2	21.9	7.98	21.92	66.2	12.28	19.24	40.84	27.9
Secchi depth (m)	2.2	1.8	2.5	1.5	1.38	1.9	2.7	4.42	2.75	1.25	3.23	2.31	1.65	3.36
TKN (mg/L)	0.850	/	/	0.611	1.075	0.71	1.1	0.67	1.033	1.5	0.78	0.72	1.338	0.85
NO_2 and NO_3 (μg/L)	/	/	/	1	/	3	29	13	7.67	15.9	5.91	26	2.5	2.5
NH_3 (μg/L)	/	/	/	3	/	2.5	124	16	72.3	108.9	28.39	24.6	31	25
DOC (mg/L)	/	/	/	/	/	/	7	/	7.35	/	/	8.3	7.8	7.06
Ca (mg/L)	/	/	/	/	/	28.85	21.13	27.2	23.75	19.5	27.62	22.83	19.8	25.8
Mg (mg/L)	/	/	/	/	/	12.65	14.12	12.87	13.85	12.5	12.84	11.43	12.6	14.2
Na (mg/L)	17.5	14.6	18.6	/	18.7	20	21	20.33	21.95	20.1	20.57	23.6	20.8	23.8
K (mg/L)	/	/	/	/	/	6.1	6.63	6.17	6.3	6.2	6.59	6.6	6.1	7.4
SO_4^{2-} (mg/L)	/	/	/	/	/	7.3	10.2	5.47	9	3.38	6.38	5.03	4.5	6
Cl^- (mg/L)	/	/	/	/	/	4	3.33	3.33	3.05	3.03	3.19	3.5	3.8	3.72
CO_3 (mg/L)	/	/	/	/	/	8	4.67	3.33	0.5	8.7	3.27	5.92	3.61	5.56
HCO_3 (mg/L)	167.5	163	190	/	168.5	183	180	198	195	161	194.53	191.6	178	184
pH	8.61	8.66	8.17	/	8.56	8.6	8.5	8.37	8.57	8.74	8.34	8.59	8.48	8.60
Conductivity (μS/cm)	281.5	293	304	/	/	313	287	321.7	309.5	286.7	164	314	298	320
Hardness (mg/L)	110.5	106	130	/	103	125	119	121	116	100.2	122	103.9	100.8	124
TDS (mg/L)	156	151	169	/	/	176.5	173	175.33	173.5	153	176	182.3333	166	190
Microcystin (μg/L)	/	/	/	/	/	/	/	/	0.087	0.173	0.1354	0.972	2.318	0.13
Total Alkalinity (mg/L $CaCO_3$)	148.5	149	156	/	151	163	155.3	165.7	160	146.7	164	156.8	154	160

Table 3: Concentrations of metals measured once in Pigeon Lake. The CCME heavy metal Guidelines for the Protection of Freshwater Aquatic Life (unless otherwise indicated) are presented for reference.

Metals (Total Recoverable)	2003	2012	2014	2015	2016	Guidelines
Aluminum μg/L	14.9	5.13	10.55	14.3	7.2	100[a]
Antimony μg/L	0.05	0.06685	0.089	0.0785	0.066	6[d]
Arsenic μg/L	1.67	1.375	2.285	2.145	2.06	5
Barium μg/L	78.5	89.75	77.35	74.1	73.5	1000[d]
Beryllium μg/L	0.02	0.00675	0.004	0.004	0.004	100[c,e]
Bismuth μg/L	0.0025	0.00125	0.0005	0.00325	0.001	/
Boron μg/L	27.9	29.85	27.4	28.5	31.1	1500
Cadmium μg/L	0.01	0.00325	0.002	0.004	0.005	0.26[b]
Chromium μg/L	0.27	0.015	0.5235	0.09	0.04	/
Cobalt μg/L	0.11	0.00605	0.006565	0.018	0.005	1000[e]
Copper μg/L	1.08	0.2255	0.4155	0.235	0.5	4[b]
Iron μg/L	39	2.04	15.75	144.2	20.6	300
Lead μg/L	0.145	0.0167	0.245	0.0595	0.028	7[b]
Lithium μg/L	8.6	9.09	8.29	9.175	11.2	2500[f]
Manganese μg/L	54.1	16.9	15.75	49.65	6.48	200[f]
Molybdenum μg/L	0.62	0.704	0.731	0.728	0.907	73[c]
Nickel μg/L	0.16	0.0025	0.3465	0.0205	0.219	150[b]
Selenium μg/L	0.25	0.103	0.35	0.03	0.21	1
Silver μg/L	0.0025	0.0015	0.00681	0.002	0.003	0.25
Strontium μg/L	245	234	261	233	249	/
Thallium μg/L	0.0015	0.00105	0.00291	0.000875	0.0075	0.8
Thorium μg/L	0.0015	0.008725	0.003575	0.011425	0.01	/
Tin μg/L	0.05	0.0549	0.0231	0.0355	0.027	/
Titanium μg/L	1.5	0.8925	1.4355	3.125	1	/
Uranium μg/L	0.086	0.1805	0.1945	0.167	0.161	15
Vanadium μg/L	0.26	0.1545	0.456	0.14	0.26	100[e,f]
Zinc μg/L	1.5	0.899	1.56	0.65	0.9	30

Values represent means of total recoverable metal concentrations.

[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).

A forward slash (/) indicates an absence of data or guidelines.

A BRIEF INTRODUCTION TO LIMNOLOGY

INDICATORS OF WATER QUALITY

Water samples are collected in LakeWatch to determine the chemical characteristics that characterize general water quality. Though not all encompassing, the variables collected in LakeWatch are sensitive to human activities in watersheds that can cause degraded water quality. For example, nutrients such as phosphorus and nitrogen are important determinants of lake productivity. The concentrations of these nutrients in a lake are impacted (typically elevated) by land use changes such as increased crop production or livestock grazing. Elevated nutrient concentrations can cause increases in undesirable algae blooms resulting in low dissolved oxygen concentrations, degraded habitat for fish and noxious smells. A large increase in nutrients over time may also indicate sewage inputs which in turn may result in other human health concerns associated with bacteria or the protozoan *Cryptosporidium*.

TEMPERATURE AND MIXING

Water temperature in a lake dictates the behavior of many chemical parameters responsible for water quality. Heat is transferred to a lake at its surface and slowly moves downward depending on water circulation in the lake. Lakes with a large surface area or a small volume tend to have greater mixing due to wind. In deeper lakes, circulation is not strong enough to move warm water to depths typically greater than 4 or 5 m and as a result cooler denser water remains at the bottom of the lake. As the difference in temperature between warm surface and cold deeper water increases, two distinct layers are formed. Limnologists call these layers of water the epilimnion at the surface and the hypolimnion at the bottom. The layers are separated by a transition layer known as the metalimnion which contains the effective wall separating top and bottom waters called a thermocline. A thermocline typically occurs when water temperature changes by more than one degree within one meter depth. The hypolimnion and epilimnion do not mix, nor do elements such as oxygen supplied at the surface move downward into the hypolimnion. In the fall, surface waters begin to cool and eventually reach the same temperature as hypolimnetic water. At this point the water mixes from top to bottom in what is often called a turnover event. Surface water cools further as ice forms and again a thermocline develops this time with 4° C water at the bottom and near 0° C water on the top.

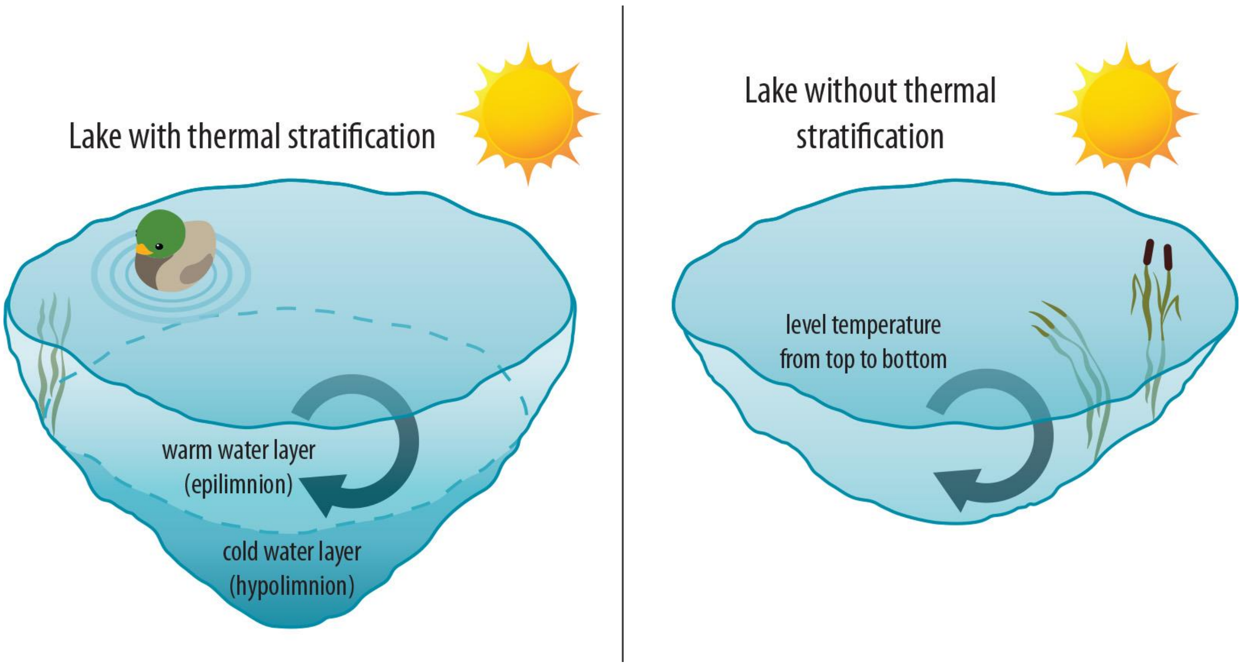

Figure A: Difference in the circulation of the water column depending on thermal stratification.

In spring another turnover event occurs when surface waters warm to 4° C. Lakes with this mixing pattern of two stratification periods and two turnover events are called **dimictic** lakes. In shallower lakes, the water column may mix from top to bottom most of the ice-free season with occasional stratification during periods of calm warm conditions. Lakes that mix frequently are termed **polymictic** lakes. In our cold climate, many shallow lakes are **cold monomictic** meaning a thermocline develops every winter, there is one turnover event in spring but the remainder of the ice free season the lake is polymictic.

DISSOLVED OXYGEN

Oxygen enters a lake at the lake surface and throughout the water column when produced by photosynthesizing plants, including algae, in the lake. Oxygen is consumed within the lake by respiration of living organisms and decomposition of organic material in the lake sediments. In lakes that stratify (see temperature above), oxygen that dissolves into the lake at the surface cannot mix downward into the hypolimnion. At the same time oxygen is depleted in the hypolimnion by decomposition. The result is that the hypolimnion of a lake can become **anoxic**, meaning it contains little or no dissolved oxygen. When a lake is frozen, the entire water column can become anoxic because the surface is sealed off from the atmosphere. Winter anoxic conditions can result in a fish-kill which is particularly common during harsh winters with extended ice-cover. Alberta Surface Water Quality Guidelines suggest dissolved oxygen concentrations (in the epilimnion) must not decline below 5 $mg \bullet L^{-1}$ and should not average less than 6.5 $mg \bullet L^{-1}$ over a seven-day period. However, the guidelines also require that dissolved oxygen concentrations remain above 9.5 $mg \bullet L^{-1}$ in areas where early life stages of aquatic biota, particularly fish, are present.

GENERAL WATER CHEMISTRY

Water in lakes always contains substances that have been transported by rain and snow or have entered the lake in groundwater and inflow streams. These substances may be dissolved in the water or suspended as particles. Some of these substances are familiar minerals, such as sodium and chloride, which when combined form table salt, but when dissolved in water separate into the two electrically charged components called **ions**. Most dissolved substances in water are in ionic forms and are held in solution due to the polar nature of the water molecule. **Hydrophobic** (water-fearing) compounds such as oils contain little or no ionic character, are non-polar and for this reason do not readily dissolve in water. Although hydrophobic compounds do not readily dissolve, they can still be transported to lakes by flowing water. Within individual lakes, ion concentrations vary from year to year depending on the amount and mineral content of the water entering the lake. This mineral content can be influenced by the amount of precipitation and other climate variables as well as human activities such as fertilizer and road salt application.

PHOSPHORUS AND NITROGEN

Phosphorus and nitrogen are important nutrients limiting the growth of algae in Alberta lakes. While nitrogen usually limits agricultural plants, phosphorus is usually in shortest supply in lakes. Even a slight increase of phosphorus in a lake can, given the right conditions, promote algal blooms causing the water to turn green in the summer and impair recreational uses. When pollution originating from livestock manure and human sewage enters lakes not only are the concentrations of phosphorus and nitrogen increased but nitrogen can become a limiting nutrient which is thought to cause blooms of toxic algae belonging to the cyanobacteria. Not all cyanobacteria are toxic, however, the blooms can form decomposing mats that smell and impair dissolved oxygen concentrations in the lake.

CHLOROPHYLL-A

Chlorophyll *a* is a photosynthetic pigment that green plants, including algae, possess enabling them to convert the sun's energy to living material. Chlorophyll *a* can be easily extracted from algae in the laboratory. Consequently, chlorophyll *a* is a good estimate of the amount of algae in the water. Some highly productive lakes are dominated by larger aquatic plants rather than suspended algae. In these lakes, chlorophyll *a* and nutrient values taken from water samples do not include productivity from large aquatic plants. The result, in lakes like Chestermere which are dominated by larger plants known as macrophytes, can be a lower trophic state than if macrophyte biomass was included. Unfortunately, the productivity and nutrient cycling contributions of macrophytes are difficult to sample accurately and are therefore not typically included in trophic state indices.

SECCHI DISK TRANSPARENCY

Lakes that are clear are more attractive for recreation, whereas those that are turbid or murky are considered by lake users to have poor water quality. A measure of the transparency or clarity of the water is performed with a Secchi disk with an alternating black and white pattern. To measure the clarity of the water, the Secchi disk is lowered down into the water column and the depth where the disk disappears is recorded. The Secchi depth in lakes with a lot of algal growth will be small while the Secchi depth in lakes with little algal growth can be very deep. However, low Secchi depths are not caused by algal growth alone. High concentrations of suspended sediments, particularly fine clays or glacial till, are common in plains or mountain reservoirs of Alberta. Mountain reservoirs may have exceedingly low Secchi depths despite low algal growth and nutrient concentrations.

The euphotic zone or the maximum depth that light can penetrate into the water column for actively growing plants is calculated as twice the Secchi depth. Murky waters, with shallow Secchi depths, can prevent aquatic plants from growing on the lake bottom. Conversely, aquatic plants can ensure lakes have clear water by reducing shoreline erosion and stabilizing lake bottom sediments. In Alberta, many lakes are shallow and bottom sediments contain high concentrations of nutrients. Without aquatic plants, water quality may decline in these lakes due to murky, sediment laden water and excessive algal blooms. Maintaining aquatic plants in certain areas of a lake is often essential for ensuring good water clarity and a healthy lake as many organisms, like aquatic invertebrates and insects, depend on aquatic plants for food and shelter.

TROPHIC STATE

Trophic state is classification of lakes into four categories of fertility and is a useful index for rating and comparing lakes. From low to high nutrient and algal biomass (as chlorophyll) concentrations, the trophic states are; **oligotrophic**, **mesotrophic**, **eutrophic** and **hypereutrophic (Table 2)**.

A majority of lakes in Alberta contain naturally high levels of chlorophyll *a* (8 to 25 µg/L) due to our deep fertile soils. These lakes are usually considered fertile and are termed eutrophic. The nutrient and algal biomass concentrations that define these categories are shown in the following table, a figure of Alberta lakes compared by trophic state can be found on the ALMS website.

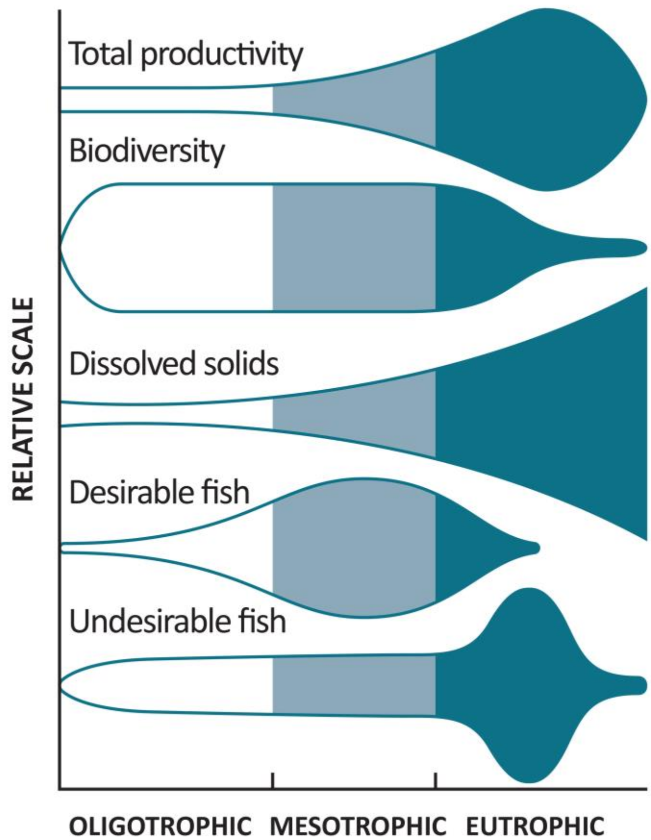

Table A - Trophic status classification based on lake water characteristics.

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