BC Lake Stewardship and Monitoring Program

Charlie Lake 2003-2005 & 2016-2018

A partnership between the BC Lake Stewardship Society
and the BC Ministry of Environment and Climate Change Strategy

The Importance of Charlie Lake & its Watershed

British Columbians want lakes to provide good water quality, aesthetics, and recreational opportunities. When these features are not apparent in recreational lakes, questions arise. People begin to wonder if the water quality is getting worse, if the lake has been affected by land development, and what conditions will result from more development within the watershed.

The BC Lake Stewardship Society (BCLSS), in collaboration with the Ministry of Environment and Climate Change Strategy (ENV), has designed a program, entitled *The BC Lake Stewardship and Monitoring Program*, to address these concerns. Through regular water sample collections, we can come to understand a lake's current water quality, identify the preferred uses for a given lake, and monitor water quality changes resulting from land development within the lake's watershed. There are different levels of lake monitoring and assessment. The level appropriate for a particular lake depends on the funding and human resources available. In some cases, data collected as part of a Level I or II program can point to the need for a more in-depth Level III program. This report gives the 2016-2018 results of a Level III program for Charlie Lake and historical volunteer sampling data from 2003-2005.

The BCLSS can provide communities with both lake-specific monitoring results and educational materials on general lake protection issues. This useful information can help communities play a more active role in the protection of the lake resource. Finally, this program allows government to use its limited resources efficiently with the help of local volunteers and the BCLSS.

The Charlie Lake volunteer monitoring was conducted by the Charlie Lake Conservation Society (CLCS). This group has also conducted shoreline clean-ups, watershed initiatives to reduce soil erosion from oil and as sites, community education programs, conservation projects, and aquatic plant surveys.

A **watershed** is defined as the entire area of land that moves the water it receives into a common waterbody. The term watershed is misused when describing only the land immediately around a waterbody or the waterbody itself. The true definition represents a much larger area than most people normally consider.

Watersheds are where much of the hydrologic cycle occurs and play a crucial role in the purification of water. Although no "new" water is ever made, it is continuously recycled as it moves through watersheds and other hydrologic compartments. The quality of the water resource is largely determined by a watershed's capacity to buffer impacts and absorb pollution.

Every component of a watershed (vegetation, soil, wildlife, etc.) has an important function in maintaining good water quality and a healthy aquatic environment. It is a common misconception that detrimental land use practices will not impact water quality if they are kept away from the area immediately surrounding a waterbody. Poor land use practices in a watershed can eventually impact the water quality of the downstream environment.

Human activities that impact water bodies range from small but widespread and numerous *non-point* sources throughout the watershed to large *point* sources of concentrated pollution (e.g. waste discharge outfalls, spills, etc.). Undisturbed watersheds have the ability to purify water and repair small amounts of damage from pollution and alterations. However, modifications to the landscape and increased levels of pollution impair this ability.

Charlie Lake is located approximately 9 km northwest of Fort St. John in the Peace Region of BC. The lake lies at an elevation of 691 m, has a surface area of 18 km2, maximum and mean depths of 15 m and 6.4 m respectively, is 15 km long, 3 km wide, and has a shoreline perimeter of 38 km (Fish Inventories Data Queries, 2020).

Charlie Lake has several inflow sources with two named sources, the largest of which is Stoddart Creek, followed by Coffee Creek. Charlie Lake was historically the main water source for the City of Fort St. John and is currently still used as a backup source. A weir was built on the Fish Creek (Lower Stoddart Creek) outlet from the lake in the early1980s to aid in this purpose and is still maintained by the City.

The flushing rate, a factor that affects water quality, is the rate of water replacement in a lake and depends on the amount of inflow and outflow of a lake. The higher the flushing rate, the faster excess nutrients can be removed from the system. The flushing rate of Charlie Lake is approximately 5-7 years (French and Petticrew, 2007).

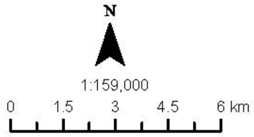
Charlie Lake recreational uses include fishing, boating, swimming, hiking, camping, mountain biking, ATVing, as well as snowmobiling, snowshoeing, and cross-country skiing in the winter. Fish present include Walleye, Burbot, Yellow Perch, Northern Pike, White Sucker, Lingcod, and Spottail Shiner (Angler's Atlas, 2020).

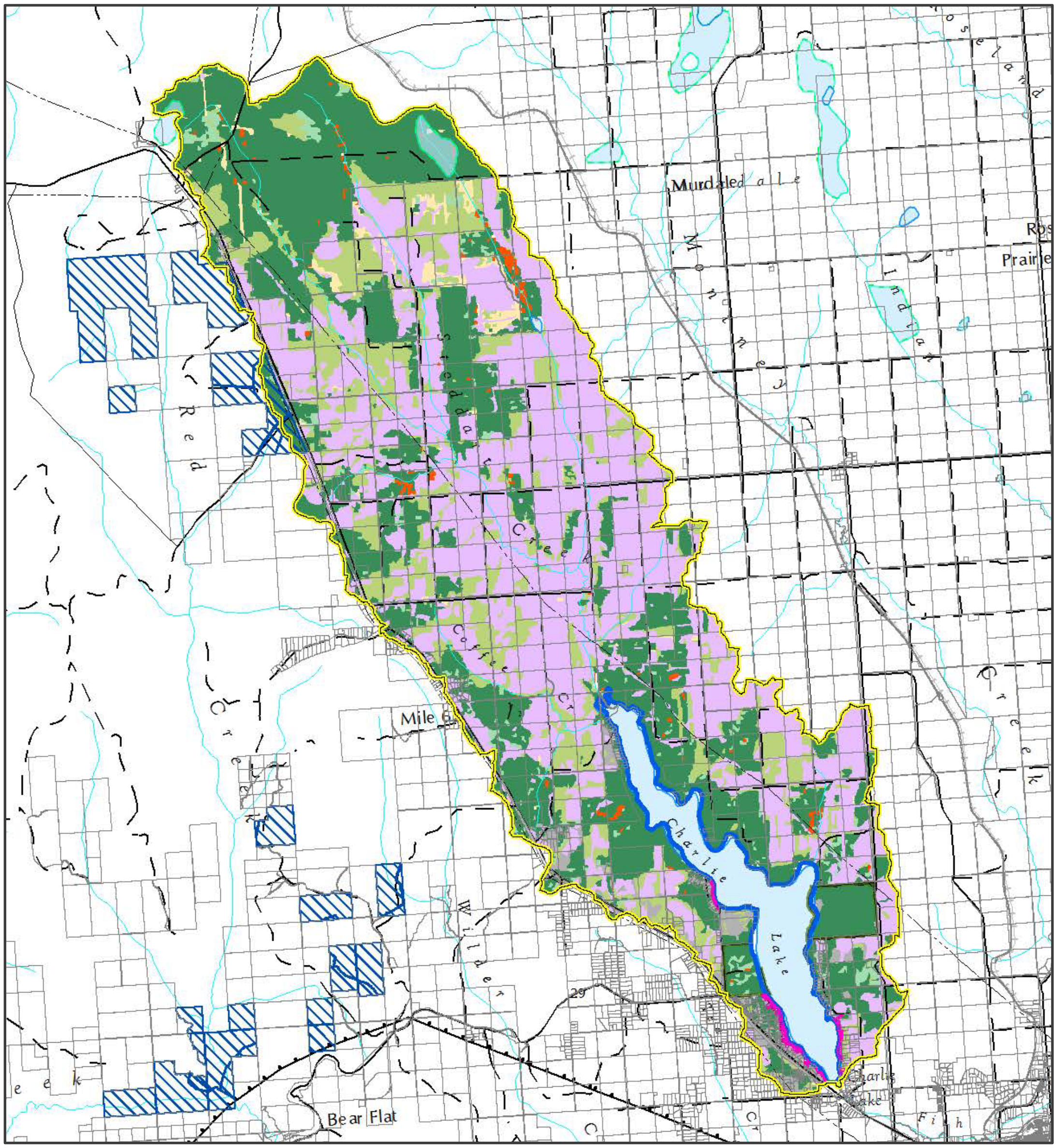
The map on the following page shows the Charlie Lake watershed and its associated land use practices which include agriculture, range/grazing, oil and gas, forestry, recreation, and residential development. The watershed is approximately 298 km^2.

The Charlie Lake shoreline is highly developed with approximately 1,500-2,000 private residents, two provincial parks, a Rotary Park, and a golf course on the lakeshore. Beatton Provincial Park and Charlie Lake Provincial Park span a combined area of 506 ha and provide users with boat launches, pit and flush privies, and two group picnic sites. Charlie Lake Provincial Park also provides sani-station services to park users. The Ross H. MacLean Rotary RV Park provides additional camping for and amenities including showers, laundry, water, and sewer.

A concern among residents is the high loading of sediment and nutrients from inflowing tributaries and shoreline practices. This nutrient addition to the lake has led to an increased intensity of both green and blue-green algal blooms (French and Booth, 2004) and is a potential contributor in the recent resurgence in aquatic vegetation around the lake (Kosugi, 2020). The main source of these sediments and nutrients could originate from poorly construct road crossings, riparian land clearing, livestock access to stream channels, poor management practices at oil and gas sites, domestic waste, and foreshore development (French and Booth, 2004).

Charlie Lake Watershed and Land Use Map





Watershed Characteristics

Watershed Area: 298 km^2

Percent Land Use (approximate):

Agricultural	38%
Forested	32%
Open Range/Grasslands	15%
Water	7%
Developed	3%
Forest Cover Openings	3%
Shrub Land	1%
Barren/Sparsely Vegetated	1%
Wetlands	<1%

Map provided by Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2020.

Non-Point Source Pollution and Charlie Lake

Point source pollution originates from municipal or industrial effluent outfalls. Other pollution sources exist over broader areas and may be hard to isolate as distinct effluents. These are referred to as non-point sources of pollution (NPS). Shoreline modification, urban stormwater runoff, onsite septic systems, agriculture, and forestry are common contributors to NPS pollution. One of the most detrimental effects of NPS pollution is phosphorus loading to water bodies. The amount of total phosphorus (TP) in a lake can be greatly influenced by human activities. If local soils and vegetation do not retain this phosphorus, it will enter watercourses where it will become available for algal production.

Agriculture

Agriculture including grains, livestock, and mixed farming, can alter water flow and increase sediment and chemical/bacterial/parasitic input into water bodies. Potential sources of nutrients (nitrogen & phosphorus) include chemical fertilizers and improperly situated winter feeding areas.

Forestry

Timber harvesting can include clear cutting, road building, and land disturbances, which alter water flow and potentially increase sediment and phosphorus inputs to water bodies.

Atmospheric Deposition

Gases and particulates released to the atmosphere from combustion sources such as motor vehicle emissions, slash burning, and industrial sources contain nitrogen, sulphur and metal compounds which eventually settle to the ground as dust or fall to the earth in rain and snow. These contaminants can fall directly into a waterbody, filter slowly into groundwater, or be washed into surface waters with runoff.

Onsite Septic Systems and Grey Water

Onsite septic systems effectively treat human wastewater and wash water (grey water) as long as they are properly located, designed, installed, and maintained. When these systems fail, they become significant sources of nutrients and pathogens Poorly maintained pit privies, used for the disposal of human waste and grey water, can also be significant contributors.

Properly located and maintained septic tanks do not pose a threat to the environment, however, mismanaged or poorly located tanks can result in a health hazard and/or excessive nutrient loading to the lake. Excessive nutrients such as phosphorus can cause a variety of problems including increased plant growth and algal blooms.

Stormwater Runoff

Lawn and garden fertilizer, sediment eroded from modified shorelines or infill projects, oil and fuel leaks from vehicles, snowmobiles and boats, road salt, and litter can all be washed by rain and snowmelt from properties and streets into watercourses. Phosphorus and sediment are of greatest concern, providing nutrients and/or a rooting medium for aquatic plants and algae. Pavement prevents water infiltration to soils, collects hydrocarbon contaminants during dry weather and increases direct runoff of these contaminants to lakes during storm events.

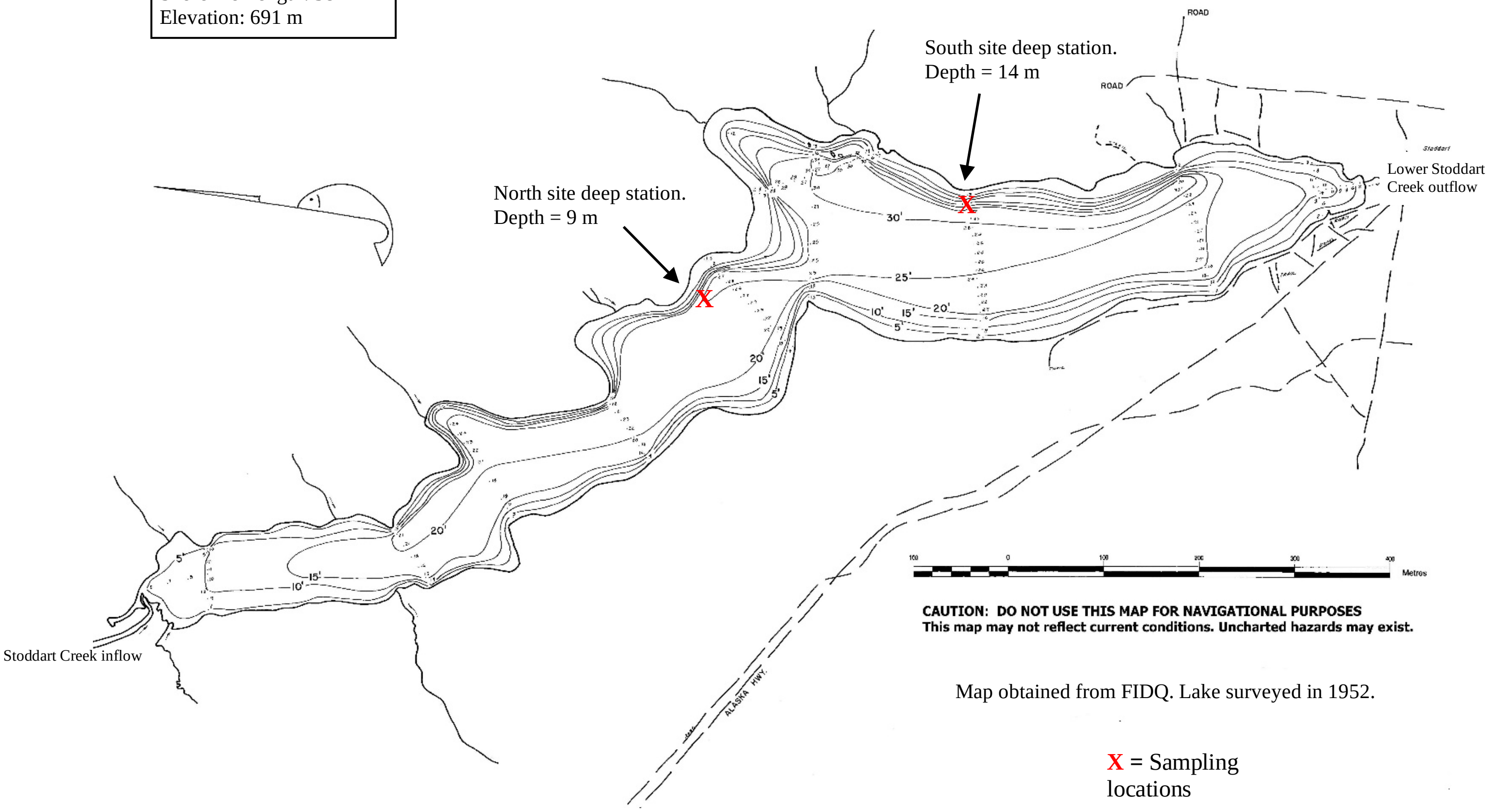
Boating

Oil and fuel leaks are the main concerns of boat operation on small lakes. With larger boats, sewage and grey water discharges are issues. Other problems include the spread of aquatic plants and the dumping of litter. In shallow water operations, the churning up of bottom sediments and nutrients is a concern.

Charlie Lake Bathymetric Map

Lake Characteristics

Area: 18 km^2
Max Depth: 15 m
Mean Depth: 6.4 m
Shoreline Length: 38 km
Elevation: 691 m



South site deep station.
Depth = 14 m

North site deep station.
Depth = 9 m

Lower Stoddart
Creek outflow

Stoddart Creek inflow

CAUTION: DO NOT USE THIS MAP FOR NAVIGATIONAL PURPOSES
This map may not reflect current conditions. Uncharted hazards may exist.

Map obtained from FIDQ. Lake surveyed in 1952.

X = Sampling
locations

Trophic Characteristics	2003		2004		2005		2016		2017		2018	
	North	South	North	South	North	South	North	South	North	South	North	South
Max. Surface Temp (°C)	20.0	19.0	21.0	21.0	-	19.0*	22.0	22.0	19.5	19.5	20.8	19.2
Min. Near-bottom Oxygen (mg/L)	1.00	5.00	1.00	0.60	-	3.00	1.00	0.00	0.57	0.14	0.30	0.50
Avg. Summer Surface TP (µg/L)	72.3	75.8	53.0	68.0	-	104.0	56.0	48.6	70.4	61.5	69.6	52.0
Avg. Chlorophyll *a* (µg/L)	28.2	24.8	16.2	19.8	-	31.0	14.6	22.0	29.8	33.5	67.7	50.2
Avg. Summer Secchi Depth (m)	1.4	1.6	2.2	2.2	-	2.5	2.5	2.7	1.5	1.8	1.7	1.6

*estimated

What's Going on Inside Charlie Lake?

Temperature

Lakes show a variety of annual temperature patterns based on their location and depth. Most interior lakes form layers (stratify), with the coldest water near the bottom. Because colder water is more dense, it resists mixing into the warmer, upper layer for much of the summer. When the warmer oxygen rich surface water distinctly separates from the cold oxygen poor water in the deeper parts of the lake, it is said to create a thermocline, a region of rapid temperature change between the two layers.

In spring and fall, these lakes usually mix from top to bottom (overturn) as wind energy overcomes the reduced temperature and density differences between surface and bottom waters. In the winter, lakes re-stratify under ice with the densest water (4°C) near the bottom. Because these types of lakes turn over twice per year, they are called dimictic lakes. These are the most common type of lake in BC.

Charlie Lake is not a typical dimictic lake. It is in the transition area between being a dimictic lake and a polymictic lake. A true cold polymictic lake would mix throughout the summer with occasional stratification and have stratification under ice cover. A true dimictic lake has fairly stable stratification and which Charlie Lake does not demonstrate, as it is partially or completely mixed at various times during the summer (Nordin, 2020).

Surface temperature readings serve as an important ecological indicator. By measuring surface temperature, we can record and compare readings from season to season and year to year. Temperature stratification patterns are also very important to lake water quality. They determine much of the seasonal oxygen, phosphorus, and algal conditions. When abundant, algae can create problems for lake users.

The timing of freeze-up and break-up of BC lakes is important information for climate change research. Charlie Lake volunteers have been collecting ice data since 1983. The lake normally freezes over from November to May (CLCS, 2020). Ice off dates for Charlie Lake during sampling years were April 21, 2016, May 9, 2017, and May 9, 2018 compared to May 11, 2003, April 29, 2004, and April 25, 2005.

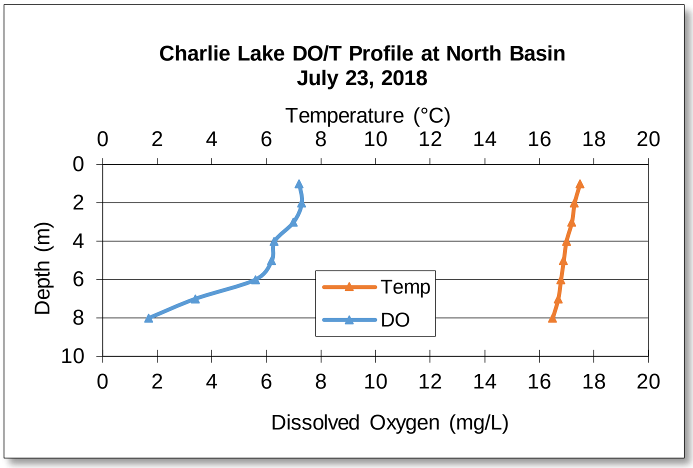
As indicated on the bathymetric map on Page 5, monitoring took place at two sites on Charlie Lake: the North Arm Deep Station (North site) and the Deep Station 1.2 km East of Park Site (South site).

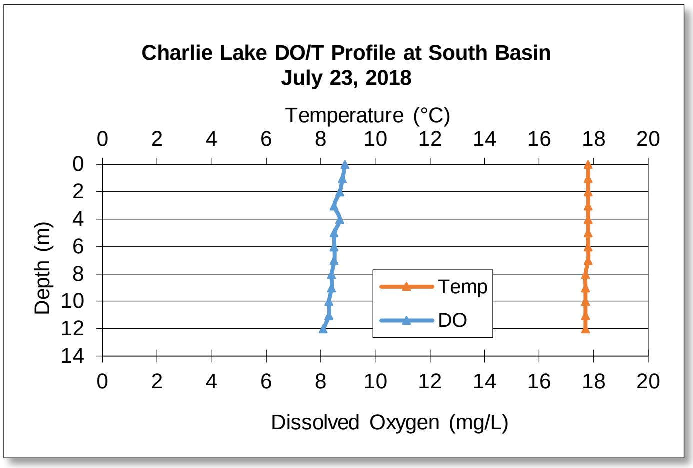
Dissolved Oxygen (DO) and temperature (T) data were collected at both sites from 2016-2018. For June and July sampling dates in 2016, a Winkler kit was used by volunteers to measure DO at three depths (surface, mid, and bottom) only, therefore complete vertical profiles are not available.

The DO/T profiles collected during Spring overturn sampling each year show that the lake was not completely mixed at the time. This could indicate that the lake either stratifies very quickly after ice-out or does not completely mix at overturn. In both basins, for all sampling years, the lake shows stratification in mid to late May.

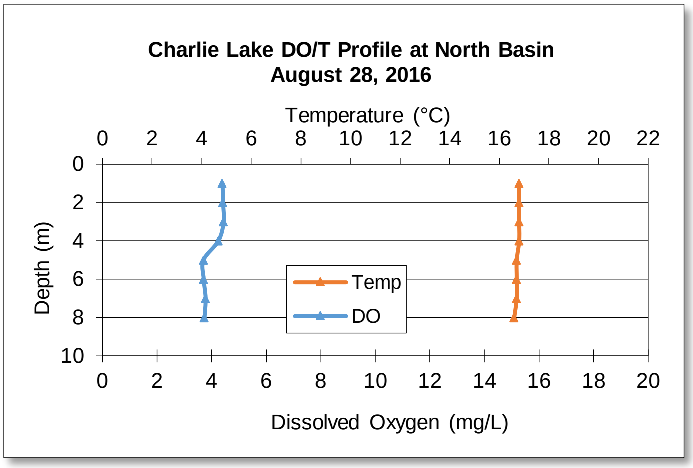
Although the lake does stratify, the shallow depth and weather conditions are such that stratification does not persist through the summer and the lake appears to undergo random mixing (destratification) events that may or may not have been captured by the sampling schedule. The recommended sampling frequency of once every two weeks was not sufficient enough to document the dynamics of the mixing taking place. In the case of a dynamic lake such as Charlie Lake, sampling once per week would be optimal.

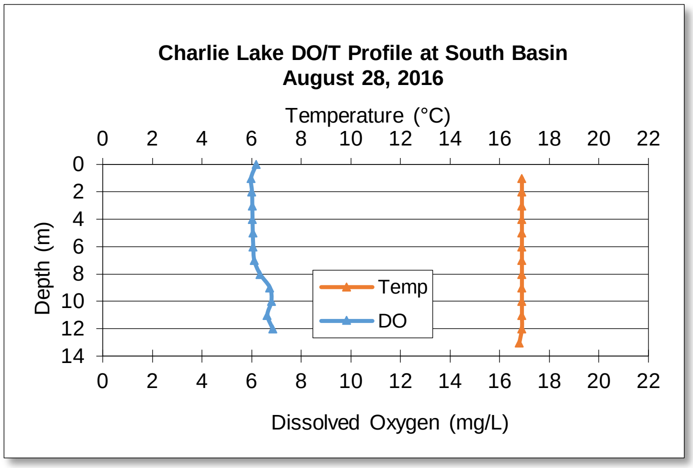
On July 23, 2018, the North site DO/T profile, shown below, indicated a slight T gradient (17.5°C at surface and 16.5°C at bottom) however DO was not homogenous (7.2 mg/L at surface and 1.70 mg/L at bottom). On the same date, the South site DO/T profile, shown below, indicates that the lake had undergone mixing, with a similar T (17.8°C at surface and 17.7°C at bottom) and DO (8.9 mg/L at surface and 8.1 mg/L at bottom) throughout the water column. The North basin is approximately 2 m shallower than the South basin. It would be expected that the North basin being shallower would be more susceptible to temperature changes, wind mixing, and destratification that the South basin. However, this is not always the case as seen in the July 23, 2018 profiles shown below, where the stratification in the North basin was stronger than in the South basin. Field notes indicated steady rain and wind over the previous 3 days which could have been a factor in this mixing event. After this date, data indicates that the lake stratifies again until Fall.



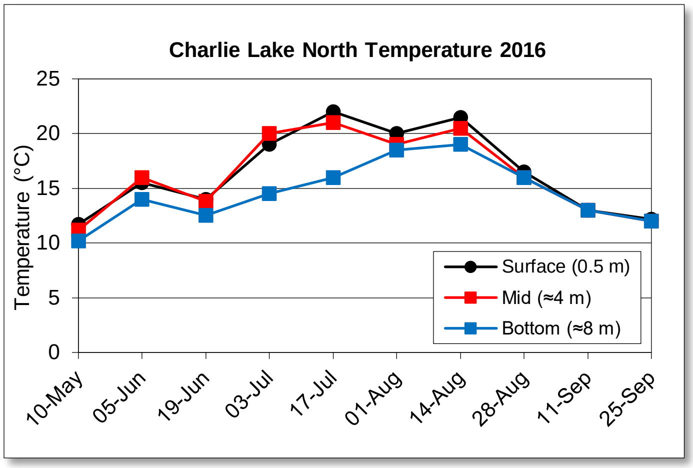


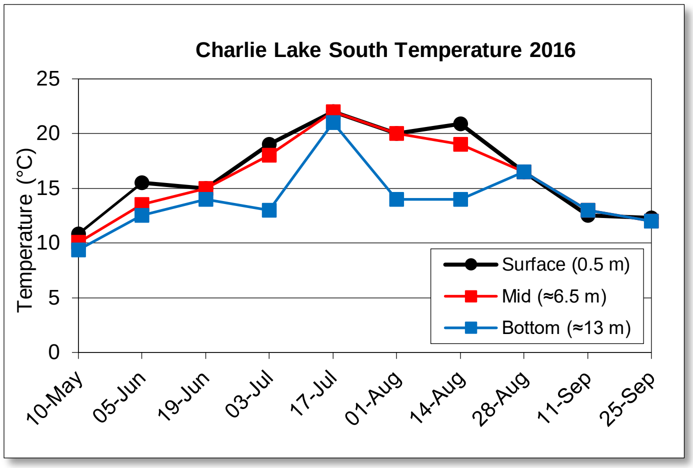
Charlie Lake was isothermal (at the same temperature from the top to the bottom) at both sites on August 28, 2016, shown in the following DO/T profiles, indicating that Fall overturn had occurred.





The following figures show the temperature at both sites for all sampling dates in 2016 and confirm that Fall overturn had occurred at August 28, as the lake was still shown to be mixed through September 25.





In 2017, data indicate that both sites were thermally mixed on August 20, however the lake then weakly stratified and was shown to be mixed again during sampling on September 17.

Fall overturn was not captured in August of 2018, as on August 19 the DO/T profile for both sites shows the lake was still stratified. The subsequent profiles were taken on September 30 and show that the lake was fully mixed.

The maximum surface temperatures for both volunteer sampling programs are shown in the Trophic Characteristics table on Page 5. Maximum surface temperatures were similar for all sampling years; however, it is important to note that the 2005 value was estimated. The previous Charlie Lake report indicated that the thermometer used was defective, resulting in values to be recorded 6-7°C cooler than actual temperatures during 2005 (Jacklin, 2005).

Dissolved Oxygen

Oxygen is essential to life in lakes. It enters lake water from the air by wind action and also through plant photosynthesis. Oxygen is consumed by respiration of animals and plants, including the decomposition of dead organisms by bacteria. A great deal can be learned about the health of a lake by studying oxygen patterns and levels.

Lakes that are less productive (oligotrophic) will have sufficient oxygen to support life at all depths throughout the year. But as lakes become more productive (eutrophic) and increasing quantities of plants and animals respire and decay, more oxygen consumption occurs, especially near the bottom where dead organisms accumulate.

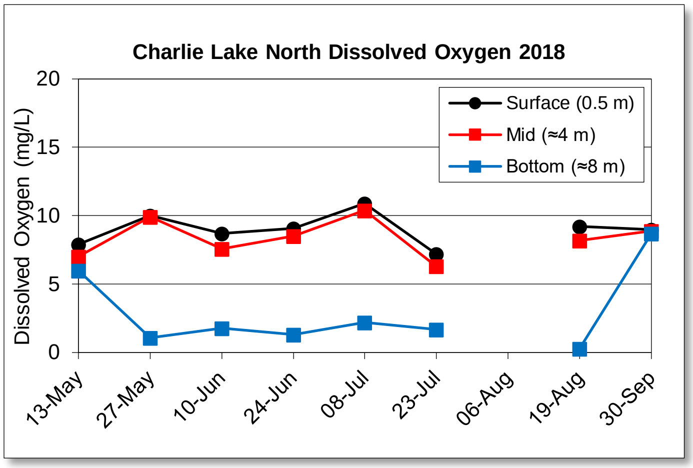
In productive lakes, oxygen in the isolated bottom layer may deplete rapidly (often to anoxia), forcing fish to move into the upper layer (salmonids are stressed when oxygen levels fall below about 20% saturation) where temperatures may be too warm. Fish kills can occur when decomposing or respiring algae use up the oxygen. In the summer, this can happen on calm nights after an algal bloom, but most fish kills occur during late winter or at initial spring mixing because oxygen has been depleted under winter ice.

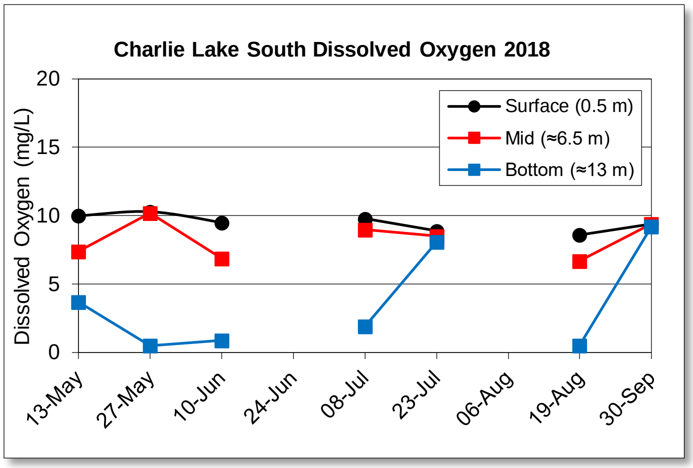
Oxygen levels in Charlie Lake are generally in the moderate to high range, allowing for the support of fish at all depths, with the exception of bottom waters during periods in the summer (Heslop, 2017). For the 2016-2018 sampling years, dissolved oxygen ranged from 0-16 mg/L. The typical range expected for DO values is 0-12 mg/L and higher values are often the result of algal blooms or heavy aquatic plant growth, both of which Charlie Lake has in abundance in the summer. Atypical values could be the result of sampling error or a storm event with heavy rains, high winds, and flooding inflows from inlet streams. Extreme outliers were removed from the data set.

As previously mentioned, full DO/T profiles for 2016 were not available until August, however values were collected at surface, mid, and bottom depths. Low DO concentrations (< 4 mg/L) were recorded in bottom waters of the North site in July and during July and August at the South site.

Low dissolved oxygen conditions were observed in bottom waters of Charlie Lake shortly after Spring overturn in 2017 and 2018 and continue through the summer months. Anoxic conditions (< 2 mg/L) are evident in bottom waters at both sites by August in each year. The minimum near bottom dissolved oxygen levels are shown in the Trophic Status chart on Page 5.

The July 23, 2018 DO/T profiles on Page 7 indicate low oxygen conditions in bottom waters of the North site, whereas the South site was mixed, with DO replenished at all depths throughout the water column. This is also shown in the 2018 DO graphs below.





On Page 7, the Fall overturn DO/T figure for the North site on August 28, 2016 indicate that DO concentrations had not been fully replenished, with values ranging from 3.70-4.44 mg/L. The DO/T figure for the South site indicates that DO had been replenished throughout the water column with Fall overturn.

No evident differences in DO concentrations were observed between the two monitoring periods, 2016-2018 and 2003-2005. This indicates that Charlie Lake has experienced relatively stable oxygen levels over time.

Trophic Status

The term *trophic status* is used to describe a lake's level of productivity and depends on the amount of nutrients available for plant growth, including tiny floating algae called phytoplankton. Trophic status is often determined by measuring levels of phosphorus, algal chlorophyll *a* (chl. *a*) and water clarity. Establishing the trophic condition of a lake allows inter-lake comparisons and general biological and chemical attributes of a lake to be estimated.

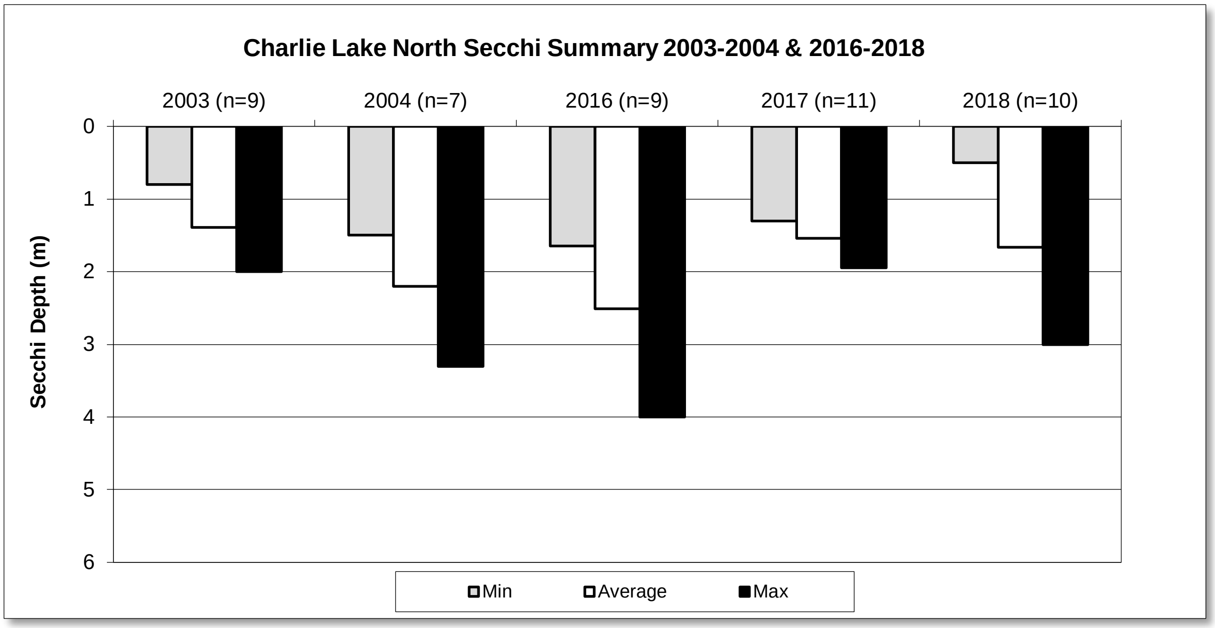
Lakes of low productivity are referred to as ***oligotrophic***, meaning they are typically clear water lakes with low nutrient levels (1-10 µg/L TP), sparse plant life (0-2 µg/L chl. *a*) and low fish production. Lakes of high productivity are ***eutrophic***. They have abundant plant life (>7 µg/L chl. *a*) because of higher nutrient levels (>30 µg/L TP). Lakes with an intermediate productivity are called ***mesotrophic*** (10-30 µg/L TP and 2-7 µg/L chl. *a*) and generally combine the qualities of oligotrophic and eutrophic lakes.

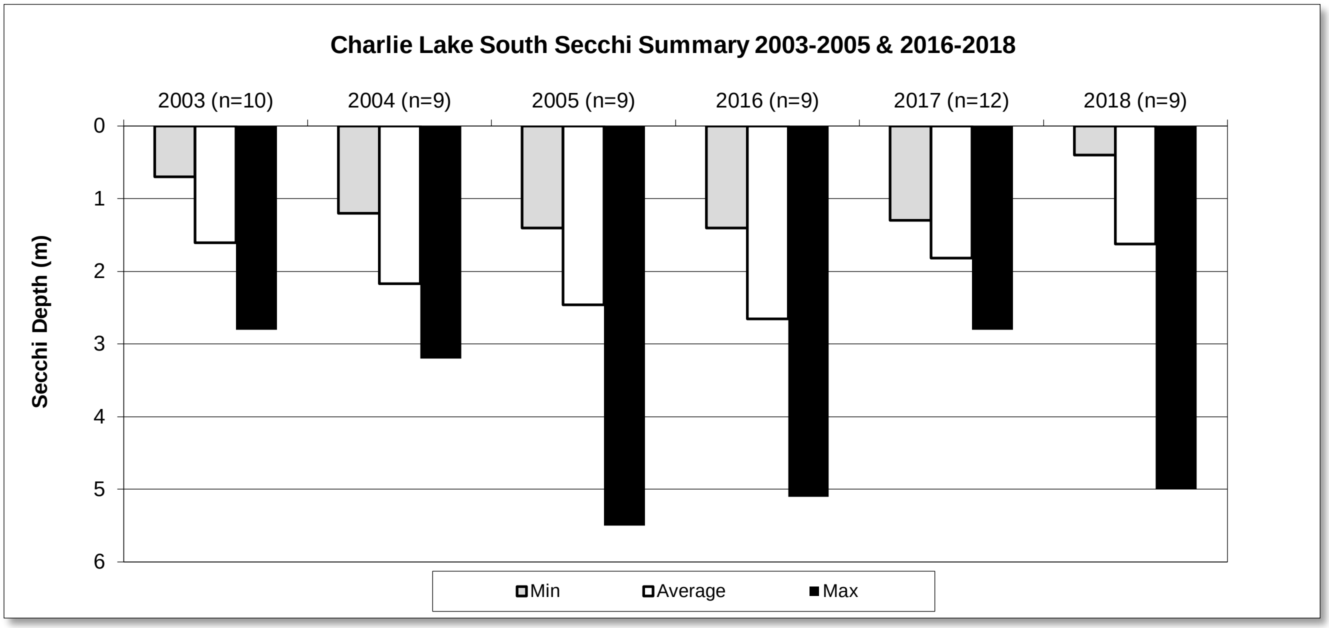
Water Clarity

As mentioned in the previous section, one method of determining productivity is water clarity. The more productive a lake is, the higher the algal growth and, therefore, the less clear the water becomes. The clarity of the lake water can be evaluated by using a Secchi disc, a black and white disc that measures the depth of light penetration.

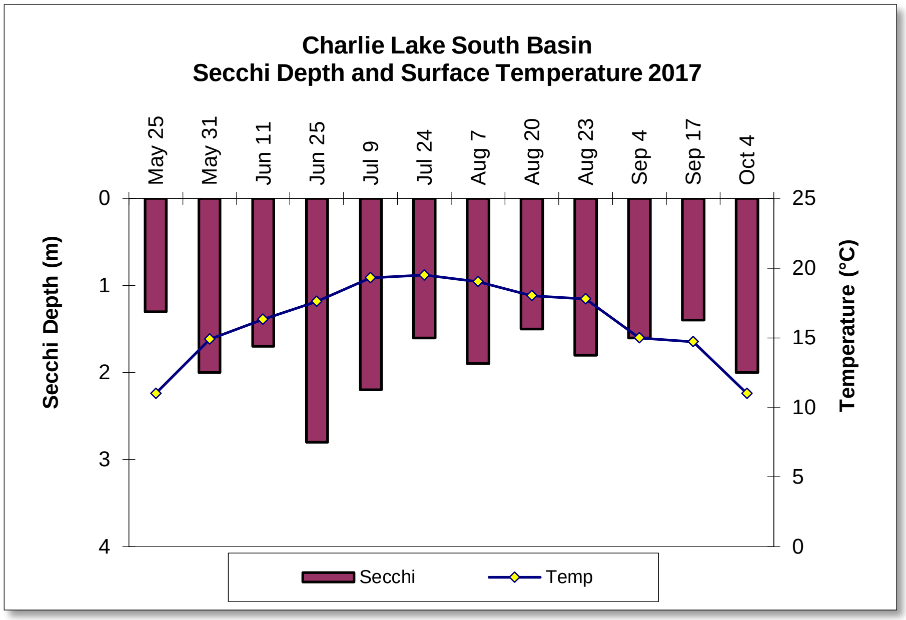
The following graphs shows the minimum, average and maximum Secchi depths recorded at both sites on Charlie Lake from 2016-2018 along with readings from 2003-2004 and 2005 at the South site only. The number of readings each year (n) indicate that the minimum data requirement of 12 readings was not met for each year, making comparison between the years difficult.

During these years of sampling, the average Secchi depth measurements ranged from 1.39 m (2003) to 3.23 m (2016) at the North site and 1.61 m (2003) to 2.65 m (2016) at the South site. There is no apparent increasing or decreasing trend with Secchi readings. Based on the average Secchi values, Charlie Lake was exhibiting eutrophic conditions during the sampling periods (Nordin, 1985).





Natural variation and trends in Secchi depth and temperature not only occur between years, but also throughout one season. In general, as temperature increases during the summer months, the Secchi depth decreases. As temperature increases, some species of algae increase in abundance. Due to the increase in algae, the water clarity decreases and the Secchi depth decreases. This relationship is not apparent in the 2017 South basin data (n=12), shown in the following Secchi depth and surface temperature graph.



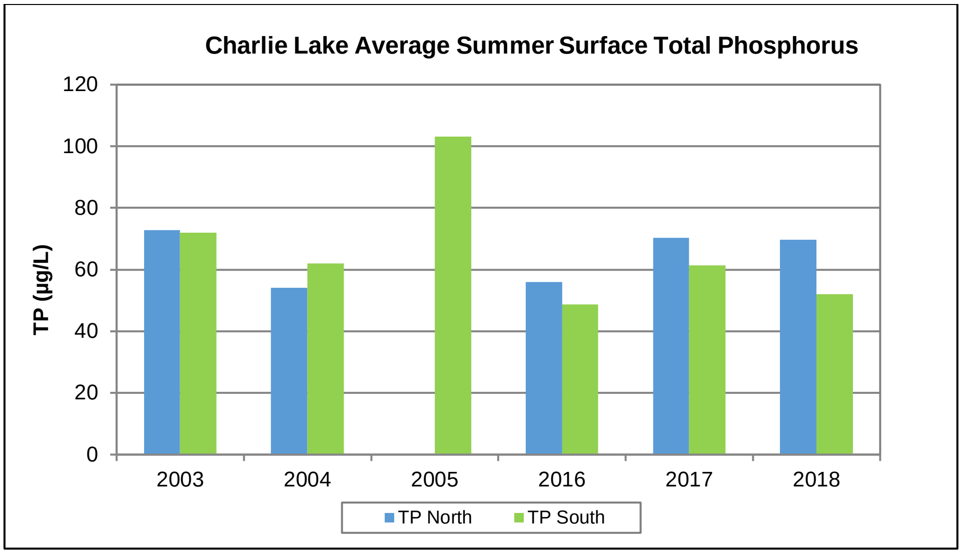
Phosphorus

As mentioned previously, productivity can also be determined by measuring phosphorus levels. Phosphorus concentrations measured during spring overturn can be used to predict summer algal productivity. Productivity is dependent on the amount of nutrients (phosphorus and nitrogen) in a lake, which are essential for plant growth, including algae. Algae are important to the overall ecology of a lake because they are the food for zooplankton, which in turn are the food for other organisms, including fish. In most lakes phosphorus is the nutrient in shortest supply and thus acts to limit the production of aquatic life. When in excess, however, phosphorus accelerates growth and artificially ages a lake. Total phosphorus (TP) in a lake can be greatly influenced by human activities.

Lake sediments can themselves be a major source of ortho-phosphorus (OP), a form of total dissolved phosphorus (TDP). If deep-water oxygen becomes depleted (i.e. anoxic), a chemical shift occurs in bottom sediments. This shift causes sediment to release phosphorus to overlying waters. This *internal loading* of phosphorus can be natural but is often the result of phosphorus pollution. Lakes displaying internal loading have elevated algal levels and generally lack recreational appeal.

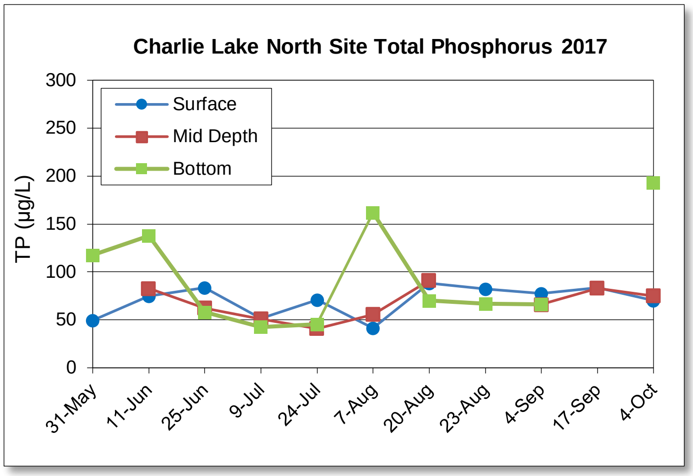
As noted in the 2003-2005 Charlie Lake report, although Spring TP concentration is often used to predict summer productivity levels, it is often difficult to do so when the lake exhibits internal phosphorus loading. This loading, which is dependant on the bottom level dissolved oxygen concentration, can influence algal productivity when bio-available (ortho) phosphorus is released. Charlie Lake usually exhibits internal loading each summer (Jacklin, 2005).

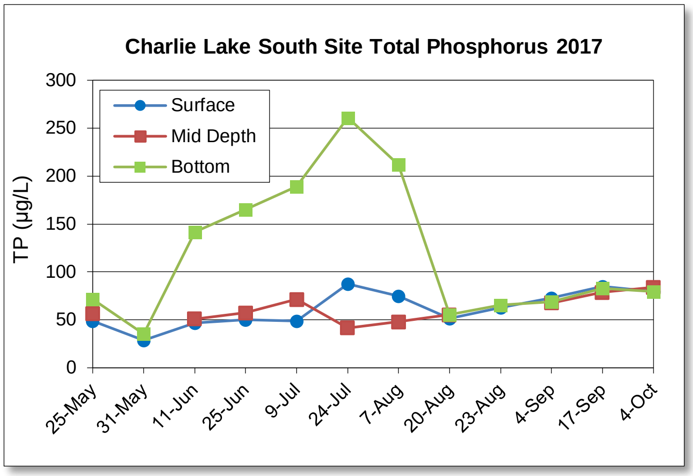
As previously indicated, DO/T profiles show that the lake was not mixed at the time of the Spring overturn sampling from 2016-2018. Since optimal Spring overturn phosphorus data is not available, average summer TP (surface readings only) were used to determine trophic status. The following graph shows the average summer surface TP values for both sites from 2003–2005 and 2016–2018. Sampling did not take place in 2005 at the North site. The variation in TP could be attributable to changing rates of internal phosphorus loading, which can be affected by bottom depth oxygen levels and the amount of algae and vegetation growth throughout the summer. This variation might also be influenced by external TP loading rates.

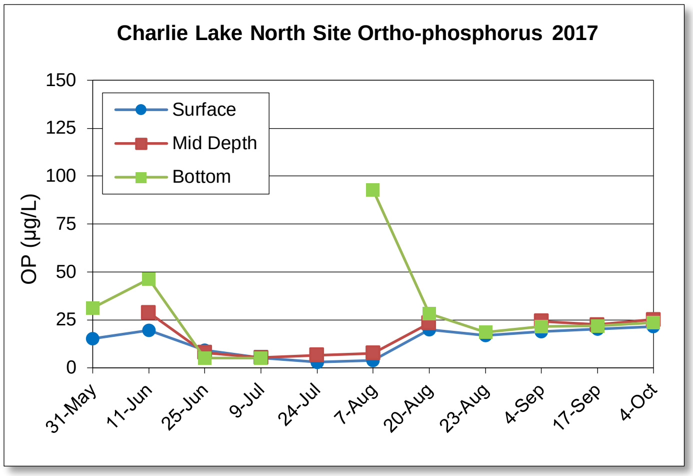


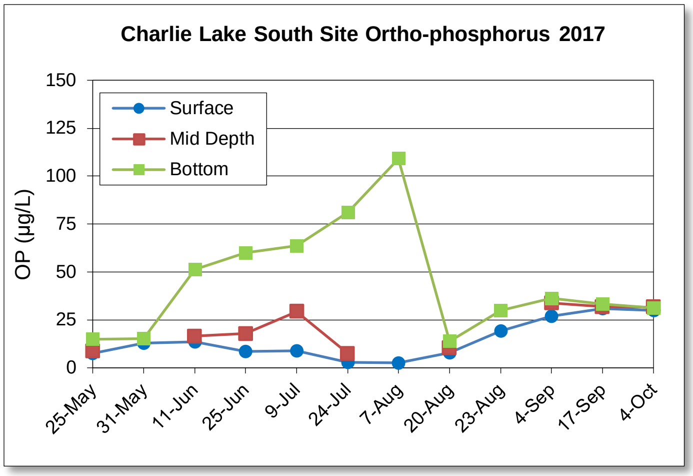
Summer surface TP values indicate eutrophic conditions (TP > 30 µg/L) (Nordin, 1985). This corresponds with most historical data collected between 1974 through 2005 (Jacklin, 2005).

The following figures show TP and ortho-phosphorus (OP) trends at the North and South sites in 2017. The July 24 OP bottom depth reading and September 17 TP and TDP bottom depth readings at the North site and the August 7 OP mid depth reading at the South site were excluded from the data set as the relative percent difference (RPD) calculated during Quality Assurance/Quality Control (QA/QC) indicated problems with the data.









The 2017 phosphorus data indicates that TP values are relatively low in the surface and mid depths throughout the sampling season, with higher values sporadically occurring in the bottom waters. Phosphorus data from 2016 and 2018 show similar patterns, which coincides with the 2003 to 2005 data.

At the North site, TP bottom water concentrations are elevated on May 31, with OP concentrations somewhat higher as well. However, since the TP bottom concentration is significantly higher than the coinciding increase in OP, the elevated value could be due to the bottom sediment being disturbed during sampling. This may also be the case for the June 11 and October 4 TP bottom water samples as the bottom water concentration is significantly higher than the corresponding OP. TP bottom waters increase to 162 µg/L on August 7, with OP showing a corresponding increase. Low DO was also present in bottom waters on this date, which, with high OP concentrations in the bottom waters, is indicative of internal loading.

At the South Site, TP bottom water concentrations are elevated from June 11 through to August 7, with the highest concentration of 261 ug/L on July 24. DO/T profiles from June 11 to August 7 show low oxygen conditions in bottom waters which, along with high OP concentrations in bottom waters, is indicative of internal loading.

Nitrogen

Nitrogen is the second most important nutrient involved in lake productivity. In BC lakes, nitrogen is rarely the limiting nutrient for algae growth (see phosphorus). In most lakes, the ratio of nitrogen to phosphorus is well over 15:1, meaning excess nitrogen is present. In lakes where the N:P is less than 5:1, nitrogen becomes limiting to algae growth and can have major impacts on the amount and species of algae present.

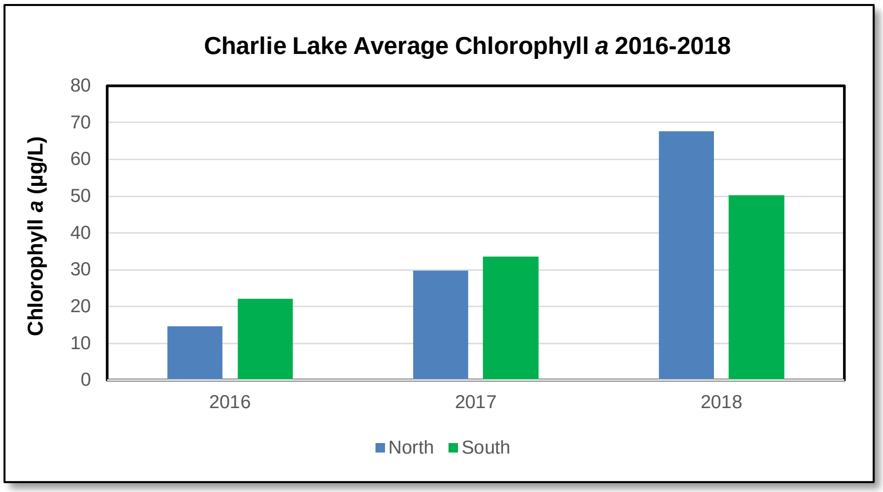
Nitrogen was not collected as part of the volunteer sampling program or in 2003-2005 during the Ministry of Environment and Climate Change Strategy's Spring overturn sampling. As previously noted, DO/T profiles indicate sites were not fully mixed during Spring sampling in 2016-2018. As Spring overturn was not captured in any of the sampling years, the N:P ratio for Charlie Lake was calculated in two ways, which results in different interpretations (Nordin, 2020).

Using Spring water column values (even though the lake was not fully mixed) indicates phosphorus limitation (N:P >15). Comparing water column averages of Spring N to Summer average P, results in an indication that there may be co-limitation with N and P (N:P between 5 and 15). The data does not show any evidence of N limitation (< 5) (Nordin, 2020).

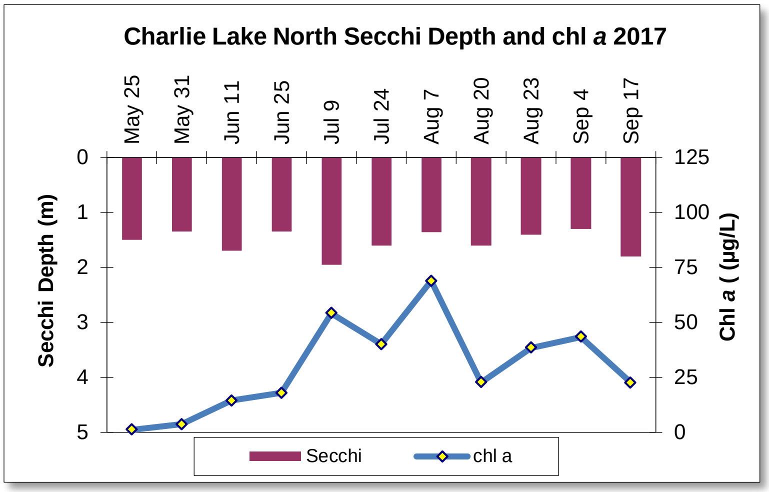
Chlorophyll *a*

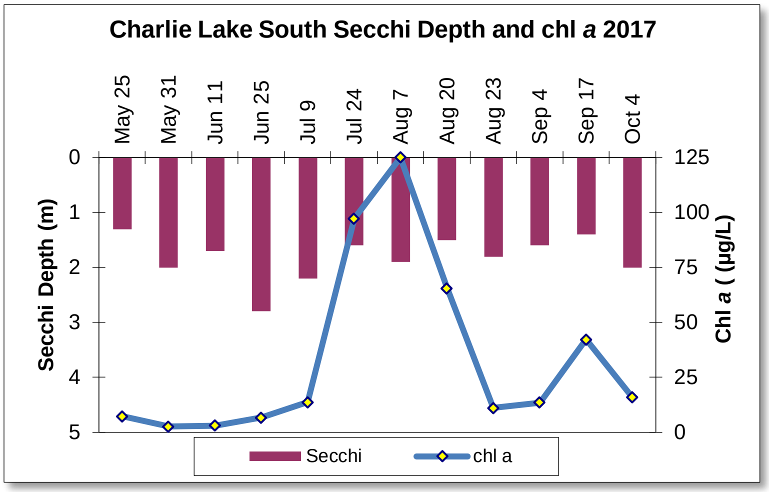
Chlorophyll *a* is the common green pigment found in almost all plants. In lakes, it occurs in plants ranging from algae phytoplankton) to rooted aquatic forms (macrophytes). Chlorophyll captures the light energy that drives the process of photosynthesis. While several chlorophyll pigments exist, chlorophyll *a* is the most common. The concentration of chlorophyll *a* in lake water is an indicator of the density of algae present in that same water.

Average seasonal chlorophyll *a* is shown in the following figure for the North and South sites. Chlorophyll *a* averages had remained relatively stable over the sampling years and show an increase in 2018 due to two very high readings. On August 19, 2018, the North site had a chlorophyll *a* value of 493 µg/L and field notes indicated algae suspended in surface waters. On July 23, 2018, the South site had a chlorophyll a value of 263 µg/L and field notes indicated a thick blue green algae layer at this site but not the North site. Average chlorophyll *a* values indicate eutrophic conditions (> 7 µg/L) (Nordin, 1985).



The following figures show the correlation between chlorophyll *a* and Secchi depth in Charlie Lake in 2017. As algal concentrations increase, Secchi readings often decrease, suggesting Secchi values are a reasonable indicator of chlorophyll *a*. However, this correlation is not strong in the following figures.





In general, the highest chlorophyll *a* values are in July and August, indicating the greatest growth during these months. The increase in chlorophyll *a* values in early fall could be a result of algal cells and other detritus being washed down from input streams later in the fall (Heslop, 2017).

Aquatic Plants

Aquatic plants are an essential part of a healthy lake. They play an important role in the lifecycle of aquatic insects, provide food and shelter from predators for young fish, and also provide food for waterfowl, beavers and muskrats.

Factors that affect the type and amount of plants found in a lake include the level of nutrients (i.e. phosphorus), temperature, and introduction of invasive species.

Since 2011, Charlie Lake has shown an increase from few plants to extensive plant beds all around the lake. Although they are non-invasive plants, the have created issues with lake residents and boaters. In the late seventies, prior to the raising of the lake level by 1 metre, there were plant beds around the lake. After the raising of the lake level when a weir was installed at the outlet of the lake, the plant beds disappeared except for two limited locations (Kosugi, 2017).

Aquatic plant surveys are a general assessment that provides a snapshot of existing conditions within a lake that can be compared to other surveys of that lake over time or to lakes in other areas of the province. The data can add to any information already collected or serve as a baseline for future surveys and studies.

Aquatic plant species were surveyed in Charlie Lake (Warrington, 1980) and include: *Potamogeton L., Scirpus L., Potamogeton perfoliatus L., Polygonum amphibium L., Callitriche L., Potamogeton pectinatus L., Myriophyllum exalbescens fern., Scirpus lacustris L., Polygonum L., Potamogeton praelongus wulf., Callitriche stagnalis scop..*

In 2012, 2014, and 2016, plant surveys were conducted by the Charlie Lake Conservation Society and the Ministry of Forest, Lands and Natural Resources Operations which represented the first time aquatic plant distribution in Charlie Lake was quantified spatially. All plants observed were native to the area, and no invasives were identified. Previously undocumented plants have been identified and include: *Potamogeton zosteriformis* and *Elodea canadensis.*

The BC Lake Stewardship Society provided further aquatic plant survey training in 2018 as part of a LakeKeepers workshop and Charlie Lake Conservation society conducted surveys in 2019 and 2020 along 5 transects in Charlie Lake. It was observed that *Elodea canadensis* had become a dominant species within each of the transects over one year (Kosugi, 2020).

Aquatic plant species can spread between lakes via boaters. Be sure to check for and remove all organic material and mud from boats, trailers, and equipment (boots, waders, fishing gear). Drain onto land all items that can hold water (buckets, wells, bilge, and ballast) and dry all items before launching into another body of water (ISCBC, 2020).

Should Further Monitoring Be Done on Charlie Lake?

Charlie Lake is one of the most eutrophic freshwater lakes in British Columbia (Reavie et al, 1995). This high productivity results in algae blooms and aquatic plants which impact recreation activities and aesthetics. Water quality assessments of the lake have shown that dense blue-green algae blooms have occurred consistently over the last four decades of record (Heslop, 2017).

The data collected by volunteers on Charlie Lake indicates that the water quality has remained relatively stable over the sampling years. There does not appear to be any evident trend over the 40 year period for which sampling has been done (Nordin, 2020). Secchi data, total phosphorus levels, and chlorophyll *a* concentrations support the eutrophication classification of Charlie Lake. Algae blooms were reported during sampling years and an increase in aquatic plants has been observed (CLCS, 2020).

Although volunteer monitoring programs can accurately document current lake quality, it cannot reveal historical "baseline" conditions or long term water quality trends. Coring lake sediments can provide valuable historical information on lakes. Past changes in water quality can be inferred by studying the annual deposition of algal cells (in this case diatoms) on the lake bottom. Diatoms are a type of phytoplankton (algae) commonly found in lake environments. Their glass-like shell (known as a frustule) is composed of silicon. This frustule leaves a permanent record of diatom history in lake bottoms. Historical changes in relative diatom abundance are measured directly by microscopy. By knowing the age of various core sections and the phosphorus preference of the specific diatom in each section, historical changes in lake phosphorus concentrations, chlorophyll, and water clarity can be estimated. Quantitative analysis of a sediment core collected from Charlie Lake indicate that the lake was highly productive before human development existed on the lake. Analysis also indicates that the TP concentrations have increased approximately 40 µg/L from the 1870s to 1991, during the period of human settlement, deforestation, agricultural development, and sewage disposal in the area (Heslop, 2017) which thereby increased algal abundance.

Based on land use such as agriculture and industrial development, chemistry could be sampled again in 5 years. Future programs should include more frequent sampling of dissolved oxygen and temperature to better capture mixing patterns. Local volunteers are encouraged to continue to record Secchi and surface temperature readings, with an emphasis on collecting a minimum of 12 evenly spaced readings between ice-off and ice-on. These data are important for long term records and will help identify early warning signs should there be a deterioration in water quality from its current state. Local volunteers are also encouraged to continue with their aquatic plant mapping program and recording ice-on and ice-off dates.

Tips to Keep Charlie Lake Healthy

Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
- Minimize high maintenance grassed areas.
- Replant lakeside grassed areas with native vegetation.
- Do not import fine fill.
- Use paving stones instead of pavement.
- Stop or limit the use of fertilizers and pesticides.
- Do not use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.
- Do not apply fertilizers or pesticides before or during rain due to the likelihood of runoff.
- Hand pull weeds rather than using herbicides.
- Use natural insecticides such as diatomaceous earth. Prune infested vegetation and use natural predators to keep pests in check. Pesticides can kill beneficial and desirable insects, such as lady bugs, as well as pests.
- Compost yard and kitchen waste and use it to boost your garden's health as an alternative to chemical fertilizers.

Agriculture

- Winter feeding of cattle should be a minimum of 30 m from a watercourse and located where no direct run off to streams and lake will occur.
- Install barrier fencing to prevent livestock from grazing on streambanks and lakeshore.
- Maintain or create a buffer zone of vegetation along a streambank, rivers or lakeshores.
- Ranchers are encouraged to have an Environmental Farm Plan for their operation (contact the Ministry of Agriculture).

Onsite Sewage Systems

- Inspect your system yearly, and have the septic tank pumped every 2 to 5 years by a septic service company. Regular pumping is cheaper than having to rebuild a drain-field.
- Use phosphate-free soaps and detergents.
- Do not put toxic chemicals (paints, varnishes, thinners, waste oils, photographic solutions, or pesticides) down the drain because they can kill the bacteria at work in your onsite sewage system and can contaminate waterbodies.
- Conserve water: run the washing machine and dishwasher only when full and use only low-flow showerheads and toilets.
- Use biodegradable household cleaners instead of bleach or other hazardous products (which will kill the good bacteria in your system).
- Avoid planting trees or shrubs near the drainfield because their roots can damage or plug the pipes.

Camping and Recreation

- Ensure black and grey water are contained and disposed of at a sanitation station.
- When washing yourself or your dishes, dip water out of the lake using a clean container and move 30 m away.
- Dispose of used water by throwing it over a large area away from your site, the sites of others, and flowing or standing water.
- Use phosphate-free, biodegradable soaps.
- If you pack it in, pack it out. Remove all garbage including biodegradable soaps.
- Ensure all vehicles are well maintained and tuned to prevent fuel leaks.

Auto Maintenance

- Use a drop cloth if you fix problems yourself.
- Recycle used motor oil, antifreeze, and batteries.
- Use phosphate-free biodegradable products to clean your car. Wash your car over gravel or grassy areas, but not over sewage systems.

Boating

- Do not throw trash overboard or use lakes or other waterbodies as toilets.
- Use biodegradable, phosphate-free cleaners instead of harmful chemicals.
- Conduct major maintenance chores on land.
- Use absorbent bilge pads to soak up minor leaks or spills.
- Clean, Drain, Dry. Clean off all organic material and mud from boat and equipment (boots, waders, fishing gear). Drain onto land all items that can hold water (buckets, wells, bilge, and ballast). Dry all items completely before launching into another body of water (ISCBC, 2020)
- Do not use metal drums in dock construction. They rust, sink and become unwanted debris. Use blue or pink closed-cell extruded polystyrene billets or washed plastic barrel floats. All floats should be labeled with the owner's name, phone number, and confirmation that barrels have been properly emptied and washed.
- Untreated cedar is the best choice for dock construction. In some places, pressure-treated wood is banned for waterfront use because it can leach chemicals into the environment.
- Leading by example is often the best method of improving practices - help educate fellow boaters.

Who to Contact for More Information

The BC Lake Stewardship Society
1257 Erskine Street Coquitlam, BC V3B 6R3
Phone: 604.474.2441
Email: info@bclss.org
Website: www.bclss.org

Charlie Lake Conservation Society
info@charlielakeconservationsociety.ca
http://www.charlielakeconservationsociety.ca/

BC Ministry of Environment and Climate Change Strategy
Kirsten McNeill
Public Feedback Welcomed
3rd Floor, 1011-4th Ave Prince George, BC, V2L 3H9
Phone: (250) 565-7201
Email: Kirsten.McNeill@gov.bc.ca

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Greg Warren (Ministry of Environment and Climate Change Strategy)
Dawn Roumieu (BC Lake Stewardship Society)

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