



Somenos Marsh WILDLIFE SOCIETY

Stewards of the S'amunu/Somenos Watershed



S'AMUNU | SOMENOS WATER QUALITY REPORT 2021

Somenos Marsh Wildlife Society

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Summary / Recommendations

Based on activities and results obtained in 2021, the Society recommends the following course of actions for year 2022:

Tributaries

- Continue measuring all Somenos Watershed tributaries and Somenos lake and locations recommended by the Municipality of North Cowichan to identify trends
- Send a full spectrum lab nutrient sample for each watercourse to be analysed at a lab and compare results to our YSI 9300 Photometer equipment

Somenos lake

- More frequent sampling (weekly) of Nitrate and Nitrites during high algal growth season to be able to compare the data and analyse trends.
- Determine timing of spring stratification (April or May) in 2022
- recommend doing blue-green algae toxicity testing during bloom in 2022 for public safety

Somenos Creek

- Check to ensure hobo data loggers are functioning properly every 2 weeks and download data to ensure we have enough information for each month.
- Test water quality in water discharging from culverts into Somenos Creek
- Investigate sources of high phosphate levels by sampling nutrients before and after it rains adjacent to farm fields along the creek
- Monitor dissolved oxygen levels more frequently during fall spawning migration season to determine cause of fluctuations and possible groundwater influences

Watershed

- Initiate a ground water study investigation to determine the source of Somenos Creek dissolved oxygen fluctuations, and other fluctuations in: TDS and conductivity that were observed this year.
- Create a trend report from 2014 to present to analyse changes of water quality parameters over time in the watershed.

Introduction

The S'amunu | Somenos Watershed (the Watershed) covers 71 km² located on land that includes the Municipality of North Cowichan (MNC), Cowichan Tribes, and discharges into a small section of the City of Duncan. The Watershed includes tributaries that flow from Mt. Prevost and Mt. Richards at Crofton Lake. The major tributaries are Richards, Averill, and Bings Creeks which flow into Somenos Lake, and exit into Somenos Creek. The end of the Watershed study area is where Somenos creek meets the Cowichan River. The Somenos Marsh Wildlife Society (The Society) has coordinated water quality monitoring in Somenos Lake for the MNC since 2014. In 2020-2021, the Society included monitoring the four major tributaries Richards, Averill, Bings, and Somenos Creeks.

The Watershed is impacted by agriculture, development, and a growing demand for more housing developments and supporting infrastructure. Runoff and airborne precipitation from these areas can discharge into the Watershed which may contain compounds that can cause an impact to the Watershed aquatic ecology.

Monitoring water quality allows us to understand the current state of the Watershed so we can identify impacts over time, and the location of anthropogenic sources from land-water connections. The monitoring results allow the Society to provide recommendations of future monitoring requirements, additional sampling parameters, and land use mitigations to the MNC and appropriate governing bodies.

Methods

Under the Municipality of North Cowichan Service Agreement for 2021, the Somenos Marsh Wildlife Society (The Society) Water Quality Monitoring parameters include:

- Weekly (Summer: May 01- Sep 30): Somenos Creek and Somenos Lake for T, DO, pH, conductivity with YSI
- Monthly (Winter: OCT 01 – Dec 31): Somenos Creek and Somenos Lake for T, DO, pH, conductivity with YSI
- Hourly (data loggers): Somenos Lake for T (lake station), Somenos Creek for T + irradiance (~6 stations)
- Monthly: 3 sites: Richards Creek, Somenos Lake, Somenos Creek for total phosphate, orthophosphate, ammonia, nitrate, nitrite, total nitrogen

In addition, the SMWS included weekly summer, and monthly winter sampling on Bings Creek and Averill Creek for:

- T, DO, pH, conductivity with YSI.

- Monthly sampling for total phosphate, orthophosphate, ammonia, nitrate, nitrite, total nitrogen

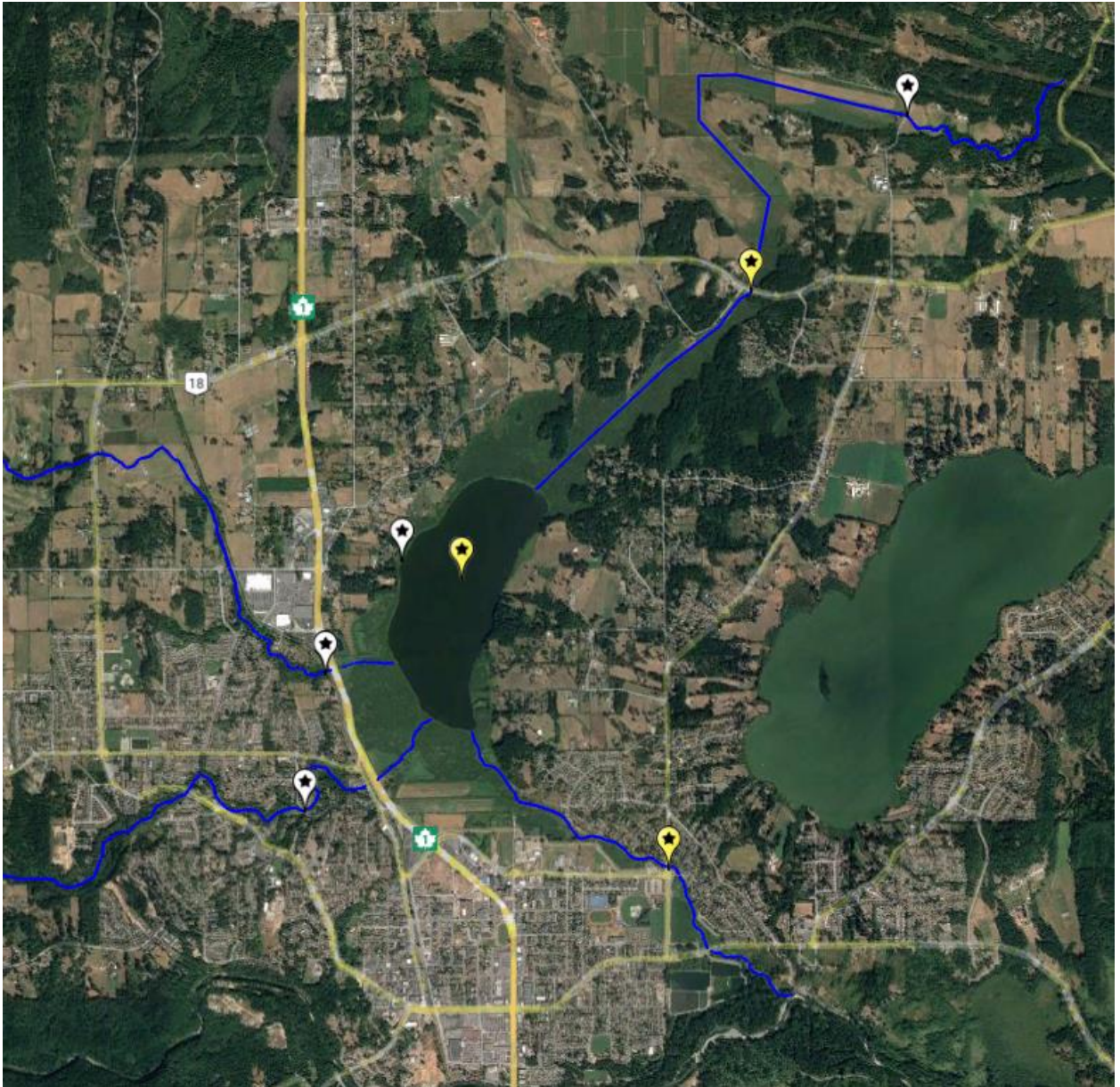


Figure 1: Locations of Water Quality Stations in 2021. Yellow starred sites represent Municipality required water quality stations.

The equipment used for collecting the water quality data parameters for temperature, pH, dissolved oxygen, turbidity, and specific conductivity in all the waterbodies was the YSI Professional Series Multi-probe. The probe was used twice a week and was fully calibrated once a month. The dissolved oxygen probe was replaced every 2 months, and the pH probe replaced once. Due to delays in shipments a pH probe replacement was delayed in September; therefore, a hand-held pH probe was

used to sample the surface and bottom of the lake using the Van Dorn water sampler. The Van Dorn was also used to collect the water samples from the Lake at the surface and bottom, and two of the deeper creeks at 1-meter depths (Somenos and Richards Creeks) for total phosphate, orthophosphate, ammonia, nitrate, nitrite, total nitrogen.

The data loggers used to monitor the hourly temperatures of the lake were Onset Hobo Pendants. Six data loggers were set at the lake in a profile, where 2 pairs were placed at 0m, 3m and 6m depths in Somenos Lake. Three more stations were set with 4 data loggers at each site. These stations are located on Somenos creek at the Lakes Road footbridge (station 1), mid-creek between Lakes Road and Somenos Lake (station 2), and station 3 at the Pond Liner (Figure 2). Two data loggers were set on the surface, and 2 at the bottom of the creek at each station.

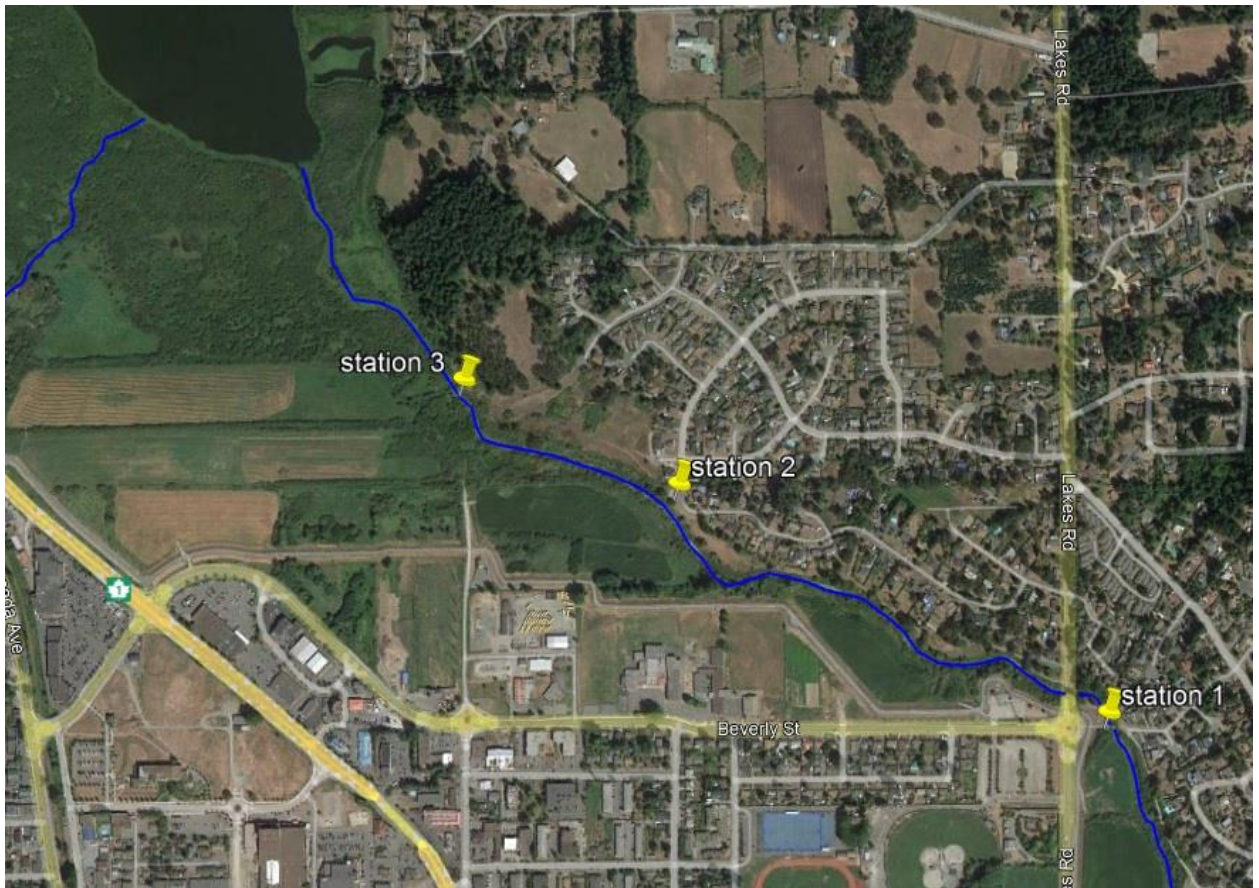


Figure 2: Water Quality Data Logger Stations on Somenos Creek.

Results

Somenos Lake

The weekly, monthly measurements of dissolved oxygen (DO), pH, temperature, conductivity profiles are represented in Charts 1 to 5. The monthly nutrient sampling of total phosphate, orthophosphate, nitrate, nitrite, total nitrogen is shown in Chart 6-12. Lake depths and hourly temperature data logger recordings are shown in Charts 13-14.

Temperature and Dissolved Oxygen

Dissolved oxygen levels and temperatures are important to monitor as an indicator of biological activities, lake stratification and fish habitat. Thus, looking at these two parameters will help us understand the biological activity in the lake and if fish are able to inhabit the lake at certain times of the year.

In Somenos Lake, temperature stratification began in May (6) and lasted until mixing occurred by September (30) (Chart 1). The dissolved oxygen stratification lasted from May (6) to September (23) and was evenly mixed by late September (30) (Chart 2). This shows similar stratification timing of temperature and dissolved oxygen in spring to summer and fall mixing with a slight delay in dissolved oxygen turnover in the fall by a few weeks.

In addition, it is possible the lake temperatures and dissolved oxygen spring stratification began in April; however, this month was not measured due to SMWS staffing transitions.

Chart 1: Somenos Lake Average Monthly Temperature Depth Profiles January to December 2021.

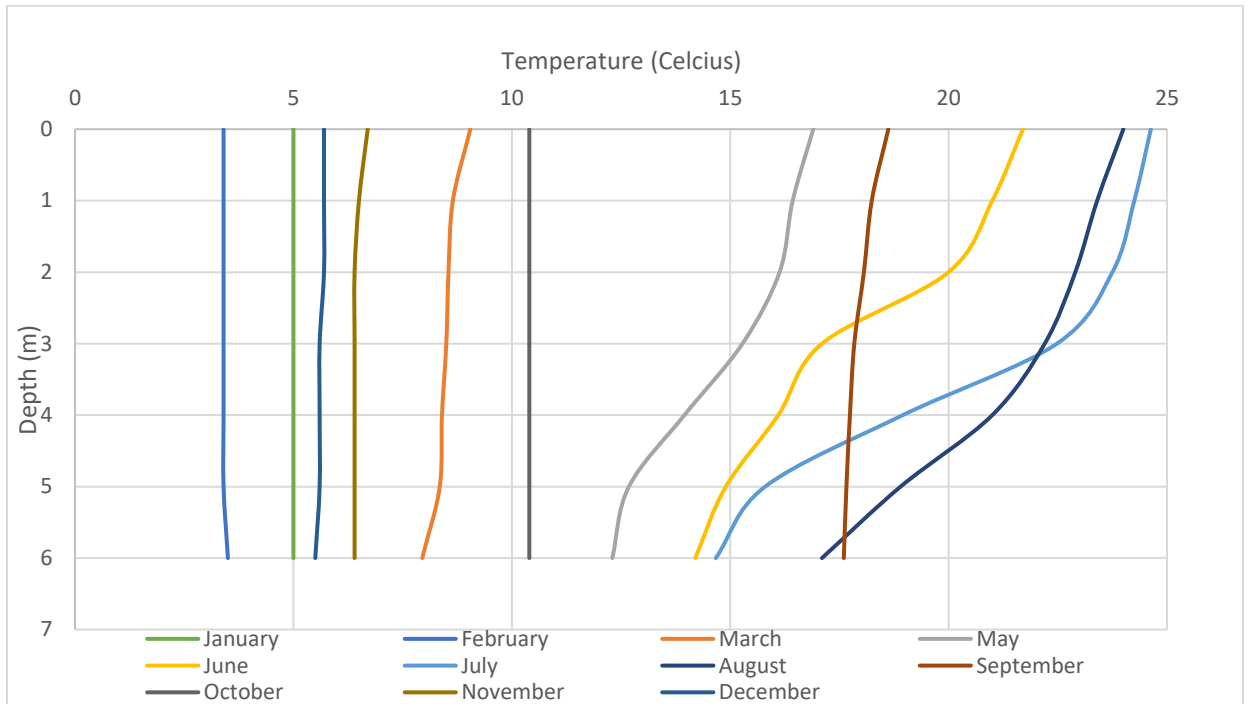
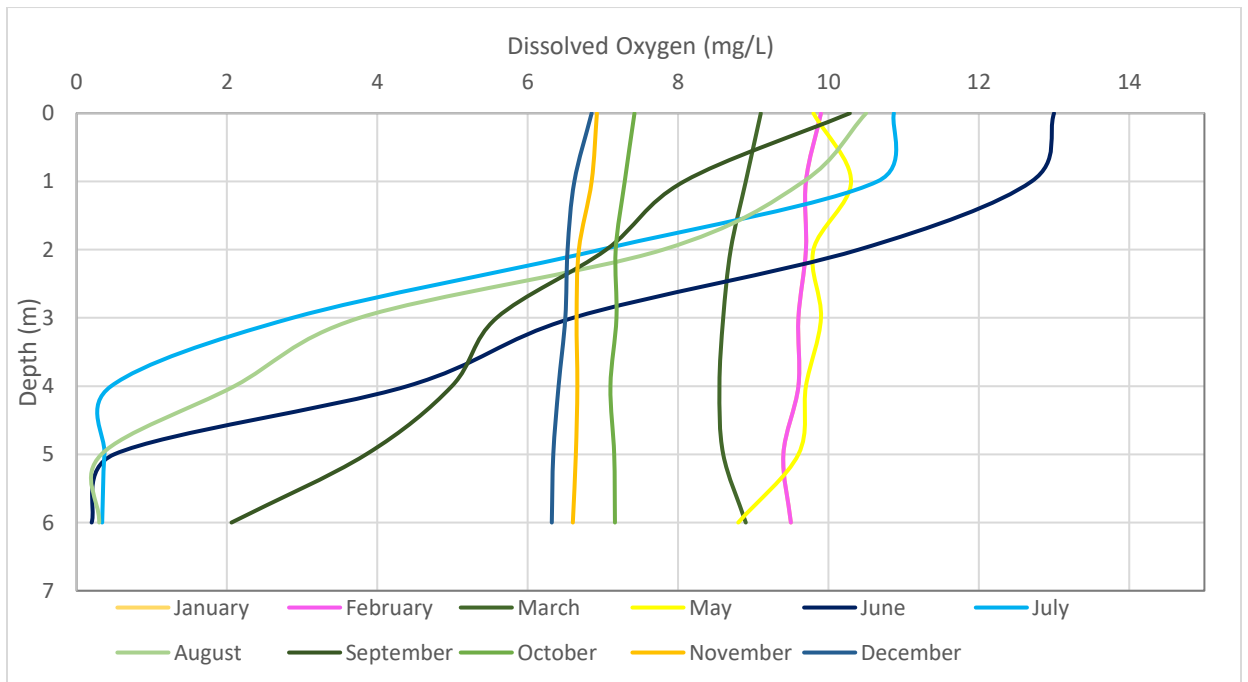


Chart 2: Somenos Lake Average Monthly Dissolved Oxygen Depth Profiles January to December 2021



The similar stratification times between lake temperatures and dissolved oxygen may be explained due to the thermal changes to the lake. When a lake stratifies, three different layers typically form. The shallowest layer is that warm surface layer, called the epilimnion. The epilimnion is the layer of water that interacts with the wind and sunlight, so it becomes the warmest and contains the most dissolved oxygen. The epilimnion is directly related to light penetration that can be measured as secchi depth (Chart 3) (Mazumder et.al.,1990). The deepest layer is called the hypolimnion which has colder, and thus denser water, that does not interact with the surface or obtain heat from sunlight. This layer has the least amount of dissolved oxygen and commonly becomes anoxic (EMS 2019). We can see this effect in Somenos Lake (Chart 3) as it becomes stratified.

The point of greatest temperature difference (and density difference) is called the thermocline and occurs between the top and bottom layers. This can be seen Chart 3 where the graph creates an S-shape from the 1 to 5 meter depths. This is where the monthly temperatures and dissolved oxygen dramatically change, and the thermocline transition can be seen more clearly. In Somenos Lake, these two parameters change at the same time, between May to September.

Charts 3a-k: Somenos Lake Dissolved Oxygen, Temperature, pH and Clarity profiles by Month

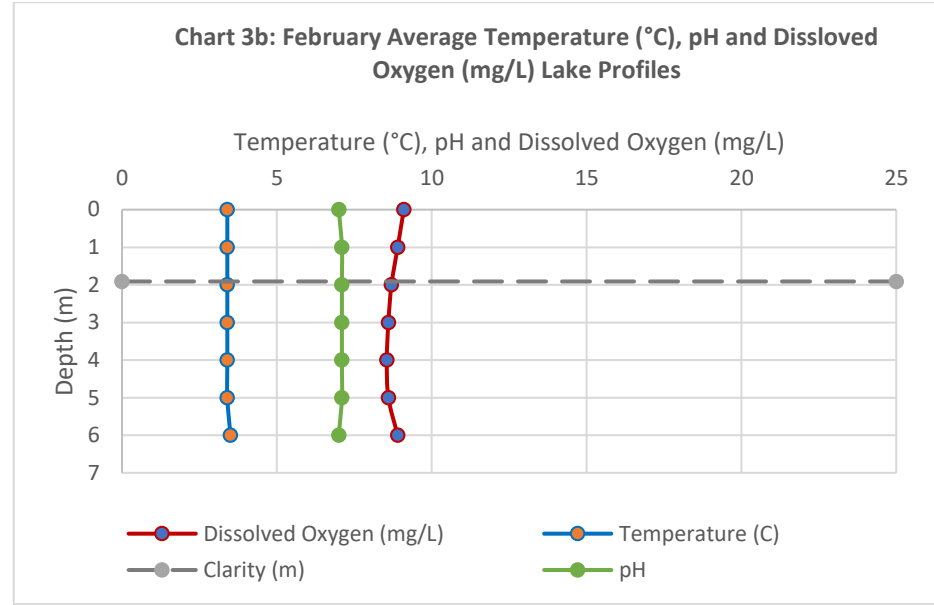
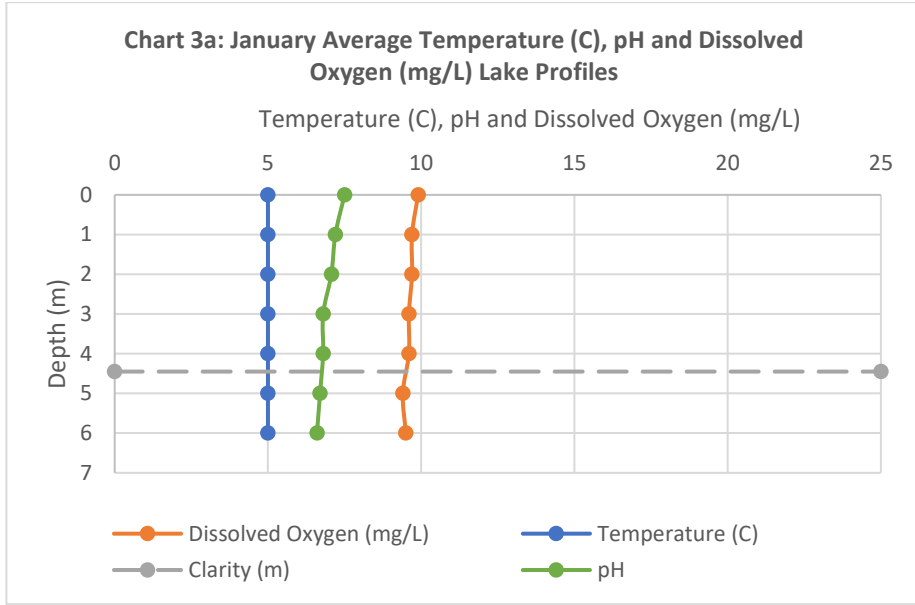


Chart 3d: May Average Temperature (C), pH and Dissolved Oxygen (mg/L) Lake Profiles

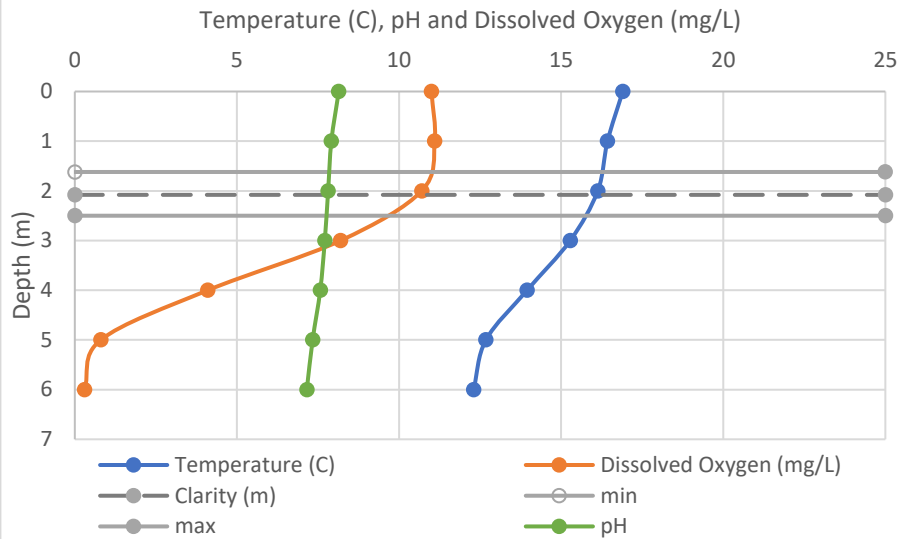


Chart 3d: May Average Temperature (C), pH and Dissolved Oxygen (mg/L) Lake Profiles

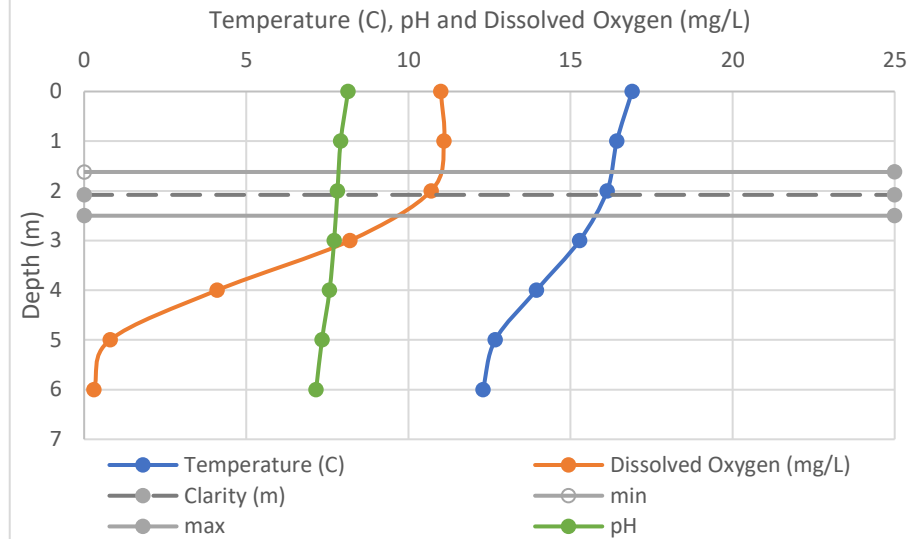


Chart 3e: June Average Temperature (°C), pH and Dissolved Oxygen (mg/L) Lake Profiles

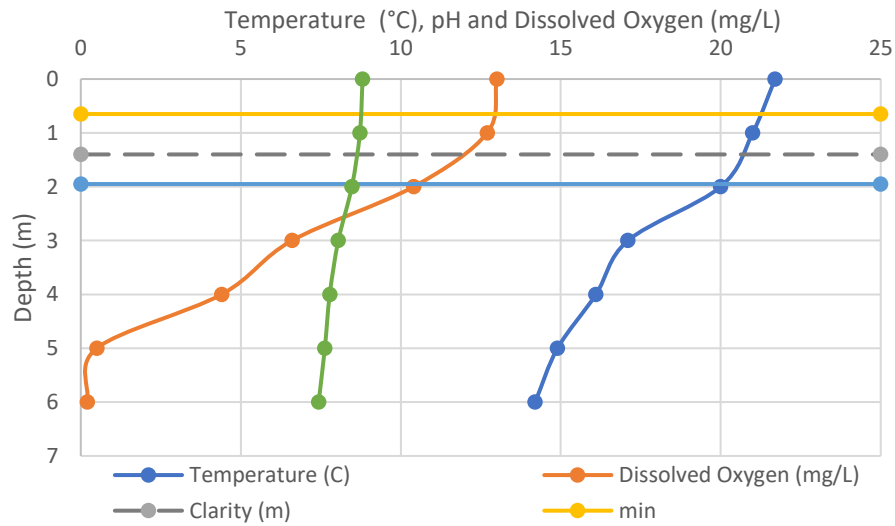


Chart 3f: July Average Temperature (°C), pH and Dissolved Oxygen (mg/L) Lake Profiles

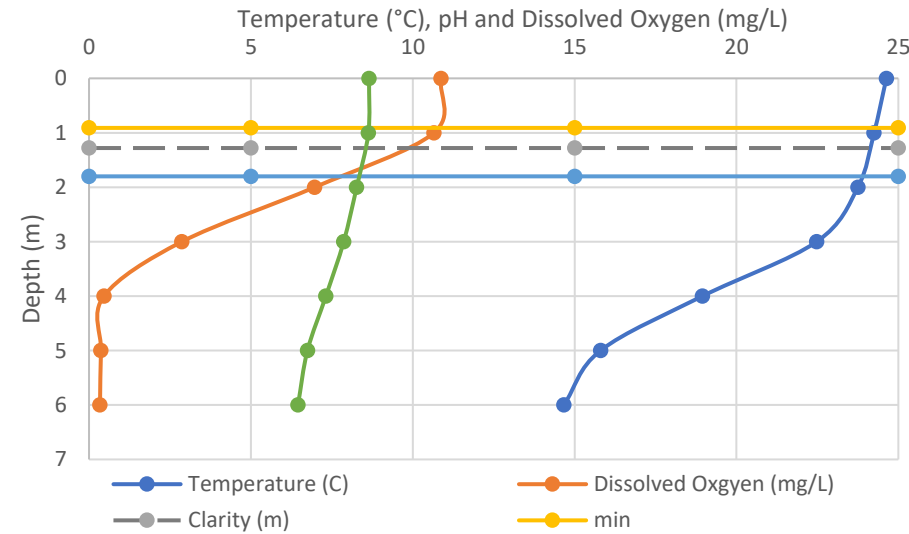


Chart 3g: August Average Temperature (C), pH and Dissolved Oxygen (mg/L) Lake Profiles

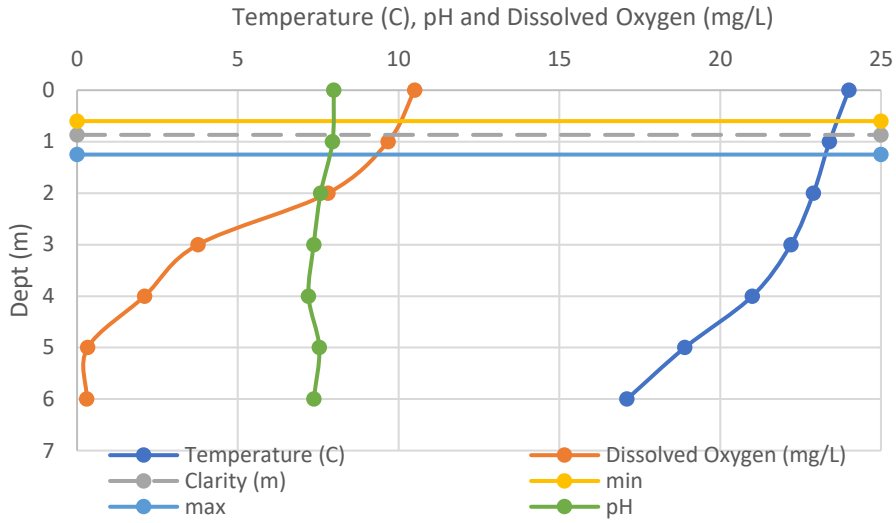


Chart 3h: September Average Temperature (°C), pH and Dissolved Oxygen (mg/L) Lake Profiles

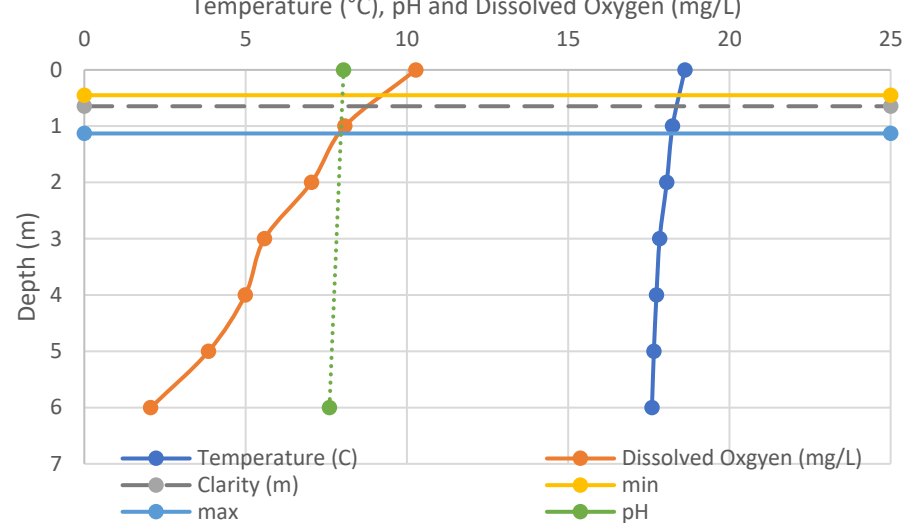


Chart 3i: October Average Temperature (°C), pH and Dissolved Oxygen (mg/L) Lake Profiles

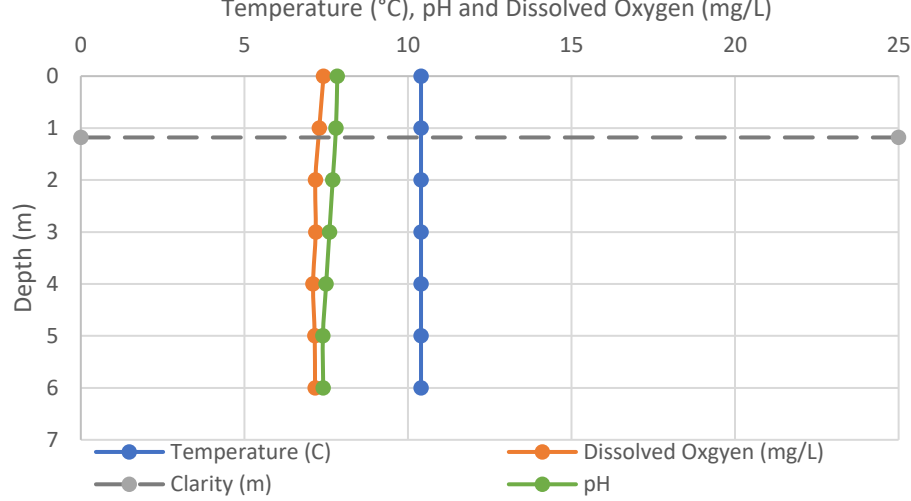


Chart 3j: November Average Temperature (°C), pH and Dissolved Oxygen (mg/L) Lake Profiles

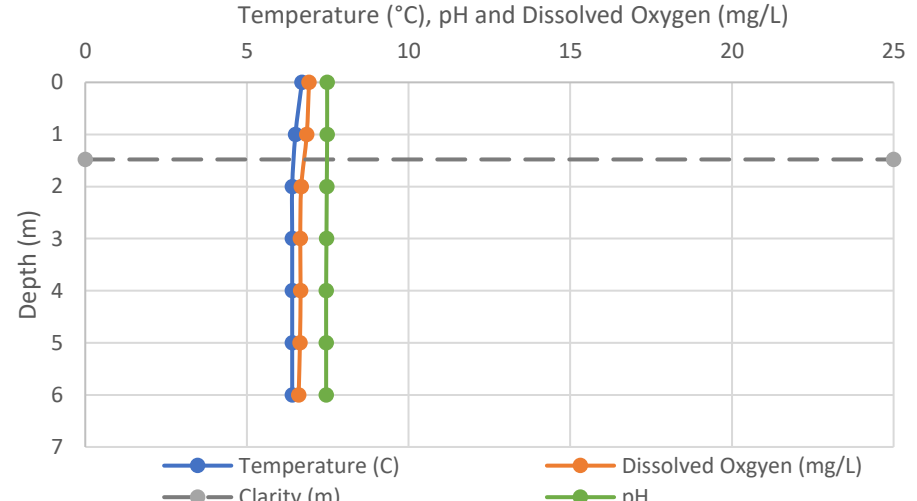
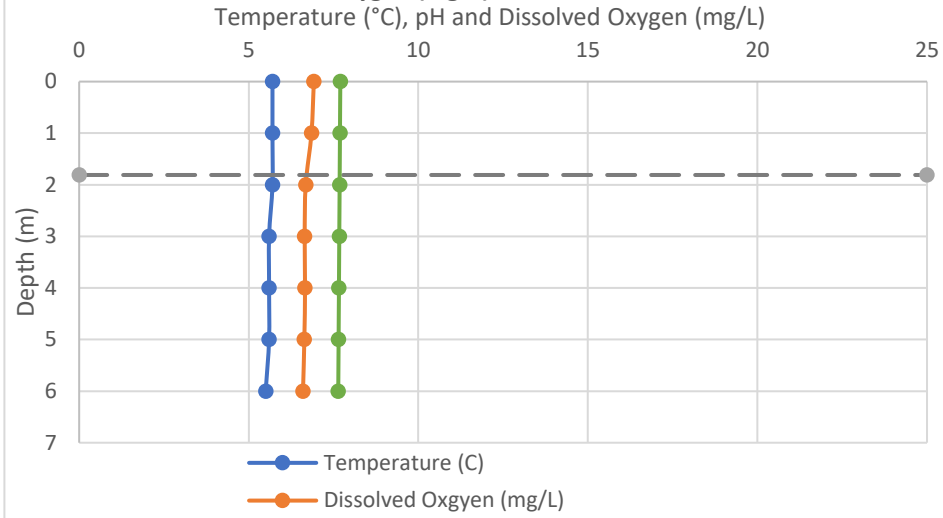


Chart 3k: December Average Temperature (°C), pH and Dissolved Oxygen (mg/L) Lake Profiles



One main importance of lake stratification observations is to determine where pockets of adequate temperature and dissolved oxygen levels exist in the lake, allowing fish to survive. Salmonids are known to use Somenos Lake as a migratory pathway and a refuge; however fish kills have been known to occur in the past due to summer anoxic conditions. Their dissolved oxygen thresholds range from: anoxia 0-4 mg/L; hypoxia 4.1-7 mg/L, sub-optimal 7.1-10 mg/L and optimal oxygen above 10 mg/L (Davis 1975). Salmonids are also intolerant to high water temperatures and depending on life stage and species their preferred temperatures are listed in Table 1.

Table 1: Optimum Temperature Ranges of Specific Life History Stages of Salmonids and Other Coldwater Species for Guideline Application Species

Species	Incubation °C	Rearing °C	Migration °C	Spawning °C
Chinook	5 to 14	10 to 15.5	3.3 to 19	5.6 to 13.9
Chum	4 to 13	12 to 14	8.3 to 15.6	7.2 to 12.8
Coho	5 to 13	9 to 16	7.2 to 15.6	4.4 to 12.8
Pink	6 to 13	9.3 to 15.5	7.2 to 15.6	7.2 to 12.8
Sockeye	7 to 13	10 to 15.5	7.2 to 15.6	10.6 to 12.8

Source: Water Quality Guidelines for Temperature: Overview Report (2001).

Dissolved oxygen levels in Somenos Lake (Chart 3) were lower in the summer (except at the surface) when the lake became stratified and recovered to higher levels in the fall with a lake turn-over occurring on September 30, 2021. Specifically, anoxic conditions began in May at a 4m depth, then June to September below 2-3m in the water column. During this time, when oxygen was sufficient for salmonid species survival near the surface, the temperatures were on average above 20°C, exceeding optimum temperatures for salmonids at any life stage (Table 1). Also, migration temperatures were not ideal for Coho, Chum, Pink or Sockeye until October. Chinook is the only salmonid that may have been able to begin migration in September near the surface of the lake, if conditions in Somenos Creek allowed.

The top 2 meters of the lake ranged between optimal (7 mg/L) to optimal (>10 mg/L) from spring to fall. The maximum dissolved oxygen reached 19.4 mg/L on June 17, 2021 at the surface of the lake. The high levels of dissolved oxygen observed at this time are due to super-saturated oxygen at the surface, caused by the photosynthetic production of oxygen from algae growth. Algae are buoyant and require photosynthesis to create energy, therefore they need to occupy the upper surface of a waterbody as they grow (Schindler and Vallentyne 2008).

As summer progressed, dissolved oxygen levels rapidly declined from the lake bottom up to only a few metres below the surface. It is in this period that blooms of algae become extensive, creating significant volumes of biomass near the surface. After the algal biomass uses up the available nutrients a mass die-off of algae occurs. With this die-off, oxygen levels collapse as turbidity increases, photosynthesis decreases, and bacterial decomposing consume the remaining depleting dissolved oxygen (Schindler and Vallentyne 2008).

Conductivity and TDS

Conductivity and TDS also have a correlated relationship and is also linked to changes in temperatures. A

decrease in the viscosity, or friction of water, increases the mobility of ions in water (EMS 2019). As such, an increase in temperature will mobilize ions, and increase conductivity. Conductivity increases 2-3% per 1°C increase in temperature (EMS 2019).

The second way temperature can affect conductivity is through ionic concentration. Many salts are more soluble at higher temperatures and as salt dissolves, it breaks down into its respective ions (EMS 2019). As warm water can dissolve several minerals and salts more easily than cold water, the ionic concentration is often higher. These dissolved solutes are often referred to as Total Dissolved Solids, or TDS. These salts and minerals enter the water from rocks and sediment in contact with it. As they dissolve and the ionic concentration increases, and so will the conductivity of water (EMS 2019). That is why in the warmer months as temperatures within the water column heat up, the TDS and conductivity increases at the bottom of the lake where it is in contact with the sediment (Charts 4 and 5).

Chart 4: Somenos Lake Average Monthly Conductivity Depth Profiles January to December 2021

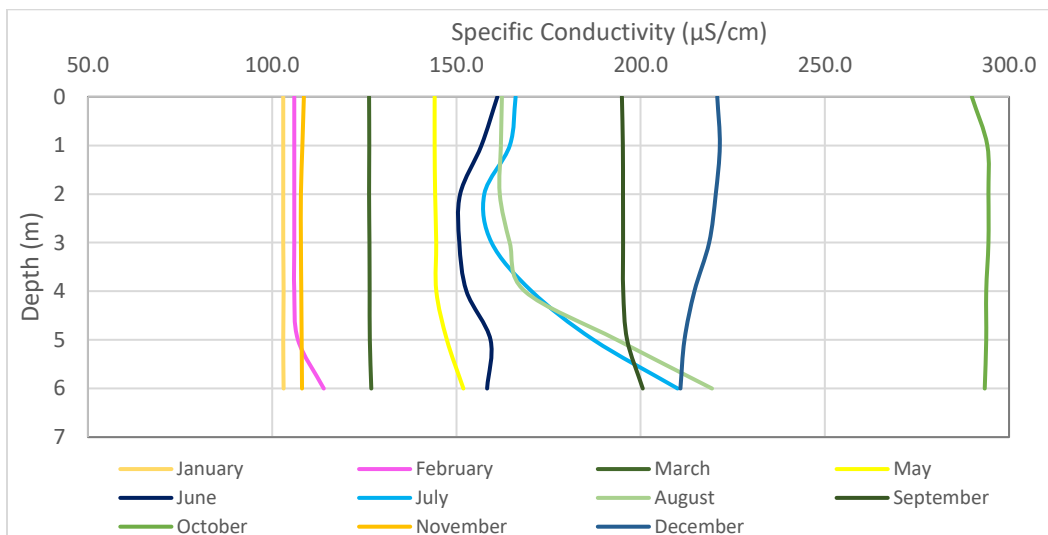
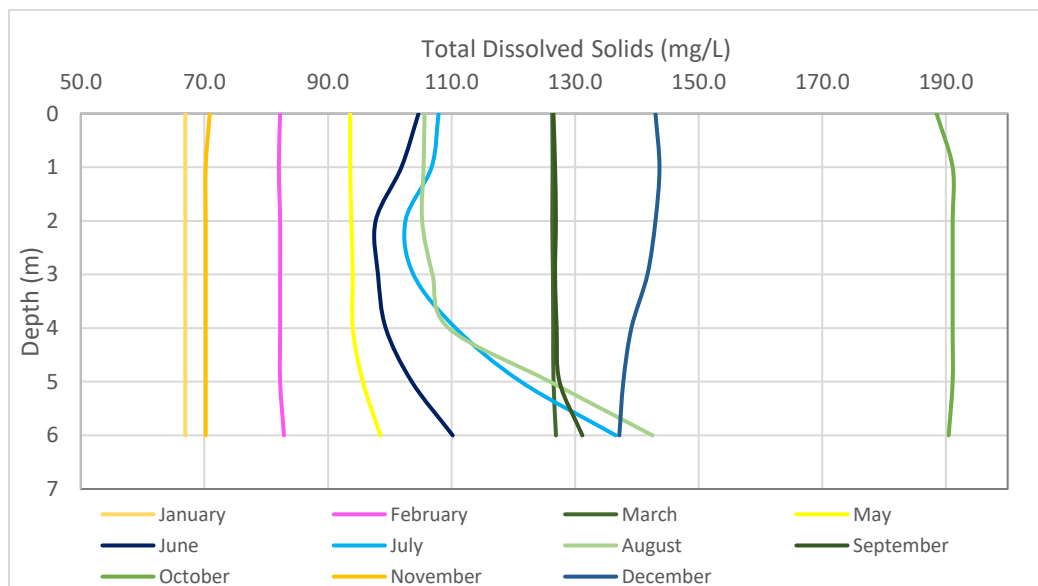


Chart 5: Somenos Lake Average Monthly Total Dissolved Solids Depth Profiles January to December 2021



pH and Ammonia

Somenos Lake is known as a eutrophic lake due to its enrichment of nutrients. As part of the monitoring program the nutrients studied were phosphorus, nitrate, nitrite, and ammonia. These nutrients accumulate in the lake and have the potential to increase growth of aquatic plants and algae, which can deplete oxygen levels. Depleted oxygen levels are a concern if the lake becomes anoxic and uninhabitable for fish that require it for a refuge.

Ammonia is an important compound to measure because it is principally used in the production of nitrogenous fertilizers (CCME 2010), and the Somenos watershed is abundant in agriculture activities. Ammonia is also an important component of the nitrogen cycle and because it is oxidized in the environment by microorganisms (i.e., nitrification), it is a large source of available nitrogen in the environment (CCME 2010).

It is also important to consider the relationship between water temperatures and pH, which affects ammonia levels. Generally, the CCME guideline for the protection of aquatic life in freshwater for un-ionized ammonia is 0.019 mg/L (CCME 2010). However, this varies due to the relationship between pH and temperatures of the water, which fluctuates throughout the year.

Table 2 shows how ammonia CCME guidelines change according to changes in temperature and pH. Ammonia guidelines are inversely related to temperature and pH. As temperatures and pH increases increase, ammonia toxicity concentration guidelines decrease, becoming more stringent. When pH and temperatures lower, ammonia guidelines increase, becoming less stringent (Table 2).

Table 2: Water quality guidelines for total ammonia for the protection of aquatic life (mg/L NH₃)

Temp (°C)	pH							
	6	6.5	7	7.5	8	8.5	9	10
0	231	73	23.1	7.32	2.33	0.749	0.25	0.042
5	153	48.3	15.3	4.84	1.54	0.502	0.172	0.034
10	102	32.4	10.3	3.26	1.04	0.343	0.121	0.029
15	69.7	22	6.98	2.22	0.715	0.239	0.089	0.026
20	48	15.2	4.82	1.54	0.499	0.171	0.067	0.024
25	33.5	10.6	3.37	1.08	0.354	0.125	0.053	0.022
30	23.7	7.5	2.39	0.767	0.256	0.094	0.043	0.021

Guidelines in the shaded area should be used with caution. Source: CCME 2010 guidelines for aquatic life.

At 1m and 6m lake depths, Charts 6 and 7 show the pH, temperatures, and ammonia levels and how they correlate with estimated guidelines based on Table 2.

As previously mentioned, Ammonia guidelines are inversely related to temperature and pH. For instance, at 6 m in July when pH dropped from ~ 7.5 to 6.5 without temperature changes, the CCME (2010) guideline level increased significantly from 2.22 to 22 mg/L (Chart 7). This is because the more acidic the water becomes - depending on temperatures - the less toxic ammonia is to aquatic life.

Chart 6: Somenos Lake Surface Ammonia Levels (1m) and estimated CCME guidelines

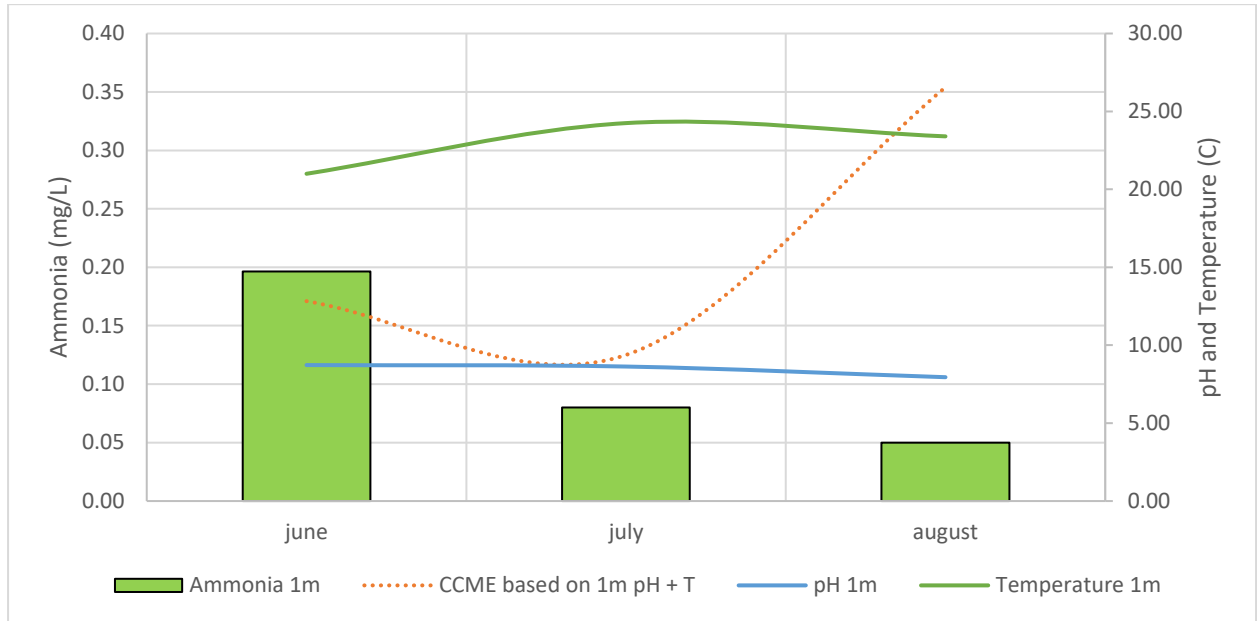
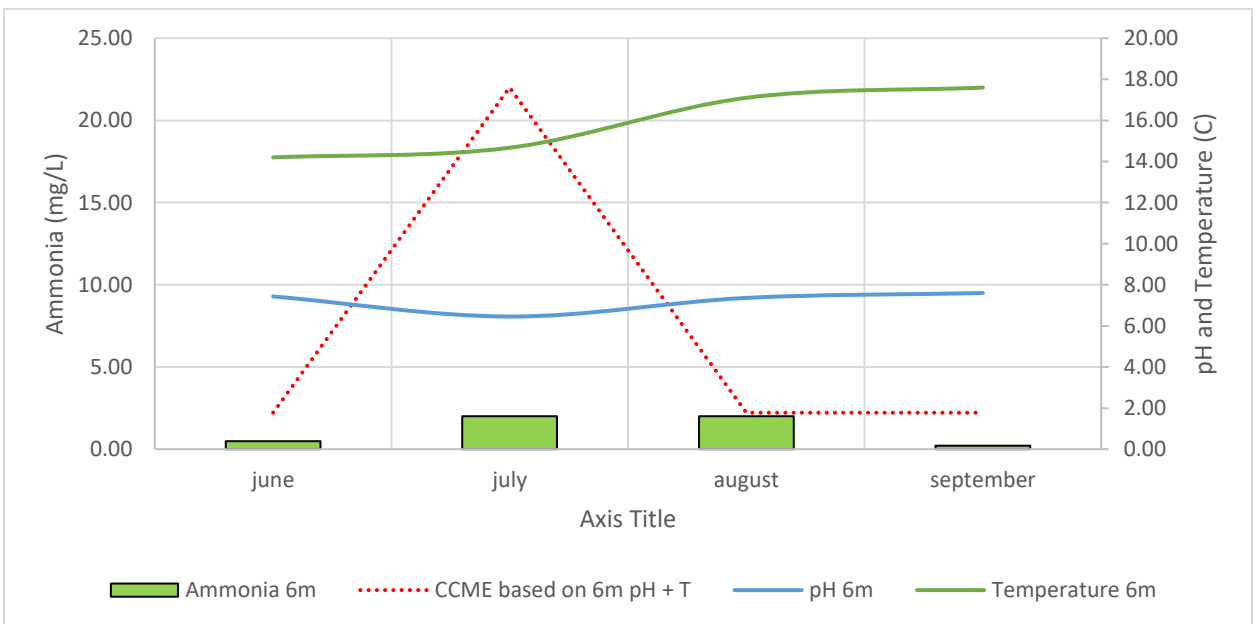
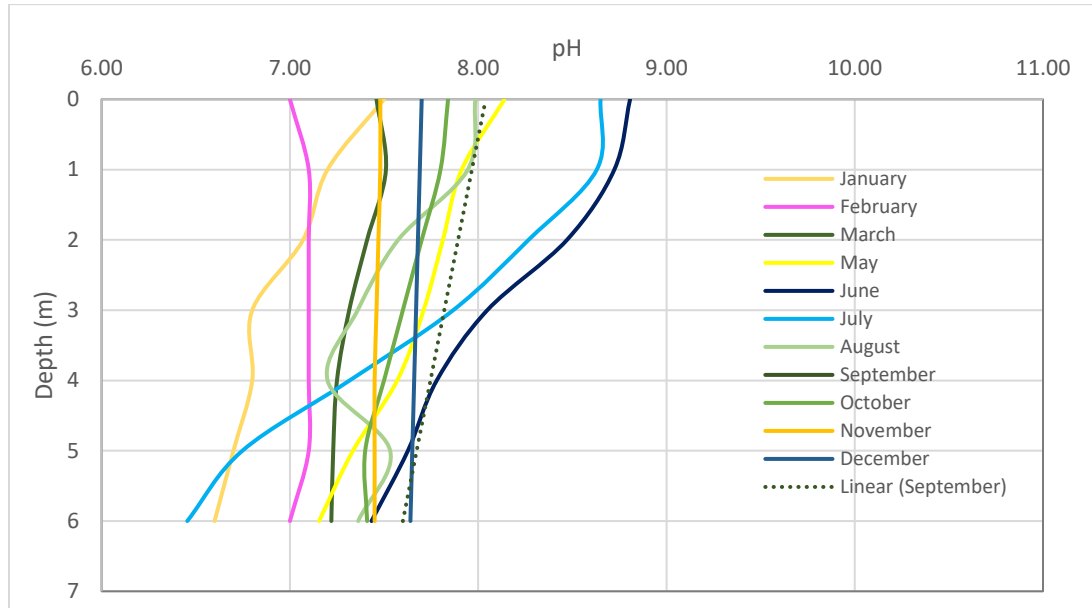


Chart 7: Somenos Lake Bottom Ammonia Levels (6m) and estimated CCME guidelines (2010)



Overall, ammonia exceeded CCME guidelines (2010) at 1m in June (Chart 6) and had no exceedances at 6m (Chart 7). The one exceedance was due to elevated temperatures overall at the surface vs bottom, and higher pH values at the surface in June (Chart 8).

Chart 8: Somenos Lake Average Monthly pH Profiles from January to December 2021



Note: September pH results were taken with a hand-held Hanna probe at the surface and 6m depths using a Van Dorn water sampler due to delays in shipments of a new YSI pH probe replacement

Phosphate

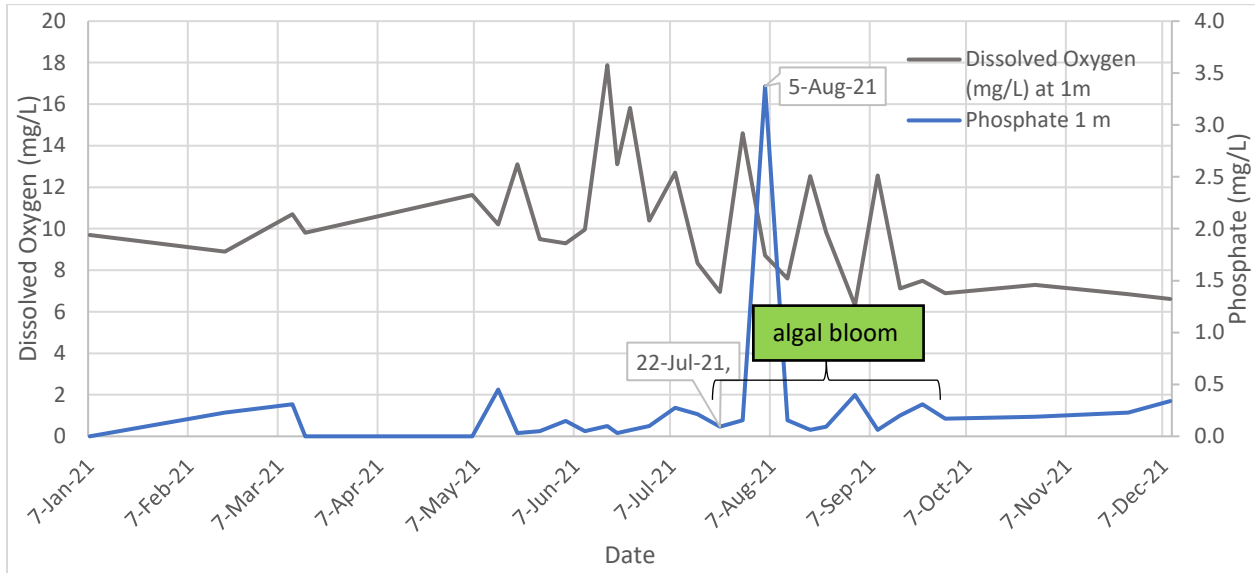
Phosphate is an important nutrient in the growth of aquatic plants and organisms. Excessive levels of phosphate can cause further degradation of conditions in eutrophic lakes (CCME 2004).

Chart 9 and 10 show the comparison of phosphate measurements with dissolved oxygen levels at the surface and bottom of the lake.

Dissolved oxygen levels fluctuated at the surface between May and mid-September. These fluctuations could have been due to variable environmental conditions on the surface (wind, air temperature, precipitation, cloud cover, etc). Dissolved oxygen levels can also vary due to algae growth and die-off (Schindler and Vallentyne 2008). That being said there is no clear parameter that is the cause of this on the surface (Chart 9).

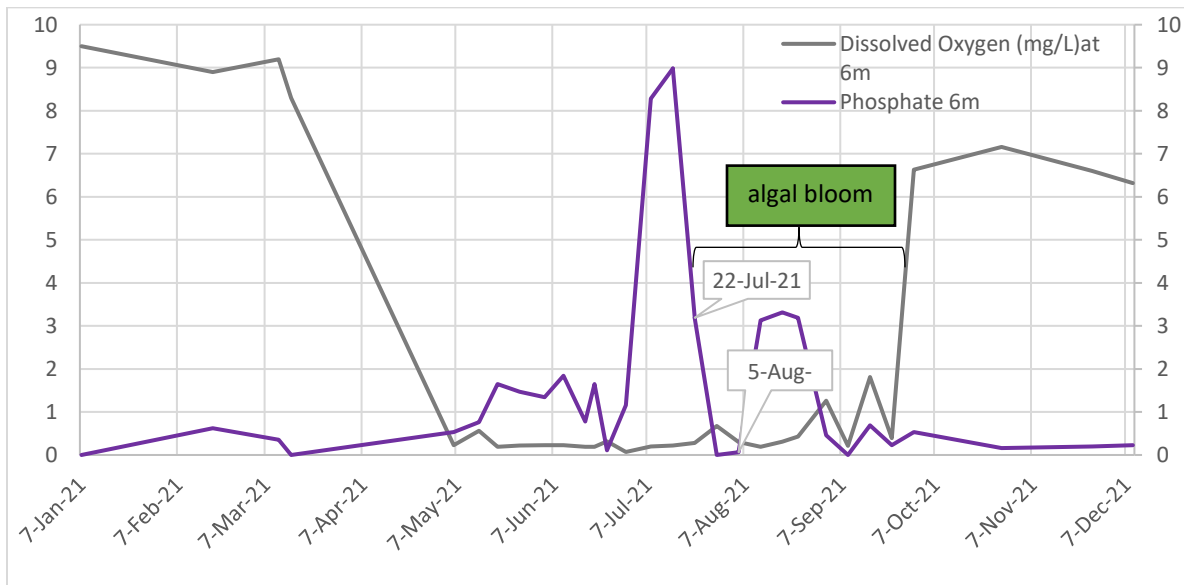
At the bottom of the lake, a peak measurement of phosphate (8.98 mg/L) occurred on July 15th (Chart 10), the week before the algal bloom (phytoplankton) was first observed on July 22, 2021, then dropped suddenly. The following week, a large concentration of phosphate (3.4 mg/L) occurred at the surface of the lake on August 5th (Chart 9). These high values of the phosphate on these dates are unexpected and require further investigation into the cause.

Chart 9: Somenos Lake monthly total phosphate and dissolved oxygen at 1m.



As seen in Chart 10, dissolved oxygen decreased to anoxic levels at the bottom of the lake during the stratification period. It began to sharply rise by mid-September when the lake mixed and the algal bloom died off. The subsequent effect of the algal growth and die off in the lake could be a factor in the sustained low oxygen level period in the lake as seen in Chart 10 below (Schindler and Vallentyne 2008).

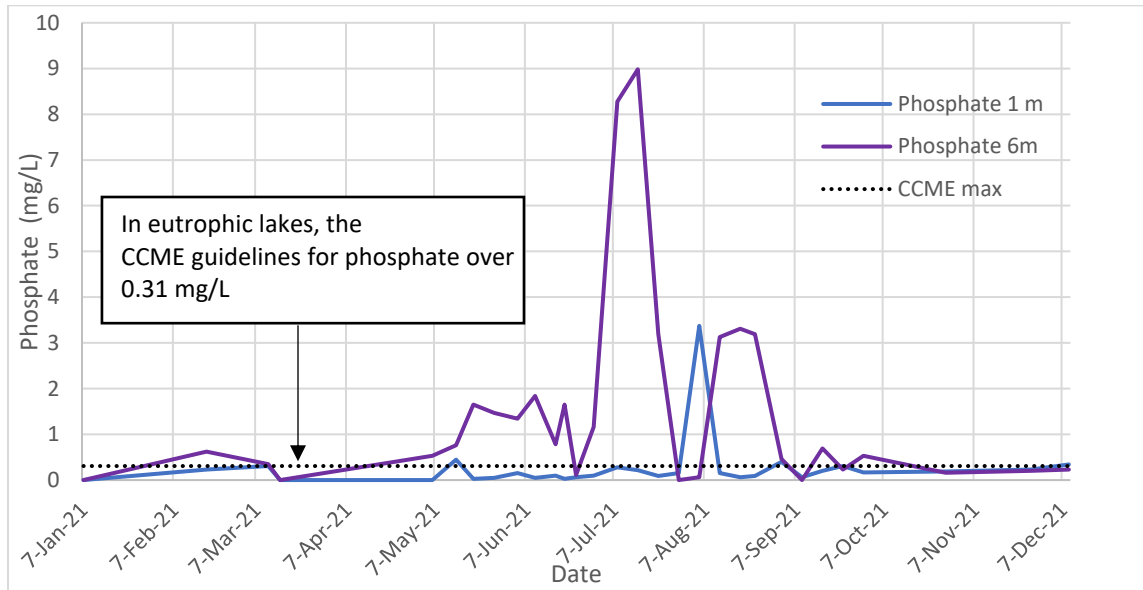
Chart 10: Somenos Lake monthly total phosphate and dissolved oxygen at 6m.



The majority of the phosphate levels in the water column at the bottom of the lake (6m) exceeded CCME guidelines (2004) from February to September (Chart 11). At this depth there were three major exceedences in June, July and August. In contrast, the majority of the phosphate levels at the surface of the lake

(1m) did not exceed the CCME guidelines of 0.31mg/L, except a few small occurrences in May, September and December with one large spike in levels in August.

Chart 11: Somenos Lake Phosphate Concentrations at the surface and bottom



Note: CCME guidelines (2004) were available only as Phosphorous and thus the eutrophic range between 35-100 µg/L was multiplied by 3.066, and divided by 1000 to obtain Phosphate (mg/L). The range is 0.11 – 0.31 mg/L; 0.31mg/L being the upper limit recommended trigger for response to investigate further and subsequent management decisions.



Photo 1: Green algae bloom observed on July 22, 2021 throughout Somenos Lake.

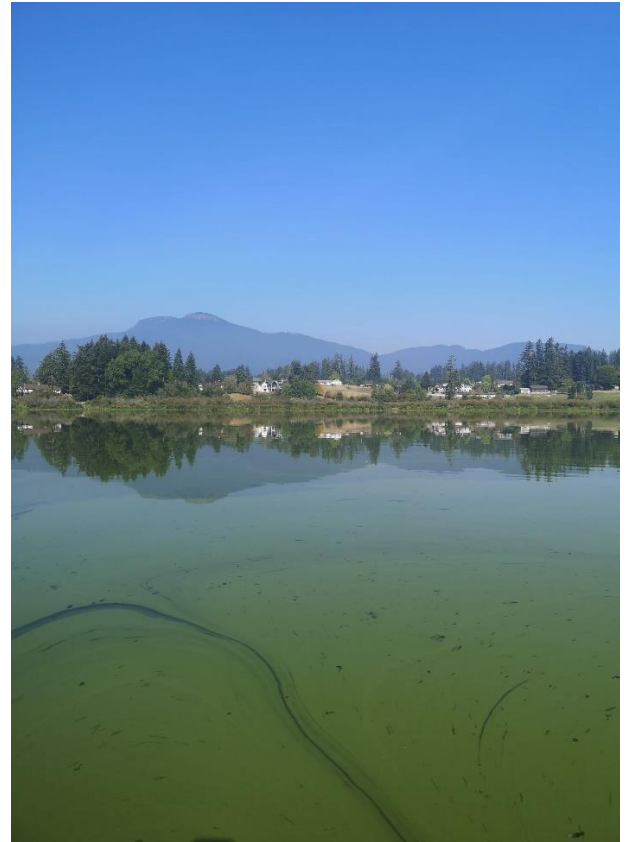
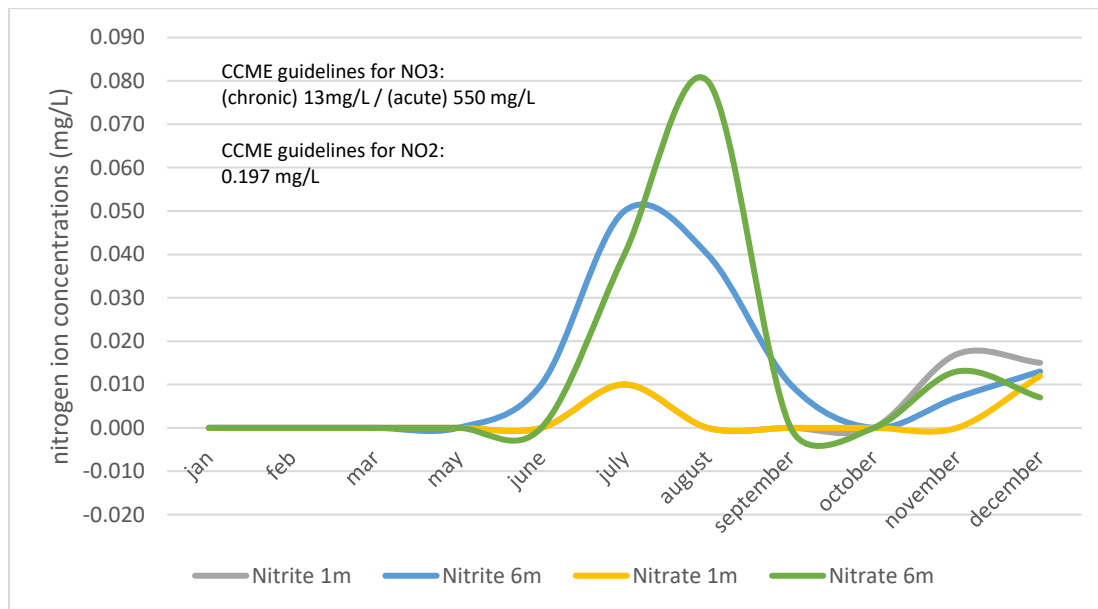


Photo 2: View of the algal bloom looking northwest on Somenos Lake, July 22, 2021. Note a thick layer of green algae on the surface

Nitrate and Nitrite

Nitrate and Nitrite levels in Chart 12 do not exceed CCME guidelines at the top or bottom of the lake for acute (Nitrate 13 mg/L, CCME 2012; Nitrite 0.197 mg/L, CCME n.d.) or chronic exposures (Nitrate 13 mg/L; CCME 2012). These levels did increase simultaneously in July to August and November (except surface Nitrate). It is difficult to decipher if the higher nitrogen levels correspond with algae growth because samples were taken only once during each month. I recommend future weekly sampling during the high algal growth season to be able to compare the data with other nutrients and analyse trends.

Chart 12: Somenos Lake Monthly Average Nitrate (NO₃) and Nitrite (NO₂) Levels

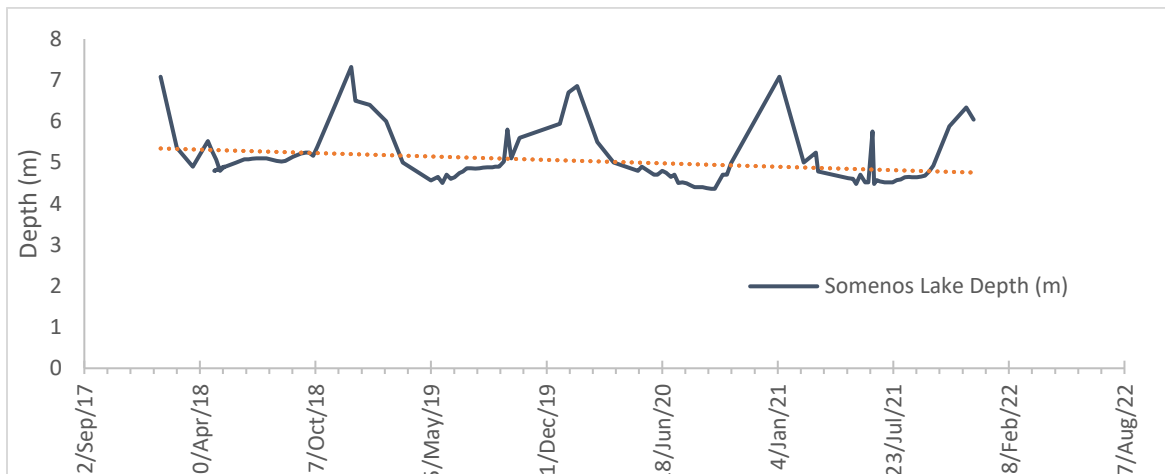


Note: CCME guidelines for acute and chronic exposures were too high to include in the graph

Somenos Lake Depth Annual Trends

A review of Somenos Lake depths from 2018 to 2021 was completed to see any changes over time. The results are presented in Chart 13 below. There appears to be a slight linear trend in a decrease in water levels over time.

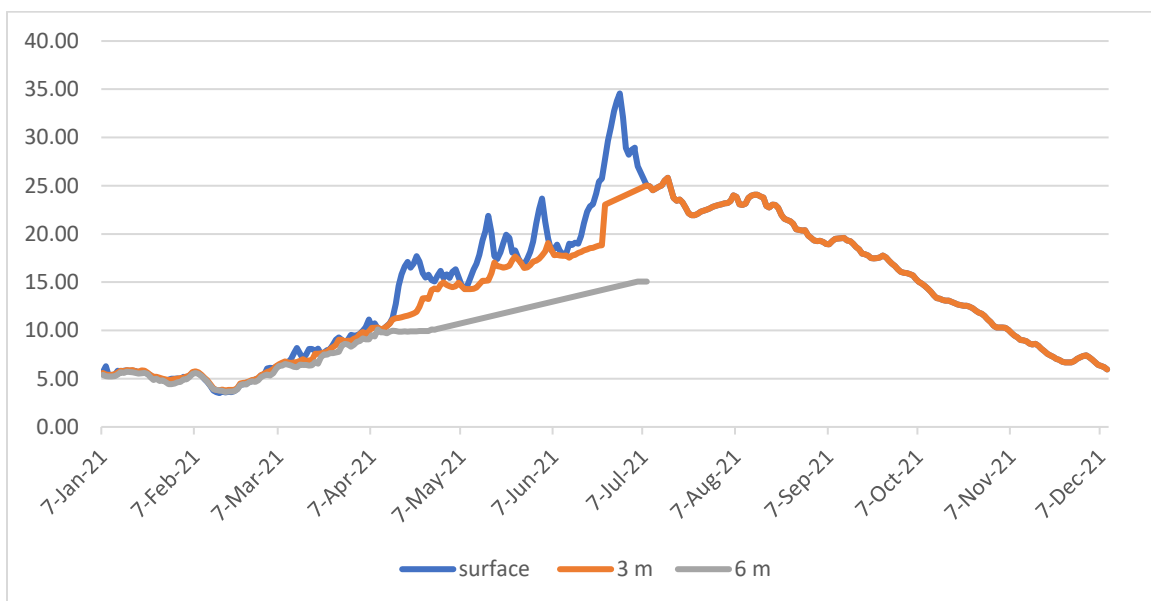
Chart 13: Somenos Lake Monthly depths from 2018 to 2021



Hourly Data Loggers

On June 25-June 29, 2021, Duncan, BC experienced a heat dome where daytime temperatures were in the high 30's and reached up to 41.1°C on June 28. This explains the sharp increase in water temperature on the surface (Chart 14) in late June and into July. Some missing data is due to malfunctioning data loggers, especially at 6m depths.

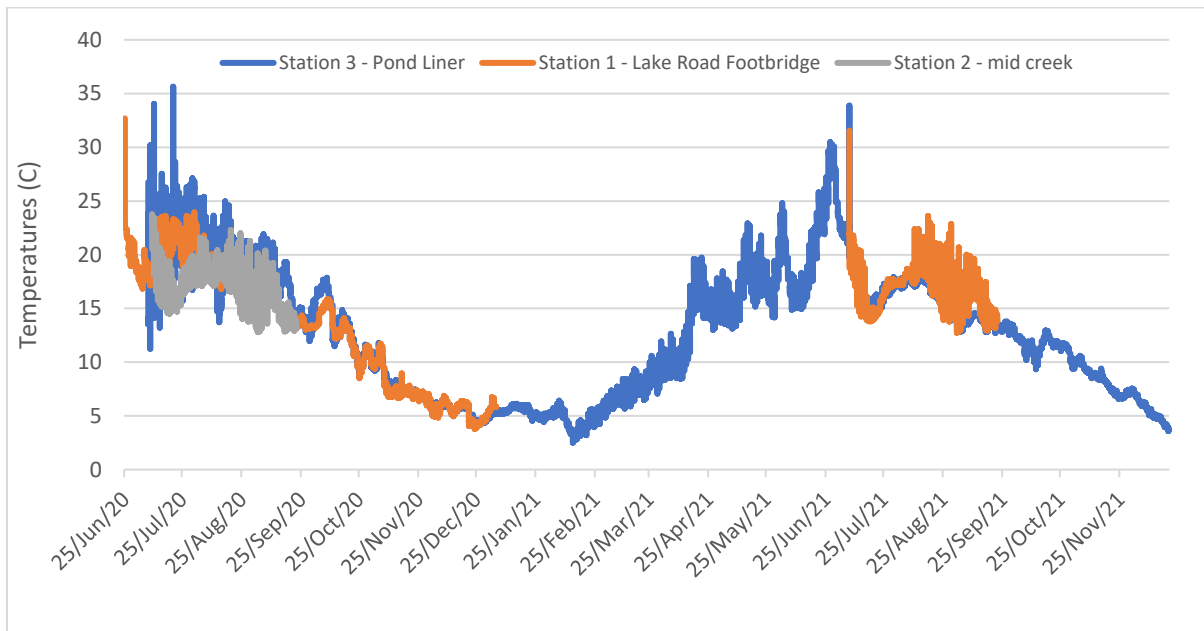
Chart 14 Somenos Lake Hourly Temperatures recorded at surface, middle, bottom of the lake, 2021.



Somenos Creek

Hourly temperature and light intensity data was recorded at three stations. The most upstream station (3) had 2 data loggers placed on a buoy next to the pond liner used in the Parrot's feather control management pilot. The second station (2) was located mid-way in Somenos creek between the other two stations. The final station (1) was located downstream at the Lakes Road pedestrian bridge. The surface temperatures at all the stations appears similar (chart 15), except slightly higher at the pond liner location. This makes sense since the pond liner is made of a black material that absorbs light and creates more heat in the surrounding area.

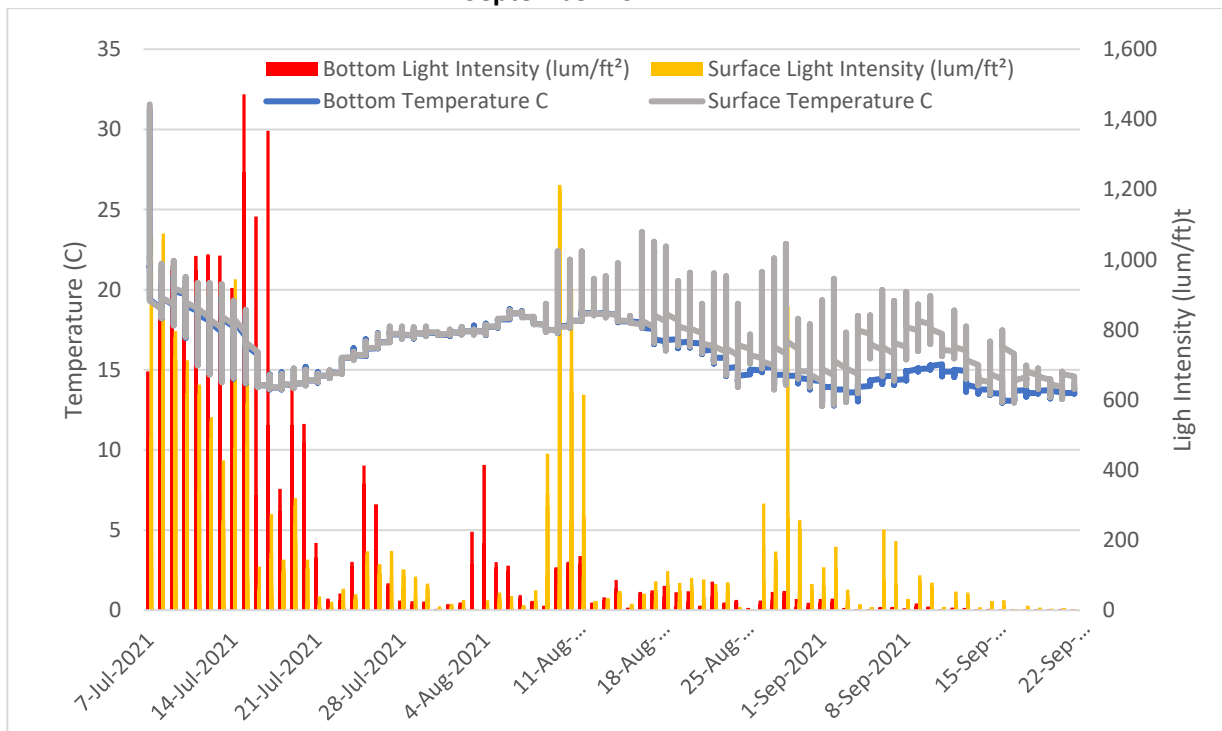
Chart 15: Somenos Creek Surface Temperatures at All 3 Stations



Station 1 – Lakes Road Footbridge

Somenos Creek Station 1 is the most downstream site located at the Lakes Road footbridge. The data loggers set last year malfunctioned in January 2021 and were reset in July. The data from this year may not be a true representation of conditions because the buoy was stolen, and rope tampered with which left the data logger sitting on the bottom substrate of the creek multiple times over the summer. Therefore, surface and bottom data loggers may have unreliable results for some periods during the summer to fall of 2021. For example, in Chart 16 light intensity for the bottom data logger is much higher than the surface for July. The data loggers were last uploaded in September of 2021 and were lost in high flood waters in November.

Chart 16: Hourly Surface and Bottom Light intensity and Temperatures in Somenos Creek at Station 1, July - September 2021

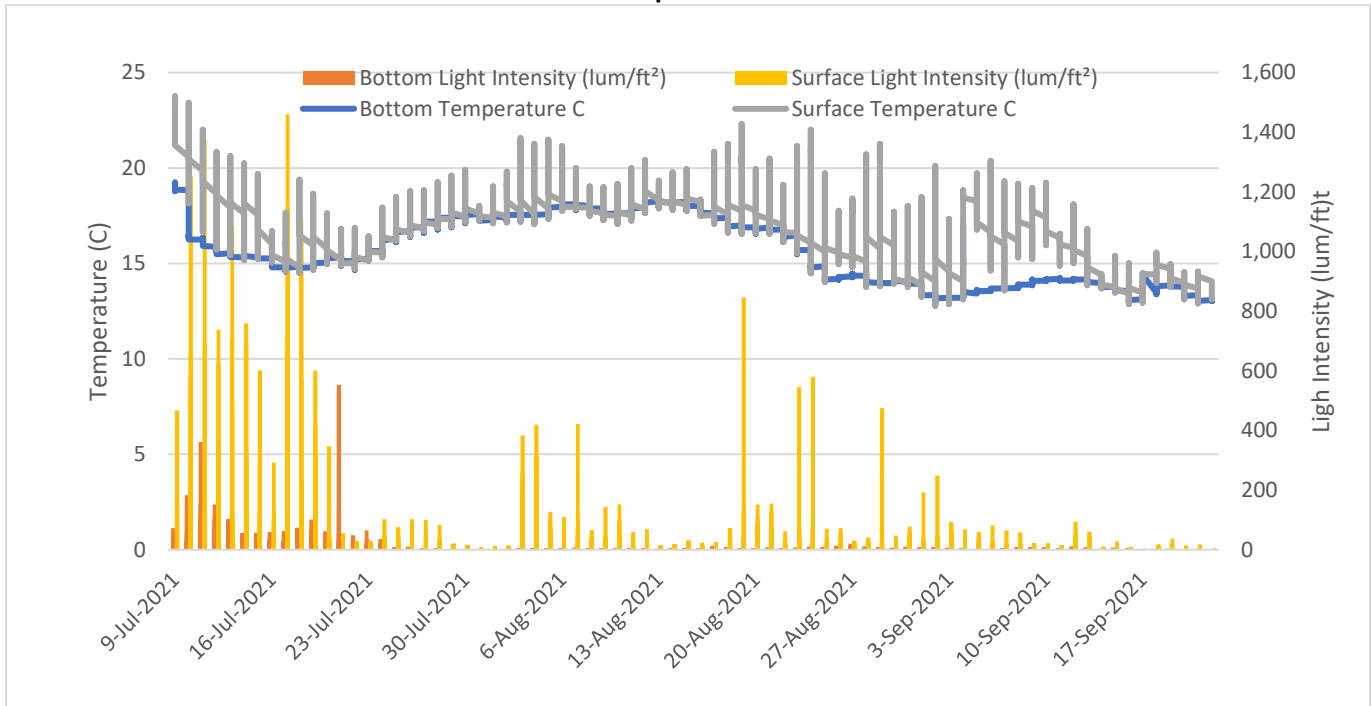


Station 2 – mid Somenos Creek

Somenos Creek Station 2 is the mid-way site located between the pond liner (station 2) and lakes road footbridge (station 1). Station 2 generally had an open mid channel, with Parrot’s feather growth along the edges. This station’s data logger was removed in 2020 due to a faulty equipment and reset in July 2021 and last updated in September 2021. Temperatures on the surface varied about 5 degrees daily and dropped to bottom temperatures, which remained consistent (chart 17). The light intensity on the surface was greater than the bottom of the creek, which makes sense. In peak summer, around July the light intensity drops which may indicate times of more Parrot’s feather growth and coverage. The data logger was anchored mid-channel where Parrot’s feather was not covering it at the time

of deployment, however dense growth may have covered the data logger from time to time.

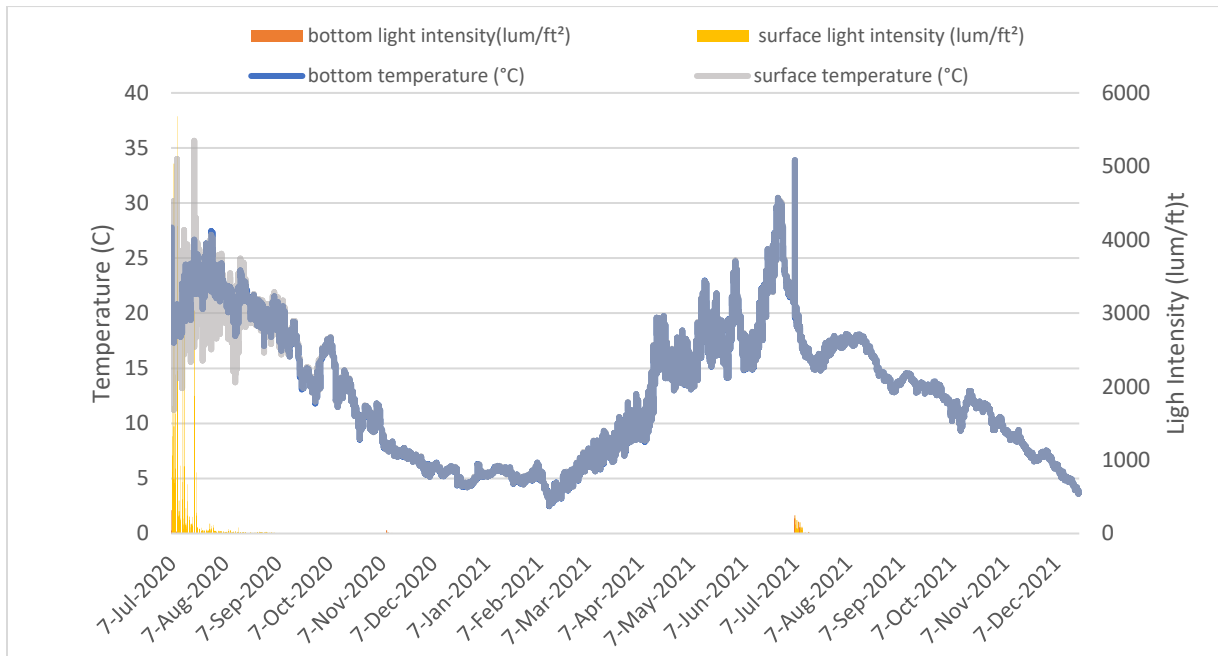
Chart 17: Hourly Surface and Bottom Light Intensity and Temperatures at the Somenos Creek Station 2, July-September 2021



Station 3 – Pond Liner

Station 3 is located at the Pond Liner Parrot’s feather control management station approximately 500 meters downstream of the Somenos Lake outlet. Hourly temperature and light intensity were recorded from July 2020 to December 2021 under the pond liner. Temperatures of the surface and bottom over this period appeared similar (Chart 18). In July 2021, temperatures soared, but light intensity only slightly increased on the surface compared to 2020 (Charts 18). It is likely the slight increase in light intensity in July 2021, and spike in temperature coincided to when the pond liner was re-installed. To do this, the Parrot’s feather that grew overtop of the pond liner needed to be removed. Thus, leaving a cleared area of open water around the newly installed liner that let more light into the creek until the Parrot’s feather grew back and filled in the spaces.

Chart 18: Hourly temperature and light intensity at the surface and bottom of Somenos Creek at the Pond liner 2020-2021.



Somenos Watershed Tributaries

The main tributaries in the Somenos Watershed are Somenos Creek, Bings Creek, Richards Creek in two locations (Richards Trail and Herd Road), and Averill Creek. They were all monitored for various water chemistry parameters to determine patterns and potential changes over time. These parameters were temperature, dissolved oxygen, pH, specific conductivity and dissolved oxygen, measured weekly in summer and monthly the rest of the year. Monthly parameters measured were total phosphate, ammonia, nitrate, and nitrite. The charts below show the results of testing in 2021.

Total Dissolved Solids and Specific Conductivity

The tributary total dissolved solids and specific conductivity levels in Charts 19 and 20 match very closely. There were a few peaks in all creeks of conductivity and TDS in late August/early September, October and November.

Chart 19: Somenos Watershed Tributary Total Dissolved Solids, 2021

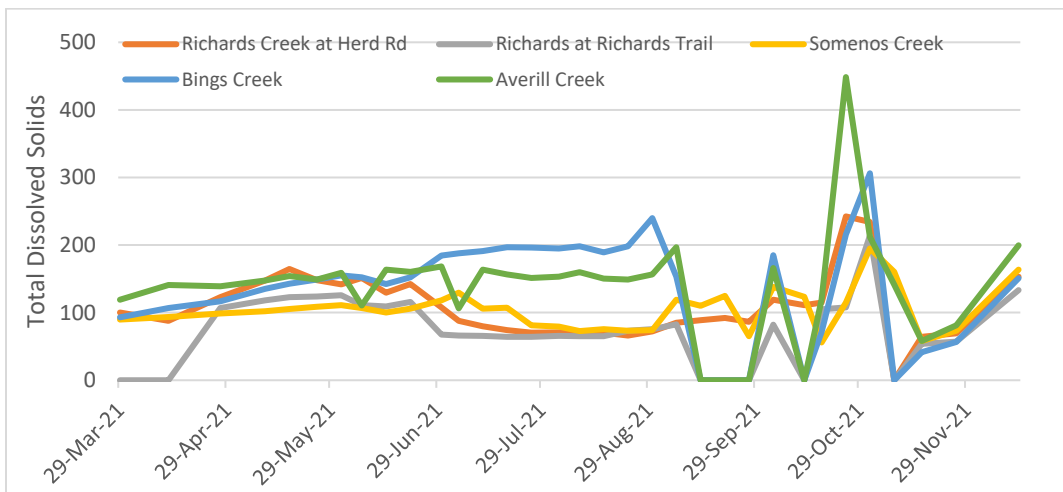
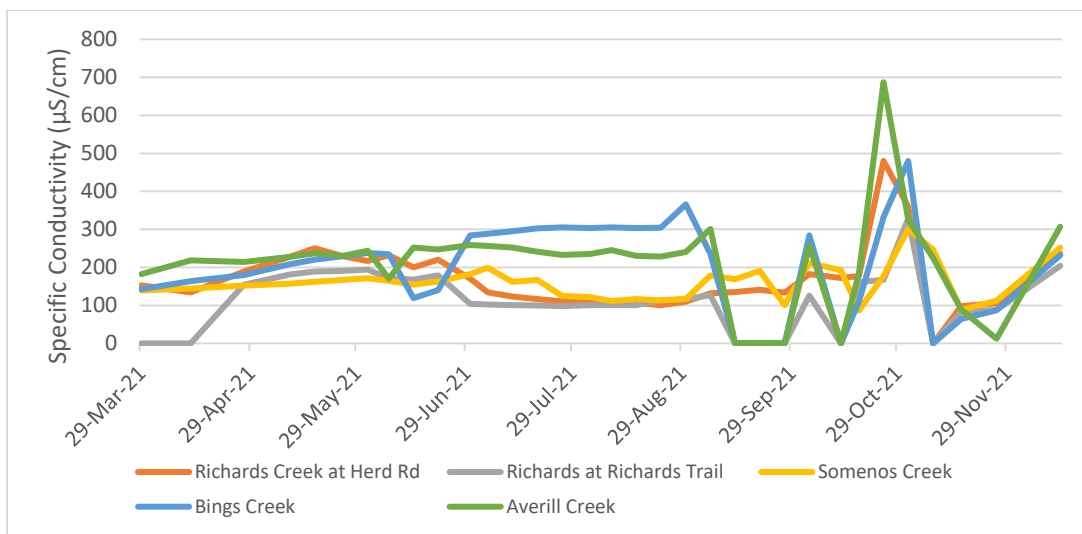
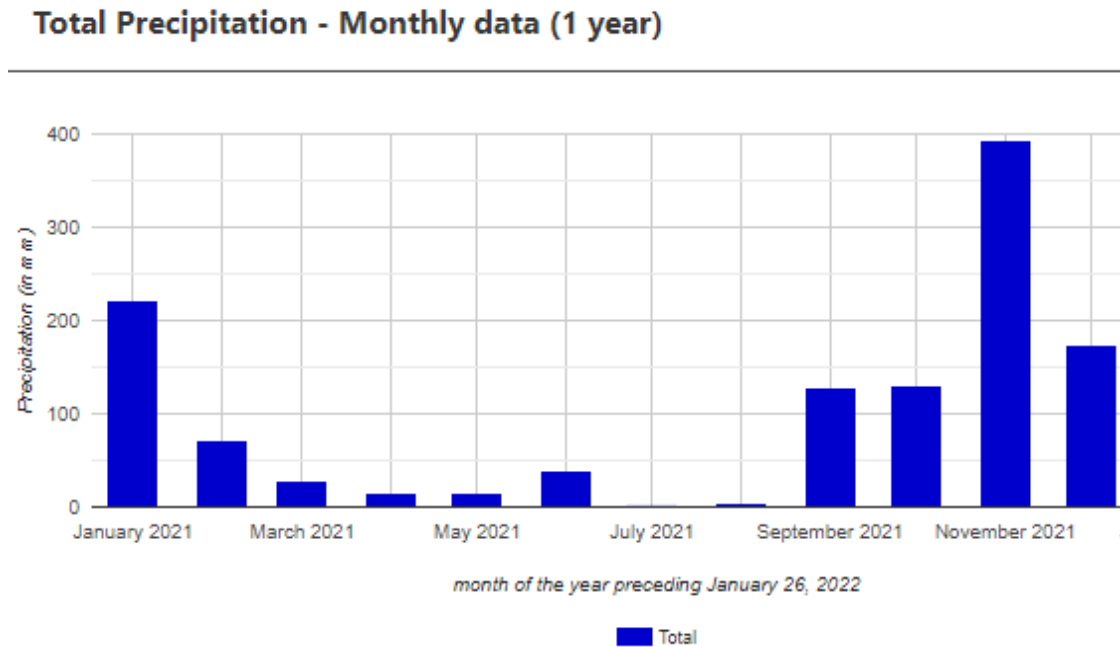


Chart 20: Somenos Watershed Tributary Specific Conductivity Levels, 2021



When these peaks occurred, water temperatures were on a gradual decline (Chart 24) and thus were not the cause. It is more likely due to the start of the rainfall in the fall, shown in Chart 21 (ECCC 2022), that can increase flows and surface water runoff increasing TDS and conductivity in the creeks.

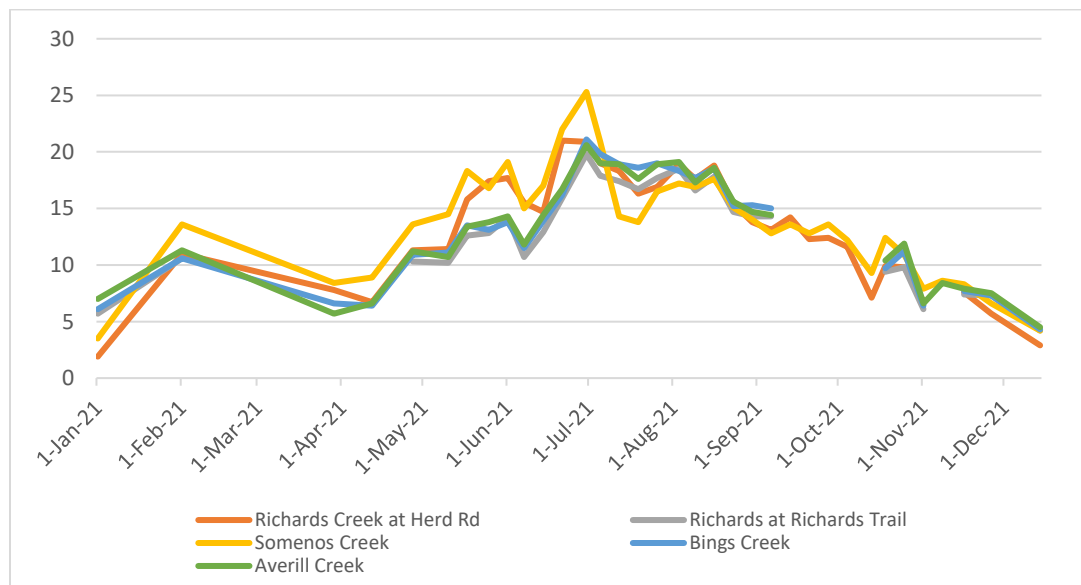
Chart 21: Environment and Climate Change Canada Total Precipitation Data for Duncan, BC, 2021.



Temperature

Tributary temperatures rise mid summer and peak on June 20, 2021 (Chart 22). At this time, Somenos Creek has the highest temperature value of 25°C compared to the other creeks approximately 20°C. By July to mid August most of the tributaries range between 16 and 19°C, except Somenos Creek, which dropped 11°C in the first 2 weeks of July and remained between 16-17 until mid-August. This may indicate a separate colder water source entering Somenos Creek. Since there were no rain events during this time its possible there is a ground water source entering the creek at various times.

Chart 22: Somenos Watershed Tributary Temperature Levels, 2021



Dissolved Oxygen

Dissolved oxygen levels vary between the creeks (Chart 23). For instance, Richards Creek at Herd Road and Somenos Creek are much lower than the other locations. Richards Creek at Herd Road has anoxic conditions throughout most of the year between 3-4 mg/L, with a few periods where levels fluctuate up to 8-10 mg/L (sub-optimal) in February, September, and December. The lowest dissolved oxygen was 0.36 mg/L on June 30 in Richards Creek at Herd Road.

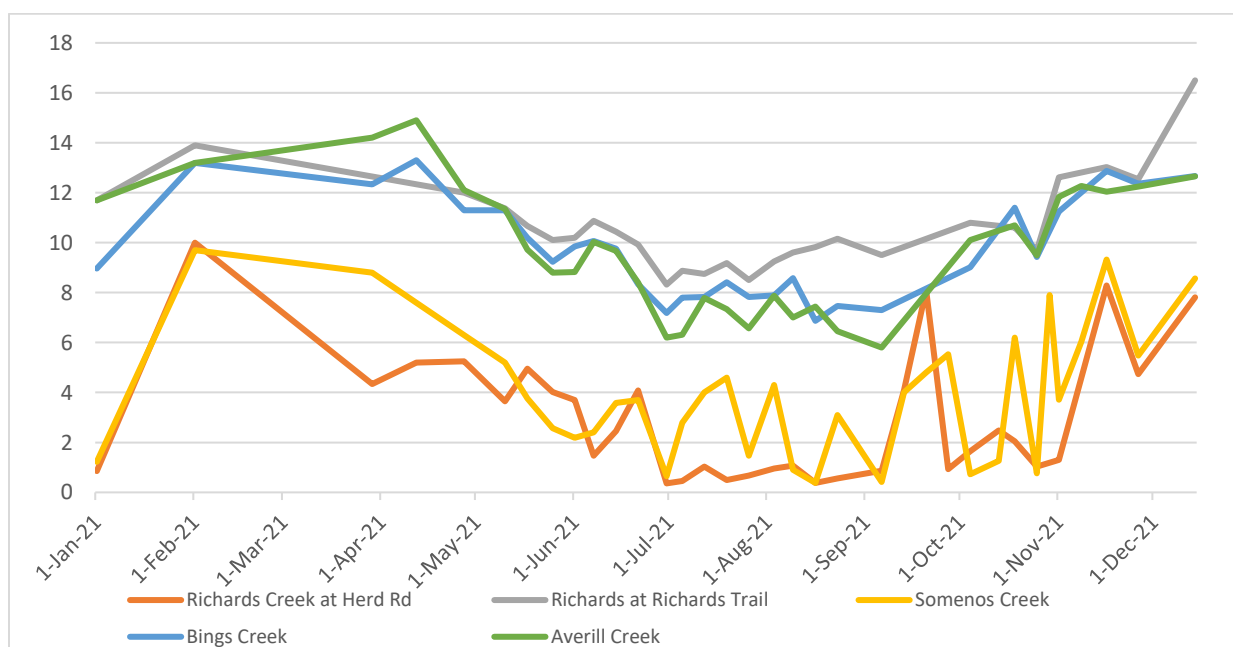
Somenos Creek's lowest dissolved oxygen level was on August 16 at 0.38 mg/L. Dissolved oxygen levels ranged between this and 4.5 mg/L throughout the summer until October. Interestingly, between October and late November dissolved oxygen levels fluctuated between anoxic and sub-optimal. By November 8, these fluctuations appeared to stabilize at sub-optimal levels (6.03-9.32 mg/L). This is important to note, as we have anecdotal information suggesting there are springs in Somenos Creek that would cause this fluctuation in dissolved oxygen. Therefore, it will be important to monitor dissolved oxygen more closely during spawning season to determine when levels would allow fish migration for fall spawning.

Richards Creek at Richards Trail remained between sub-optimal to optimal range for the entire year. The highest dissolved oxygen was 13.9 mg/L in February and lowest was 8.32 mg/L on June 30.

Bings Creek remained between sub-optimal to optimal throughout the year with one decrease to hypoxia levels of 6.87mg/L on August 16. the highest result of dissolved oxygen was in February at 13.2 mg/L.

Averill Creek levels were similar to Bings Creek, however it had more hypoxic levels that ranged between 5.8 and 6.57 mg/L where there would be one or two occurrences per month from June to early September. The Maximum dissolved oxygen level was 13.2 mg/L in February.

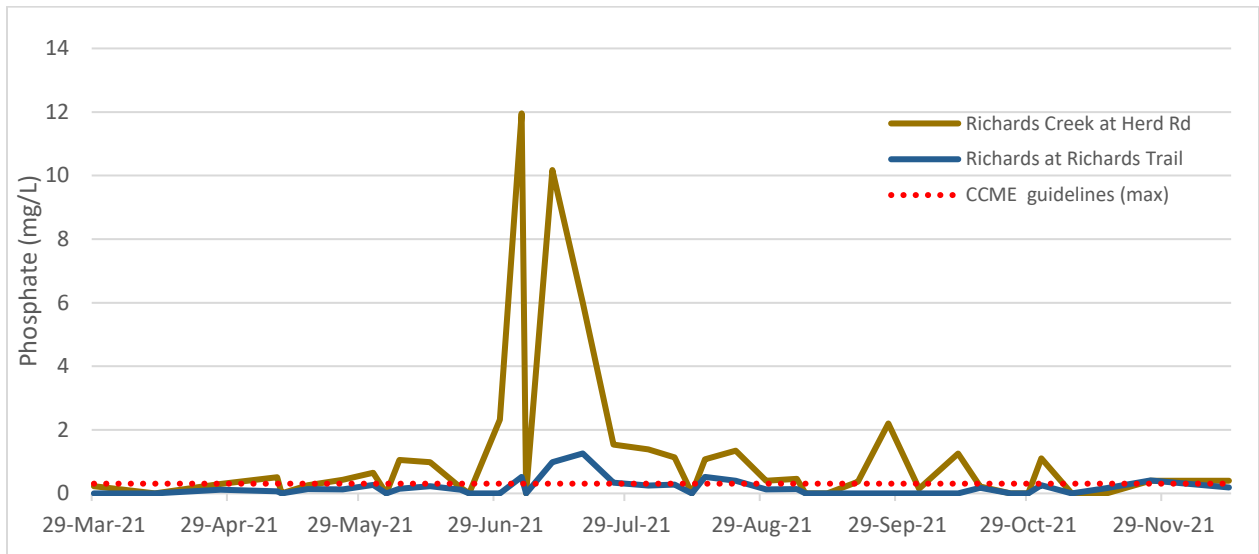
Chart 23: Somenos Watershed Tributary Dissolved Oxygen Levels, 2021



Phosphate

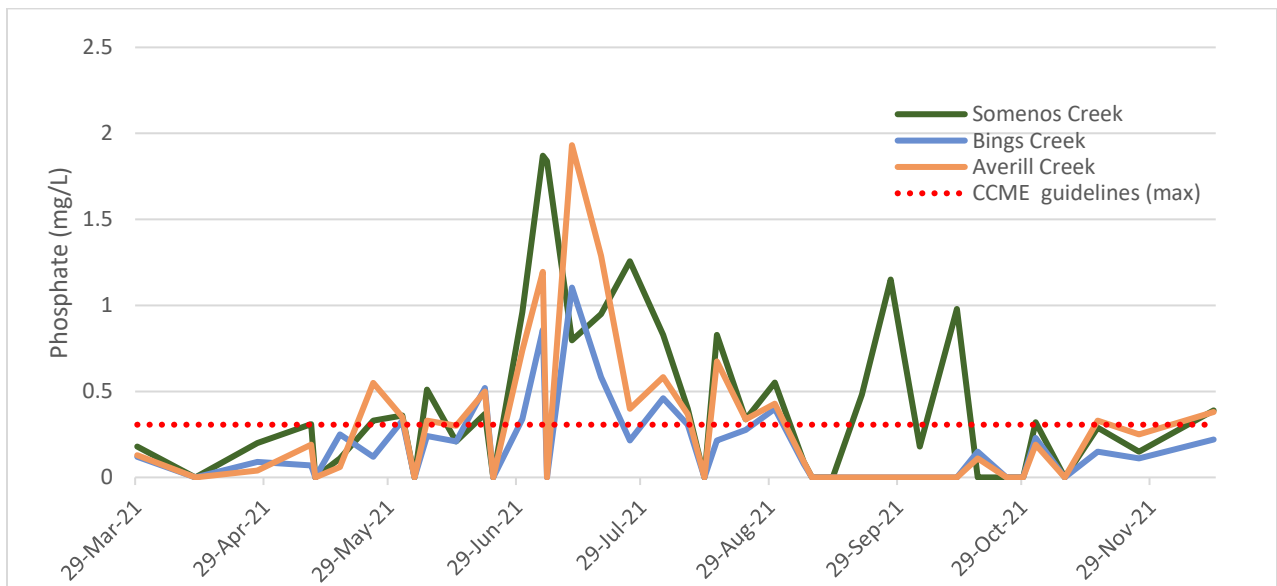
In Chart 24, Richards Creek at Herd Road has the highest levels of phosphate, peaking in July and regularly exceeds CCME guidelines for the protection of aquatic life which is 0.31 mg/L (CCME 2004).

Chart 24: Richards Creek Phosphate Levels, 2021



All the other tributary creeks in Chart 25 exceeded CCME guidelines regularly over the year as well. It is important to note all these tributaries peaked in July as well. Reasons for this are unclear and further studies of these levels in 2022 will be investigated.

Chart 25: Bings, Averill, and Somenos Creek Monthly Phosphate Levels, 2021

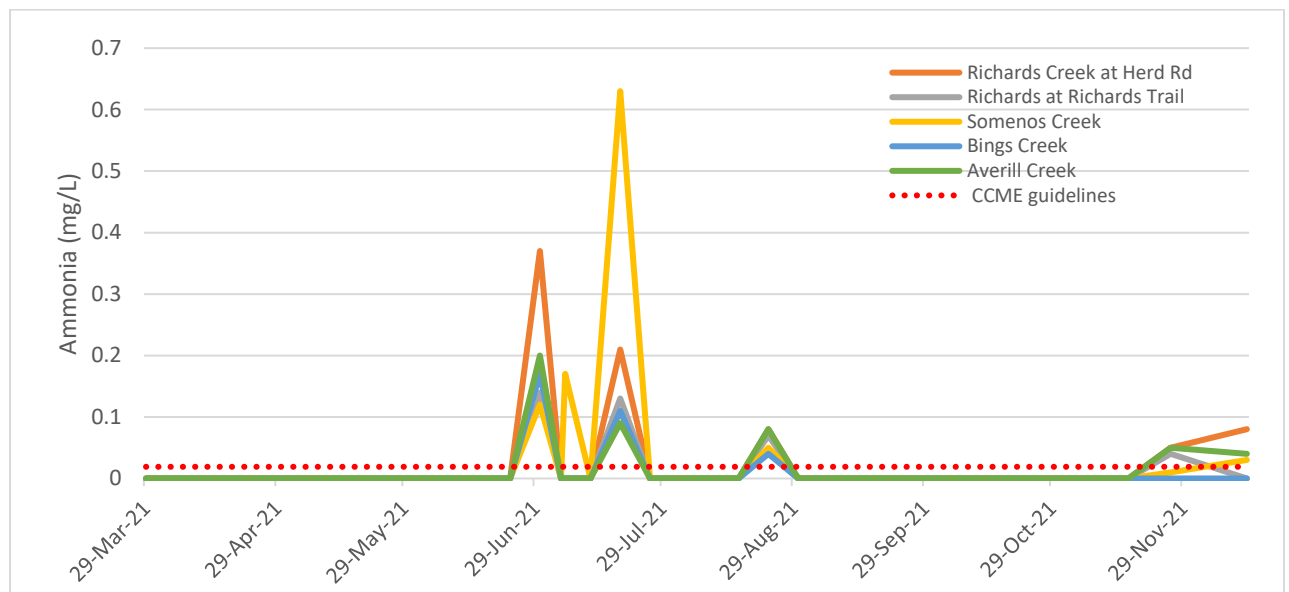


Ammonia

As mentioned before, as temperatures increase, ammonia toxicity concentration guidelines decrease becoming more stringent. If pH decreases, ammonia toxicity concentration guidelines increase to higher recommended levels, or less stringent. However, for the purpose of representing results in Chart 26, we used the general CCME guideline for the protection of aquatic life in freshwater for un-ionized ammonia is 0.019 mg/L (CCME 2010). As a result, ammonia exceeded the general CCME guidelines, at the following locations and dates:

- June 30, July 19, and August 23 - all creeks
- July 6 - Somenos Creek
- November 26 – Richards Creek (both locations) and Averill Creek
- December 14 – Richards Creek at Herd Road, Averill Creek, and Somenos Creek

Chart 26: Somenos Watershed Tributary Monthly Ammonia Levels, 2021



Nitrite and Nitrate

The CCME guidelines for acute (Nitrate 13 mg/L, CCME 2012; Nitrite 0.197 mg/L, CCME n.d.) and chronic exposures (Nitrate 550 mg/L, CCME 2012) are higher than the results at the tributaries in 2021, and thus are too high to show on Charts 27 and 28. Even though levels were well below guidelines for all the tributaries, there were a few notable increases that occurred at all tributaries. Bings Creek and Averill Creeks had the highest nitrite levels in July and August respectively. In November, all creek nitrite levels increased, with Richard Creek at Herd Road and Averill creek the highest. Richards Creek had the highest result of nitrate levels in July whereas the other creeks were undetectable or 0 mg/L. In November after the flood, Averill and Somenos creek nitrate levels showed an increase.

These levels of nitrite and nitrate are not at levels of concern for now but point to a surge in nutrient loading in the summer (June to August) and fall (November) in the tributaries. It may be important to note nitrite levels spiked (Chart 27) at the same time as ammonia levels which exceeded recommended CCME guidelines (Chart 26). Nitrate levels increased as well at the same time; but only in July and November (Chart 28).

Chart 27: Somenos Watershed Tributary Monthly Nitrite Levels, 2021

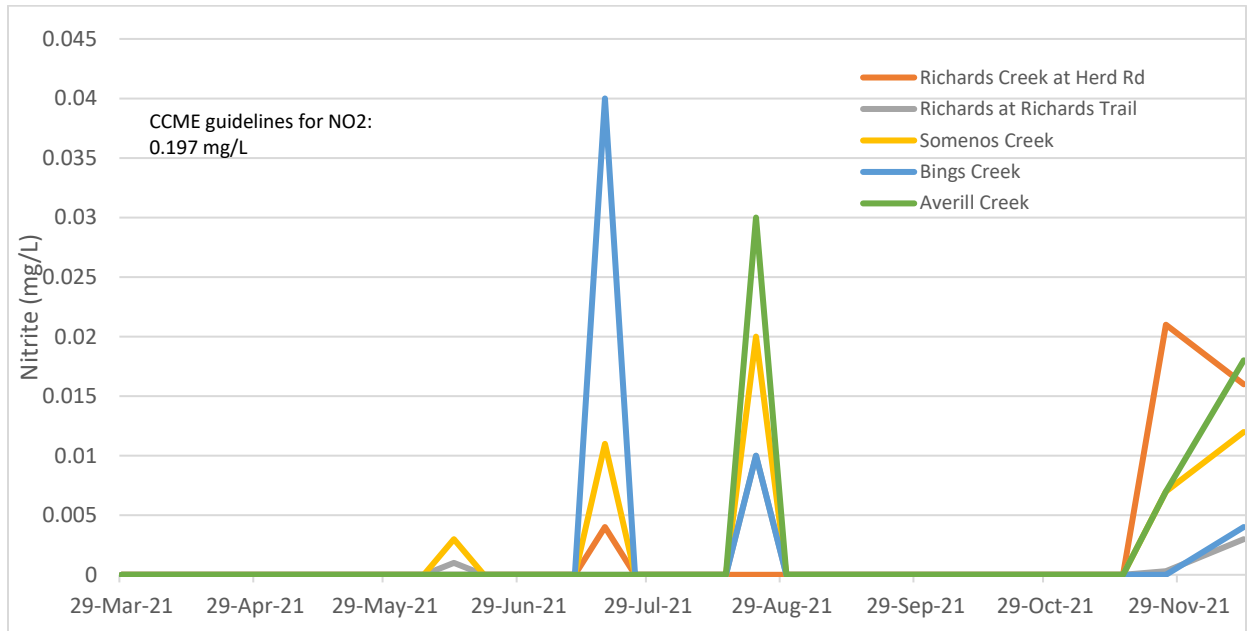
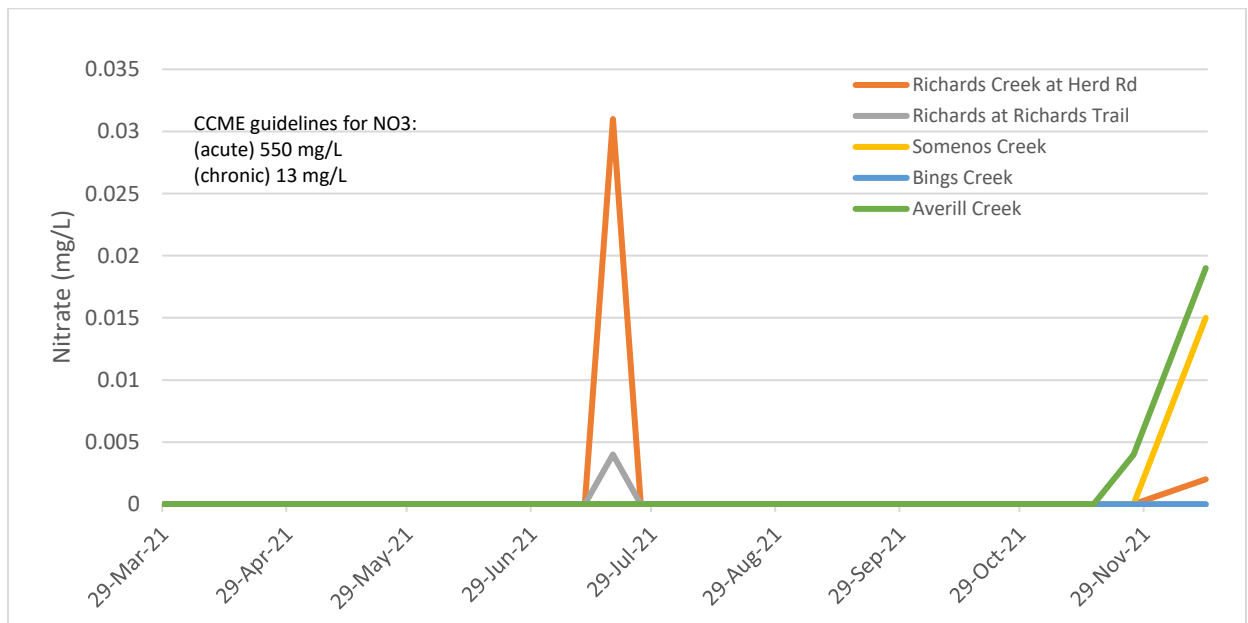


Chart 28: Somenos Watershed Tributary Monthly Nitrate Levels, 2021



Conclusions

The results of this year's annual water quality monitoring program show us a glimpse of what is happening in the Somenos Watershed regarding the water quality health and what the potential impacts are on aquatic life. This information is presented by the Somenos Marsh Wildlife Society to the public, Municipality of North Cowichan, Cowichan Tribes, and partners for future discussions on recommendations of future monitoring.

Some key conclusions made during the WQ sampling season in 2021 are as follows:

- Somenos Lake stratification occurred on May 6 and turned over by September 30 which coincided with a profile change of temperature, dissolved oxygen, conductivity and TDS.
- Somenos lake was anoxic at the bottom layer (6m depth) from May 6 to, and including September 23 which corresponds to lake stratification timing.
- The bottom 4 meters of the lake was anoxic from June 24 to September 9, 2021. One week during that period there were anoxic conditions in the bottom 5 meters on July 8, where only 1 m of lake on the surface was optimal between 12-13mg/L. However, at the same time, temperatures in July to August were between 23-25°C in the top 2 meters which is uninhabitable to fish that are not adapted to high temperatures (e.g., Salmonids).
- The Somenos Lake algae bloom occurred on July 22, 2021 and persisted until mixing of the lake occurred on September 30. After mixing, dissolved oxygen levels at 6 m went from anoxic (0.39mg/L) the week prior, to below sub-optimal (6.63 mg/L) and became evenly distributed throughout the water column. Conductivity and TDS also were the same value from the surface to the bottom by September 30, indicating mixing. At this time fish could enter the Lake from its upstream tributaries, and/ or migrate up from Somenos Creek to spawn if there was sufficient dissolved oxygen.
 - It was discovered that Somenos creek was anoxic throughout the summer months until mid-October when fluctuations in dissolved oxygen began to occur every other week, bringing it above 6 mg/L from time to time, until higher flows came in November creating more consistent sub-optimal levels. These fluctuations in Somenos Creek dissolved oxygen levels may indicate ground water inflows that helped elevate anoxic levels during fall Salmonid migration events.
 - Salmon spawning migration up Somenos Creek to the upper tributaries of Averill, Bings, Richards creeks was potentially delayed between September 30, when dissolved oxygen levels in Somenos Lake were adequate, and mid-October when Somenos Creek dissolved oxygen levels started to fluctuate between anoxic and sub-optimal.
- Richards Creek at Herd Road has anoxic conditions throughout most of the year (except a few instances in January, and November during fall spawning). In the upper reach of Richards Creek at Richards Trail

dissolved oxygen ranged between sub-optimal to optimal range for the entire year. It is important fish reach upper Richards creek to be able to reach these spawning grounds in the fall. Currently Richards creek at Herd Road is passible during fall spawning; but it should be closely monitored to ensure they are able to continue their migration upstream in the future.

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Appendix A

Monthly Somenos Lake Monthly Average Water Quality Data Profiles 2021

Month	Temperature (°C)						
	0m	1m	2m	3m	4m	5m	6m
January	5	5	5	5	5	5	5
February	3.40	3.40	3.40	3.40	3.40	3.40	3.50
March	9.05	8.65	8.55	8.50	8.40	8.35	7.95
May	16.90	16.43	16.13	15.28	13.95	12.68	12.30
June	21.7	21.0	20.0	17.1	16.1	14.9	14.2
July	24.63	24.25	23.75	22.48	18.95	15.80	14.67
August	24	23.4	22.9	22.2	21	18.9	17.1
September	18.6	18.2	18.1	17.8	17.7	17.7	17.6
October	10.4	10.4	10.4	10.4	10.4	10.4	10.4
November	6.7	6.5	6.4	6.4	6.4	6.4	6.4
December	5.7	5.7	5.7	5.6	5.6	5.6	5.5

Month	Dissolved Oxygen (mg/L)						
	0m	1m	2m	3m	4m	5m	6m
January	9.9	9.7	9.7	9.6	9.6	9.4	9.5
February	9.1	8.9	8.7	8.6	8.55	8.6	8.9
March	9.8	10.3	9.8	9.9	9.7	9.6	8.8
May	11	11.1	10.7	8.2	4.1	0.8	0.3
June	13	12.7	10.4	6.6	4.4	0.5	0.2
July	10.87	10.65	6.97	2.87	0.46	0.37	0.34
August	10.5	9.67	7.8	3.76	2.1	0.33	0.3
September	10.284	8.078	7.044	5.586	4.992	3.852	2.06
October	8.49	7.12	6.93	6.87	6.63	7.16	1.81
November	13.94	7.5	7.59	5.57	4.75	1.81	0.39
December	7	6.9	6.77	6.66	6.63	6.61	6.63

Month	pH Profile						
	0m	1m	2m	3m	4m	5m	6m
January	7.50	7.20	7.07	6.80	6.80	6.70	6.60
February	7	7.1	7.1	7.1	7.1	7.1	7
March	7.46	7.51	7.41	7.32	7.25	7.23	7.22
May	8.14	7.91	7.81	7.71	7.57	7.34	7.16
June	8.81	8.72	8.47	8.05	7.78	7.63	7.43
July	8.65	8.63	8.27	7.87	7.32	6.75	6.46
August	7.985	7.945	7.575	7.36	7.2	7.5325	7.3625
September	8.04	-	-	-	-	-	7.6
October	7.84	7.8	7.7	7.6	7.5	7.4	7.41
November	7.48	7.48	7.47	7.46	7.45	7.45	7.45
December	7.7	7.69	7.68	7.67	7.66	7.65	7.64

Month	Specific Conductivity ($\mu\text{S/cm}$)						
	0m	1m	2m	3m	4m	5m	6m
January	103.0	103.0	103.0	103.0	103.1	103.0	103.1
February	106.0	106.0	106.0	106.0	106.0	107.0	114.0
March	126.3	126.4	126.3	126.4	126.5	126.5	126.9
May	144.1	144.1	144.2	144.5	144.6	147.4	151.9
June	161.1	156.8	151.0	150.8	152.7	159.3	158.3
July	166.1	164.5	157.6	159.6	170.4	187.3	210.1
August	162.4	162.1	161.8	164.5	168.6	193.6	219.4
September	194.9	195.2	195.2	195.2	195.3	196.3	200.6
October	289.9	294.1	294.4	294.4	293.8	293.8	293.4
November	108.6	108.2	107.8	107.8	107.9	108.0	108.1
December	220.8	221.5	220.4	218.6	214.6	211.9	210.8

Month	Total Dissolved Solids (mg/L)						
	0m	1m	2m	3m	4m	5m	6m
January	66.9	66.9	66.9	66.9	66.9	66.9	66.9
February	69.0	69.0	69.0	69.0	69.0	70.0	74.0
March	82.3	82.1	82.3	82.3	82.3	82.3	82.9
May	93.6	93.6	93.8	94.0	94.0	95.6	98.5
June	104.7	101.9	97.7	98.1	99.3	103.6	110.2
July	107.9	106.8	102.5	103.8	110.7	121.2	136.6
August	105.6	105.5	105.2	106.9	109.5	125.9	142.5
September	126.5	126.8	126.9	126.8	127.0	127.5	131.2
October	188.5	191.1	191.1	191.1	191.1	191.1	190.5
November	70.9	70.2	70.2	70.2	70.2	70.2	70.2
December	143.0	143.7	143.0	141.7	139.1	137.8	137.2

Date	Phosphate (mg/L)		Ammonia (mg/L)		Nitrite (mg/L)		Nitrate (mg/L)	
	1m	6 m	1m	6m	1m	6m	1m	6m
7-Jan-21	-	-	-	-	-	-	-	-
18-Feb-21	0.23	0.62	-	-	-	-	-	-
11-Mar-21	0.31	0.35	-	-	-	-	-	-
15-Mar-21	-	-	-	-	-	-	-	-
6-May-21	-	0.53	-	-	-	-	-	-
14-May-21	0.45	0.76	-	-	-	-	-	-
20-May-21	0.03	1.65	-	-	-	-	-	-
27-May-21	0.05	1.47	-	-	-	-	-	-
4-Jun-21	0.15	1.34	-	-	-	-	-	-
10-Jun-21	0.05	1.84	-	-	-	-	-	-
17-Jun-21	0.10	0.78	-	-	-	-	-	-
20-Jun-21	0.03	1.65	-	-	-	-	-	-
24-Jun-21	0.06	0.11	0.253	0.242	0.000	0.005	0.000	0.000
30-Jun-21	0.10	1.16	0.140	0.730	-	-	-	-
8-Jul-21	0.28	8.28	-	-	-	-	-	-
15-Jul-21	0.21	8.98	-	-	-	-	-	-
22-Jul-21	0.09	3.19	-	-	-	-	-	-
29-Jul-21	0.15	>>	0.080	2.000	0.010	0.050	0.005	0.040
5-Aug-21	3.37	0.06	-	-	-	-	-	-
12-Aug-21	0.15	3.13	-	-	-	-	-	-
19-Aug-21	0.06	3.31	-	-	-	-	-	-
24-Aug-21	0.09	3.19	0.050	2.000	0.005	0.040	0.000	0.080
2-Sep-21	0.40	0.46	-	-	-	-	-	-
9-Sep-21	0.06		-	-	-	-	-	-
16-Sep-21	0.20	0.69	-	-	-	-	-	-
23-Sep-21	0.31	0.23	-	-	-	-	-	-
30-Sep-21	0.17	0.53	0.080	0.210	0.000	0.010	0.005	0.005
28-Oct-21	0.19	0.16	-	-	-	-	-	-
26-Nov-21	0.23	0.20	0.150	0.100	0.017	0.007	0.005	0.013
9-Dec-21	0.34	0.23	0.210	0.070	0.015	0.013	0.012	0.007

<< = less than 0.01 mg/L therefore 0.005 mg/L was used for these values; >> = greater than 2 mg/L, therefore 2 was used for these values

Month	Phosphate (mg/L)		Ammonia (mg/L)		Nitrite (mg/L)		Nitrate (mg/L)	
	1m	6 m	1m	6m	1m	6m	1m	6m
January	-	-	-	-	-	-	-	-
February	0.230	0.620	-	-	-	-	-	-
March	0.310	0.350	-	-	-	-	-	-
May	0.177	1.103	-	-	-	-	-	-
June	0.082	1.147	0.197	0.486	-	0.005	0.000	0.000
July	0.184	6.817	0.080	2.000	0.010	0.050	0.005	0.040
August	0.920	2.422	0.050	2.000	0.005	0.040	0.000	0.080
September	0.228	0.477	0.080	0.210	0.000	0.010	0.005	0.005
October	0.190	0.160	-	-	-	-	-	-
November	0.230	0.200	0.150	0.100	0.017	0.007	0.005	0.013
December	0.340	0.230	0.210	0.070	0.015	0.013	0.012	0.007

<< = less than 0.01 mg/L therefore 0.005 mg/L was used for these values; >> = greater than 2 mg/L, therefore 2 was used for these values

Appendix B

Somenos Watershed Tributary Monthly Average Water Quality Data 2021

Date	Temperature (°C)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
01-Jan-21	6.8	1.9	5.7	3.5	6.1	7
01-Feb-21	16.8	11	10.6	13.6	10.6	11.3
29-Mar-21	9.7	7.8	-	8.4	6.6	5.7
12-Apr-21	10.4	6.7	-	8.9	6.4	6.6
27-Apr-21	14.6	11.3	10.3	13.6	10.9	11.2
10-May-21	17.2	11.4	10.2	14.5	11.1	10.7
17-May-21	19.7	15.8	12.6	18.3	13.5	13.4
25-May-21	18.9	17.4	12.83	16.8	13.1	13.8
01-Jun-21	21.5	17.7	14.2	19.1	13.8	14.3
07-Jun-21	19.1	15.5	10.7	15	11.5	11.8
14-Jun-21	20.6	14.7	12.9	17	13.9	14.4
21-Jun-21	23.8	21	15.9	22	16.2	16.7
30-Jun-21	28	20.9	19.8	25.3	21.1	20.6
05-Jul-21	27.3	19	17.9	20.9	19.8	19
06-Jul-21	-	-	-	22.5	-	-
12-Jul-21	29.3	18.3	17.4	14.3	18.9	18.9
19-Jul-21	25.6	16.3	16.7	13.8	18.6	17.6
26-Jul-21	26.5	16.9	17.7	16.5	19	18.9
03-Aug-21	27.3	18.9	18.5	17.2	18.3	19.1
09-Aug-21	24.3	17.6	16.6	16.9	17.7	17.3
16-Aug-21	23.8	18.8	17.8	17.6	18.5	18.6
23-Aug-21	23.2	15.4	14.7	15.1	15.2	15.6
30-Aug-21	20.3	13.8	14.3	14	15.3	14.7
06-Sep-21	21	13.1	14.3	12.8	15	14.4
13-Sep-21	-	14.2	-	13.6	-	-
20-Sep-21	-	12.3	-	12.8	-	-
27-Sep-21	-	12.4	-	13.6	-	-
04-Oct-21	17	11.6	10.7	12.2	11	11.3
13-Oct-21	14	7.1	-	9.3	-	-
18-Oct-21	13.4	9.9	9.4	12.4	9.7	10.4
25-Oct-21	13.1	9.8	9.8	10.9	11.2	11.9
01-Nov-21	-	6.8	6.1	7.9	6.4	6.6
08-Nov-21	-	-	-	8.6	-	8.4
16-Nov-21	-	7.6	7.4	8.3	7.7	7.9
26-Nov-21	-	5.7	7.3	6.6	7.3	7.5
14-Dec-21	-	2.9	4.2	4.2	4.3	4.5

Date	Dissolved Oxygen (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
01-Jan-21	6.32	0.85	11.7	1.23	8.97	11.7
01-Feb-21	8.7	10	13.9	9.7	13.2	13.2
29-Mar-21	11.8	4.34	-	8.8	12.33	14.2
12-Apr-21	10.2	5.2	-	7.6	13.3	14.9
27-Apr-21	10.9	5.25	12	6.3	11.3	12.1
10-May-21	9.62	3.65	11.38	5.2	11.3	11.35
17-May-21	11.31	4.96	10.67	3.76	10.19	9.72
25-May-21	9.8	4.02	10.1	2.57	9.23	8.8
01-Jun-21	11.1	3.7	10.2	2.18	9.85	8.82
07-Jun-21	9.84	1.47	10.88	2.4	10.07	10.03
14-Jun-21	18.7	2.46	10.44	3.58	9.76	9.67
21-Jun-21	19.52	4.08	9.93	3.7	8.34	8.4
30-Jun-21	10.35	0.36	8.32	0.65	7.18	6.2
05-Jul-21	15.57	0.45	8.88	2.79	7.8	6.31
12-Jul-21	10.66	1.03	8.75	4	7.82	7.79
19-Jul-21	7.03	0.5	9.18	4.6	8.41	7.34
26-Jul-21	17.79	0.67	8.5	1.47	7.82	6.57
03-Aug-21	15.41	0.95	9.25	4.3	7.89	7.87
09-Aug-21	5.18	1.07	9.61	0.91	8.58	7
16-Aug-21	10.41	0.38	9.82	0.38	6.87	7.44
23-Aug-21	12.38	0.56	10.16	3.1	7.46	6.45
06-Sep-21	14.7	0.86	9.5	0.42	7.3	5.8
13-Sep-21	-	4.1	-	4	-	-
20-Sep-21	-	8.1	-	4.8	-	-
27-Sep-21	-	0.93	-	5.53	-	-
04-Oct-21	7.9	1.65	10.8	0.72	9.02	10.1
13-Oct-21	10.74	2.48	-	1.26	-	-
18-Oct-21	9.4	2.04	10.6	6.2	11.4	10.7
25-Oct-21	8.48	1.03	9.7	0.77	9.42	9.49
29-Oct-21	-	-	-	7.9	-	-
01-Nov-21	-	1.3	12.62	3.71	11.24	11.83
08-Nov-21	-	-	-	6.03	-	12.27
16-Nov-21	-	8.28	13.03	9.32	12.87	12.04
26-Nov-21	-	4.74	12.54	5.48	12.36	12.24
14-Dec-21	-	7.81	16.5	8.57	12.67	12.65

Date	pH					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	7.46	6.9	-	7	7.7	7.5
12-Apr-21	7.75	7.97	-	8.4	7.9	7.7
27-Apr-21	7.3	6.9	6.92	6.6	7.66	7.5
10-May-21	7.41	7.16	7.27	7.46	7.4	7.55
17-May-21	8.04	7.11	7.4	7.62	7.63	7.9
25-May-21	7.7	7.34	7.71	7.85	7.79	7.8
01-Jun-21	7.84	7.71	7.92	7.68	8.2	7.9
07-Jun-21	7.98	7.5	7.84	7.41	7.82	7.97
14-Jun-21	9.6	6.28	6.21	9.17	8.32	8.46
21-Jun-21	10.29	7.1	7.9	8.2	8.55	9.1
30-Jun-21	9.66	6.75	7.85	7.05	7.43	8.05
05-Jul-21	9.85	6.4	6.99	7.81	7.63	7.89
06-Jul-21	-	-	-	7.36	-	-
12-Jul-21	9.68	6.31	6.88	7.8	7.65	8.5
19-Jul-21	7.81	6.18	7	7.17	7	7.1
26-Jul-21	9.8	6.11	6.75	6.78	7.44	7.86
03-Aug-21	9.72	6.5	6.9	7.2	7.14	7.89
09-Aug-21	6.77	6.14	6.45	6.36	6.59	6.45
16-Aug-21	8.07	6.81	6.93	6.68	7.01	7.44
23-Aug-21	8.43	7.37	6.8	6.89	7.84	7.5
30-Aug-21	7.49	6.79	6.59	6.66	8.18	7.91
06-Sep-21	9.6	9.3	10.1	10.8	9.8	9.5
13-Sep-21	-	6.63	-	6.47	-	-
20-Sep-21	-	6.66	-	6.63	-	-
27-Sep-21	-	9.18	-	9.13	-	-
04-Oct-21	7.78	6.83	7.75	6.63	6.77	7.64
13-Oct-21	7.58	7.01	-	6.96	-	-
18-Oct-21	7.69	6.84	7.7	7.2	7.61	7.76
25-Oct-21	7.32	6.79	7.45	7.07	7.57	7.59
01-Nov-21	-	6.87	6.94	7.01	7.41	7.39
08-Nov-21	-	-	-	7.48	-	7.44
16-Nov-21	-	-	7.68	7.54	7.61	7.47
26-Nov-21	-	6.91	7.22	7.01	7.46	7.23
14-Dec-21	-	7	7.54	7.25	7.65	7.35

Date	Specific Conductivity ($\mu\text{S}/\text{cm}$)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	132	153	-	139	143	182
12-Apr-21	133	134	-	144	164	218
27-Apr-21	138	189	154	152	180	214
10-May-21	143.6	227.7	181.6	156.6	208.3	227.4
17-May-21	145.2	250.7	188.9	161.6	219.7	237.2
25-May-21	146.9	229	191	167	229.6	230
1-Jun-21	148	217	194	171	238	244
7-Jun-21	149.7	231.7	171	164.4	234.4	170.5
14-Jun-21	160	199.6	167.6	154.2	119	252.3
21-Jun-21	184.4	219.7	178.6	163.2	140	247
30-Jun-21	165.3	170.2	104.2	182.2	283.8	258.5
5-Jul-21	182.9	134.6	102.3	199.1	288.7	256.1
6-Jul-21	-	-	-	237.4	-	-
12-Jul-21	171.4	123.4	100.8	161.9	295	252
19-Jul-21	158.3	116.4	99.3	166.7	302.8	240.8
26-Jul-21	191	111	98.3	125.2	304.9	232.9
3-Aug-21	184.9	108.3	100.7	121.8	303.4	235.5
9-Aug-21	167	107.2	100.3	111.5	305	245.7
16-Aug-21	161.7	106.6	100.5	116.5	303.4	230.2
23-Aug-21	161.6	100.7	112.8	113	304.5	228.8
30-Aug-21	159.5	110.1	116.2	116.6	366	240.7
6-Sep-21	166	132	127	179	235	301
13-Sep-21	-	135	-	169	-	-
20-Sep-21	-	141	-	191	-	-
27-Sep-21	-	133	-	100.6	-	-
4-Oct-21	167	182	126	212	284	257
13-Oct-21	166	172.3	-	192.4	-	-
18-Oct-21	165.5	177	161	86.5	109.6	184.4
25-Oct-21	450	480	166.7	177.2	331.7	687
1-Nov-21	-	360.1	328.1	300.7	479.7	326.5
8-Nov-21	-	-	-	246.4	-	224.2
16-Nov-21	-	98.4	83.3	87.6	64.4	89
26-Nov-21	-	105.3	87.5	112.3	86.8	12.47
14-Dec-21	-	236	204	251.9	231.5	306.5

Date	Total Dissolved Solids (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	86	100	-	90	93	119
12-Apr-21	86.5	88	-	93.6	107	141
27-Apr-21	90	123	107	99	117	139
10-May-21	93.6	147.6	118.3	102.1	135.2	147.6
17-May-21	94.25	164.45	122.85	105.3	143	154.05
25-May-21	95.5	148	124	108.5	149	149
1-Jun-21	96.2	141.7	126	111	155	159
7-Jun-21	96.85	151.45	111.15	106.6	152.1	110.5
14-Jun-21	104	129.35	109.2	100.1	142.35	163.8
21-Jun-21	119.6	142.35	115.7	105.95	152.1	160.55
30-Jun-21	107.25	107.9	67.6	118.3	184.6	168.35
5-Jul-21	118.95	87.75	66.3	129.35	187.85	106.4
6-Jul-21	-	-	-	158.25	-	-
12-Jul-21	111.1	79.95	65.65	105.95	191.1	163.8
19-Jul-21	102.7	74.4	64.35	107.25	196.95	156.65
26-Jul-21	124.8	70.2	64.35	81.25	196.3	151.45
3-Aug-21	120.9	70.85	65.65	79.3	195	153.4
9-Aug-21	108.55	68.25	65	72.8	198.25	159.9
16-Aug-21	104.65	70.2	65	75.4	189.45	150.5
23-Aug-21	105.3	66.3	73.45	73.45	198.25	148.85
30-Aug-21	103.35	72.15	75.4	74.1	239.85	156.65
6-Sep-21	108	85	82.6	119	153	197
13-Sep-21	-	89	-	110	-	-
20-Sep-21	-	92	-	125	-	-
27-Sep-21	-	86.45	-	65	-	-
4-Oct-21	109	119	82	138	185	166
13-Oct-21	107.9	111.15	-	123.5	-	-
18-Oct-21	108	115	105	55.9	71.5	119.6
25-Oct-21	242.4	242.4	107.9	115	215.8	448.5
1-Nov-21	-	234	213.85	195	306.2	211.9
8-Nov-21	-	-	-	160.55	-	141.25
16-Nov-21	-	64.35	53.95	57.85	41.6	57.85
26-Nov-21	-	69.55	57.2	73.45	56.55	81.25
14-Dec-21	-	153.4	133.26	163.8	150.8	199.5

Date	Phosphate (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	0.08	0.23	-	0.18	0.12	0.13
27-Apr-21	0.1	0.3	0.12	0.2	0.09	0.04
10-May-21	0.21	0.51	0.07	0.31	0.07	0.19
17-May-21	0.1	0.26	0.14	0.11	0.25	0.06
25-May-21	0.1	0.43	0.13	0.33	0.12	0.55
1-Jun-21	0.12	0.65	0.27	0.36	0.33	0.35
7-Jun-21	0.15	1.05	0.15	0.51	0.24	0.33
14-Jun-21	0.02	0.98	0.23	0.21	0.21	0.3
21-Jun-21	0.14	0.19	0.12	0.37	0.52	0.5
30-Jun-21	0.29	2.32	<<	0.96	0.34	0.74
5-Jul-21	0.21462	11.9574	0.52122	1.87026	0.85848	1.19574
6-Jul-21	-	-	-	1.8396	-	-
12-Jul-21	0.4599	10.17912	0.98112	0.79716	1.10376	1.93158
19-Jul-21	<<	6.00936	1.25706	0.95046	0.58254	1.28772
26-Jul-21	<<	1.533	0.33726	1.25706	0.21462	0.39858
3-Aug-21	<<	1.3797	0.24528	0.82782	0.4599	0.58254
9-Aug-21	0.49056	1.13442	0.27594	0.39858	0.3066	0.36792
16-Aug-21	0.18396	1.0731	0.52122	0.82782	0.21462	0.67452
23-Aug-21	0.21462	1.34904	0.39858	0.33726	0.27594	0.33726
30-Aug-21	0.27594	0.39858	0.12264	0.55188	0.39858	0.42924
6-Sep-21	0.58254	0.4599	0.141036	0.09198	0.079716	0.09198
13-Sep-21	-	-	-	-	-	-
20-Sep-21	-	0.37	-	0.48	-	-
27-Sep-21	-	2.2	-	1.15	-	-
4-Oct-21	0.3	0.15	-	0.18	-	-
13-Oct-21	0.31	1.25	-	0.98	-	-
18-Oct-21	-	0.22	0.18	-	0.15	0.11
25-Oct-21	-	-	-	-	-	-
1-Nov-21	-	1.1	0.26	0.32	0.23	0.19
8-Nov-21	-	-	-	-	-	-
16-Nov-21	-	-	0.17	0.29	0.15	0.33
26-Nov-21	-	0.4	0.41	0.15	0.11	0.25
14-Dec-21	-	0.4	0.19	0.39	0.22	0.38

Date	Ammonia (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	-	-	-	-	-	-
12-Apr-21	-	-	-	-	-	-
27-Apr-21	-	-	-	-	-	-
10-May-21	-	-	-	-	-	-
17-May-21	-	-	-	-	-	-
25-May-21	-	-	-	-	-	-
1-Jun-21	-	-	-	-	-	-
7-Jun-21	-	-	-	-	-	-
14-Jun-21	<<	<<	<<	<<	-	-
21-Jun-21	-	-	-	-	-	-
30-Jun-21	0.13	0.37	0.14	0.12	0.17	0.2
5-Jul-21	-	-	-	-	-	-
6-Jul-21	0	0	0	0.17	0	0
12-Jul-21	-	-	-	-	-	-
19-Jul-21	0.09	0.21	0.13	0.63	0.11	0.09
26-Jul-21	-	-	-	-	-	-
3-Aug-21	-	-	-	-	-	-
9-Aug-21	-	-	-	-	-	-
16-Aug-21	-	-	-	-	-	-
23-Aug-21	0.07	0.08	0.07	0.05	0.04	0.08
30-Aug-21	-	-	-	-	-	-
6-Sep-21	-	-	-	-	-	-
13-Sep-21	-	-	-	-	-	-
20-Sep-21	-	-	-	-	-	-
27-Sep-21	-	-	-	-	-	-
4-Oct-21	-	-	-	-	-	-
13-Oct-21	-	-	-	-	-	-
18-Oct-21	-	-	-	-	-	-
25-Oct-21	-	-	-	-	-	-
1-Nov-21	-	-	-	-	-	-
8-Nov-21	-	-	-	-	-	-
16-Nov-21	-	-	-	-	-	-
26-Nov-21	-	0.05	0.04	0.01	<<	0.05
14-Dec-21	-	0.08	<<	0.03	<<	0.04

Date	Nitrite (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	-	-	-	-	-	-
12-Apr-21	-	-	-	-	-	-
27-Apr-21	-	-	-	-	-	-
10-May-21	-	-	-	-	-	-
11-May-21	-	-	-	-	-	-
17-May-21	-	-	-	-	-	-
25-May-21	-	-	-	-	-	-
1-Jun-21	-	-	-	-	-	-
4-Jun-21	-	-	-	-	-	-
7-Jun-21	-	-	-	-	-	-
14-Jun-21	0.001	0	0.001	0.003	-	-
21-Jun-21	-	-	-	-	-	-
23-Jun-21	-	-	-	-	-	-
30-Jun-21	0	0	0	0	0	0
5-Jul-21	-	-	-	-	-	-
6-Jul-21	0	0	0	0	0	0
12-Jul-21	-	-	-	-	-	-
19-Jul-21	0	0.004	<<	0.011	0.04	0
26-Jul-21	-	-	-	-	-	-
3-Aug-21	-	-	-	-	-	-
9-Aug-21	-	-	-	-	-	-
13-Aug-21	-	-	-	-	-	-
16-Aug-21	-	-	-	-	-	-
23-Aug-21	0	<<	0.01	0.02	0.01	0.03
30-Aug-21	-	-	-	-	-	-
6-Sep-21	-	-	-	-	-	-
8-Sep-21	-	-	-	-	-	-
13-Sep-21	-	-	-	-	-	-
20-Sep-21	-	-	-	-	-	-
27-Sep-21	-	-	-	-	-	-
4-Oct-21	-	-	-	-	-	-
13-Oct-21	-	-	-	-	-	-
18-Oct-21	-	-	-	-	-	-
25-Oct-21	-	-	-	-	-	-
29-Oct-21	-	-	-	-	-	-
1-Nov-21	-	-	-	-	-	-
8-Nov-21	-	-	-	-	-	-
16-Nov-21	-	-	-	-	-	-
26-Nov-21	-	0.021	0.0003	0.007	<<	0.007
14-Dec-21	-	0.016	0.003	0.012	0.004	0.018

Date	Nitrate (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
29-Mar-21	-	-	-	-	-	-
12-Apr-21	-	-	-	-	-	-
27-Apr-21	-	-	-	-	-	-
10-May-21	-	-	-	-	-	-
17-May-21	-	-	-	-	-	-
25-May-21	-	-	-	-	-	-
1-Jun-21	-	-	-	-	-	-
7-Jun-21	-	-	-	-	-	-
14-Jun-21	<<	<<	<<	<<	-	-
21-Jun-21	-	-	-	-	-	-
30-Jun-21	0	0	0	0	0	0
5-Jul-21	-	-	-	-	-	-
6-Jul-21	0	0	0	0	0	0
12-Jul-21	-	-	-	-	-	-
19-Jul-21	<<	0.031	0.004	<<	<<	0
26-Jul-21	-	-	-	-	-	-
3-Aug-21	-	-	-	-	-	-
9-Aug-21	-	-	-	-	-	-
16-Aug-21	-	-	-	-	-	-
23-Aug-21	<<	<<	<<	<<	<<	<<
30-Aug-21	-	-	-	-	-	-
6-Sep-21	-	-	-	-	-	-
13-Sep-21	-	-	-	-	-	-
20-Sep-21	-	-	-	-	-	-
27-Sep-21	-	-	-	-	-	-
4-Oct-21	-	-	-	-	-	-
13-Oct-21	-	-	-	-	-	-
18-Oct-21	-	-	-	-	-	-
25-Oct-21	-	-	-	-	-	-
1-Nov-21	-	-	-	-	-	-
8-Nov-21	-	-	-	-	-	-
16-Nov-21	-	-	-	-	-	-
26-Nov-21	-	<<	<<	<<	<<	0.004
14-Dec-21	-	0.002	<<	0.015	<<	0.019