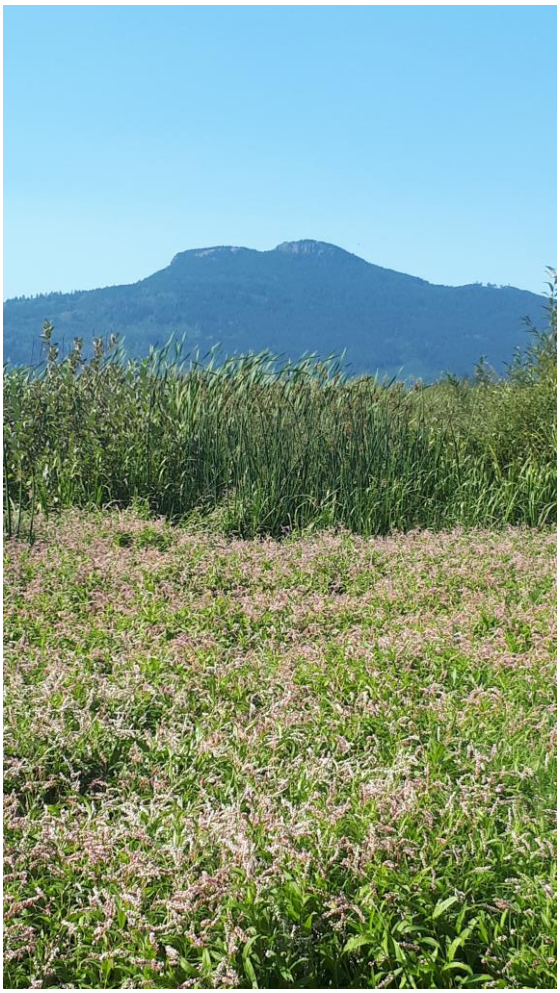

MUNICIPALITY OF NORTH COWICHAN SERVICE AGREEMENT WITH THE SOMENOS MARSH WILDLIFE SOCIETY

ANNUAL REPORT 2022

Prepared for: Municipality of North Cowichan

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2 EXECUTIVE SUMMARY

This report describes work completed by the Somenos Marsh Wildlife Society (the Society) on behalf of the Municipality of North Cowichan (MNC). The work is described in the 2022 Service Agreement between the Society and the Municipality. The 2022 Service Agreement is the second such agreement between the parties and has proven to be an excellent method of defining and tracking important environmental projects in the largest watershed in the Municipality. North Cowichan Environment Staff and the Society established the service agreement in 2021 to support North Cowichan Council's 2020 strategic Plan goal of leading "…in environmental policies and practices to support the future health of our community." Specifically, the Society-MNC service agreement provides monitoring and data that supports the Council Strategic Plan action of evaluating "…options for environmental improvements to Quamichan and Somenos Lakes." Furthermore, environmental work done through the Society-MNC service agreement such as tree planting, riparian habitat restoration, and aquatic habitat restoration are practical examples of environmental improvement in Somenos Lake and its watershed. This restoration work relies on collaboration between staff from SMWS and MNC and the support of dozens of volunteers from our community.

The Somenos Marsh Wildlife Society is a non-profit society founded in 1987. The SMWS mission statement includes these words: "to operate, maintain, manage, restore and preserve areas for research, nature study, observance of flora and fauna, protection of wildlife habitat, instruction in natural history and other purposes of a like nature". The Society's activities are fully funded by grants and donations. Currently the Society has one full time staff member who is a Registered Professional Biologist in the Province of BC. The fieldwork of the Society is mostly carried out by staff, volunteers, and Society directors. The Society has carried out many projects on behalf of the Municipality over the years.

The first section of this report describes the water quality data collection work completed in 2022 in the Somenos watershed. Water quality is important for human health and for the flora and fauna that live in and next to our lakes and streams. The data collected informs the Municipality's Environmental Services Department about the condition of Somenos Lake. The lake is shallow and has elevated levels of nutrients, leading to algae blooms in the summer. The lake used to support recreational fishing. Tracking water quality is a valuable tool in finding the way back to a healthier lake.

Water quality measurements in the creeks flowing into and out of Somenos Lake are also covered in the report. These measurements help identify where contaminants come into the watershed, and where water conditions support healthy biodiversity. The Somenos Watershed has a population of salmon that return to spawn each year. 2022 was a difficult year for migration of spawning salmon into the watershed due to low oxygen levels in Somenos Creek, low flow in all creeks, and recent cold temperatures. The watershed can support a much greater population of spawning salmon than is currently seen.

The second section of the Service Agreement report documents how the Society monitored the 2022 growth of the invasive aquatic weed Parrot's Feather, a vigorous weed introduced into Somenos Creek eight years ago. This section describes how Parrot's Feather has once again spread out to cover most of the water surface of the creek by September. High water levels and flow rates in the winter flush most of the Parrot's Feather into the Cowichan River, with regrowth occurring the following spring. Parrot's Feather appears to be an impediment to spawning salmon migration in Somenos Creek due to its characteristic of reducing water oxygen levels. It is also an impediment to recreational use of the creek for kayaking in the summer.

The third section of the report describes how the Somenos Marsh Wildlife Society is assisting the Municipality in exploring Parrots Feather control methods. One effective but long-term measure is to increase the amount of shading along Somenos Creek as Parrot's Feather prefers high light levels. The Society has planted over 1500 trees in three areas along the creek in 2022, as part of the work defined in the Service Agreement. These native trees will eventually create a natural riparian zone along the creek that will help limit the growth of Parrot's Feather and have many other benefits for

riparian and aquatic life. The trees were planted by Society volunteers, Cowichan High School students, and Cowichan Tribes workers.

The last section of the Service Agreement report describes the restoration work done along Bings (Holmes) Creek in the area between the Island Highway and Somenos Lake. The creek flows close to the boardwalk created and maintained by the Society and is in a degraded state compared to its original condition. The Society has added shade trees and removed invasive grasses to improve water quality. Spawning gravel was added to improve spawning conditions for salmon. This section of Bings Creek is of special interest as it is connected via culverts to the area around the RCMP building on Canada Ave. This building, and Canada Avenue, may be the site of demolition or construction in the next few years and monitoring of water quality parameters will be critical at that time.

The Somenos Marsh Wildlife Society has had a long working relationship with the Municipality of North Cowichan. The Society appreciates the support of the Municipality, and in return carries out efficient, low-cost restoration and monitoring work in the unique Somenos watershed. North Cowichan is fortunate in having such a diverse geography and biodiversity within its boundaries. The Somenos Marsh Wildlife Society looks forward to continuing our joint efforts to maintain and restore this precious environment for the residents of this valley.

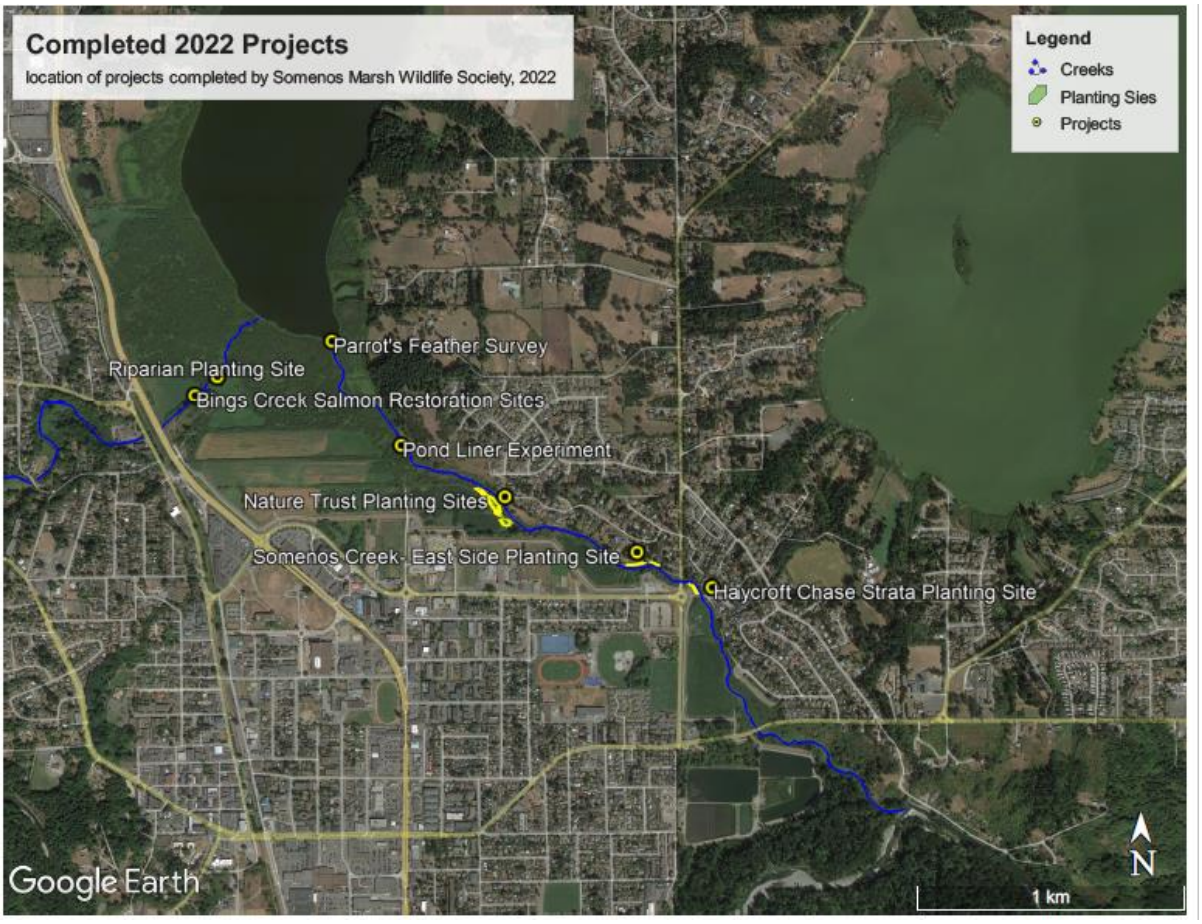


FIGURE 1: 2022 COMPLETED PROJECTS

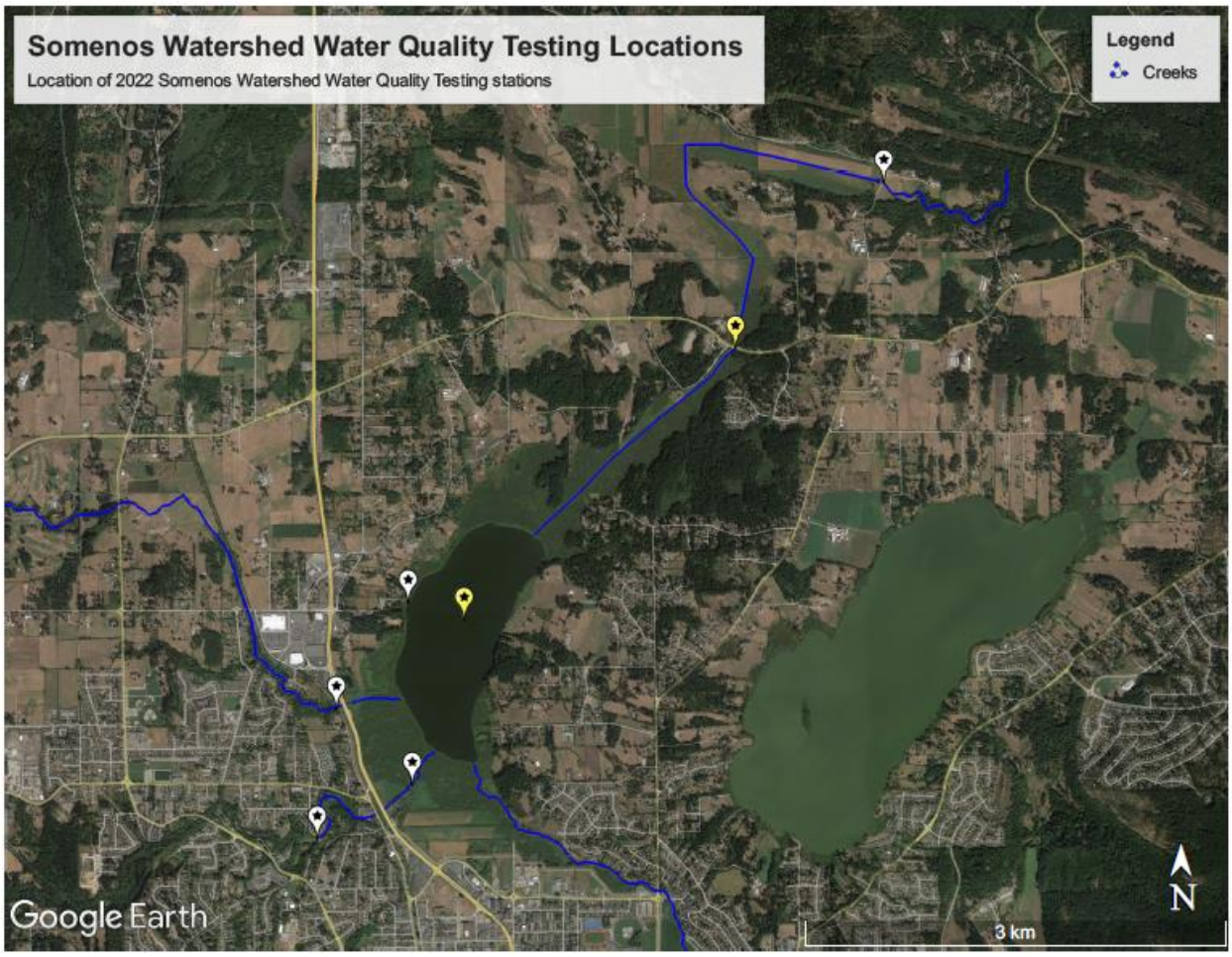


FIGURE 2: SOMENOS WATERSHED WATER QUALITY 2022 TESTING LOCATIONS.

3 WATER QUALITY MONITORING PROGRAM

3.1 THE S'AMUNU | SOMENOS WATERSHED

The S'amunu | Somenos Watershed (the Watershed) covers 71 km2 within unceded Cowichan Tribes Territory, and is mostly located within the boundaries of the Municipality of North Cowichan. Portions of the Watershed encompass Cowichan Tribes land, land within the City of Duncan, and the CVRD. 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 Society has conducted water quality monitoring in Somenos Lake for the MNC since 2014 and, beginning in 2020, added monitoring of the four major tributaries; Richards, Averill, Bings, and Somenos Creeks.

3.2 PURPOSE OF THE WATER QUALITY MONITORING PROGRAM

The Somenos Watershed is being impacted by agriculture, development, and a growing demand for more housing developments and supporting infrastructure. Runoff and airborne precipitation from these impacts can discharge into the watershed and may contain compounds that can harm the watershed's aquatic ecology. Monitoring water quality allows us to understand the current state of the watershed's health allowing us to identify impacts over time as well as

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.

3.3 WATER QUALITY PARAMETERS COLLECTED

Under the Municipality of North Cowichan Service Agreement for 2022, the Somenos Marsh Wildlife Society Water Quality Monitoring parameters include:

- Weekly (Summer: May 01- Sep 30): Somenos Creek and Somenos Lake for T (temperature), DO (dissolved oxygen), pH (acid balance), SPC (specific conductivity) and TDS (total dissolved solids)
- Monthly (Winter: OCT 01 – Dec 31): Somenos Creek and Somenos Lake for T, DO, pH, SPC and TDS
- Hourly (data loggers): Somenos Lake for T (lake station), Somenos Creek for T + irradiance (~6 stations)
- Monthly: 3 locations: Richards Creek, Somenos Lake, Somenos Creek for total phosphate, ammonia, nitrate, nitrite, total nitrogen

In addition, the Society included weekly summer, and monthly winter sampling on Bings Creek (2 sites), Averill Creek (1 site), and an extra site on Richards Creek (Richards Trail) for:

- T, DO, pH, SPC and TDS
- Monthly sampling for total phosphate, orthophosphate, ammonia, nitrate, nitrite, total nitrogen

3.4 METHOD OF WATER QUALITY DATA COLLECTION

In the fall, weekly testing of temperature and dissolved oxygen was included to determine when the tributaries were within the accepted range of values for salmon spawning migration. Specifically, Somenos Creek at Lakes Road and Richards Creek at Herd Road were below survivable levels in the summer and were monitored closely. In 2022 a dissolved oxygen and temperature probe was installed at the Lakes Road bridge in September to sample every 10 minutes on Somenos Creek to monitor fluctuations.

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. From Spring to Fall the probe was used twice a week and was fully calibrated once a month. The dissolved oxygen membrane was replaced every 2 months, pH proper replaced, and conductivity probe replaced once. Due to delays in shipping, a replacement pH probe was delayed until February 2022; 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.

3.5 WATER QUALITY DATA AND CHARTS

Refer to the appendices to review the results of the water quality data collection program.

3.6 SOME CONCLUSIONS ABOUT THE WATER QUALITY TEST RESULTS

The results of this year's annual water quality monitoring program show us a glimpse of what is happening in the Somenos Watershed regarding water quality health and what the potential impacts are on aquatic life. Some key conclusions made during the WQ sampling season in 2022 are as follows:

- Somenos Lake stratification occurred in July and finally turned over by November which coincided with a profile change of temperature, dissolved oxygen, conductivity, and TDS. In 2021 stratification occurred from May to September, so this year stratification and turn-over shifted forward a few months.
- Somenos lake dissolved oxygen was low (<6mg/L) at the bottom (6m depth) from late June, and by August 4 the entire water column followed suit.
- August 4 until November 17 the entire water column was > 15.6°C which is above the optimal range for rearing and migration of salmonids.
- Generally, where temperatures were cool enough for salmon, the dissolved oxygen was too low (bottom of the lake), where temperatures were too warm (first few meters of the lake) oxygen was adequate for salmonids. Therefore, the lake was not adequate for rearing or migration for most salmon in the summer.
- The Somenos Lake algae bloom was not obvious this summer. The surface of the lake turned 'green' from July 14-28. By August 4 to September 22 the lake had turned a brown color, then turned green again from September 29 to November 17. The lake was clear of algae by December.
- The SMWS Salmon Watch event in the fall of 2022 observed that the salmon migration up Somenos Creek to the upper tributaries of Averill, Bings creek was delayed this year. Spawners were first observed by a Society member on Jan. 6, 2023. In previous years (2020 – 2021) salmon were observed in late November. Unfavorable water quality conditions prior to early January (Appendix B, Chart 26) which may have contributed to the delay in spawner migration are as follows:

    - Low levels of dissolved oxygen in Somenos Creek until early December. Low flows, and heavy coverage of Parrot's Feather remaining in place is a probable cause of this.
    - Low levels of dissolved oxygen in Richards Creek until mid- December likely prevented migration upstream to spawning sites in this creek.
    - DO levels rose in December, but this was followed by a rapid drop in water temperature due to a cold snap.
    - Tributary flows in the watershed were very low until late December due to a long period of low precipitation.

- A salmon watch of volunteers checked weekly until Dec 19 and did not see any salmon in their usual spawning grounds in Averill Creek, Richards Creek, and Bings Creek. The only evidence of fish was a fresh severed salmon tail in Bings Creek at Westwood Estates, which may have been from the creek but no other salmon were spotted spawning, and an eagle was located nearby. It's possible the salmon were in the creek but not spawning yet.

4 PARROT'S FEATHER SURVEY WORK

Parrot's Feather (*Myriophyllum aquaticum*) is an invasive aquatic plant that has been taking a hold of Somenos Creek ever since being first found back in 2014 (Preikshot, 2019). It is a plant that has been introduced from the Amazon River in South America and has spread throughout North America. Parrot's Feather thrives in warm, freshwater and is commonly found in relatively shallow and slow-moving water and is well adapted to nutrient-rich environments (Washington State Department of Ecology, 2001). Unfortunately, these conditions exist in Somenos Creek for Parrot's Feather growth in the summer months.

Although introduced in 2014, Parrot's Feather has quickly taken a hold of Somenos Creek, a roughly 3km long stretch of water that drains Somenos Lake into the Cowichan River. Somenos Creek is high in nutrients, in part because the watershed is host to extensive agriculture that includes both crop growth and livestock leading to nutrient-rich runoff that ends up in Somenos Lake and Somenos Creek.

The immediate concern is that Somenos Creek is the gateway from the Cowichan River to the Somenos Watershed, a watershed that has supported substantial populations of salmon throughout history. Populations of Coho (*Oncorhynchus kisutch*) and Chum (*Oncorhynchus mykiss*) salmon use the watershed's tributaries (Richards Creek, Averill Creek, and Bings Creek) as their spawning grounds (Burns 2002). However, in recent years the only salmon observed has been Coho, which has a longer migration time than chum.

While the exact impacts are still under investigation, it has been posited that the mats of Parrot's Feather in the creek could present as a physical and water quality barrier to fish migration until fall break-up occurs. In this case, it is probable that fish migration will be delayed until the cold weather and higher Somenos Creek flows return. Eventually flows will cause the Parrot's Feather to die off and get flushed down the creek.

It is reasonable to think that with incoming drier and hotter summers attributed to anthropogenic climate change, the growth season of Parrot's Feather will increase in length, thus leading to greater coverage, thicker mats, and more permanent changes to the ecology of the creek system.

4.1 SURVEY OF AREA

4.1.1 Purpose

The Somenos Marsh Wildlife Society has been formally surveying and cataloguing the extent of the Parrot's Feather since the summer of 2020. The surveys are aimed at monitoring the fluctuation of Parrot's Feather coverage in Somenos Creek year-to-year, and month-to-month. In 2022, the SMWS performed monthly surveys, summarized into four seasons: winter, spring, summer, late summer-fall. The intention of the survey schedule was to monitor the plant's growth throughout the growing season, and to determine how much remains into the rainy season, and how much washes downstream.

4.1.2 Methods

The surveys were completed by SMWS staff and performed through streambank observations with instream observations with kayaks. The abundance of Parrot's Feather was determined by visual inspection and the percentage was recorded based length and width of channel. Channel widths were measured and averaged for area calculations using a combination of Google Earth Pro and Gaia GPS. As the SMWS staff walked Somenos Creek, waypoints were taken (Gaia GPS Android app) when there was an obvious change in the amount of parrot's Feather coverage observed. The

change in coverage was noted at each of these points, and the data (in KML form) was then input into Google Earth Pro to create colour-coded Parrot's Feather coverage maps (see Results section).

For the purpose of these surveys, Somenos Creek was split into three reaches (Figure 3):

- Reach 1: Somenos Lake to Lakes Road Footbridge (Municipality of North Cowichan)
- Reach 2: Lakes Road Footbridge to Tzouhalem Road (Municipality of North Cowichan)
- Reach 3: Tzouhalem Road to Cowichan River (Cowichan Tribes)

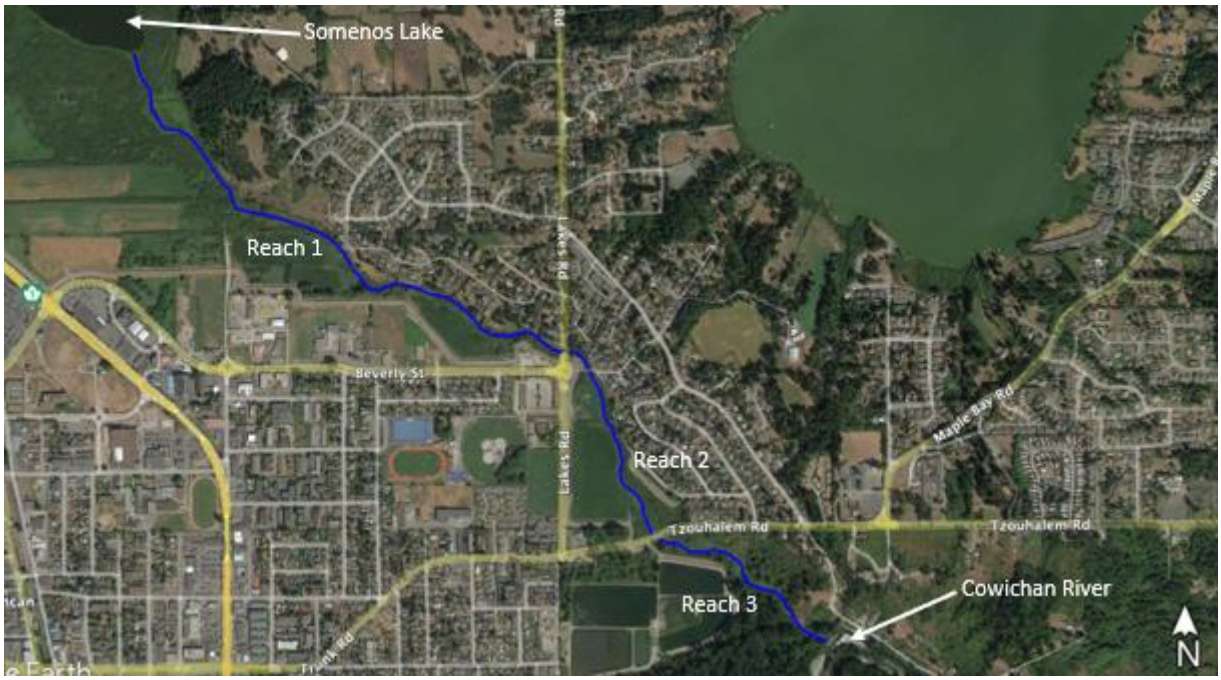


FIGURE 3: SOMENOS CREEK SURVEY REACHES 1-3

4.1.3 Results

Parrot's Feather has grown at a slower rate compared to last year. The total amount of Parrot's Feather and peak growth in 2021 vs 2022 in all the reaches are shown below in Table 2. The results of peak growth this year are significantly lower than last year reaching only 53% coverage of Parrot's Feather overall in 2022 vs 73% at the same time last year. It is possible the cold temperatures and heavy rain in the spring of 2022 during the La Nina weather pattern may have delayed the start of Parrot's Feather regrowth, and cold temperatures in spring kept it from growing as much as it would in a normal year. Figure 4 shows the temperature on Somenos Creek from 2021 to 2022.

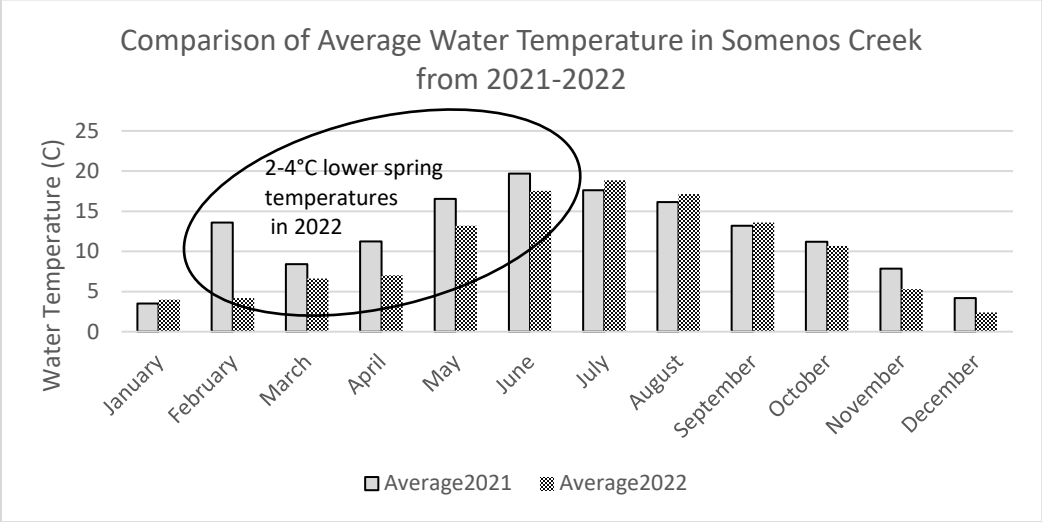


FIGURE 4: WATER TEMPERATURE COMPARISON BETWEEN 2021-2022

Table 2: Percent growth of Parrot's Feather comparison of 2021-2022

Location	2021 peak growth (August)	2022 peak growth (August – October)
Reach 1	68%	44%
Reach 2	96%	67%
Reach 3	70%	63%
Overall Somenos Creek	73%	53%

Photo 7: Typical Parrot's Feather growth in Reach 1 covers the entire channel. 2022

Photo 8: Parrot's Feather coverage in Reach 1 of Somenos Creek. We are investigating why it has not spread across the creek in some areas vs others. 2022

Photo 9: upstream view of typical Parrot's Feather coverage in Reach 2. 2022

Photo 10: downstream view of typical Parrot's Feather coverage in Reach 2. 2022

Photo 11: Upstream view of new 1.2 m high beaver dam (BD#2) barrier at the end of Reach 3. 2022

Photo 12: Downstream view from BD#2 to the Cowichan River confluence. Note: new areas of Parrot's Feather growth on Somenos Creek are reaching the Cowichan River. 2022

4.2 OBSERVATIONS

Major observations include:

- A cold spring and high spring precipitation may have delayed initial Parrot's Feather growth
- In Reach 3 another beaver dam was built since the last survey and was blocking the Chum salmon run up into Fish Gut Alley by the October site visit (Oct. 21, 2022). By the time of the site visit on November 7th SMWS observed visible salmon waiting below the dam which was now passable for fish.

- Parrot's Feather has not migrated toward Somenos Lake; however, it has been found downstream in the Cowichan River in very small amounts.
- Other aquatic vegetation growth may help to clarify why Parrot's Feather grows in some areas and not in others. For example, Pond Lilies were observed growing where Parrot's Feather does not. The same was observed for Duckweed. Future mapping will include neighboring aquatic vegetation where the Parrot's Feather is growing while future studies will include measuring environmental parameters to determine if there are differences in these aquatic habitats that may inhibit Parrot's Feather growth.
- Dissolved oxygen levels returned to passible for salmon on December 5th in Somenos Creek, and December 12th in Richards Creek. However, temperatures were too cold for fish migration which may be the reason fish were not observed in their regular spawning sites in Bings, Averill, and Richard's creek in the following two weeks.

The monthly monitoring showed that Parrot's Feather reached its peak growth by late summer and, due to a warm, dry fall, maintained its maximum growth in the creek up until mid- December. Thus, due to the lack of high precipitation and flows this fall has prevented the Parrot's Feather from breaking up and being pushed out of the system, as it has previously at this time of year. SMWS will continue to monitor when the Parrot's Feather is flushed out of Somenos Creek, where it ends up, and how much remains.

4.3 RECOMMENDATIONS

Future monitoring should include:

1. Transect locations in each Reach to record seasonal information:
    - At each transect Record Parrot's Feather F % and environmental parameters that may impact growth. For example, water quality (dissolved oxygen, temperature, conductivity, pH, and total dissolved solids), substrate, shade %, depths, and the % area of other aquatic plants present.
2. Continue monitoring new Beaver Dams on Somenos Creek Reach 3 to determine if it remains intact after high flows in the fall-winter.
3. Include monitoring of Parrot's Feather on Cowichan River in 2023
4. Compare parameters such as precipitation and temperature of Somenos Creek in 2021 vs 2022 to confirm suspicions that this may have caused a slower growth rate of Parrot's Feather this year.

4.4 POND LINER REMOVAL SUMMARY

4.4.1 Purpose

The Municipality of North Cowichan hired SMWS to complete experimental control measures using pond liner to suppress the growth of Parrot's Feather in the Somenos Creek channel. The pond liner was installed in 2020 and permanently removed in 2022, ending the experiment.

4.4.2 Methods

The method behind this treatment is to place sheets of heavy duty 'aquatic certified safe' pond liner on top of the creek in the summer to smother the above-water growth of Parrot's Feather. Once the top growth is killed and the water levels in the creek rise in the fall, the liner is sunk down to the bottom of the waterway and left for the winter, thus, smothering the rhizomes keeping them from coming up in spring. In theory, the killing of the leafy growth and rhizomes for a year or two should prevent Parrot's Feather from returning during the growth season following the treatment.

The pond liner was checked underneath for plant growth every year, then re-deployed in the fish window at the same location (Station 3) in Somenos Creek (Figure 5).

FIGURE 5: LOCATION OF THE POND LINER EXPERIMENT ON SOMENOS CREEK.

The 1600 ft^2 of pond liner was inspected in spring and appeared to be firmly in place (Photo 13) after being left in all winter since August of 2021. In August 2022 the pond liner was removed over 2 days with the help of summer staff and the Municipality of North Cowichan Operations Staff.

Methods of pond liner removal:

- To remove the pond liner, the concrete anchor blocks were located, cut, and taken to shore.
- The edge of the liner, which was weighted down and zip-tied to rebar, was located then cut free. Each piece of rebar was taken to shore.
- the pond liner was covered in a thick mat of Parrot's Feather, which needed to be cut away to pull the liner to shore (Photo 14).
- Once the liner was pulled to shore the area was exposed for inspection of plant growth under where the liner was located from 2020-2022.

4.4.3 Results

- Pond liner was inspected on April 1, 2022. High flows covered the pond liner and dead mats of Parrot's Feather were observed on the surface of the creek (Photo 13).
- On August 12th the first section of the pond liner was removed by SMWS staff (Photo 14-16)
- On August 30th, the last section of the pond liner was removed by SMWS staff with MNC Operations crew.
- The pond liner was removed from site and not redeployed, August 30, 2022.

Photo 13: Pond liner inspection on April 1, 2022. Buoy is a temperature data logger at Station 3.

Photo 14: Parrot's Feather growing on top of the pond liner

As you can see in Photo 16, when the liner was removed there was a cleared area which is due to the surface mat being cut away to remove the liner. Underneath the mat there were roots present but very little re-growth.

Photo 15: Before removal on August 12th.

Photo 16: After removal on August 30th

4.4.4 Conclusion

After completing the Pond Liner Experiment, SMWS concluded that it will be very difficult to adequately control the growth of Parrot's Feather on Somenos Creek using pond liner. The main reason is there is too much biomass in Somenos Creek already to control it by smothering it. If it had been caught right away, when it first entered the system and did not yet have a chance to take hold, it is possible it could have worked. Currently there is so much Parrot's Feather biomass that it just grows overtop of the impermeable pond liner.

5 Riparian Planting and Invasive Plant Control

5.1 Purpose and Area of Activity

Parrot's Feather shading involves invasive removal and tree planting to provide adequate shade along Somenos Creek. The goal is to block light and reduce growing season temperatures in the creek to reduce Parrot's Feather growth and biomass, ultimately increasing dissolved oxygen in the creek thus allowing earlier fish migration in fall.

Three locations were chosen in 2022 to provide riparian shading (Figure 6). They include:

1. The south-west side of the Haycroft Chase Strata property and MNC right of way,
2. Nature trust property currently used as a corn field, and
3. East side of Somenos Creek near Lake Road

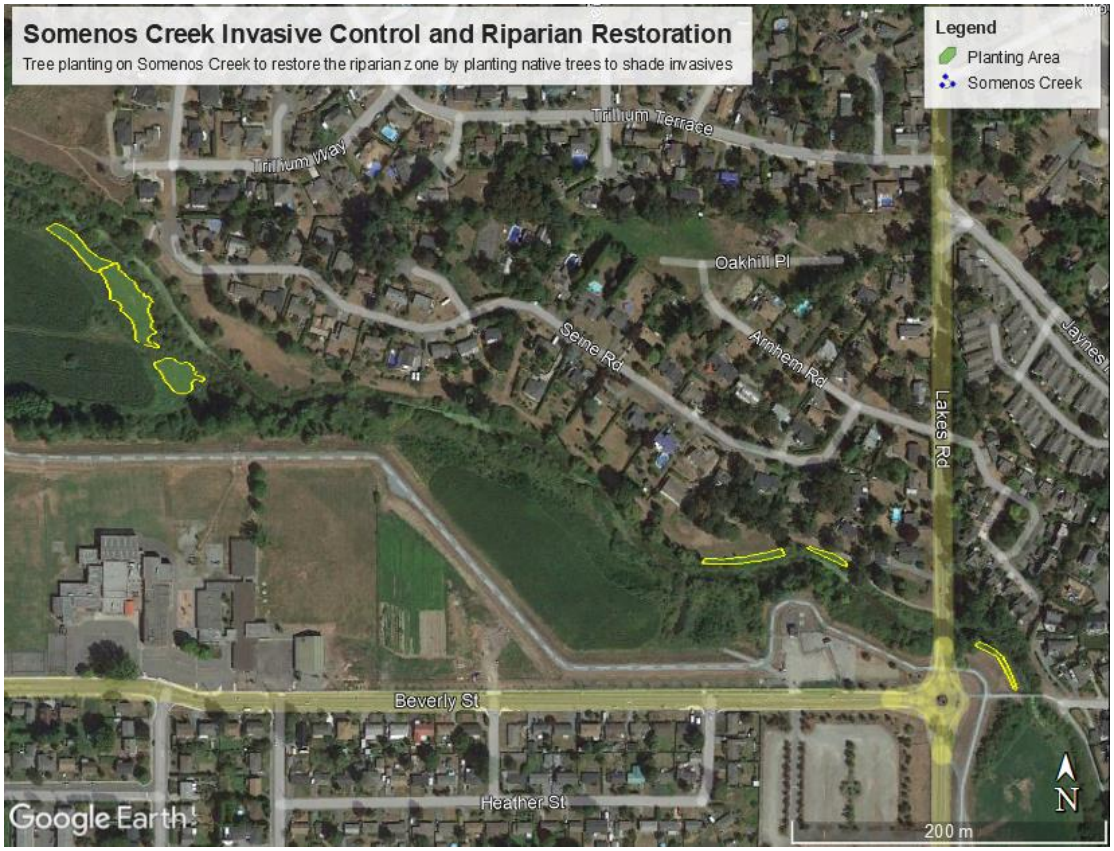


FIGURE 6: THREE LOCATIONS CHOSEN FOR 2022 INVASIVE CONTROL AND RIPARIAN RESTORATION.

5.2 ACQUISITION OF PLANT MATERIAL

Trees were purchased from Satin Flower Nursery, Saanich, and Peels Nursery from the Mainland. They were brought in by truck and delivered to Cowichan Green Community where we had an agreement to store the trees until they were planted (Photos 17-18). After the first batch of trees were planted in the spring, the remaining trees were watered every other day on an automatic watering system to keep them alive until planted in fall.

Photo 17: Tree shipment from Peel's Nursery

Photo 18: Trees stored at Cowichan Green Community prior to planting

Table 3: A Summary Overview of Work Completed for Riparian Restoration and Shading Projects, 2022

Project	**Volunteer and Cowichan Tribes Hours**	**Weight of Invasives Removed (pounds)**	**Invasives Removed (Area m²)**	**No. Trees Planted**	**Amount of Habitat Restored (Area m2)**
Somenos Creek: Haycroft Chase Strata Tree Planting Site	38	80 (H. Blackberry)	112 (H. Blackberry)	166	225
Somenos Creek: Nature Trust: Tree Planting Site 1-3	498	-	2,769 (reed canary grass)	1,500	2,769
East side of Somenos Creek	42	95 (H. Blackberry)	530 (H. Blackberry)	100	530
TOTAL	**578**	**175**	**3,411**	**1,766**	**3,524**

Details of each of the three tree planting projects are described below.

5.3 HAYCROFT CHASE STRATA / MUNICIPAL RIPARIAN TREE PLANTING

5.3.1 Purpose

The Haycroft Chase Strata owns part of the property on the south-west side of Somenos Creek next to the roundabout on Lakes Road and Beverly Street (Zone 2). The Municipality of North Cowichan also has a Right of Way bordering Somenos Creek in the same area (Zone 1). With permission from both landowners, this area was selected to increase the riparian area with tall trees for Parrot's Feather shading.

On May 13, 2022, a site visit was completed by the Somenos Marsh Wildlife Society (SMWS) and Keona Wiley, Manager of Parks, and Trails with the Municipality of North Cowichan. The area was assessed, and recommendations made by the Parks Manager were incorporated into the planting plan (See Figure 7).

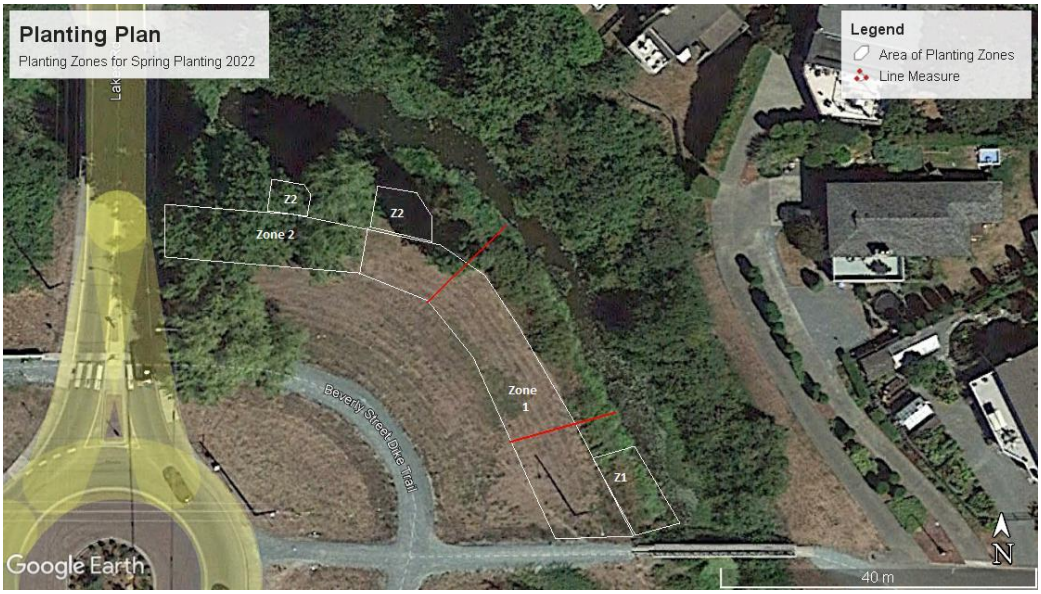


FIGURE 7: RIPARIAN PLANTING ZONES ALONG SOMENOS CREEK.

5.3.2 Methods

During the site visit on May 13, 2022, measurements were taken to determine the area proposed for planting. This was approximately 14 meters from the creek edge, half of which was grown in with native roses along the edge in Zone 1. These roses provide a good native shrub layer and were left in place as a protective riparian buffer. In Zone 2 a few large willows provide shade to the creek; however, there are some exposed areas along the banks and between the trees that we planted with native willow species (*Salix scouleriana),* Hardhack shrubs *(Spiraea douglasii)* and Red-osier Dogwood trees (*Cornus sericea)* which will protect the bank in future flood events and increase biodiversity.

To prepare the site for planting we first had volunteers come out on May 14, 2022, to help remove the invasive Himalayan Blackberries (*Rubus armeniacus*) that were covering the south end of the site near the footbridge.

Photo 19: Volunteers cutting invasives *(*Himalayan Blackberry, *Rubus armeniacus)* from riparian planting zone (May 14, 2022)

Photo 20: After invasives were removed. A few native species were left in the riparian area such as a Maple tree (*Acer macrophyllum*), Oregon Grape (*mahonia aquifolium)*, Garry Oak (*Quercus garryana), etc*. (May 14, 2022).

We were informed by the Parks Manager, that the MNC Engineering team had recently completed a drilling project in Zone 2 which revealed their plans to expand the Lakes Road bridge by two meters next year. To plan for this, SMWS did not plant within this extent and a 5-meter distance from the toe of the dike will be avoided with room to spare (Photos 21 and 22). This still allows for a large area of mowed turf for public use, and planting within a riparian zone of 14 m; which is the minimal width for a healthy riparian zone.

May 18th, 25th, and June 1st SMWS held three volunteer events to plant the trees on the property. Following the riparian restoration rule of thumb to plant one tree per square meter (DNV, date unknown). Native shrubs were planted in a row or two, close to the creek edge, and then a layer of trees was planted behind the shrub layer. The shrub layer provides increased bank stability and offers some in-stream cover and habitat features as it grows out of the bank. The subsequent tree layer will grow tall, providing shade for the creek's width.

This strategy used the Hardhack (*Spiraea douglasii)* which grows 2 meters tall*,* and Red-osier Dogwood (*Cornus sericea)* at 1- 6 m tall*,* as the shrub layer. This provided the first layer of protection along the creek. The tree layer follows as a mix of willows (*Salix scouleriana*) which grow between 2 - 12 meters, and six Sitka Spruce (*Picea sitchensis*) which can grow up to 90 meters tall providing future shade to the creek. Poplars (*Populus balsamifera*) grow up to 50 meters in height however they were not planted at the request of the Parks Manager due to concerns of an increase in area maintenance. These shrubs and trees were specifically chosen for the area because they are native species known to survive in wet conditions, such as during our winter rainy season that can lead to flooding in the area.

Photo 21: View looking north of the riparian zone to be planted within the 14 m setback (May 16, 2022).

Photo 22: View looking north of the riparian zone planted within the 14 m setback (May 25th, 2022).

After the trees were planted local tree leaves were collected and added as mulch, when we noticed the soil was dry and sandy. The plants were continually watered 1-2 times a week during the hot months to allow them to establish. The warm weather continued into the fall (late October) which was unusual, and with limited resources, watering was discontinued by the end of August. If the trees were not established well enough by then, there is potential for some added stress to the plants which may impact growth and tree health. This will be monitored closely in the coming spring of 2023.

5.3.3 Results

The outcome of the Somenos Creek riparian restoration work on the Haycroft-Chase Strata/ Municipality property includes the following:

- 80 pounds/ 112 m^2 invasive plants removed (*Rubus armeniacus)*
- 38 volunteer hours
- 166 trees planted which included a mix of: Sitka Spruce (*Picea sitchensis), S*couler's Willow (*Salix scouleriana*), Hardhack (*Spiraea douglasii),* and Red-osier Dogwood (*Cornus sericea)*

5.4 Nature Trust Riparian Tree Planting

5.4.1 Purpose

The goal was to increase shading of Somenos Creek, as this is a section of the creek that experiences significant Parrot's Feather growth. The plan was to plant trees that will grow tall enough to eventually shade the creek and seed the area over time with new growth. There are currently willows, Red-osier Dogwood, and Hardhack along the banks, and invasive Reed Canary Grass (*Phalaris arundinacea)* in open areas where planting is planned in Sites 1-3 (Figure 8).

FIGURE 8: THE AREA TO BE PLANTED IS ON THE WEST SIDE OF SOMENOS CREEK BORDERING THE NATURE TRUST PROPERTY

5.4.2 Methods

In 2022, flood tolerant trees and shrubs such as: *S*couler's Willow (*Salix scouleriana*), Hardhack (*Spiraea douglasii),* Poplar *(Populus balsamifera)*, Red Alder (*Ulnus rubra*), and Red-osier Dogwood (*Cornus sericea)* were purchased for planting.

As mentioned before, typically we would plant one tree/m^2; however, in this location we could only plant on existing higher, and drier mounds due to flooding in the area. Therefore, we had to double the distance and plant every 2 m^2 because the mounds are further apart.

Th planting area is a section along Somenos Creek, a low-lying wet area next to a corn field owned by the Nature Trust of BC. The land floods in the fall during high water until late spring; however, multiple areas have been treated with a 'rough and loose' method where holes were dug, and planting mounds remain. In Figure 9, the areas planted are shaded light green as Sites 1, 2, and 3 which are: 737, 1,414, and 618 square meters, respectively (measured with Gaia GPS and Google Earth pro).

Planting was planned for the spring of 2022 but was delayed by contracts and approvals that resulted in the plants being purchased late in the spring. Local nurseries were out of stock by this time, so plants were sourced from the mainland at Peels Nursery. This delayed spring planting to over the summer and into fall.

5.4.3 Results

Prior to planting on Site 3, Nature Trust staff installed bird box posts along the border of the corn field and planting area to prevent further farming equipment encroachment into the riparian zone. This area had been previously farmed to the edge of Somenos Creek and willow debris pushed down the bank into the creek. On June 11, 2022, 140 plants (a mix of 40 Red Alder, 60 Poplar trees, 40 Scoulers Willow) were planted at Site 3 by volunteers and SMWS staff.

On June 22, Site 2 was prepped by removing the invasive Reed Canary Grass *(Phalaris arundinacea)*. This required assistance of three staff from Nature Trust and 3 mowers to cut the area before planting. On June 29th, 72 more trees were planted by volunteers and SMWS staff.

In late fall, Site 1 work started with the help of a work crew from Cowichan Tribes who cleared the planting area of the extensive Reed Canary Grass with a Stihl weed-trimmer with blade attachment. After an area was cleared, the crew and volunteers planted 1,288 trees. This was done over the month from October 4th to November 9th. During that time, there were also 5 volunteer events that included Cowichan Secondary High School students, VIU students, and public members.

Due to the hot weather this year in fall, the newly planted trees were watered every few days to ensure survival. In addition, heavy beaver activity and deer browsing in this area required caging of some planted trees, specifically the more susceptible trees such as poplar and red alders.

The outcome of the Somenos Creek riparian restoration work on Sites 1-3 on the Nature Trust property includes the following:

- ~2,769 m^2 of invasive plants were removed (reed canary grass*)* from the planting sites
- 498 volunteer hours and Cowichan Tribes work hours
- 1500 trees planted which included a mix of: *S*couler's Willow (*Salix scouleriana*), Hardhack (*Spiraea douglasii),* Poplar *trees (Populus balsamifera)*, Red Alder (*Ulnus rubra*), and *R*ed-osier Dogwood (*Cornus sericea)*

5.5 Somenos Creek Shading on the North Side

5.5.1 Purpose

The planting area along the north side of Somenos Creek on the Municipality of North Cowichan property was selected and approved for riparian restoration and tree planting by the MNC Parks Manager (Figure 9). The purpose is to restore the riparian zone to its native vegetation and provide shading in the creek to reduce the instream Parrot's Feather growth.

FIGURE 9: MAP OF THE RIPARIAN RESTORATION AREA ON THE NORTH SIDE OF SOMENOS CREEK, NEAR LAKES ROAD.

5.5.2 Methods

The riparian zone was covered in invasive plants such as: Himalayan Blackberry (*Rubus armeniacus)* and Field Bindweed / Morning Glory (*Convolvulus arvensis),* which needed to be removed before trees were planted along the shoreline. The planting area was cleared of blackberries in the fall of 2021 and the tree seedlings (1–2-gallon pots) were planted by volunteers in the spring of 2022. In the summer of 2022, the site was revisited to monitor tree growth only to discover that the invasive plants were covering the new seedlings. In July, volunteers removed the roots of blackberries and Morning Glory where possible, but most were cut down to their base to allow the trees to grow to a height where they will survive if the invasives returned (Photos 23-25).

Photo 23: Trees that were covered in invasives were located, flagged, and cleared of them to enhance seedling survival.

Photo 24: volunteers and staff removing invasives from planting area.

Photo 25: volunteers and staff digging out blackberry roots and Morning Glory roots from the planting area.

5.5.3 Results

The outcome of the riparian restoration work on the North side of Somenos Creek includes the following:

- 530 m^2 area or 95 pounds of invasive plants were removed from the planting site. Invasive plants included: Himalayan Blackberry (*Rubus armeniacus)* and Field Bindweed/ Morning Glory (*Convolvulus arvensis)*
- 42 volunteer hours
- 100 trees planted which included a mix of: *S*couler's Willow (*Salix scouleriana*), Hardhack (*Spiraea douglasii),* Poplar *trees (Populus balsamifera)*, Red Alder (*Ulnus rubra*), and *R*ed-osier Dogwood (*Cornus sericea)*
- Native trees and plants such as Garry Oak (*Quercus garryana*) seedlings and Oregon Grape (*Mahonia aquafolium*) were seen growing in the planting area and flagged for protection. The Garry Oak was likely seeded from the mature oak trees nearby.

Recommendations:

- Future monitoring of tree seedling growth and health in 2023.
- Not all invasive plant roots were possible to remove therefore future events should be organized to remove the regrowth of invasives.
- Observations included that areas that did not have invasive plant growth were covered in native grasses and naturalized weeds. Therefore, one recommendation is to seed the exposed soil with native grasses to outcompete the invasives.

6 Bings Creek Restoration Work

6.1 Purpose

The 2022 Service Agreement included Reach 1 Bings Creek spawning salmon habitat enhancement work. The Bings Creek restoration projects included:

- Adding two more spawning salmon restoration sites (Sites 3 and 4)
- Invasive plant removal and riparian tree planting
- Improve Bings Creek backwater connectivity.

Reach 1 of Bings Creek is where it was historically altered into a straight ditch from the Trans-Canada highway to Somenos Lake, and the riparian area was flattened for logging and farming (Clough 2020). Since then, 20 years ago (Burns 2000) it was planted with coniferous trees that now have grown into a large canopy creating ideal shade for fish cover. The channel in the first section of Reach 1 was also recontoured for approximately 200m, from a 1m ditch to 5m a wider channel creating ideal areas for habitat enhancement. In this section, SMWS enhanced two spawning beds in 2021 (Sites 1 and 2) which had successful Coho spawners use it in the fall immediately after construction. Due to the success of this program, it was continued in 2022 by adding two more sites (Sites 3 and 4) to enhance spawning in areas identified as good locations in the Clough 2020 report.

At the end of Site 4, there is a backwater pond created previously (Burns 2000) to be a rearing habitat for fish in summer, but it does not have enough oxygen for salmonids. The solution is to create a connecting channel on the downstream side of Site 4, which will flush open during the high flows in winter. This added flow of water all year round will aid in oxygenating this backwater and providing additional rearing habitat for growing fish.

Downstream of the recontouring section, the creek becomes a narrow channel. There is Reed Canary Grass along both its banks, providing no cover for fish or thermal protection during the hot summer months. This area was selected to be cleared of the invasive Reed Canary Grass and replanted with flood tolerant, native trees.

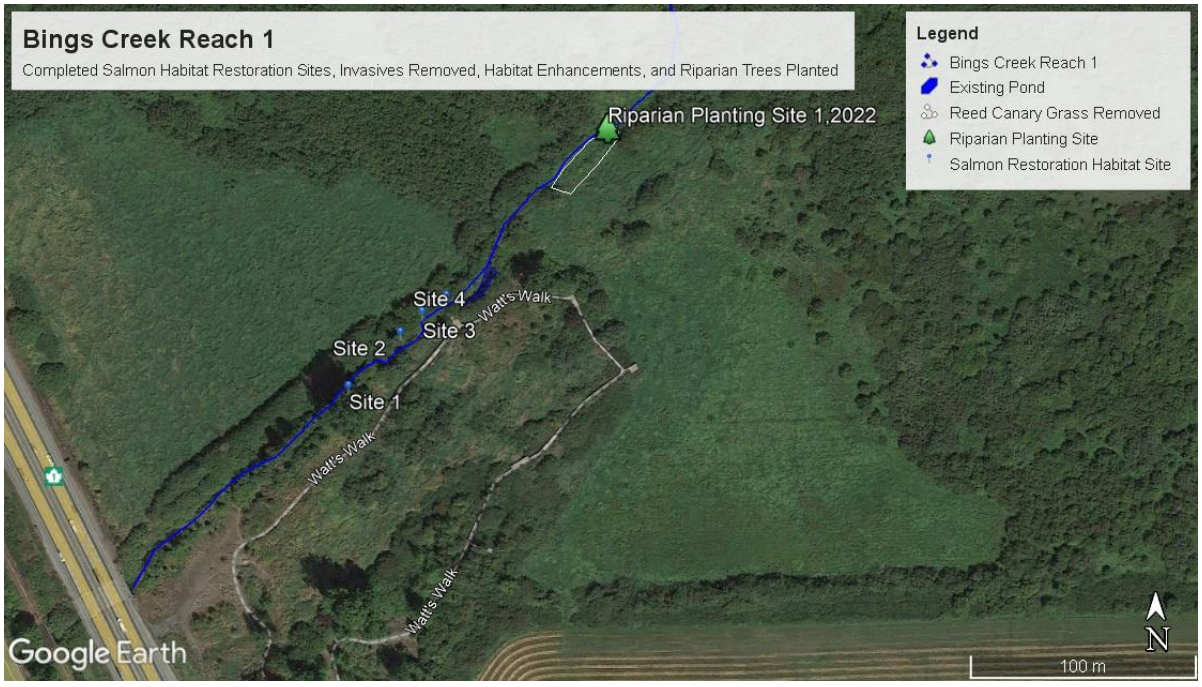


FIGURE 10: SALMON SPAWNING HABITAT RESTORED ON BINGS CREEK REACH 1 FROM 2021-2022. SITES 3, 4, THE RIPARIAN PLANTINGS, AND CONNECTIVITY DITCH TO THE POND WERE COMPLETED IN 2022.

Table 1: A Summary Overview of Work Completed by Project on Bings Creek, 2022

Project	Volunteer Hours	Invasives Removed (m^2)	No. Trees Planted	No. live staking (Dogwood)	Gravel Installed (tons)	Habitat Restored (m2)
Reach 1: tree planting	3	330 m^2 Reed Canary Grass	90	-	-	330 m^2
Reach 1: Spawning Restoration site 3 and 4	6	-	-	40	3 tons	50 m^2
Reach 1: Bings creek Backwater Connectivity	24	-	-	-	-	130 m^2
TOTAL	33 hours	330 m^2	90	40	3 tons	510 m^2

6.2 Spawning Salmon Restoration Sites

A site survey of Bings Creek was completed in 2021 by SMWS in Bings Creek, Reach 1. Under the direction of D.R.Clough Consulting the recommended spawning salmon habitat rehabilitation sites were chosen (labelled as Sites 3, 4; Photos 1-4) and directions given on how to proceed with the restoration.

These sites had a lack of spawning substrate. The substrate consists of silt, small gravel, and some embedded large woody debris (LWD). Some of the LWD will hold the gravel in place, acting as a catchment area (Keely and Walters, 1994) so it was left in place where possible.

To begin, loose woody debris, detritus and organics was raked out of the stream and mounded on the shoreline for later use after which a half ton of anchor rock was placed across the channel in 2-3 rows to create a weir structure to hold the gravel in place. The weir was filled with salvaged muck and clay that formed a seal on the upstream side of the anchor rock. Then gravel was placed in the channel by volunteers above the weir over a 3m x 3m area using 20-liter pails during the fish work window. The gravel was emptied into the creek about 4-6 inches thick. Improvements to each site included the addition of 1.5 tons of gravel and cobble mix which will support a variety of salmon species known to spawn in the watershed.

In the future, additional gravel may be needed to extend both spawning areas. This is because once the organic debris was removed the depth of the water increased which required more gravel to fill than anticipated.

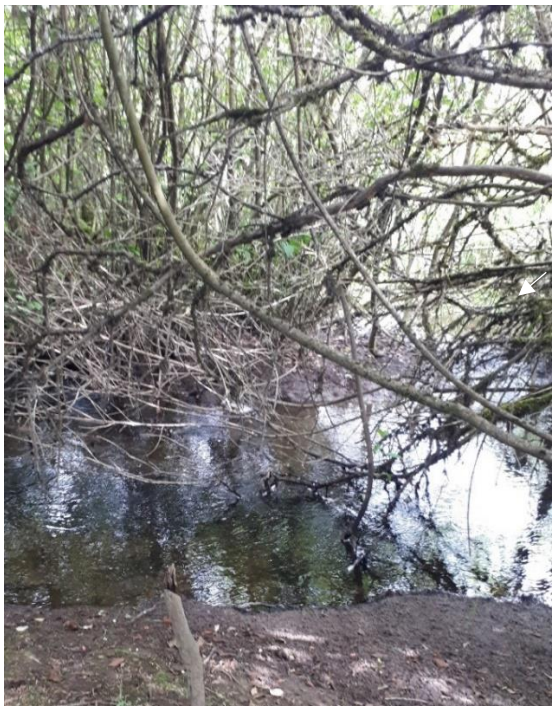


Photo 1: View looking across at left bank prior to restoration at Site 3. Habitat was mainly silt, sand, and organics.

Photo 2: View looking across at left bank after restoration at Site 3. 1.5 tons of gravel and half ton of anchor rock were added to create spawning beds.

Photo 3: View looking at left downstream bank before restoration at Site 4. Habitat mainly was silt, sand, and organics.

Photo 4: View looking at left downstream bank after restoration at Site 4. 1.5 tons of gravel and half ton of anchor rock were added to create spawning beds.

6.3 Riparian Tree Planting and Invasive Removal

On July 20th the Society planted 60 trees comprising of 30 Black Poplar *(Populus balsamifera)*, 20 Red Alder (*Alnus rubra),* and 10 Scoulers Willow (*Salix scouleriana)* along Bings Creek Reach 1 (Photo 5). The site is downstream of the historical channelization and habitat enhancements and was chosen as ideal for riparian restoration due to the lack of overhead cover. The area was also covered with the invasive Reed Canary Grass (*Phalaris arundinacea*) which first had to be removed.

Four field personnel prepared the planting site over 3 days. Initially, the 125 m^2 area was cleared of reed canary grass which required a gas-powered Stihl trimmer with saw blade attachment. Each tree planting location was marked out with a small sickle which removed the grass and roots on the surface of the soil. The trees were placed 1m^2 apart to increase potential coverage in the area. Narrow headed trenching shovels were the best tool for digging through the thick mats of roots that covered the ground. Volunteers were invited out to plant trees in the afternoon. By the end of the volunteer event, 90 trees were planted in 2 and a half hours. A thick layer of cut grass was placed around each tree

to provide protective mulch and reduce the growth of the grass around the base next season to allow adequate light to reach the seedling. Future monitoring will be required in 2023 to count surviving plants and cut grass around the seedlings in spring. Our belief is that this will be a successful planting area due to a few Poplar and Red Alder tree seedlings that were planted the year before that are thriving without any watering or invasive maintenance.

Photo 5: Riparian planting in Bings Creek Reach 1. Invasive Reed Canary Grass was removed, and 90 trees were planted. July 20, 2022

6.4 Backwater Connectivity Work

When Bings Creek was restored in 2000 (Burns 2000) a backwater pool was created that was originally designed to be fish rearing habitat. The backwater pool starts at the end of the boardwalk, is connected to Bings Creek about 60m downstream of Site 4 and has an approximate width of 2-3 meters. Currently in summer it is anoxic to fish in the creek; therefore, it cannot be used for summer rearing.

Somenos Marsh Wildlife Society wanted to restore the flow of water from the creek into the backwater pool to aerate it so it can be used as originally designed in the summer months by fish. In 2022 a connectivity ditch was dug between Site 4 and the upper end of the backwater pool (Photo 6). The work was completed in the dry in fall and left isolated from the creek until water levels rose in the winter months, creating flow through the channel. Much of the natural soil consists of sand and gravel at the base of the channel. A heavy root system from the surrounding native willows and red osier dogwood provides bank stability. Monitoring of the channel will occur in spring 2023. The backwater pool area (125m2) plus the channel (5m2) created 130m2 of fish habitat.

Photo 6: Bings Creek, Reach 1, immediately downstream of Site 4 a connectivity ditch was created to increase flows into an anoxic backwater pool to increase rearing habitat for fish in summer.

7 Appendix A – Water Quality results for Somenos Lake

The weekly, monthly measurements of dissolved oxygen (DO), temperature, conductivity profiles are represented in Charts 1 to 5. The monthly nutrient sampling of total phosphate, ammonia (and pH), 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 IN SOMENOS LAKE

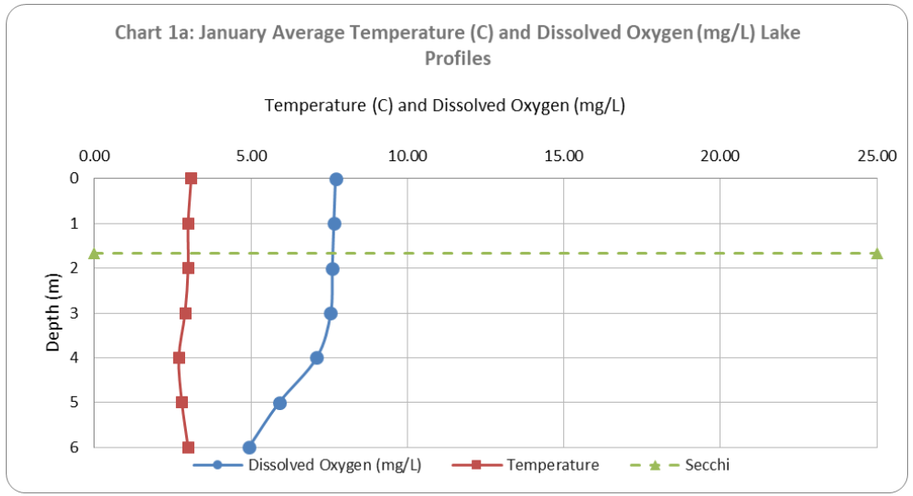
Dissolved oxygen levels and temperatures are important to monitor as an indicator of biological activities, lake stratification and fish habitat. Thus, looking at these two parameters will help us understand the biological activity in the lake and if fish are able to inhabit the lake at certain times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

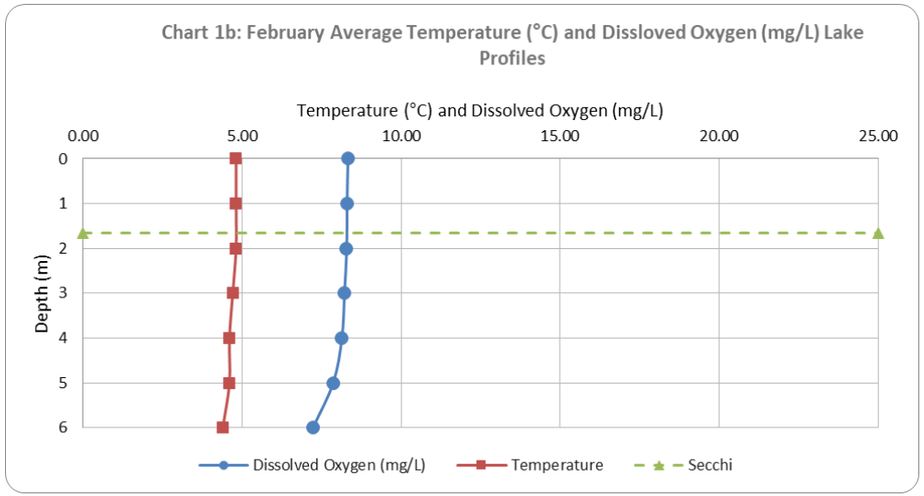
The results show that Somenos Lake temperatures stratify in July and last until mixing occurred late September whereas, dissolved oxygen stratified in July to the start of November (Chart 1). The timing of temperature and dissolved oxygen stratification was similar in spring but mixing in fall was delayed by a month for dissolved oxygen compared to temperature.

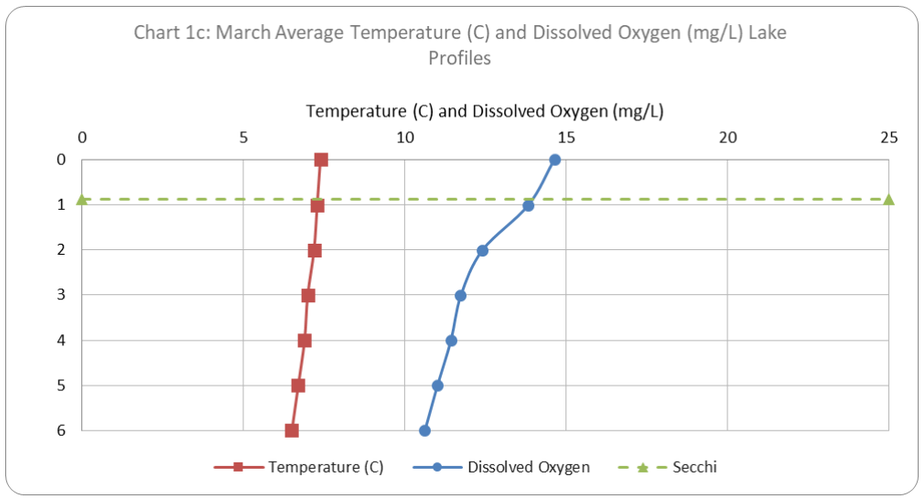
In comparison to 2021, spring stratification occurred in April; however, this year (2022) it occurred in July pointing to other potential climatic influences. It is assumed that stratification was delayed in 2022 because the cold, rainy spring caused by la Nina.

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 1) (Mazumder et.al.,1990). This layer is also where a lot of the algae growth and photosynthesis takes place. 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) which we can see in Somenos Lake in summer. When the temperature and dissolved oxygen on Somenos Lake are graphed, we can see the stratification represented as an S-shaped profile (Chart 1). This is where the temperatures and dissolved oxygen dramatically change, and the thermocline transition can be seen more clearly.

Charts 1a-l: Somenos Lake Dissolved Oxygen, Temperature and Clarity profiles by Month







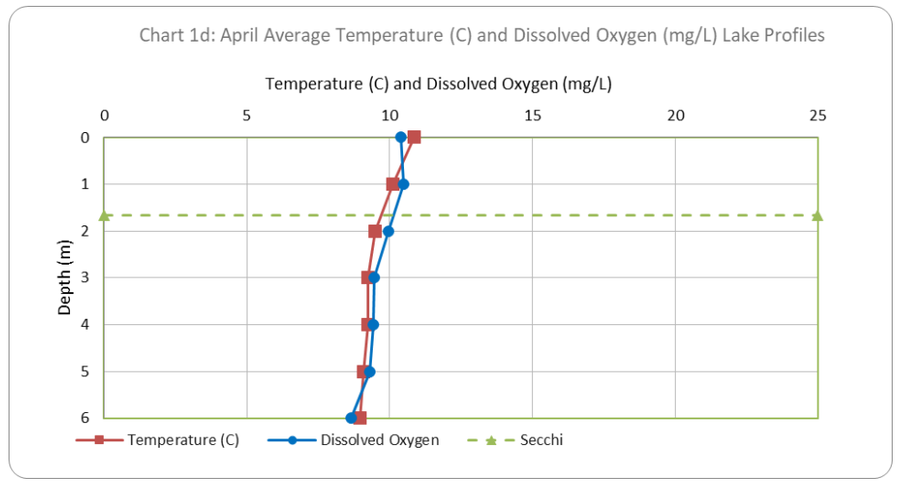


Chart 1e: May Average Temperature (C) and Dissolved Oxygen (mg/L) Lake Profiles

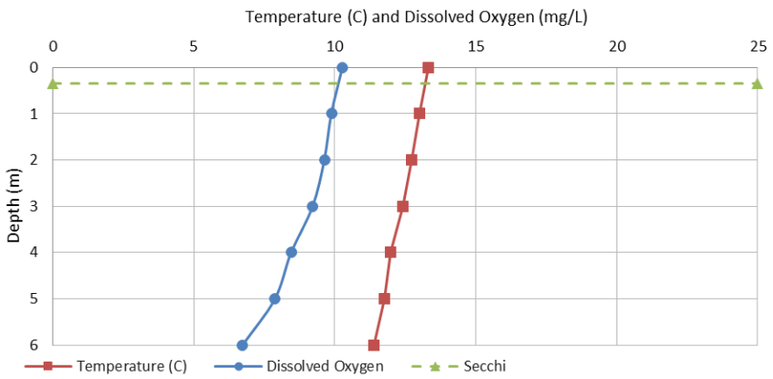


Chart 1f: June Average Temperature (°C) and Dissolved Oxygen (mg/L) Lake Profiles

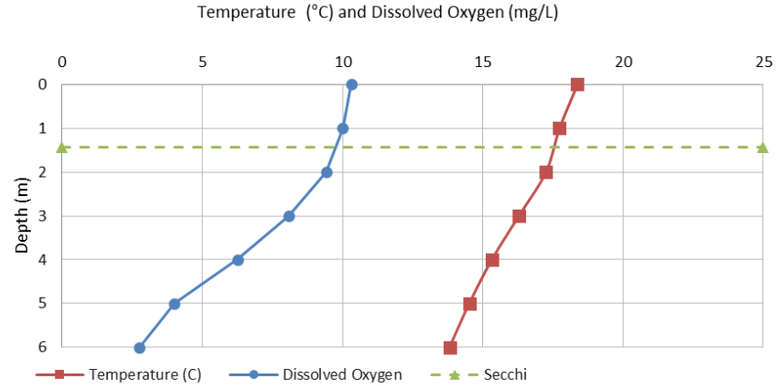


Chart 1g: July Average Temperature (°C) and Dissolved Oxygen (mg/L) Lake Profiles

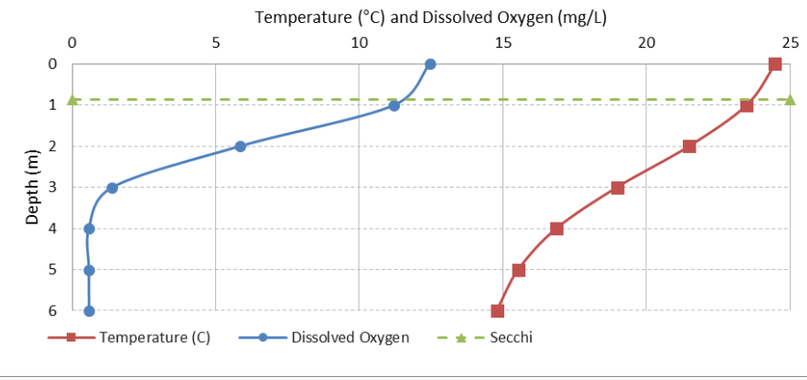


Chart 1h: August Average Temperature (C) and Dissolved Oxygen (mg/L) Lake Profiles

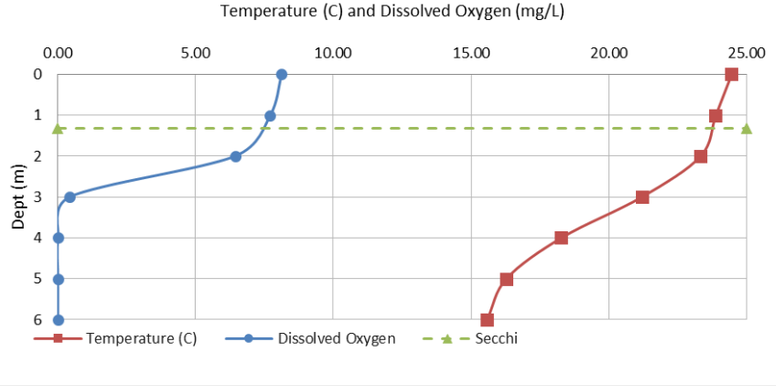


Chart 1i: September Average Temperature (°C) and Dissolved Oxygen (mg/L) Lake Profiles

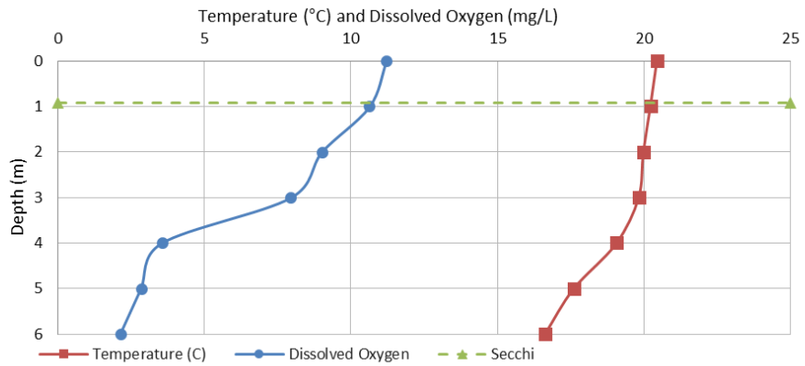


Chart 1j: October Average Temperature (°C) and Dissolved Oxygen (mg/L) Lake Profiles

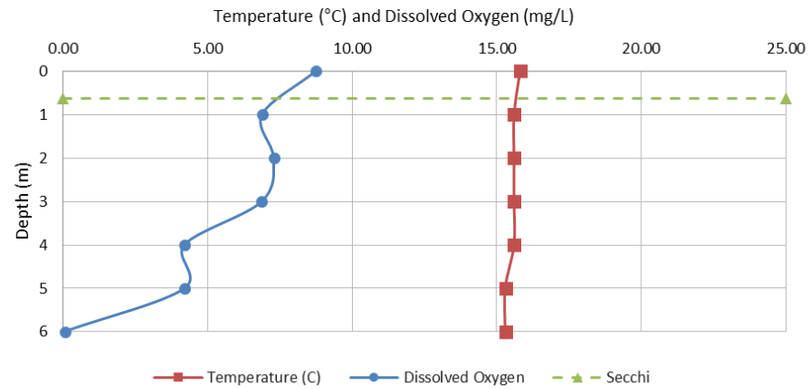


Chart 1k: November Average Temperature (°C) and Dissolved Oxygen (mg/L) Lake Profiles

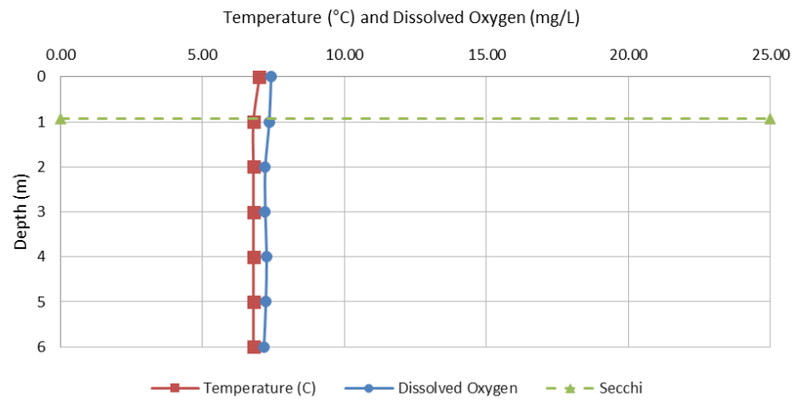
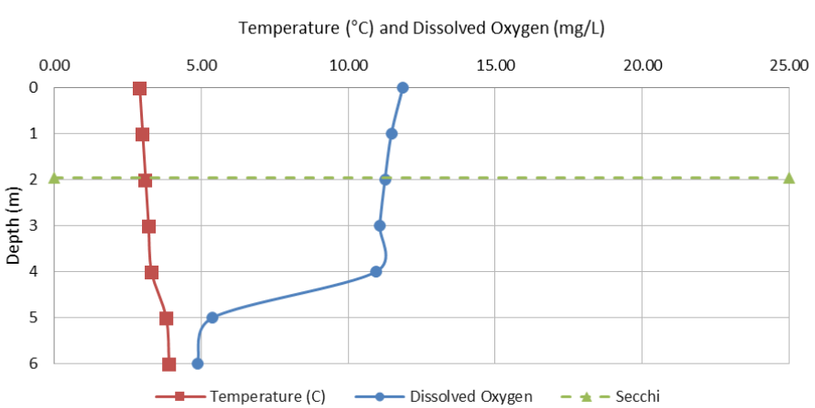


Chart 1l: December Average Temperature (°C) and Dissolved Oxygen (mg/L) Lake Profiles

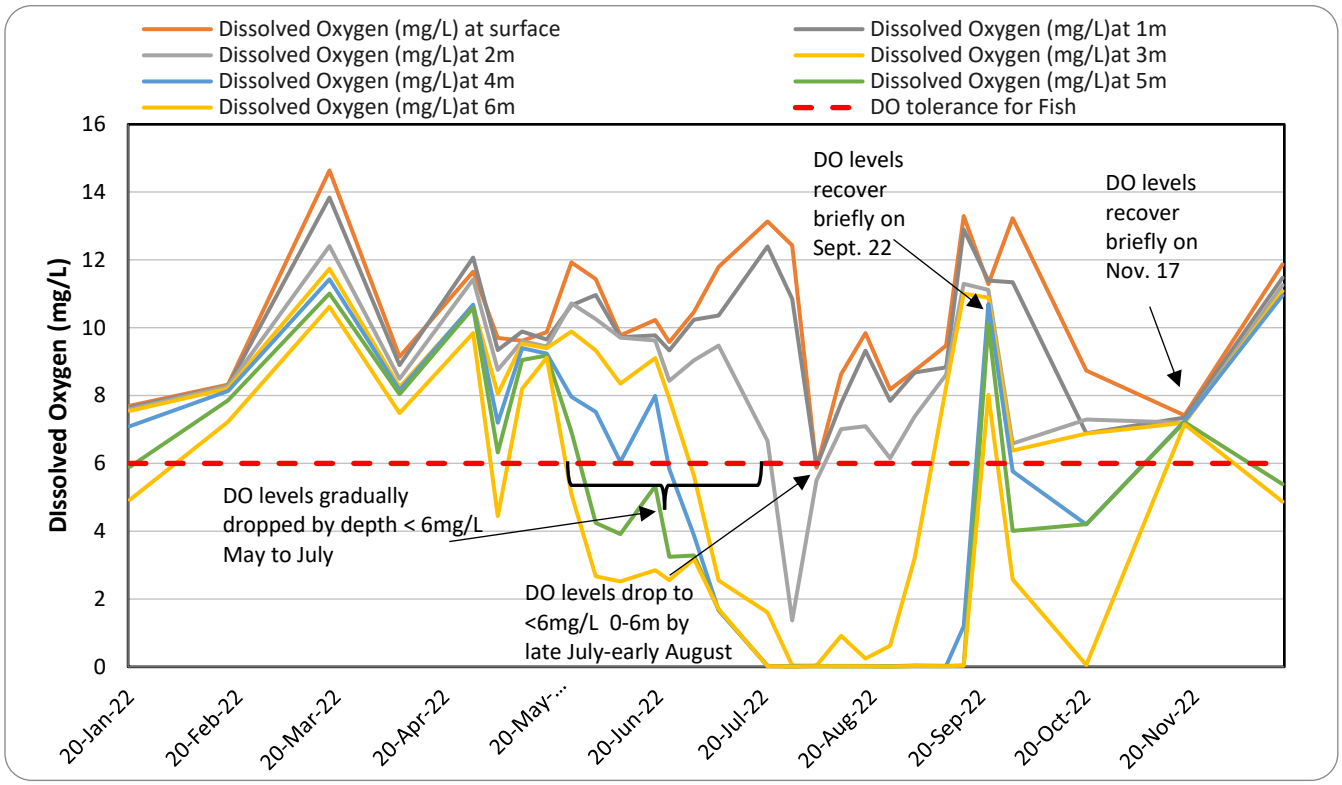


One main importance of lake stratification observations is to determine where pockets of adequate temperature and dissolved oxygen levels exist in the lake, allowing fish to survive. Salmonids are known to use Somenos Lake as a migratory pathway and a refuge; however, fish kills have been known to occur 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 consistently avoid concentrations below 6mg/L (Carter 2005).

Dissolved oxygen levels in Somenos Lake were lower in the summer (except the first few meters at the surface) and somewhat recovered in the fall with a lake turn-over occurring in November. Specifically, dissolved oxygen was anoxic-hypoxic below 2 m depth starting by late June, and by August 4 the entire water column was < 6mg/L. Dissolved oxygen improved by September 10 to >6mg/L above 3 m, and on 2 events - September 22 and November 17 - were above 6mg/L in the entire water column. However, conditions returned to hypoxic at depths below 3-4 meters for the rest of the fall and into December (Chart 2).

During the summer, when oxygen was sufficient for salmonid species survival - only near the surface - the temperatures averaged above 20°C, exceeding optimum temperatures for most salmonids at any life stage (Carter 2005; BCMOE 2001) (Table 1). Some salmonids even avoid temperatures above 15.6C (Table 1, BCMOE 2001). So when oxygen was ok for salmonids (on the surface) the temperatures were too high, and where temperatures were good deeper in the lake (cooler), the oxygen was too low (Chart 2). This made the lake uninhabitable in the summer for salmonids. In addition, migration temperatures were not ideal for Coho, Chum, Pink, or Sockeye until October with the possible higher oxygen window of November 17th. Unfortunately, another migration barrier is that Somenos Creek had low oxygen until the first week of December, keeping salmon from entering the lake.

Chart 2: Somenos Lake Water Quality Profile and Dissolved Oxygen Tolerance for Salmon



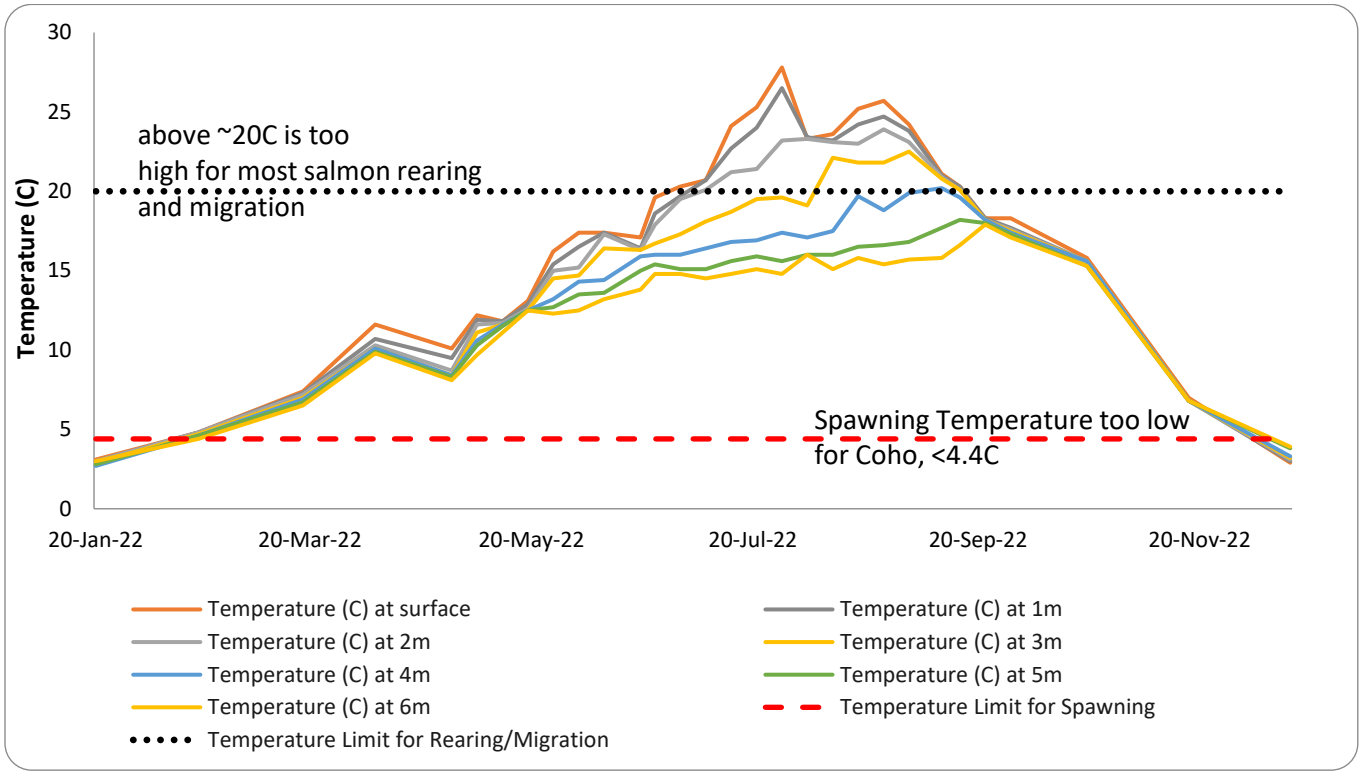
Another obstacle observed this fall for migrating spawning salmon was when cold temperatures occurred in the watershed. When December oxygen levels recovered in Somenos Creek to allow salmon migration to the lake, the temperatures dropped below 4.4C in both the creek and lake. According to studies, and after discussions with municipal biologist (pers.comm. Dave Priekshot) temperatures below this level may cause many spawning salmon (Coho specifically; see Table 1) to stop migrating and wait until temperatures warm up. This was confirmed with Salmon watch volunteers not finding any spawners in the upper tributaries at that time. Unfortunately, the cold weather in the fall has kept water temperatures continually below 4C, and parts of Richards creek, Somenos Creek and Somenos Lake have developed surface ice.

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: BCMOE (2001).

Chart 3: Somenos Lake Water Quality Profile and Temperature Tolerance for Salmon



CONDUCTIVITY AND TDS IN SOMENOS LAKE

Conductivity and TDS have a correlated relationship and is 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, 2022)

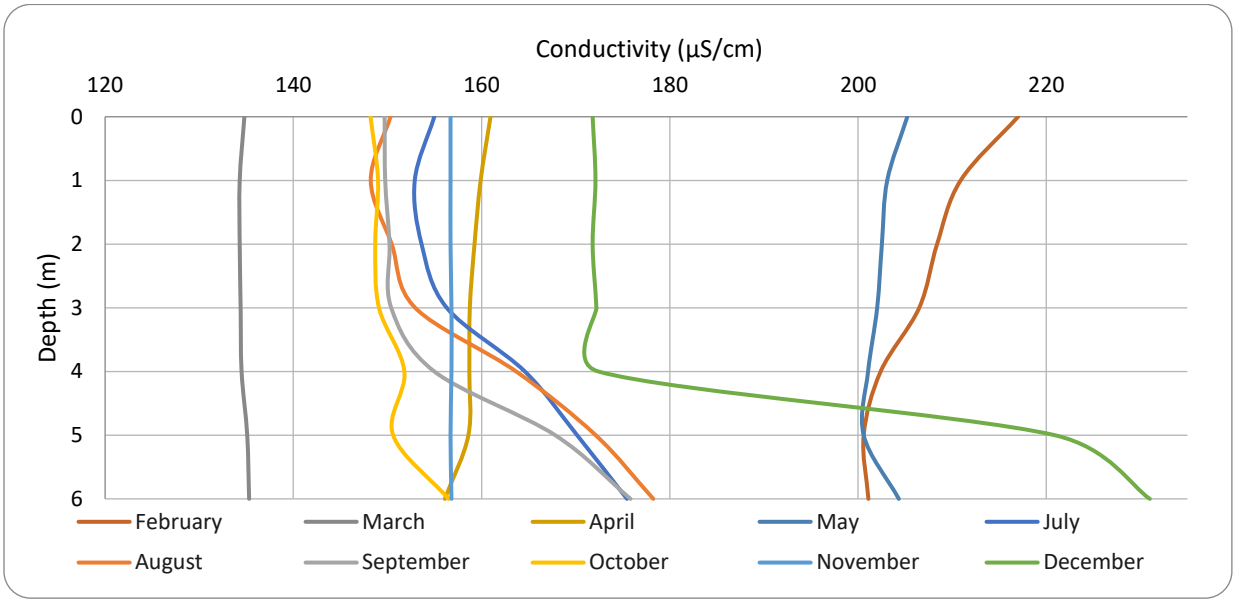
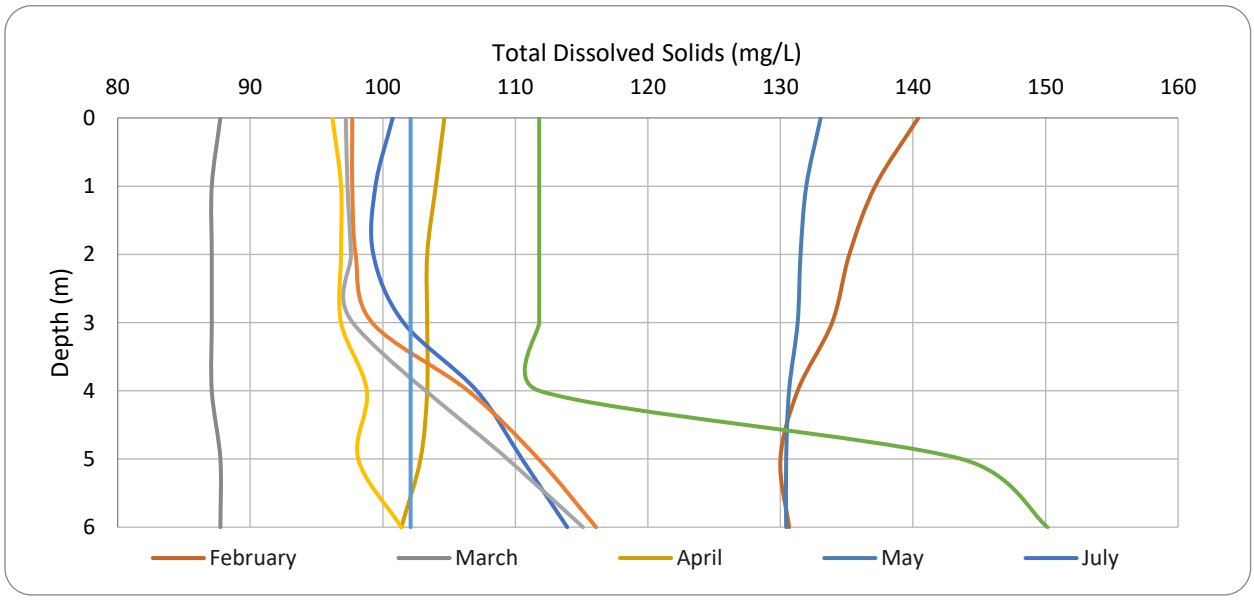


Chart 5: Somenos Lake Average Monthly Total Dissolved Solids Depth Profiles (January to December, 2022)



NUTRIENTS IN SOMENOS LAKE

Somenos Lake is known as a eutrophic lake due to its enrichment of nutrients. As part of the monitoring program the nutrients studied were nitrate, ammonia, nitrite, and phosphorus. 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.

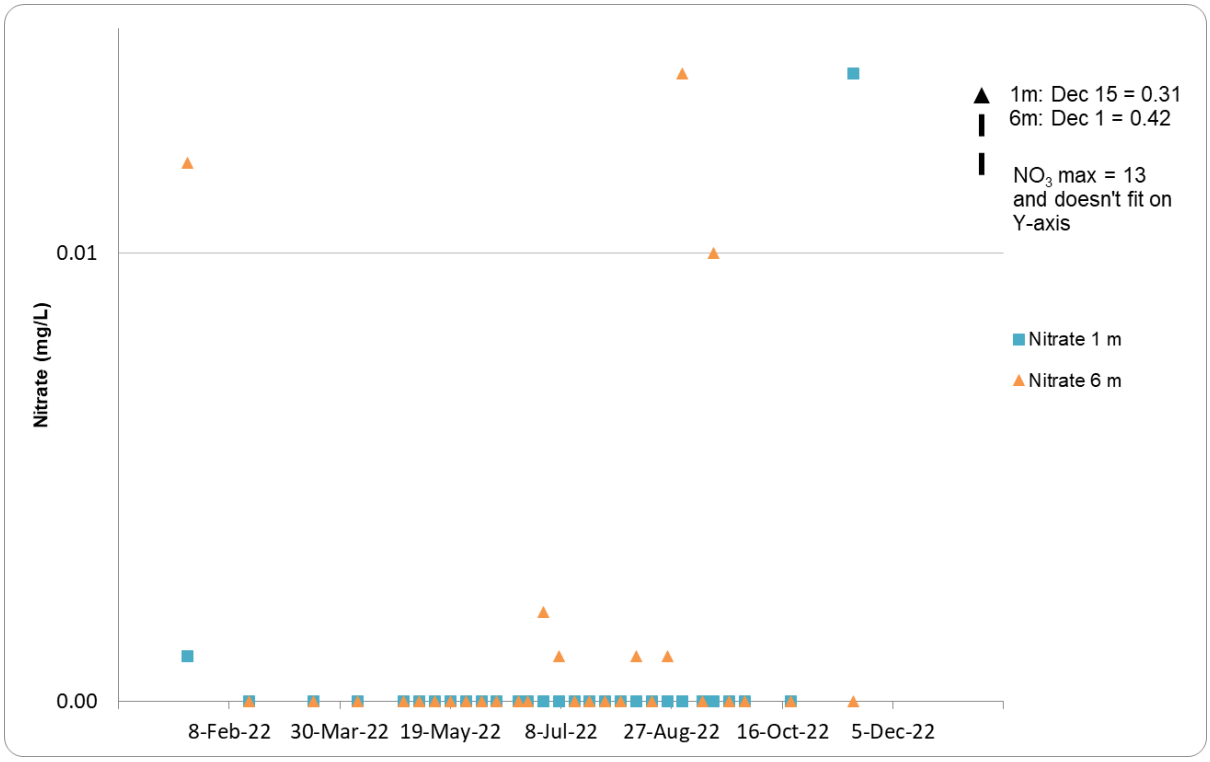
NITRATE IN SOMENOS LAKE

When looking at the Nitrogen cycle in lake systems, generally Nitrate is consumed first by microorganisms, then Ammonia, and lastly Nitrite which is how the results are presented in this section.

Nitrate levels in Chart 6 do not exceed CCME guidelines at the top or bottom of the lake for acute or chronic exposures (Nitrate 13 mg/L, CCME 2012). Results for both 1m and 6m depths were too low to represent the max guidelines in Chart 10.

NITRITE IN SOMENOS LAKE

Chart 6: Somenos Lake Monthly Average Nitrate (NO_3) Levels



AMMONIA IN SOMENOS LAKE

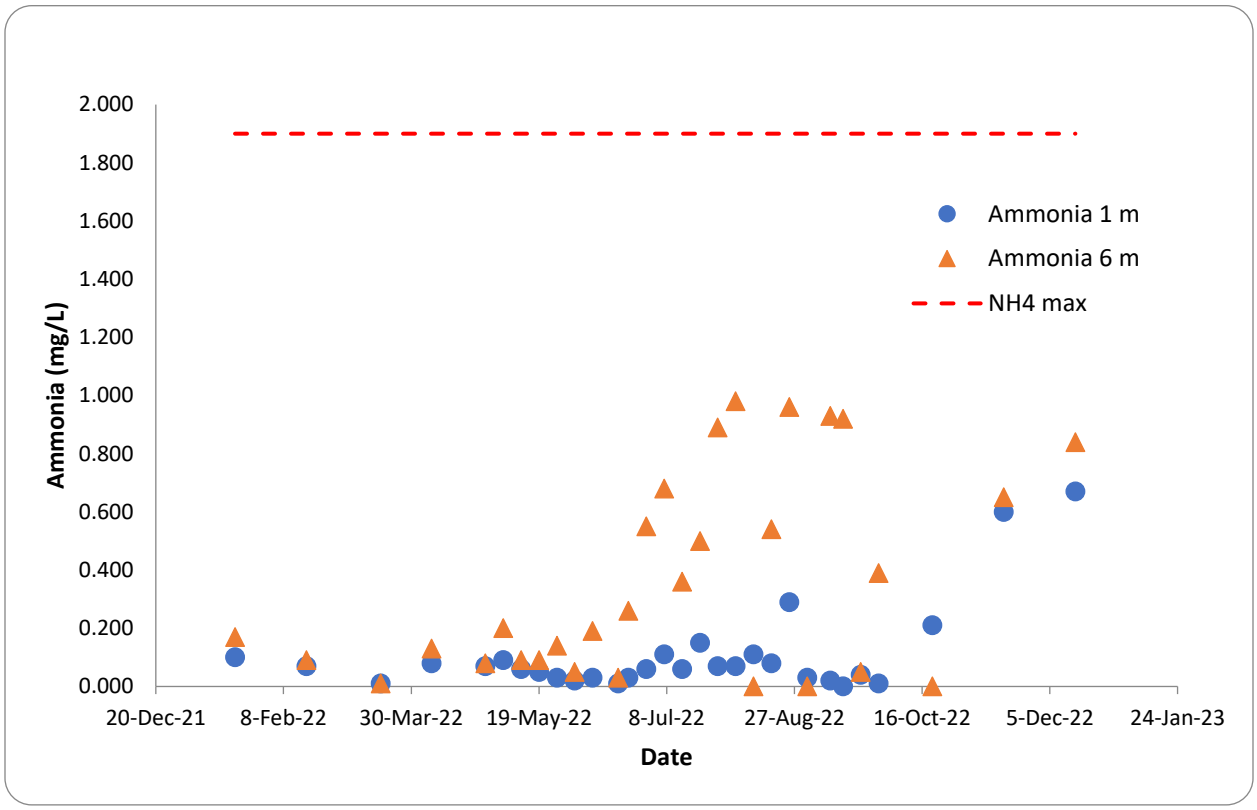
Ammonia is an important compound to measure because it is principally used in the production of nitrogenous fertilizers (CCME 2010), and the Somenos watershed is abundant in agriculture activities. Ammonia is also an important component of the nitrogen cycle and because it is oxidized in the environment 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 EPA guideline for the protection of aquatic life in freshwater for un-ionized ammonia used in this report is 1.9 mg/L (EPA 2013). However, this varies due to the relationship between pH and temperatures of the water, which fluctuates throughout the year. For simplicity, we used this guideline for the analysis.

Chart 7 shows the ammonia levels at 1m and 6m lake depths, and how they correlate with EPA guidelines for aquatic life (EPA 2013). If we don't factor in pH or temperature the result is a below the recommended amount of ammonia in the lake at both depths (Chart 11).

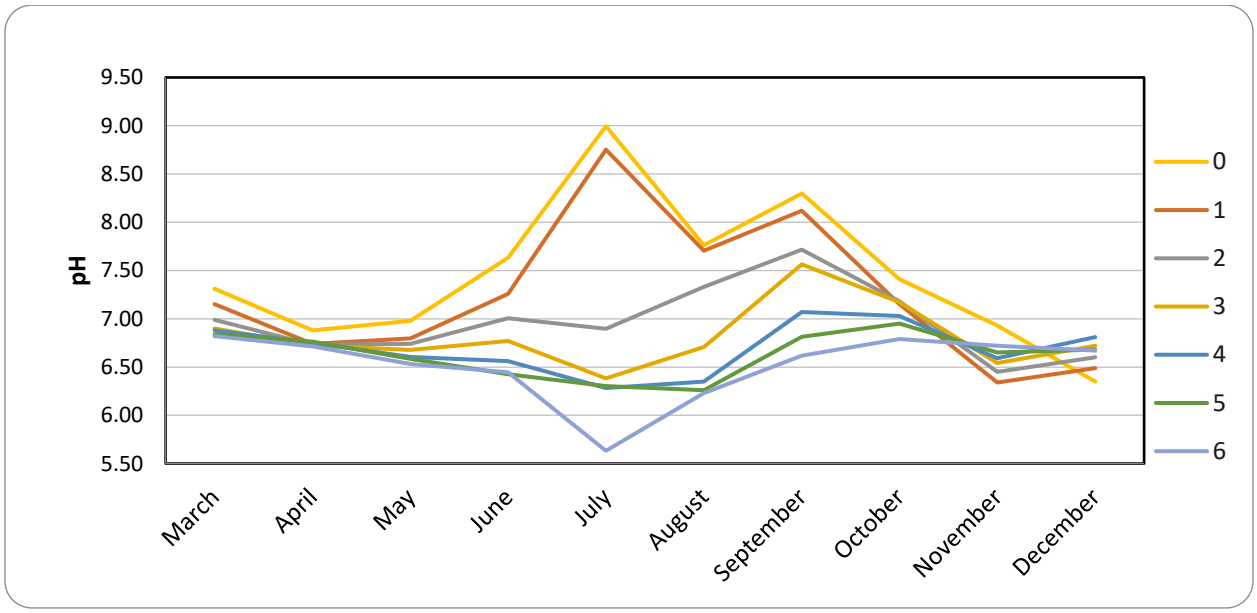
Chart 7: Somenos Lake Ammonia Levels (1m and 6 m) and EPA (2013) guidelines



If we include pH, Chart 8 shows the pH profile in 2022 from the surface of the lake to 6 meters depth. Generally when pH is high (basic) in the lake (example at 0-1m in summer), ammonia toxicity increases. Thankfully concentrations of ammonia are very low at this depth (near the surface). Whereas, the pH is low (more acidic), ammonia toxicity is reduced even if ammonia concentration is higher, such as at 6 m

depth. Generally, since ammonia concentrations are high at 6m depth (but not over the limit), we would be more concerned about toxicity and exceeding limits if the pH was basic.

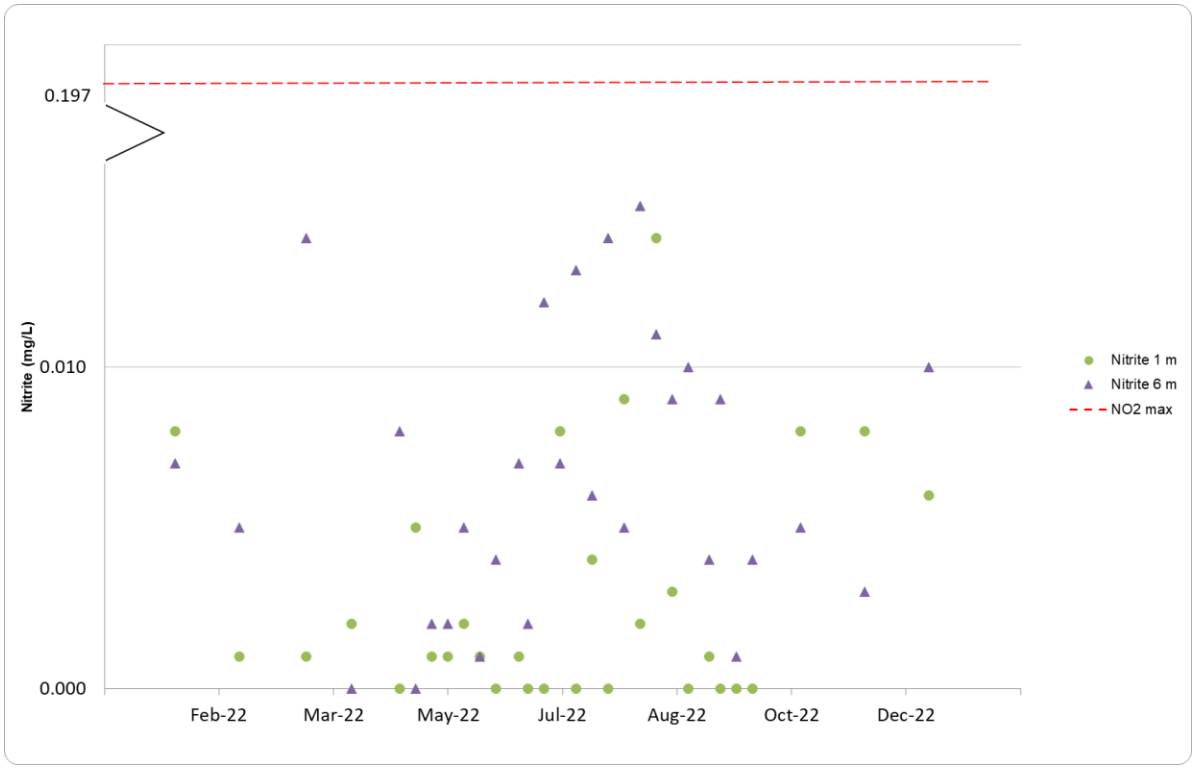
Chart 8: Somenos Lake pH Levels (1m to 6 m)



NITRITE IN SOMENOS LAKE

Nitrite levels in Chart 9 do not exceed CCME guidelines at the top or bottom of the lake (Nitrite 0.197 mg/L, CCME n.d.).

Chart 9: Somenos Lake Monthly Average Nitrite (NO_2) Levels

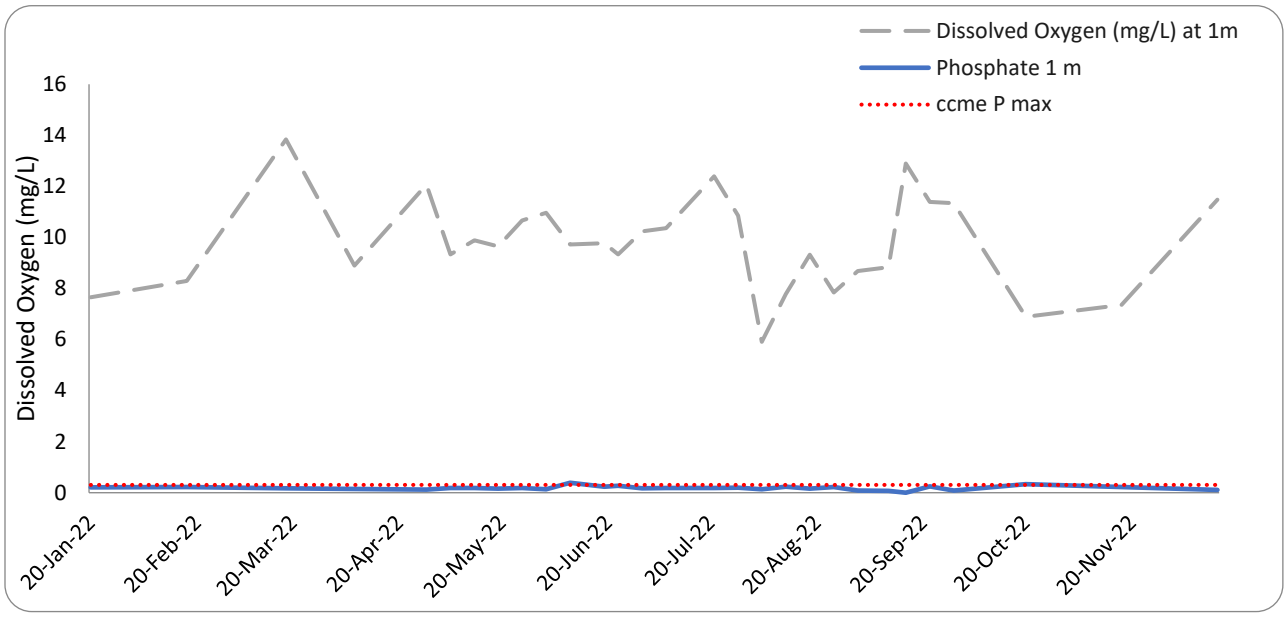


PHOSPHATE IN SOMENOS LAKE

Phosphate is 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 10 and 11 show the comparison of phosphate measurements with dissolved oxygen levels at the surface and bottom of the lake, respectively.

At the lakes' surface, there were three phosphate readings over guidelines. These single incidents occurred in spring, summer, fall, respectively on June 9th, July 14th, and October 20th (Chart 12). Over the warm season, which in 2022 extended into the fall, algal growth and die off, and higher dissolved oxygen levels at the surface may cause fluctuations in phosphate levels.

Chart 10: Somenos Lake monthly total phosphate and dissolved oxygen at 1m.



At the bottom of the lake, phosphate levels in spring fluctuated but were consistently over guidelines (0.5-3 mg/L) from June until December (Charts 11-12). At the bottom of the lake dissolved oxygen decreased to anoxic levels late May, around the same time that Phosphate began to increase. It is possible the aquatic plant and microorganism growth use up the oxygen during the growing season, which is why we see a decline. Phosphate accumulated in the sediment can be released during low oxygen conditions (Schindler and Vallentyne 2008). It is likely, dissolved oxygen began to sharply rise by late-September due to plant and microorganism died off (Schindler and Vallentyne 2008).

Chart 11: Somenos Lake monthly total phosphate and dissolved oxygen at 6m.

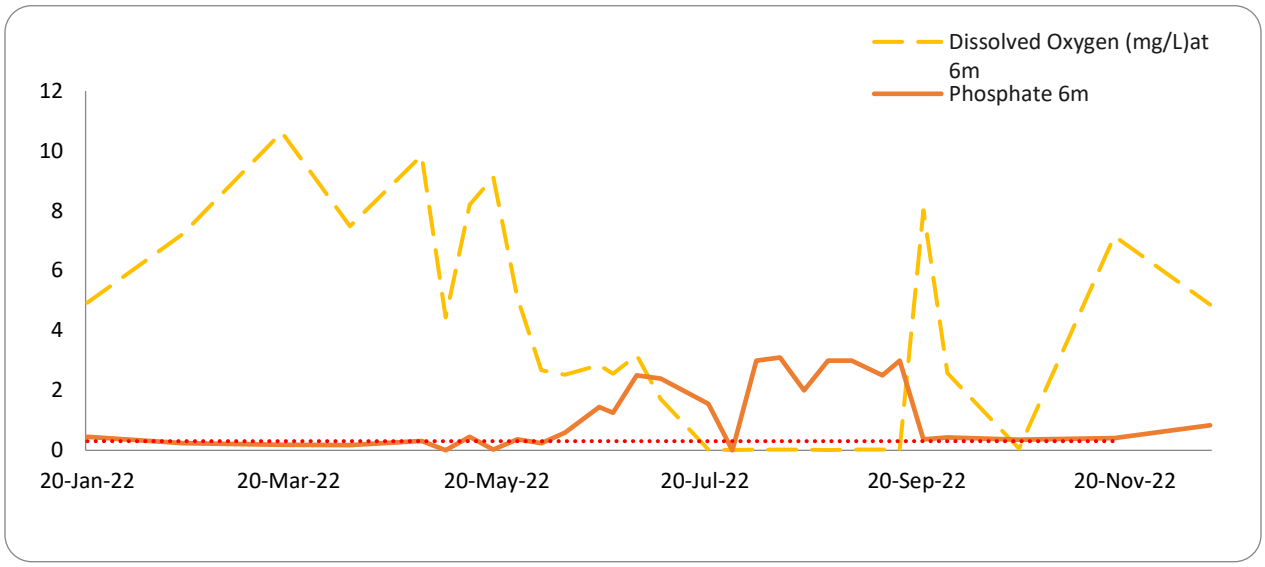
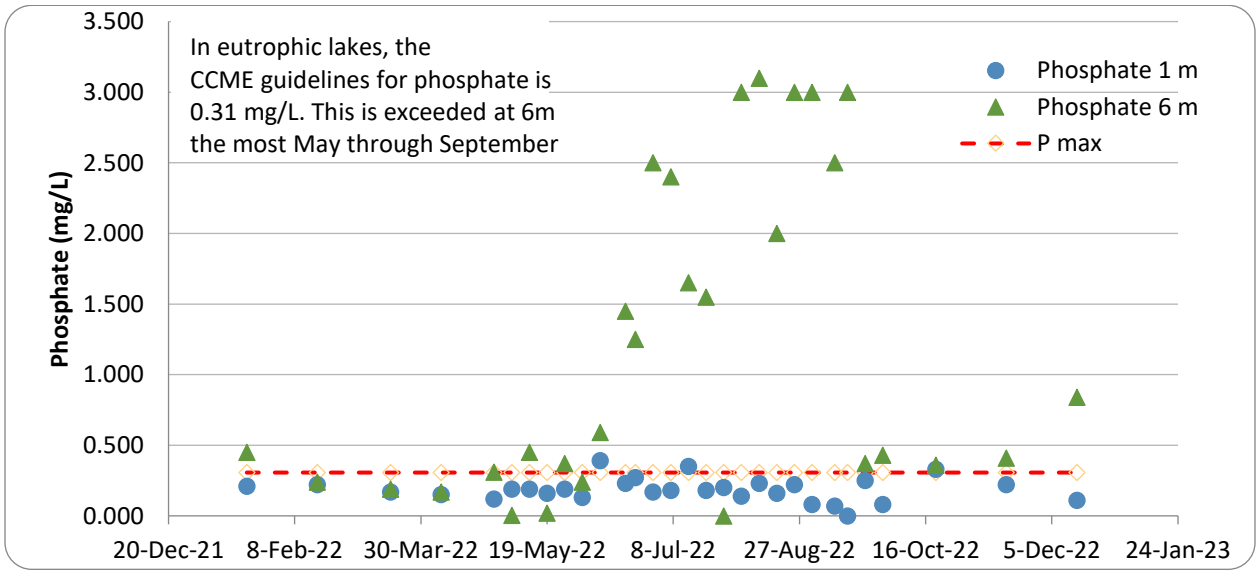


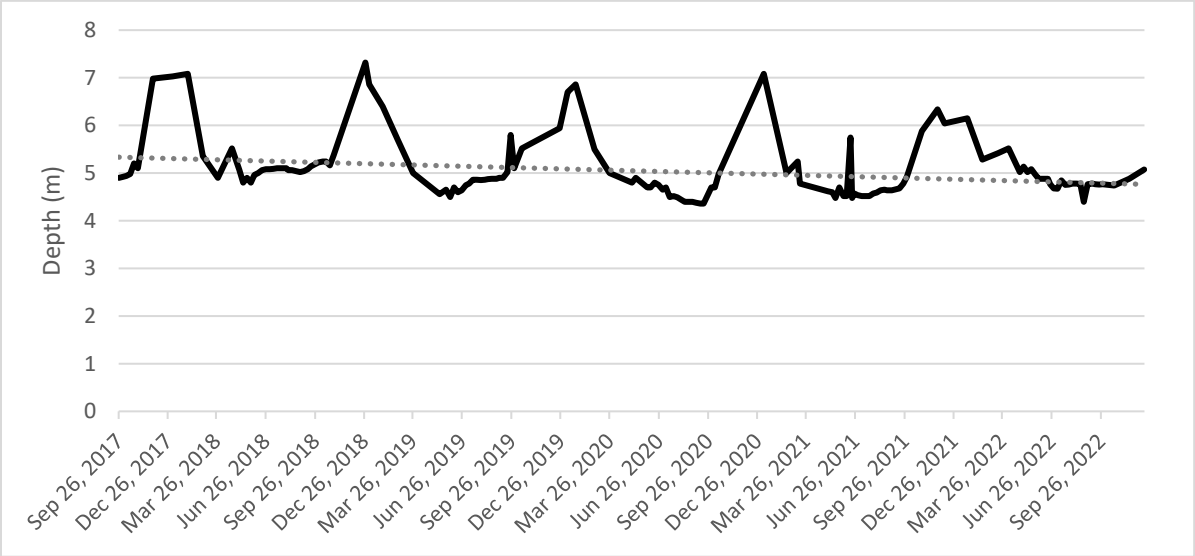
Chart 12: Somenos Lake Phosphate Concentrations at the surface and bottom



SOMENOS LAKE DEPTH ANNUAL TRENDS

A review of Somenos Lake depths from 2017 to 2022 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.

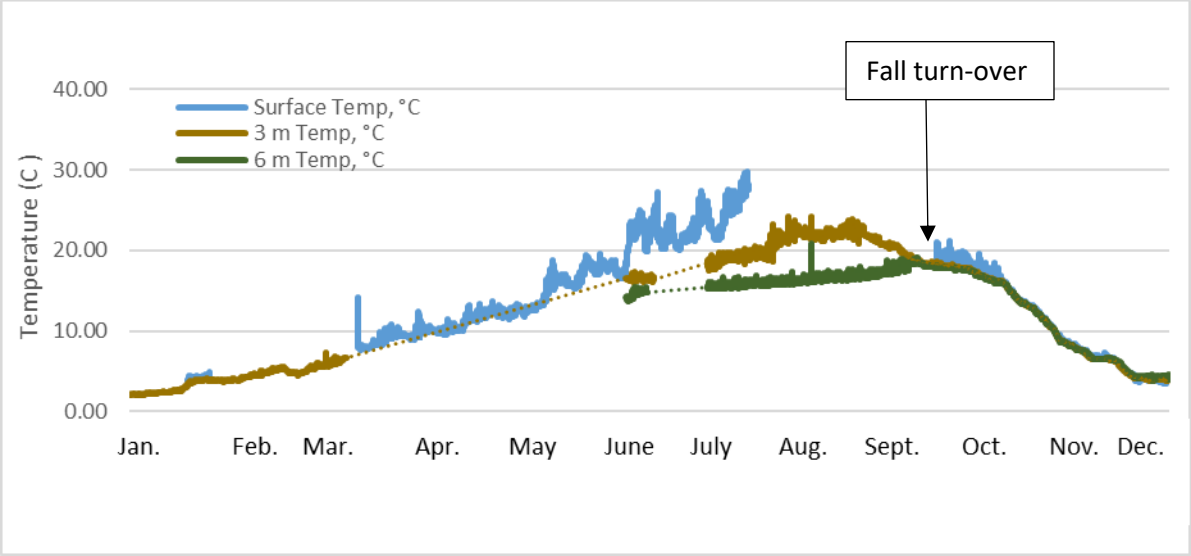
Chart 13: Somenos Lake Monthly depths from 2017 to 2022



HOURLY DATA LOGGERS IN SOMENOS LAKE

Data loggers (tidbit hobos) were deployed in Somenos Lake to measure hourly temperatures at the surface, 3m and 6m depths (Chart 14). Some data is missing due to malfunctioning loggers throughout the year. However, you can generally see that the surface temperature (0m) is warmer than at 3m, and 6m depths are colder than the upper layers during the warmer months when it was stratified. When turnover occurs in fall you can see when temperatures at multiple layers mix and become similar.

Chart 14: Somenos Lake Temperatures recorded at surface, middle, bottom of the lake, 2022.



SOMENOS CREEK

Hourly temperature and light intensity data was recorded at three stations in Somenos Creek. The most upstream station (3) had data loggers fixed to a buoy next to the pond liner that was used in the Parrot's Feather control management project. 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 (Figure 11).

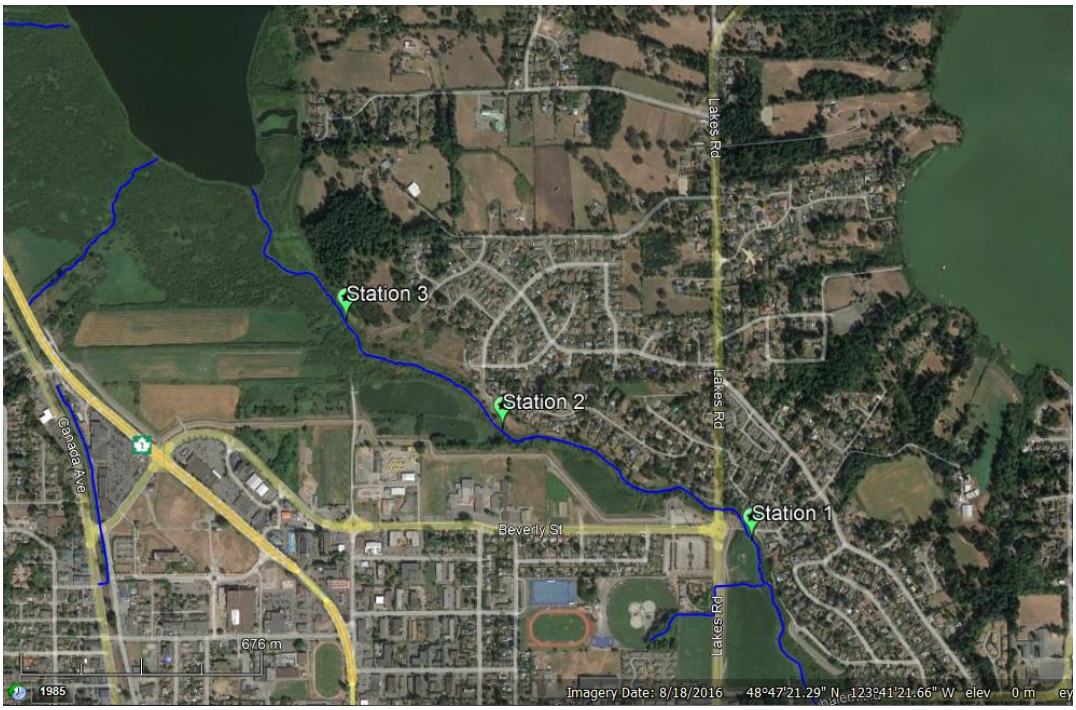


FIGURE 11: DATA LOGGER STATIONS 1-3 MEASURING TEMPERATURE AND LIGHT IN SOMENOS CREEK, 2022

The surface temperatures at all the stations appears similar (Chart 15). However, bottom temperatures at Station 1 were much lower than the other sites until late September when temperatures became similar and decreased at the same rate (Chart 16). As fall approached, by late October, both the surface and bottom temperatures become similar between stations and depths.

Chart 15: Hourly Temperatures at the Surface at all Stations 1-3 in Somenos Creek (July-November 2022)

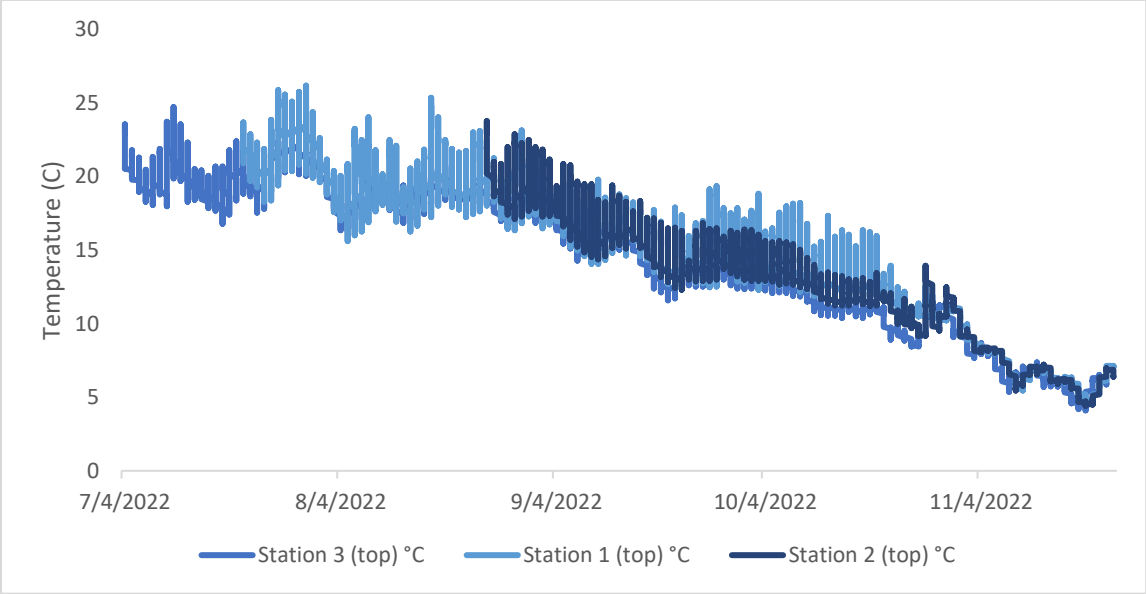
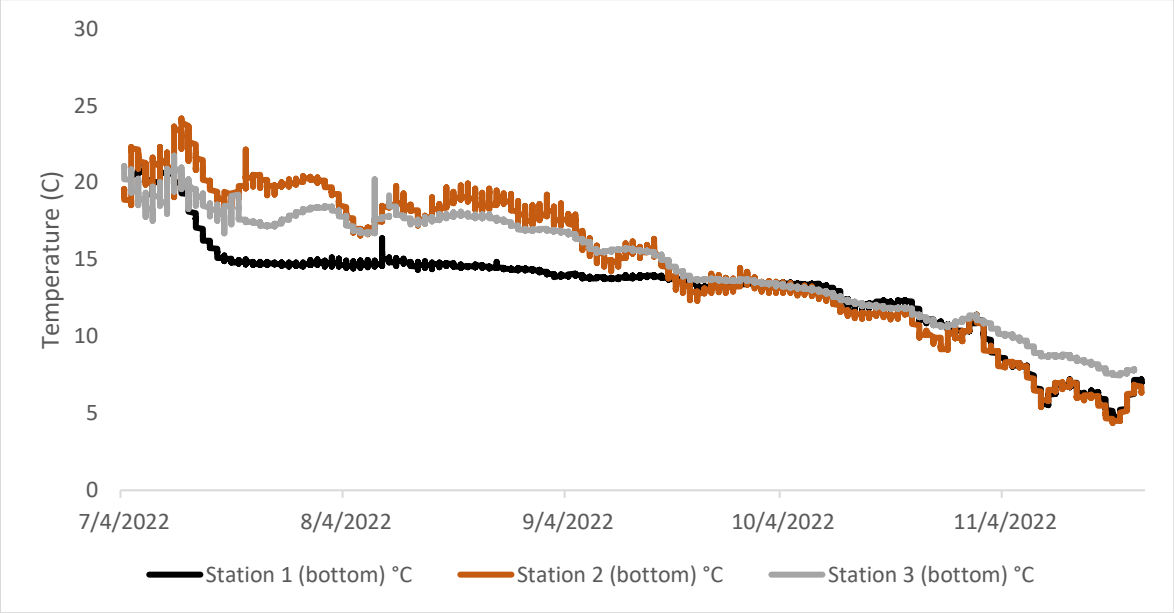


Chart 16: Hourly Temperatures at the Bottom at all Stations 1-3 in Somenos Creek (July-November 2022)



Stations 1-3 have very different light intensity profiles (Charts 17-19). One thing that stands out is that Site 3 has the least amount of light reaching the bottom and surface data loggers (Chart 17). The reason likely has to do with this location having more Parrot's Feather growth than Stations 1 and 2, and a pond liner installed. Station 1 is located under the pedestrian bridge near Lakes road and it is partially shaded, and very little parrot's Feather. Station 2 has a hard rocky bottom, leaving limited sediment for parrot's Feather to grow, and has a patch of open water in the centre of the creek where the data logger was situated. This could also explain why Station 2 has higher light intensity throughout the water column if it does not get completely covered in plant growth in the summer. Station 3 is at the pond liner experiment location and heavily covered in thick parrot's Feather mats.

Chart 17: Light Intensity (lum/ft^2) at the Surface and Bottom at Station 1 in Somenos Creek (July – November 2022)

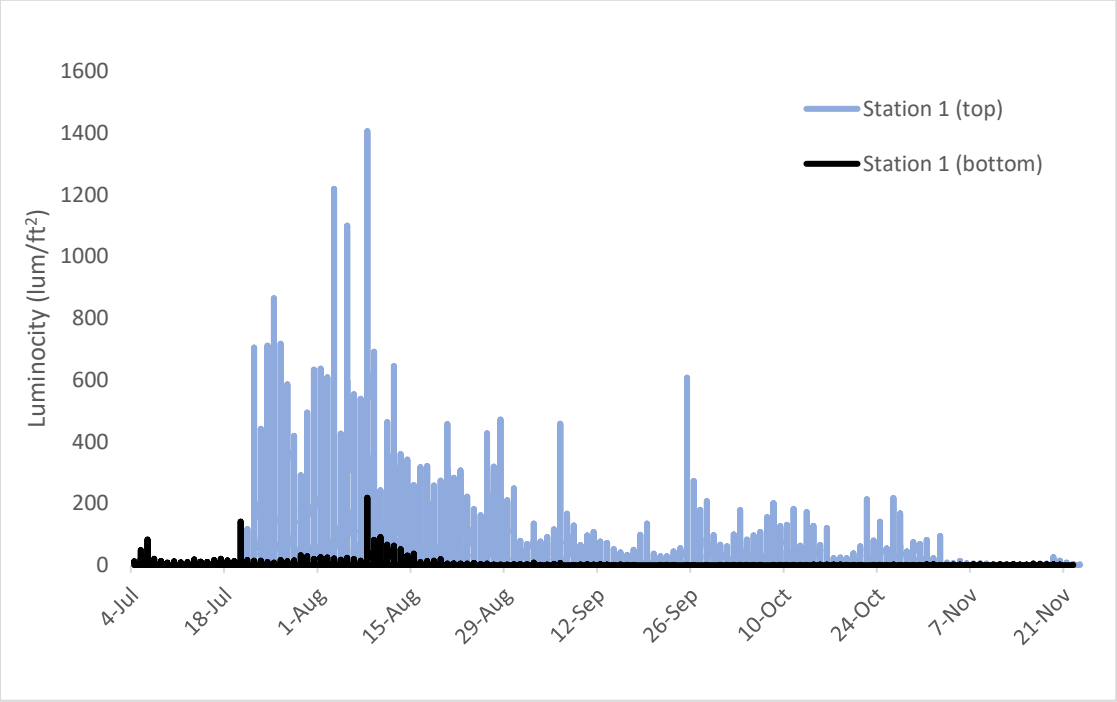


Chart 18: Light Intensity (lum/ft^2) at the Surface and Bottom at Station 2 in Somenos Creek (July – November 2022)

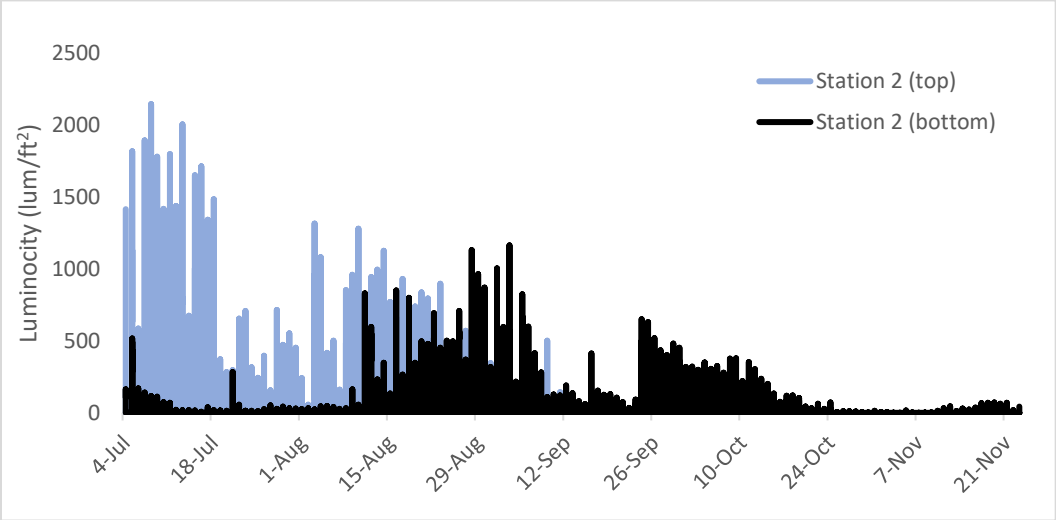
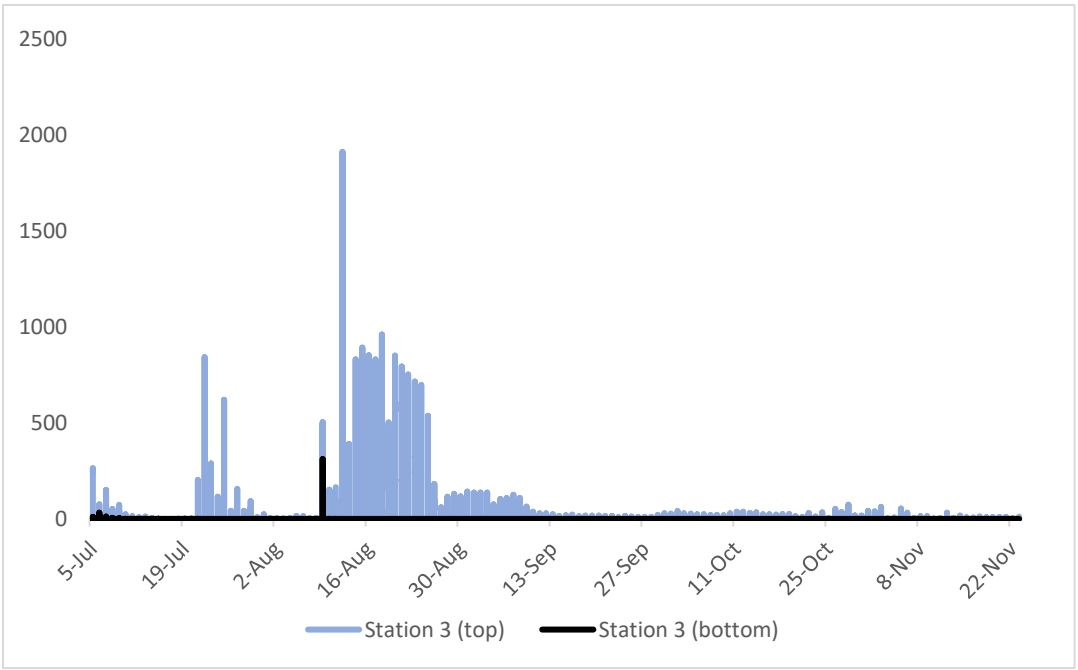


Chart 19: Light Intensity (lum/ft^2) at the Surface and Bottom at Station 3 in Somenos Creek (July – November 2022)



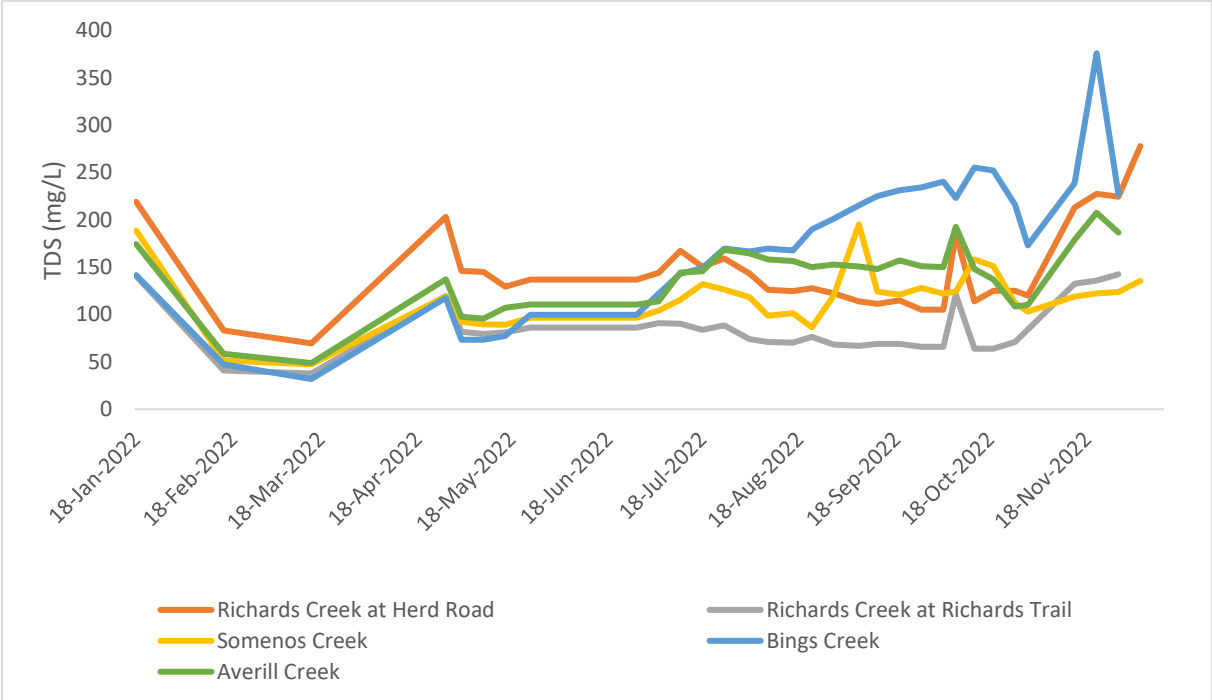
8 Appendix B - Water Quality results for the Somenos Watershed Tributaries

The main tributaries in the Somenos Watershed are Somenos Creek, Bings Creek (Mary/Phillips Street and OAC Reach 1), Richards Creek (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 2022.

TOTAL DISSOLVED SOLIDS AND SPECIFIC CONDUCTIVITY IN THE SOMENOS TRIBUTARIES

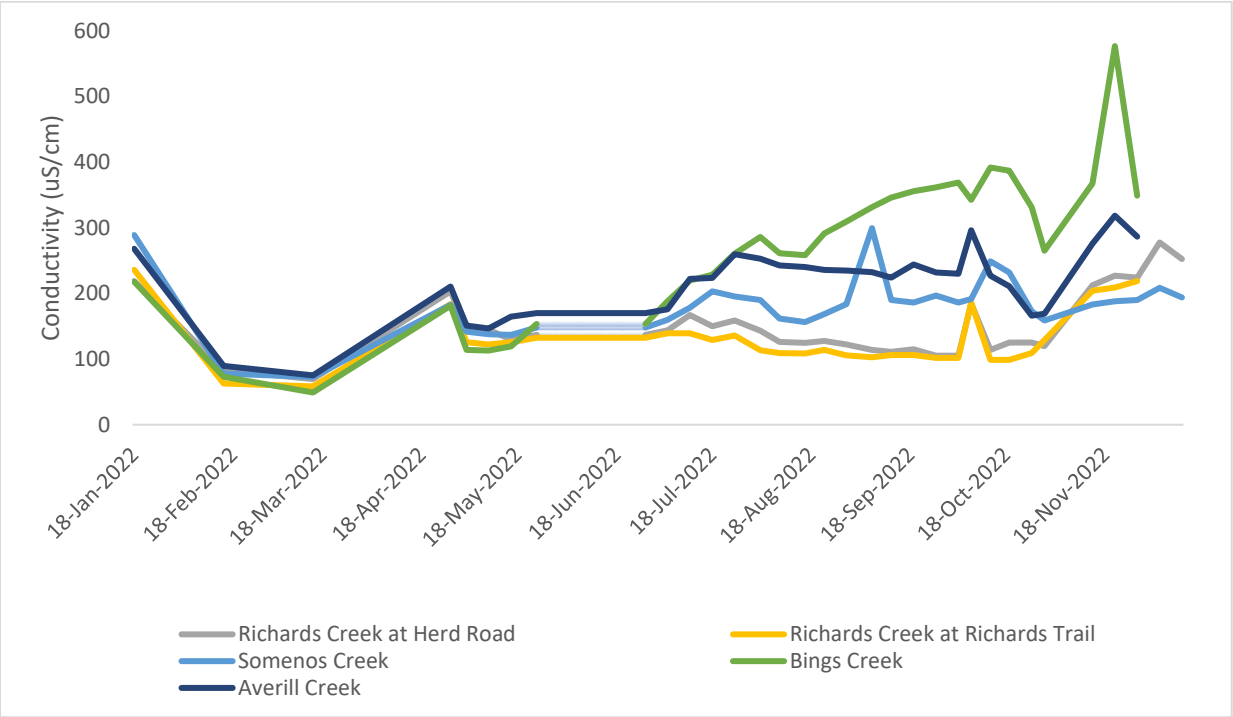
The tributary total dissolved solids (TDS) and specific conductivity levels in Charts 20 and 21 match very closely which is common. The more TDS the more conductivity of materials (mineral salts dissolved in water that are conductive) in the water column. There were a few peaks in conductivity and TDS for all the tributaries in fall.

Chart 20: Somenos Watershed Tributary Total Dissolved Solids, 2022



Note: May 24th to June 27th were estimated because probe was being fixed

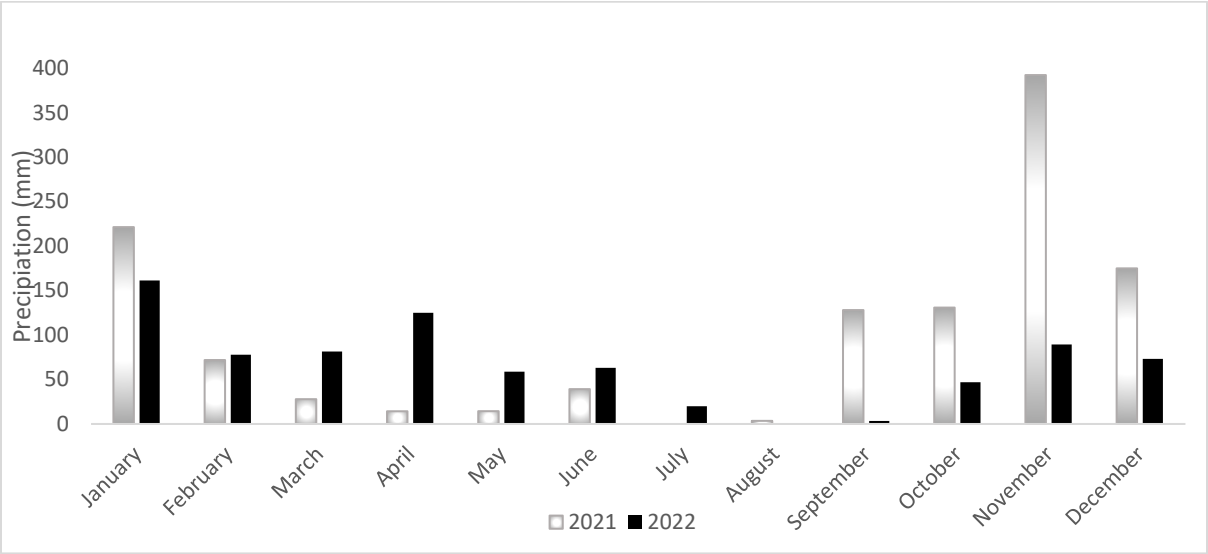
Chart 21: Somenos Watershed Tributary Specific Conductivity Levels, 2022



Note: May 24th to June 27th were estimated because probe was being fixed

When TDS and conductivity rose, water temperatures were on a gradual decline (Chart 23) and thus were not the cause. It is more likely due to the start of the fall precipitation, shown in Chart 22 (ECCC 2022). There was less precipitation in 2022 than in 2021; however, there was still an increase in fall from the summer; which can increase flows and surface water runoff, and in-turn increase TDS and conductivity in the creeks.

Chart 22: Environment and Climate Change Canada Total Precipitation Data for Duncan, BC, 2021-2022



Source: https://duncan.weatherstats.ca/metrics/precipitation.html

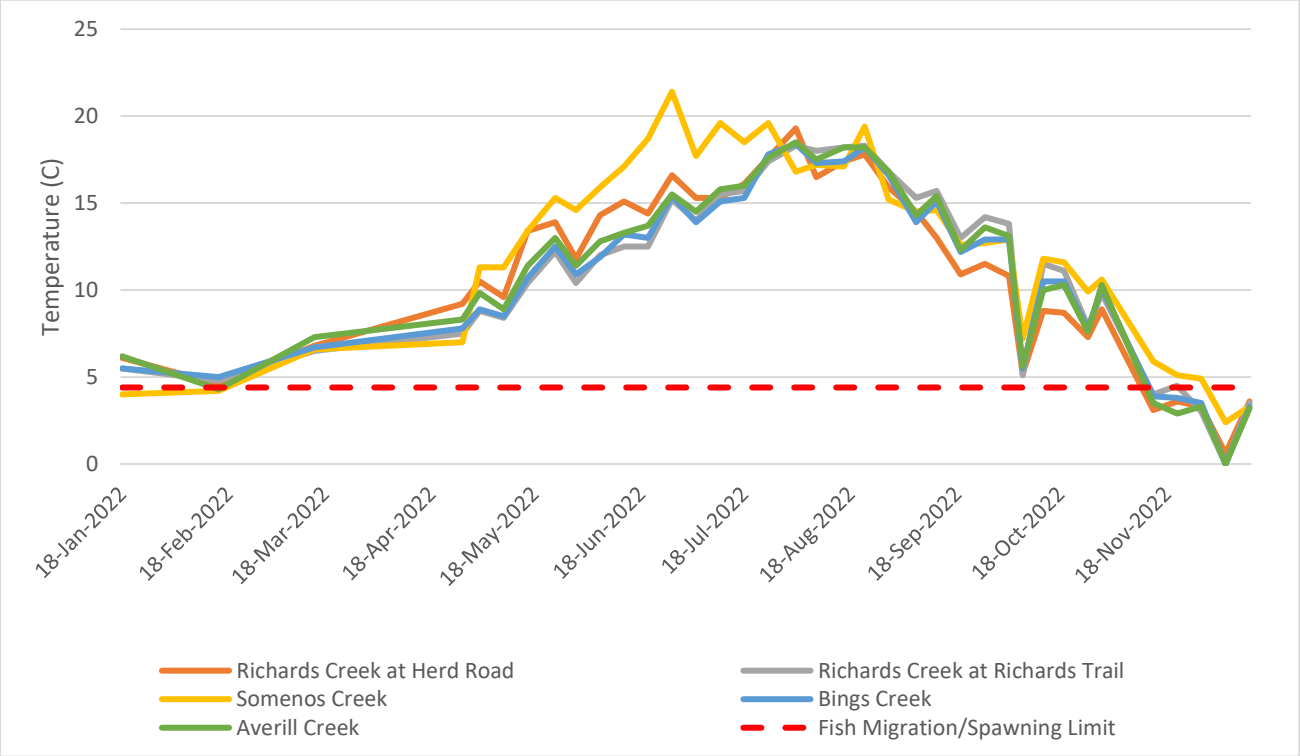
TEMPERATURE IN THE SOMENOS TRIBUTARIES

This spring was a wet (Chart 22) and cold season this year (Chart 23) where temperatures only started to rise above 15°C by June. Richards Creek at Richards Trail, Averill Creek and Bings Creek were similar in temperature over the year.

Somenos Creek had the highest temperature value of 21.4°C compared to the other creeks and peaked first on June 27, 2022 (Chart 23). Richards Creek at Richards Trail, Bings Creek and Averill Creek highest temperatures were about the same, peaking on August 2nd between 18.3-18.5°C, apart from Richards Creek at Herd Road which was a degree higher (19.3°C).

By mid August temperatures were similar in all tributaries until October 7th, during a cold week, temperatures drastically dropped by about half (ranged between 5.1-7.2°C), recovering the following week with warmer air temperatures. Creek temperatures gradually declined in the fall but had two more cold weeks that dropped water temperatures on November 14th between 3.1- 5.9°C, and on December 5th (0.6-2.4°C). It is important to note that spawning and migration occurs above 4.4°C for Coho, thus these cold temperatures in December may have caused a delay in spawning this year (Chart 23).

Chart 23: Somenos Watershed Tributary Temperature Levels, 2022

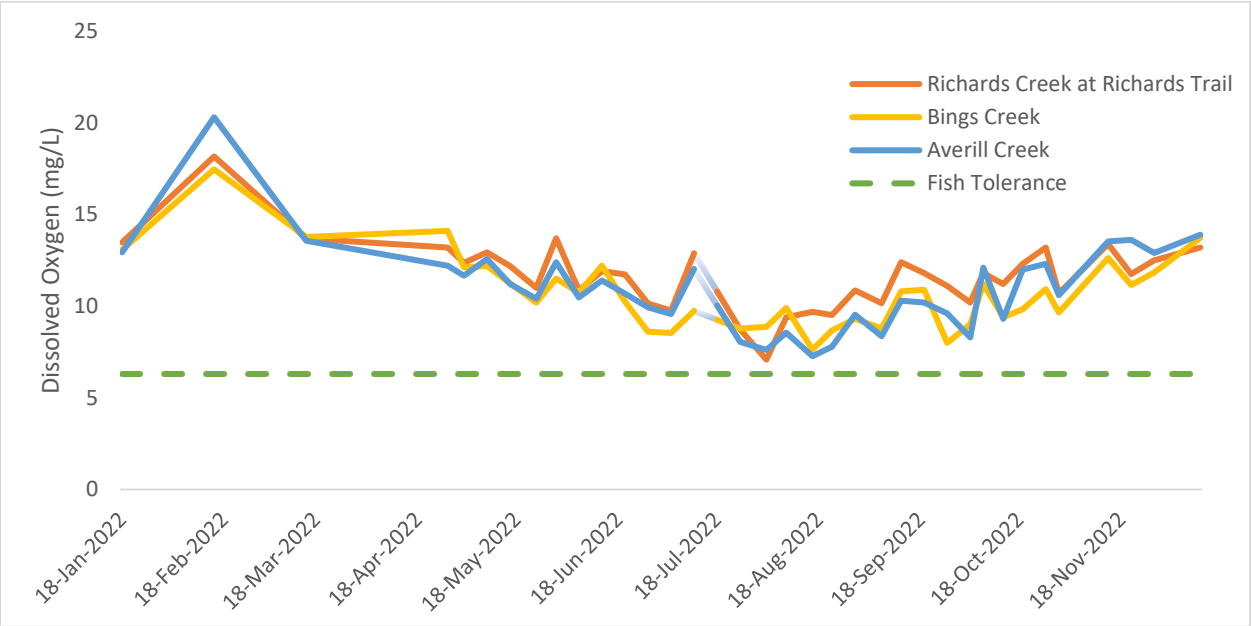


DISSOLVED OXYGEN IN THE SOMENOS TRIBUTARIES

Dissolved oxygen was measured at a 1 m depth in Richards creek at Herd road and Someons Creek. All other locations were shallow and sampled just below surface.

Dissolved oxygen levels were similar between the spawning creeks: Bings, Averill and upper Richards Creek (Richards Trail) (Chart 24). Richards Creek at Richards Trail remained between sub-optimal to optimal range for the entire year. The highest dissolved oxygen was 18.16 mg/L in February and lowest was 7.08 mg/L on August 2. Bings Creek remained between sub-optimal to optimal throughout the year. The highest result of dissolved oxygen was in February at 17.46 mg/L and lowest was 7.63 mg/L on August 16. Averill Creek levels were similar to Bings Creek. The highest result of dissolved oxygen was in February at 20.3 mg/L and lowest was 7.27 mg/L on August 16.

Chart 24: Somenos Watershed Tributary Dissolved Oxygen Levels, 2022



On the other hand, Richards Creek at Herd Road and Somenos Creek are much lower than the other locations (Chart 25). Richards Creek at Herd Road has anoxic conditions for salmonids (trout and salmon) from late May until December between 0.03-5.4 mg/L. In December levels started to rise with decreased temperatures; but did not rise above hypoxic levels (5.71mg/L) by the last testing date of December 12th. This causes a concern that even with the increase in oxygen at Richards Creek Herd Road in December, the water temperatures are too cold for spawning and migration. That means the salmon that have been waiting for oxygen levels to rise for migration, may now be waiting for temperatures to rise before heading upstream to Richards Creek above Richards Trail.

Somenos Creek has low oxygen conditions for salmonids from July until December between 0.06-6.3 mg/L. By December 5th, levels started to recover to sub-optimal levels (6.86 mg/L) which would allow salmon to migrate up to the tributaries to spawn. However, by this date, temperatures were also recorded in Somenos Creek below migration and spawning ideal levels (Charts 25-26). This causes the same concern as in Richards Creek, where low temperatures may prevent salmon migration upstream to spawn in Bings, Averill, and Richard creeks.

Chart 25: Somenos Creek at Lakes Rd. and Richards Creek at Herd Rd. Dissolved Oxygen, 2022

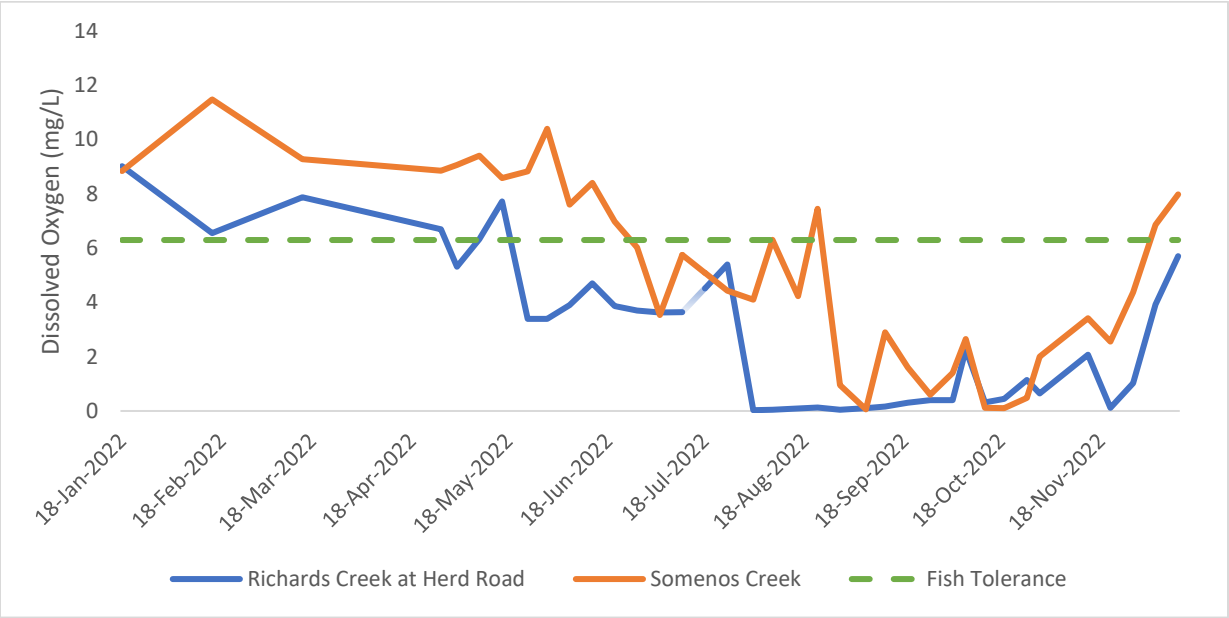
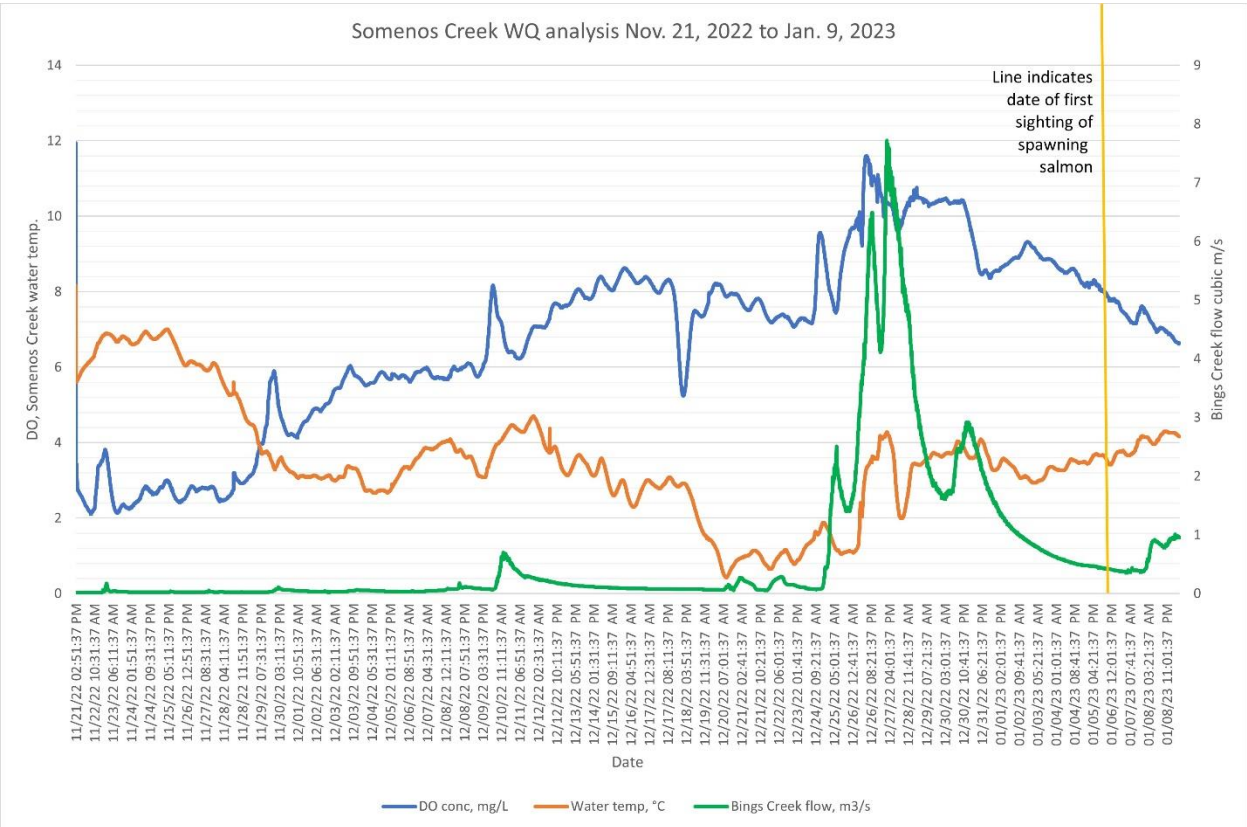


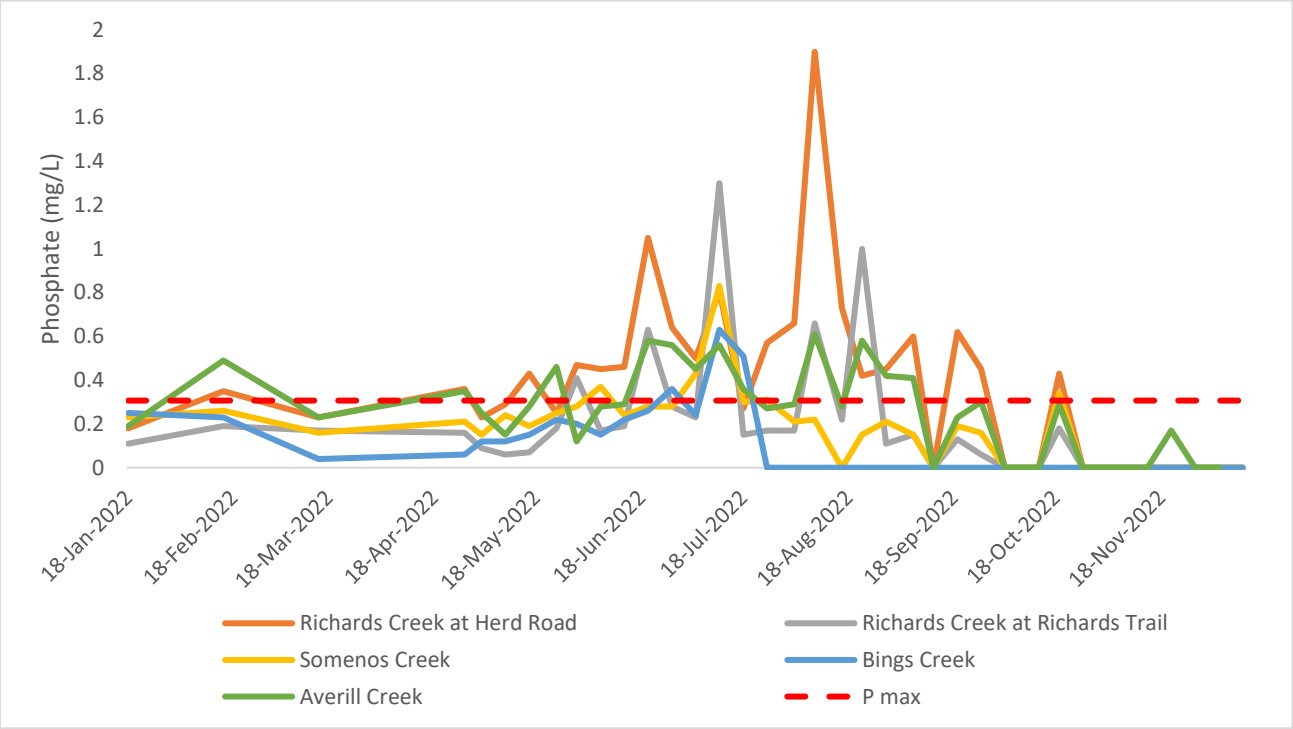
Chart 26: Probe data on Somenos Creek at Lakes Road – Fall/Winter Temperature and Dissolved Oxygen Levels in Comparison to Bings Creek high flows with first Salmon Sightings in the Watershed.



PHOSPHATE IN THE SOMENOS TRIBUTARIES

In Chart 27, all the tributaries regularly exceeded CCME guidelines for the protection of aquatic life (0.3066 mg/L; CCME 2004) from May to October. This can be a cause for concern because Phosphate can disrupt the ecology creating more plant growth, algal blooms, and deplete oxygen. The tributaries will continue to be monitored by SMWS and sources of Phosphate inputs investigated.

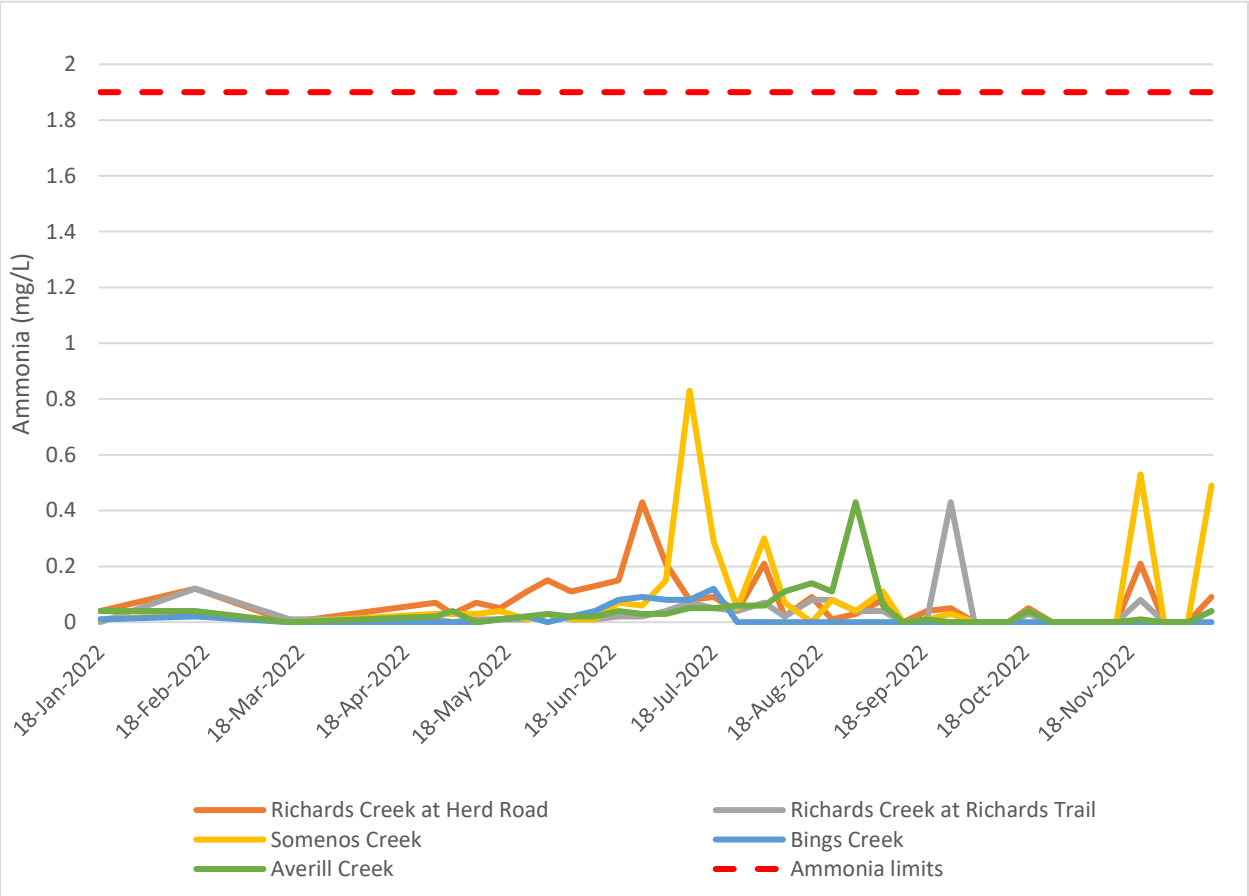
Chart 27: Tributary Phosphate Levels, 2022



AMMONIA IN THE SOMENOS TRIBUTARIES

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 28, we used the general EPA 2013 guideline for the protection of aquatic life in freshwater for un-ionized ammonia which is 1.9 mg/L to look at the results. Ammonia did not exceed the guidelines, at the tributaries; therefore, is not a concern at this time.

Chart 28: Somenos Watershed Tributary Monthly Ammonia Levels, 2022



NITRITE AND NITRATE IN THE SOMENOS TRIBUTARIES

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 2022, and thus are too high to show on Charts 29 and 30. Even though levels were well below guidelines for all the tributaries, there were a few notable increases that occurred at all tributaries. Nitrate levels were well below exceedance limits and are not of concern in the tributaries (Chart 29). In May to October Nitrite increased in a similar pattern to Ammonia, reinforcing a Nitrogen input into the system during that timeline in all the tributaries. These levels of nitrite are not at levels of concern but point to a surge in nutrient loading in the tributaries.

Chart 29: Somenos Watershed Tributary Monthly Nitrate Levels, 2022

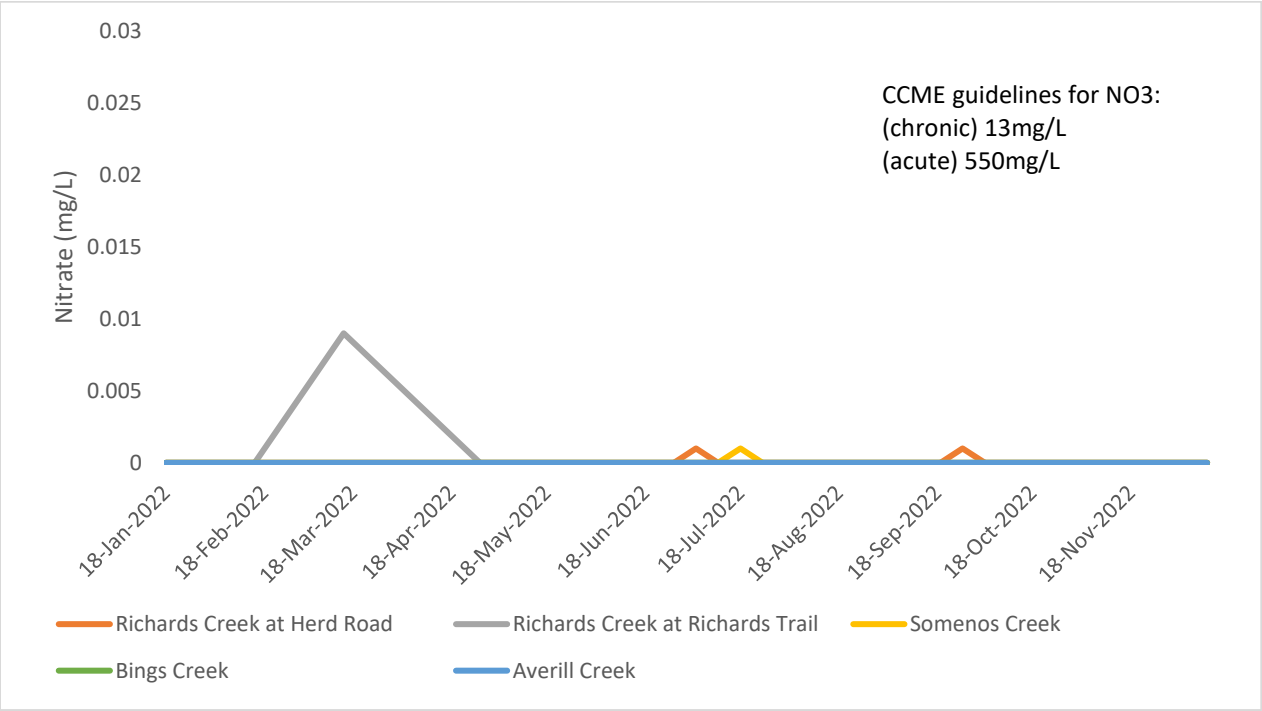
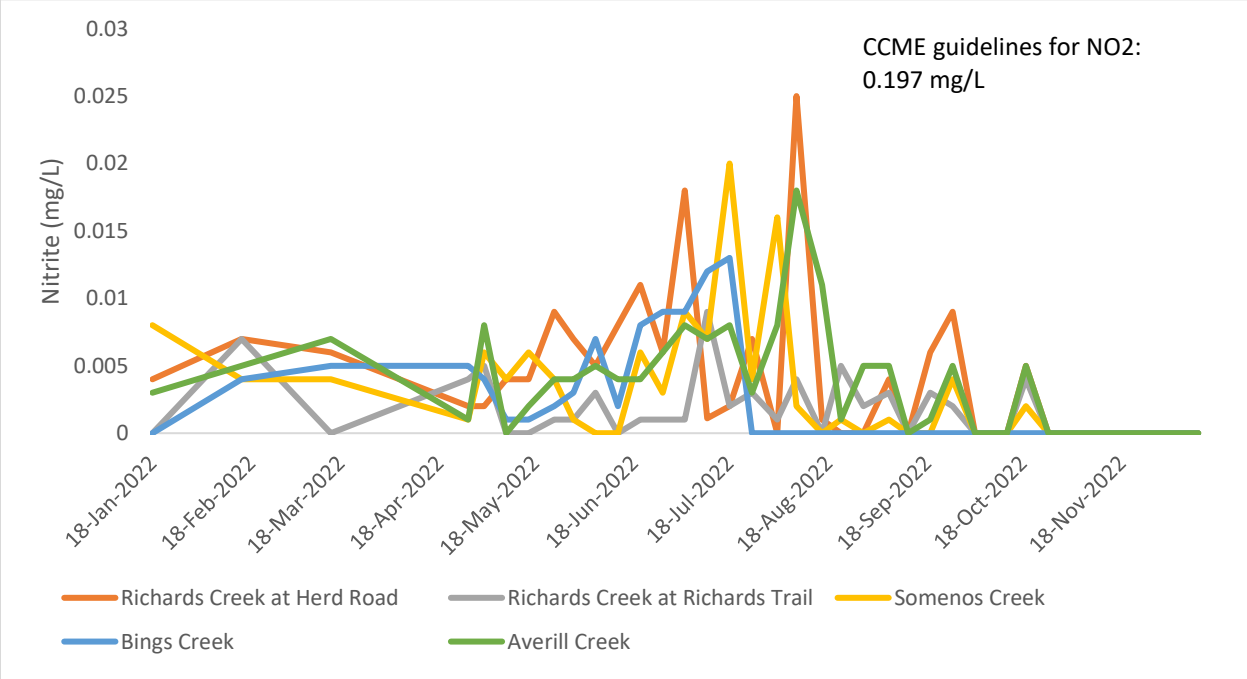


Chart 30: Somenos Watershed Tributary Monthly Nitrite Levels, 2022



9 APPENDIX C - DATA TABULATIONS FOR SOMENOS LAKE DATA

SOMENOS LAKE MONTHLY AVERAGE WATER QUALITY DATA PROFILES 2022

Month	Temperature (°C)						
	0m	1m	2m	3m	4m	5m	6m
January	3.10	3.00	3.00	2.90	2.70	2.80	3.00
February	4.80	4.80	4.80	4.70	4.60	4.60	4.40
March	7.40	7.30	7.20	7.00	6.90	6.70	6.50
April	10.85	10.10	9.50	9.25	9.25	9.10	8.95
May	13.33	13.00	12.73	12.43	11.98	11.75	11.40
June	18.36	17.72	17.24	16.28	15.32	14.52	13.82
July	24.48	23.48	21.48	18.98	16.88	15.55	14.80
August	24.45	23.88	23.33	21.20	18.28	16.28	15.58
September	20.44	20.22	19.98	19.82	19.06	17.60	16.62
October	15.80	15.60	15.60	15.60	15.60	15.30	15.30
November	7.00	6.80	6.80	6.80	6.80	6.80	6.80
December	2.90	3.00	3.10	3.20	3.30	3.80	3.90

Month	Dissolved Oxygen (mg/L)						
	0m	1m	2m	3m	4m	5m	6m
January	7.70	7.65	7.60	7.55	7.10	5.90	4.93
February	8.32	8.29	8.28	8.21	8.13	7.86	7.23
March	14.64	13.84	12.41	11.74	11.43	11.01	10.62
April	10.40	10.49	9.96	9.45	9.42	9.32	8.66
May	10.28	9.89	9.64	9.22	8.45	7.87	6.72
June	18.36	17.72	17.24	16.28	15.32	14.52	13.82
July	12.46	11.20	5.83	1.40	0.57	0.57	0.58
August	8.13	7.71	6.44	0.45	0.03	0.02	0.02
September	11.21	10.63	9.00	7.95	3.55	2.84	2.14
October	8.74	6.89	7.29	6.88	4.20	4.21	0.06
November	7.42	7.35	7.20	7.20	7.25	7.22	7.15
December	11.87	11.48	11.26	11.08	10.96	5.39	4.87

Month	pH						
	0m	1m	2m	3m	4m	5m	6m
January	7.20	-	-	-	-	-	7.28
February	6.90	-	-	-	-	-	7.44
March	7.31	7.15	6.99	6.90	6.88	6.84	6.82
April	6.88	6.74	6.73	6.73	6.75	6.77	6.72
May	6.98	6.80	6.74	6.68	6.61	6.59	6.53
June	7.63	7.26	7.00	6.77	6.56	6.42	6.45
July	9.00	8.75	6.90	6.38	6.28	6.30	5.63
August	7.76	7.71	7.33	6.71	6.35	6.26	6.23
September	8.30	8.12	7.72	7.56	7.07	6.81	6.62
October	7.41	7.15	7.18	7.17	7.03	6.95	6.79
November	6.93	6.34	6.45	6.54	6.59	6.65	6.72
December	6.35	6.49	6.60	6.72	6.81	6.68	6.67

Month	Conductivity (µS/cm)						
	0m	1m	2m	3m	4m	5m	6m
January	-	-	-	-	-	-	-
February	217	211	208	207	202	201	201
March	135	134	134	134	135	135	135
April	161	160	159	159	159	159	156
May	205	203	203	202	201	201	204
June	-	-	-	-	-	-	-
July	155	153	154	156	165	170	175
August	150	148	150	153	164	172	178
September	150	150	150	150	155	168	176
October	148	149	149	149	152	151	157
November	157	157	157	157	157	157	157
December	172	172	172	172	172	221	231

Month	Total Dissolved Solids (mg/L)						
	0m	1m	2m	3m	4m	5m	6m
January							
February	140	137	135	134	131	130	131
March	88	87	87	87	87	88	88
April	105	104	103	103	103	103	101
May	133	132	132	131	131	130	130
June	-	-	-	-	-	-	-
July	101	99	99	102	107	111	114
August	98	98	98	99	106	112	116
September	97	97	98	98	119	109	115
October	96	97	97	97	99	98	101
November	102	102	102	102	102	102	102
December	112	112	112	112	112	144	150

Date	Phosphate (mg/L)		Ammonia (mg/L)		Nitrite (mg/L)		Nitrate (mg/L)	
	1 m	6 m	1m	6m	1m	6m	1m	6m
20-Jan-22	0.21	0.45	0.1	0.17	0.008	0.007	0.001	0.012
17-Feb-22	0.22	0.24	0.07	0.09	0.001	0.005	<<	<<
18-Mar-22	0.17	0.19	0.01	0.01	0.001	0.014	<<	<<
7-Apr-22	0.15	0.17	0.08	0.13	0.002	0	<<	<<
28-Apr-22	0.12	0.31	0.07	0.08	0	0.008	<<	0
5-May-22	0.19	0.003	0.09	0.2	0.005	0	<<	<<
12-May-22	0.19	0.45	0.06	0.09	0.001	0.002	<<	<<
19-May-22	0.16	0.02	0.05	0.09	0.001	0.002	<<	<<
26-May-22	0.19	0.37	0.03	0.14	0.002	0.005	<<	<<
2-Jun-22	0.13	0.24	0.02	0.05	0.001	0.001	<<	<<
9-Jun-22	0.39	0.59	0.03	0.19	0	0.004	<<	<<
19-Jun-22	0.23	1.45	0.01	0.03	0.001	0.007	<<	<<
23-Jun-22	0.27	1.25	0.03	0.26	0	0.002	<<	<<
30-Jun-22	0.17	2.5	0.06	0.55	0	0.012	<<	0.002
7-Jul-22	0.18	2.4	0.11	0.68	0.008	0.007	0	0.001
14-Jul-22	0.35	1.65	0.06	0.36	0	0.013	<<	<<
21-Jul-22	0.18	1.55	0.15	0.5	0.004	0.006	<<	<<
28-Jul-22	0.2	>>	0.07	0.89	0	0.014	<<	0
4-Aug-22	0.14	3	0.07	0.98	0.009	0.005	0	<<
11-Aug-22	0.23	3.1	0.11	<<	0.002	0.015	<<	0.001
18-Aug-22	0.16	2	0.08	0.54	0.014	0.011	<<	<<
25-Aug-22	0.22	3	0.29	0.96	0.003	0.009	<<	0.001
1-Sep-22	0.08	3	0.03	>>	0	0.01	<<	0.014
10-Sep-22	0.07	2.5	0.02	0.93	0.001	0.004	<<	<<
15-Sep-22	-	3	-	0.92	-	0.009	<<	0.01
22-Sep-22	0.25	0.37	0.04	0.05	0	0.001	<<	<<
29-Sep-22	0.08	0.43	0.01	0.39	<<	0.004	<<	0
20-Oct-22	0.33	0.36	0.21	<<	0.008	0.005	0	<<
17-Nov-22	0.22	0.41	0.6	0.65	0.008	0.003	0.014	<<
15-Dec-22	0.11	0.84	0.67	0.84	0.006	0.01	0.314	0.425

<< = less than 0.01 mg/L

10 APPENDIX D - DATA TABULATIONS FOR SOMENOS TRIBUTARIES

Date	Dissolved Oxygen (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	9.02	13.48	8.84	13.08	12.94
15-Feb-22	-	6.55	18.16	11.48	17.46	20.3
15-Mar-22	-	7.87	13.68	9.28	13.77	13.56
27-Apr-22	8.7	6.7	13.2	8.85	14.1	12.2
02-May-22	-	5.32	12.35	9.07	12.12	11.66
09-May-22	-	6.33	12.94	9.41	12.18	12.56
16-May-22	-	7.72	12.18	8.58	11.24	11.2
24-May-22	-	3.4	11	8.83	10.2	10.4
30-May-22	-	3.4	13.7	10.4	11.5	12.4
06-Jun-22	-	3.9	10.85	7.6	10.73	10.47
13-Jun-22	-	4.7	11.9	8.4	12.2	11.4
20-Jun-22	-	3.86	11.73	6.98	10.25	10.68
27-Jun-22	-	3.7	10.14	6.02	8.61	9.93
04-Jul-22	-	3.63	9.75	3.54	8.53	9.57
11-Jul-22	-	3.64	12.89	5.75	9.74	12.02
18-Jul-22	-	*4.52*	*10.81*	*5.09*	*9.26*	*10.035*
25-Jul-22	-	5.4	8.73	4.43	8.78	8.05
02-Aug-22	-	0.03	7.08	4.1	8.87	7.61
08-Aug-22	-	0.05	9.39	6.31	9.9	8.55
16-Aug-22	-	0.09	9.69	4.23	7.63	7.27
22-Aug-22	-	0.13	9.51	7.45	8.67	7.78
29-Aug-22	-	0.04	10.86	0.95	9.31	9.53
06-Sep-22	-	0.11	10.16	0.06	8.79	8.36
12-Sep-22	-	0.16	12.4	2.9	10.8	10.3
19-Sep-22	-	0.3	11.8	1.6	10.9	10.2
26-Sep-22	-	0.4	11.1	0.6	8	9.6
03-Oct-22	-	0.4	10.2	1.4	9	8.3
07-Oct-22	7.08	2.26	11.8	2.65	11.2	12.1
13-Oct-22	6.14	0.32	11.2	0.12	9.4	9.3
19-Oct-22	7.9	0.45	12.3	0.11	9.82	12
26-Oct-22	7.61	1.14	13.2	0.48	10.93	12.3
30-Oct-22	7.4	0.65	10.7	2	9.66	10.6
14-Nov-22	8.04	2.07	13.39	3.42	12.62	13.52
21-Nov-22	7.82	0.12	11.74	2.56	11.15	13.61
28-Nov-22	8.44	1.02	12.5	4.37	11.83	12.9
05-Dec-22	-	3.92	-	6.86	-	-
12-Dec-22	7.98	5.71	13.2	7.98	13.72	13.9

note: July 18 italicized results are averages for graphing purposes

Date	Temperature °C					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	6.1	5.5	4	5.5	6.2
15-Feb-22	-	4.6	4.8	4.2	5	4.3
15-Mar-22	-	6.8	6.5	6.6	6.7	7.3
27-Apr-22	11.3	9.2	7.5	7	7.8	8.3
02-May-22	-	10.5	8.8	11.3	8.9	9.83
09-May-22	-	9.6	8.4	11.3	8.5	8.9
16-May-22	-	13.4	10.4	13.4	10.7	11.4
24-May-22	-	13.9	12.2	15.3	12.5	13
30-May-22	-	11.8	10.4	14.6	10.9	11.4
06-Jun-22	-	14.3	12	15.9	11.9	12.8
13-Jun-22	-	15.1	12.5	17.1	13.2	13.3
20-Jun-22	-	14.4	12.5	18.7	13	13.7
27-Jun-22	-	16.6	15.2	21.4	15.4	15.5
04-Jul-22	-	15.3	14	17.7	13.9	14.5
11-Jul-22	-	15.3	15.5	19.6	15.1	15.8
18-Jul-22	-	16.1	15.7	18.5	15.3	16
25-Jul-22	-	17.6	17.4	19.6	17.8	17.6
02-Aug-22	-	19.3	18.3	16.8	18.4	18.5
08-Aug-22	-	16.5	18	17.2	17.3	17.5
16-Aug-22	-	17.4	18.2	17.1	17.4	18.2
22-Aug-22	-	17.8	18.3	19.4	18.2	18.2
29-Aug-22	-	15.9	16.8	15.2	16.6	16.8
06-Sep-22	-	14.5	15.3	14.5	13.9	14.3
12-Sep-22	-	13	15.7	14.6	15.1	15.4
19-Sep-22	-	10.9	13	12.6	12.18	12.3
26-Sep-22	-	11.5	14.2	12.7	12.9	13.6
03-Oct-22	-	10.8	13.8	12.9	12.9	13.1
07-Oct-22	9.3	5.2	5.1	7.2	5.5	5.6
13-Oct-22	16.4	8.8	11.5	11.8	10.5	10
19-Oct-22	15.7	8.7	11.1	11.6	10.5	10.3
26-Oct-22	13.3	7.3	7.9	9.9	7.8	7.6
30-Oct-22	12.4	8.9	9.8	10.6	10.1	10.3
14-Nov-22	7.8	3.1	4	5.9	3.9	3.5
21-Nov-22	6.5	3.6	4.5	5.1	3.8	2.9
28-Nov-22	504	3.3	3	4.9	3.5	3.3
05-Dec-22	-	0.6	-	2.4	-	-
12-Dec-22	-	3.6	3.5	3.3	3.3	3.2

Date	pH					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	7.02	8.13	7.55	7.58	7.46
15-Feb-22	-	6.63	7.53	7.17	7.69	7.77
15-Mar-22	-	6.96	7.15	7	7.67	7.72
27-Apr-22	7.06	6.47	7.57	6.88	6.8	7.9
02-May-22	-	6.51	7.06	6.26	7.12	7.44
09-May-22	-	6.32	6.99	6.25	7.24	7.58
16-May-22	-	6.53	6.98	6.28	7.12	7.28
24-May-22	-	6.45	7.2	6.41	7.6	7.8
30-May-22	-	6.2	7.4	6.45	7.51	7.72
06-Jun-22	-	6.45	6.86	6.78	7.41	7.5
13-Jun-22	-	6.4	7.53	7.02	7.48	7.78
20-Jun-22	-	6.32	7.45	6.45	6.98	7.65
27-Jun-22	-	6.17	7.2	6.39	7.34	7.57
04-Jul-22	-	6.37	7.5	6.11	7.3	7.66
11-Jul-22	-	6.34	7.15	6.26	6.87	7.45
18-Jul-22	-	6.5	7.44	6.09	7.12	7.41
25-Jul-22	-	6.14	7.17	6.1	7.14	7.4
02-Aug-22	-	6.26	7.08	5.77	7.14	7.13
08-Aug-22	-	5.96	7.27	6.57	7.3	7.15
16-Aug-22	-	6.48	7.63	6.22	6.92	6.92
22-Aug-22	-	6.03	6.99	6.26	7.12	7.15
29-Aug-22	-	6.13	7.2	5.84	7.53	7.22
06-Sep-22	-	6.44	7.31	6.45	7.08	7.39
12-Sep-22	-	6.7	7.3	6.5	7.4	7.4
19-Sep-22	-	6.8	7.4	6.6	6.8	6.1
26-Sep-22	-	6.7	7.2	6.3	7.3	7.3
03-Oct-22	-	6.7	7.3	6.4	7.5	7.4
07-Oct-22	7.21	6.71	7.01	6.66	7.43	7.56
13-Oct-22	7.4	6.96	7.34	6.69	7.21	7.47
19-Oct-22	7.4	7.41	6.79	6.3	7.3	7.62
26-Oct-22	7.27	6.63	7	6.4	7.2	7.39
30-Oct-22	6.9	6.7	7.1	6.5	7.3	7.4
14-Nov-22	7.22	6.94	7.26	6.53	7.19	7.56
21-Nov-22	7.28	7.05	7.2	6.41	7.4	7.53
28-Nov-22	7.15	6.86	7.36	6.72	7.43	7.54
05-Dec-22		6.42		6.13		
12-Dec-22		6.63	6.97	6.3	7.37	7.11

Date	Specific Conductivity (µS/cm)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	218.8	236	289	217.7	268.3
15-Feb-22	-	83.2	62.9	78	72.8	89.8
15-Mar-22	-	69.5	58.4	72.8	49.1	75.2
27-Apr-22	183.3	203.1	183.6	183	181.4	210.8
2-May-22	-	145.9	125.9	141.7	114.2	151.3
9-May-22	-	144.8	122.3	137.7	113.2	146.8
16-May-22	-	129.4	125.5	136.7	119.4	164.6
24-May-22	-	*136.7*	*132.5*	*148.35*	*153.7*	*170.3*
30-May-22	-	*136.7*	*132.5*	*148.35*	*153.7*	*170.3*
6-Jun-22	-	*136.7*	*132.5*	*148.35*	*153.7*	*170.3*
13-Jun-22	-	*136.7*	*132.5*	*148.35*	*153.7*	*170.3*
20-Jun-22	-	*136.7*	*132.5*	*148.35*	*153.7*	*170.3*
27-Jun-22	-	*136.7*	*132.5*	*148.35*	*153.7*	*170.3*
4-Jul-22	-	144	139.5	160	188	176
11-Jul-22	-	167.2	139.2	178.4	219.9	222.4
18-Jul-22	-	150.3	128.9	203.3	228.7	223.9
25-Jul-22	-	159.1	136.1	195.3	260.7	259.7
2-Aug-22	-	143.1	113.7	190.2	286.1	253.1
8-Aug-22	-	126.1	108.9	161.6	261.1	243
16-Aug-22	-	124.8	108.5	156.5	258.5	240.3
22-Aug-22	-	127.7	113.9	168.7	291.6	235.8
29-Aug-22	-	122.2	105.5	183.7	309.5	234.9
6-Sep-22	-	114	102.8	299.6	331.4	232.4
12-Sep-22	-	111	106	190	346	224
19-Sep-22	-	115	106	186	356	244
26-Sep-22	-	105	102	197	362	232
3-Oct-22	-	105	102	186	369	230
7-Oct-22	153.5	184.5	186	191.5	342.8	296.4
13-Oct-22	149.2	114	99	249	392	227
19-Oct-22	149	125	99	232	387	211
26-Oct-22	150.5	125	109	173	331.5	166.4
30-Oct-22	151	120	129	159	265	169
14-Nov-22	156.1	212.7	204.4	183.3	367.5	276.1
21-Nov-22	157.8	227.2	209.1	188.2	577.1	318.6
28-Nov-22	160.2	224.2	218.7	190.1	349	286.6
5-Dec-22	-	277.7	-	208.8	-	-
12-Dec-22	-	252.7	239.2	194.1	181.2	290.9

note: italicized results are averages for graphing purposes

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
18-Jan-22	-	141.7	140.4	188.5	141.7	174.2
15-Feb-22	-	53.95	40.95	51.35	47.45	58.5
15-Mar-22	-	45.5	37.7	47.45	31.85	48.75
27-Apr-22	118.9	131.3	119.6	119	117.7	137.1
2-May-22	-	91	81.9	92.3	73.45	97.5
9-May-22	-	95.55	79.3	89.7	73.45	95.55
16-May-22	-	84.5	81.25	89.05	77.35	107.25
24-May-22	-	*89.05*	*86.125*	*96.525*	*99.675*	*110.625*
30-May-22	-	*89.05*	*86.125*	*96.525*	*99.675*	*110.625*
6-Jun-22	-	*89.05*	*86.125*	*96.525*	*99.675*	*110.625*
13-Jun-22	-	*89.05*	*86.125*	*96.525*	*99.675*	*110.625*
20-Jun-22	-	*89.05*	*86.125*	*96.525*	*99.675*	*110.625*
27-Jun-22	-	*89.05*	*86.125*	*96.525*	*99.675*	*110.625*
4-Jul-22	-	93.6	91	104	122	114
11-Jul-22	-	108.55	90.35	115.7	143	144.3
18-Jul-22	-	97.85	83.85	131.95	148.85	145.6
25-Jul-22	-	104	88.4	126.5	169.68	168.35
2-Aug-22	-	92.95	74.1	118.3	166.4	164.45
8-Aug-22	-	81.9	70.85	98.8	169.65	157.95
16-Aug-22	-	81.25	70.2	101.4	167.7	156.3
22-Aug-22	-	77.35	76.32	86.45	189.8	150.15
29-Aug-22	-	79.3	68.25	119.6	200.85	152.75
6-Sep-22	-	74.1	66.95	195	215.15	150.8
12-Sep-22	-	73	69	124	225	148
19-Sep-22	-	75	68.9	121	231	157
26-Sep-22	-	68	66	128	234	151
3-Oct-22	-	70	66	122	240	150
7-Oct-22	100.1	120.3	120.9	124.2	222.9	192.4
13-Oct-22	97	73	64	158	255	148
19-Oct-22	97	81	64	151	252	137
26-Oct-22	98.2	80.6	71	112	215.8	108.6
30-Oct-22	98	77	84	103	173	110
14-Nov-22	101.4	137.8	132.6	118.95	238.55	178.75
21-Nov-22	102.7	145.6	135.8	122.2	375.7	207.35
28-Nov-22	104	144.3	142.4	123.5	226.9	186.5
5-Dec-22	-	181.4	-	135.6	-	-
12-Dec-22	-	164.4	155.4	119.6	117.7	189.2

note: italicized results are averages for graphing purposes

Date	Phosphate (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	0.18	0.11	0.23	0.25	0.19
15-Feb-22	-	0.35	0.19	0.26	0.23	0.49
15-Mar-22	-	0.23	0.17	0.16	0.04	0.23
27-Apr-22	0.23	0.36	0.16	0.21	0.06	0.35
2-May-22	-	0.23	0.09	0.15	0.12	0.25
9-May-22	-	0.29	0.06	0.24	0.12	0.15
16-May-22	-	0.43	0.07	0.19	0.15	0.28
24-May-22	-	0.25	0.18	0.25	0.22	0.46
30-May-22	-	0.47	0.41	0.28	0.2	0.12
6-Jun-22	-	0.45	0.17	0.37	0.15	0.28
13-Jun-22	-	0.46	0.19	0.24	0.22	0.29
20-Jun-22	-	1.05	0.63	0.28	0.26	0.58
27-Jun-22	-	0.64	0.28	0.28	0.36	0.56
4-Jul-22	-	0.5	0.23	0.43	0.24	0.45
11-Jul-22	-	0.81	1.3	0.83	0.63	0.56
18-Jul-22	-	0.27	0.15	0.3	0.51	0.36
25-Jul-22	-	0.57	0.17	0.31	-	0.27
2-Aug-22	-	0.66	0.17	0.21	-	0.29
8-Aug-22	-	1.9	0.66	0.22	-	0.61
16-Aug-22	-	0.73	0.22	-	-	0.28
22-Aug-22	-	0.42	1	0.15	-	0.58
29-Aug-22	-	0.45	0.11	0.21	-	0.42
6-Sep-22	-	0.6	0.15	0.15	-	0.41
12-Sep-22	-	-	-	-	-	-
19-Sep-22	-	0.62	0.13	0.19	-	0.23
26-Sep-22	-	0.45	0.06	0.16	-	0.3
3-Oct-22	-	-	-	-	-	-
7-Oct-22	-	-	-	-	-	-
13-Oct-22	-	-	-	-	-	-
19-Oct-22	-	0.43	0.18	0.34	-	0.29
26-Oct-22	-	-	-	-	-	-
30-Oct-22	-	-	-	-	-	-
14-Nov-22	-	-	-	-	-	-
21-Nov-22	-	-	-	-	-	0.17
28-Nov-22	-	-	-	-	-	-
5-Dec-22	-	-	-	-	-	-
12-Dec-22	-	-	-	-	0	0.18

Date	Ammonia (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	0.04	<<	0.01	0.01	0.04
15-Feb-22	-	0.12	0.12	0.03	0.02	0.04
15-Mar-22	-	<<	0.01	<<	<<	<<
27-Apr-22	0.12	0.07	0.01	0.03	<<	0.02
2-May-22	-	0.03	<<	0.03	0	0.04
9-May-22	-	0.07	0.01	0.03	<<	0
16-May-22	-	0.05	0.01	0.04	0.01	0.01
24-May-22	-	0.11	0.01	0.01	0.02	0.02
30-May-22	-	0.15	0.03	0.03	<<	0.03
6-Jun-22	-	0.11	0.01	0.01	0.02	0.02
13-Jun-22	-	0.13	0.01	0.01	0.04	0.02
20-Jun-22	-	0.15	0.02	0.07	0.08	0.04
27-Jun-22	-	0.43	0.02	0.06	0.09	0.03
4-Jul-22	-	0.21	0.04	0.15	0.08	0.03
11-Jul-22	-	0.08	0.07	0.83	0.08	0.05
18-Jul-22	-	0.09	0.05	0.29	0.12	0.05
25-Jul-22	-	0.04	0.04	0.05	-	0.06
2-Aug-22	-	0.21	0.07	0.3	-	0.06
8-Aug-22	-	0.02	0.02	0.07	-	0.11
16-Aug-22	-	0.09	0.08	-	-	0.14
22-Aug-22	-	0.01	0.08	0.08	-	0.11
29-Aug-22	-	0.03	0.04	0.04	-	0.43
6-Sep-22	-	0.08	0.04	0.11	-	0.06
12-Sep-22	-	-	-	-	-	-
19-Sep-22	-	0.04	0.01	0.01	-	0.01
26-Sep-22	-	0.05	0.43	0.03	-	<<
3-Oct-22	-	-	-	-	-	-
7-Oct-22	-	-	-	-	-	-
13-Oct-22	-	-	-	-	-	-
19-Oct-22	-	0.05	0.03	0.04	-	0.04
26-Oct-22	-	-	-	-	-	-
30-Oct-22	-	-	-	-	-	-
14-Nov-22	-	-	-	-	-	-
21-Nov-22	-	0.21	0.08	0.53	-	0.01
28-Nov-22	-	-	-	-	-	-
5-Dec-22	-	-	-	-	-	-
12-Dec-22	-	0.09	0.04	0.49	0	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
18-Jan-22	-	0.004	<<	0.008	0	0.003
15-Feb-22	-	0.007	0.007	0.004	0.004	0.005
15-Mar-22	-	0.006	-	0.004	0.005	0.007
27-Apr-22	0.002	0.002	0.004	0.001	0.005	0.001
2-May-22	-	0.002	0.005	0.006	0.004	0.008
9-May-22	-	0.004	0	0.004	0.001	0
16-May-22	-	0.004	0	0.006	0.001	0.002
24-May-22	-	0.009	0.001	0.004	0.002	0.004
30-May-22	-	0.007	0.001	0.001	0.003	0.004
6-Jun-22	-	0.005	0.003	0	0.007	0.005
13-Jun-22	-	0.008	0	0	0.002	0.004
20-Jun-22	-	0.011	0.001	0.006	0.008	0.004
27-Jun-22	-	0.006	0.001	0.003	0.009	0.006
4-Jul-22	-	0.018	0.001	0.009	0.009	0.008
11-Jul-22	-	0.0011	0.009	0.007	0.012	0.007
18-Jul-22	-	0.002	0.002	0.02	0.013	0.008
25-Jul-22	-	0.007	0.003	0.004	-	0.003
2-Aug-22	-	<<	0.001	0.016	-	0.008
8-Aug-22	-	0.025	0.004	0.002	-	0.018
16-Aug-22	-	0.001	0	-	-	0.011
22-Aug-22	-	0	0.005	0.001	-	0.001
29-Aug-22	-	0	0.002	0	-	0.005
6-Sep-22	-	0.004	0.003	0.001	-	0.005
12-Sep-22	-	-	-	-	-	-
19-Sep-22	-	0.006	0.003	0	-	0.001
26-Sep-22	-	0.009	0.002	0.004	-	0.005
3-Oct-22	-	-	-	-	-	-
7-Oct-22	-	-	-	-	-	-
13-Oct-22	-	-	-	-	-	-
19-Oct-22	-	0.005	0.004	0.002	-	0.005
26-Oct-22	-	-	-	-	-	-
30-Oct-22	-	-	-	-	-	-
14-Nov-22	-	-	-	-	-	-
21-Nov-22	-	-	-	-	-	-
28-Nov-22	-	-	-	-	-	-
5-Dec-22	-	-	-	-	-	-
12-Dec-22	-	-	-	-	0	-

Date	Nitrate (mg/L)					
	Somenos Lake Dock	Richards Creek at Herd Road	Richards Creek at Richards Trail	Somenos Creek	Bings Creek	Averill Creek
18-Jan-22	-	<<	<<	<<	<<	<<
15-Feb-22	-	<<	<<	<<	0	<<
15-Mar-22	-	<<	0.009	<<	<<	<<
27-Apr-22	<<	<<	<<	<<	<<	<<
2-May-22	-	<<	<<	<<	<<	<<
9-May-22	-	<<	<<	<<	<<	<<
16-May-22	-	<<	<<	<<	<<	<<
24-May-22	-	<<	<<	<<	<<	<<
30-May-22	-	<<	<<	<<	<<	<<
6-Jun-22	-	<<	<<	<<	<<	<<
13-Jun-22	-	<<	<<	<<	<<	<<
20-Jun-22	-	<<	<<	<<	<<	<<
27-Jun-22	-	<<	<<	<<	<<	<<
4-Jul-22	-	0.001	<<	<<	<<	<<
11-Jul-22	-	<<	<<	0	0	<<
18-Jul-22	-	<<	<<	0.001	0	<<
25-Jul-22	-	<<	<<	<<	-	<<
2-Aug-22	-	<<	<<	<<	-	<<
8-Aug-22	-	0	<<	<<	-	0
16-Aug-22	-	<<	<<	-	-	<<
22-Aug-22	-	<<	<<	<<	-	<<
29-Aug-22	-	<<	<<	<<	-	<<
6-Sep-22	-	<<	<<	<<	-	<<
12-Sep-22	-	-	-	-	-	-
19-Sep-22	-	<<	<<	<<	-	<<
26-Sep-22	-	0.001	<<	<<	-	<<
3-Oct-22	-	-	-	-	-	-
7-Oct-22	-	-	-	-	-	-
13-Oct-22	-	-	-	-	-	-
19-Oct-22	-	0	<<	<<	-	<<
26-Oct-22	-	-	-	-	-	-
30-Oct-22	-	-	-	-	-	-
14-Nov-22	-	-	-	-	-	-
21-Nov-22	-	-	<<	0	-	-
28-Nov-22	-	-	-	-	-	-
5-Dec-22	-	-	-	-	-	-
12-Dec-22	-	-	-	-	-	-

11 APPENDIX E - REFERENCES

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