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Summary of Baseline Water Quality Monitoring in Agricultural Areas of the Regional District of Nanaimo

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EXECUTIVE SUMMARY

This report summarizes 2019 and 2021 baseline water quality data from multiple watersheds in the Regional District of Nanaimo (RDN) collected by the British Columbia (B.C.) Ministry of Environment and Climate Change Strategy (ENV) in partnership with the RDN's Community Watershed Monitoring Network (CWMN). Streams chosen for this project showed consistent exceedances of B.C. Water Quality Guidelines over three to ten years of CWMN monitoring and were recommended for further investigation in Ecoscape (2018), a ten-year trend report of CWMN data. In 2021 water quality data on pH, temperature, conductivity, turbidity, phosphorus, nitrogen species, dissolved oxygen (DO), *Escherichia coli*, and metals were collected from Morningstar Creek, Swayne Creek, Nanoose Creek, Millstone River, McGarrigle Creek, Chase River, Richards Creek, Holden Creek, and Beck Creek; in 2019 water quality data on phosphorus and chloride were collected from Grandon Creek, Beach Creek, French Creek, Shelly Creek, Morison Creek, Annie Creek, and Swayne Creek. Data were analyzed to determine potential impacts associated with agricultural activity and rainwater runoff. These baseline data were important to have early in the phasing in of the 2018 *Agricultural Environmental Management Code of Practice* (*AEM Code*) under the *Environmental Management Act*. Future monitoring and the 2019 and 2021 baseline data from this sampling program can be used to determine *AEM Code* effectiveness.

This study indicated that water quality is generally good in Swayne Creek, Nanoose Creek, Beck Creek, and the upper sections of Millstone River. These sites had nutrients and metals at acceptable levels based on B.C. Water Quality Guidelines or applicable Water Quality Objectives. Water quality was poor in Morningstar Creek, McGarrigle Creek, lower Millstone River, Chase River, Richards Creek, and Holden Creek, with nutrients or metals levels in exceedance of Water Quality Guidelines or applicable Water Quality Objectives. These elevated levels occurred downstream of areas with one or more of the following land uses (but not limited to): agriculture, land-based aquaculture, on-site septic systems, and impervious surfaces in urban areas where there is likely greater rainwater runoff. This suggests that some agricultural activities contribute to negative impacts on these streams. As more aspects of the new *AEM Code* are implemented and enforced, it is expected that water quality in the study area will improve.

It is recommended that monitoring should be expanded to include dissolved metals for comparison to applicable guidelines for some specific metals. In addition, outreach and education on nutrient impacts of various land uses, as well as on potential impacts from infiltration and rainwater runoff, is recommended for adjacent properties at Holden Creek, McGarrigle Creek, Morningstar Creek, Chase River, and Richards Creek.

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1. INTRODUCTION

The study area of this report is in the unceded territories of the Snuneymuxw, Snaw Naw As, and Qualicum First Nations communities. These prosperous lands are where the Snuneymuxw, Snaw Naw As, and Qualicum First Nations peoples made their homes since time immemorial, and the health of this environment has and will support these communities for generations.

On February 28, 2019, the B.C. Ministry of Environmental and Climate Change Strategy (ENV) released a new regulation under the *Environmental Management Act* called the *Code of Practice for Agricultural Environmental Management* (*AEM Code*) (B.C., 2020). All scales of agricultural practice are subject to the new *AEM Code* in British Columbia. The code has several key requirements for farms, such as prevention of contaminated water from entering watercourses or groundwater; no direct discharges into watercourses or groundwater; minimum setbacks from drinking water sources, watercourses, and property boundaries; and keeping records of agricultural activity for a period of at least 5 years. In high-risk areas such as high rainfall areas, phosphorus-affected areas, and vulnerable aquifer areas, or during high-risk conditions such as storms, flooding or strong winds, additional measures are required for operations (B.C., 2020; BCAC, 2020).

All of Vancouver Island is a phosphorus-affected area (B.C., 2019), meaning that watercourses may be adversely affected by high levels of phosphorus. Under the *AEM Code*, as of July 15, 2024, all agriculture operations larger than 5 hectares (ha) in phosphorus-affected areas will be required to have a Nutrient Management Plan to ensure that nutrients (e.g., commercial fertilizer, manure) applied to land match crop needs.

In 2019-20 ENV had a communications plan to help agricultural operators, stakeholders and First Nations become aware of the new *AEM Code* and its positive environmental benefits. This served as a first step to help agricultural operators comply with current requirements and voluntarily adopt future requirements of the code. The plan included outreach to large scale farmers and ranchers through presentations to different associations and groups, and at different events in 2019-20, with ad-hoc presentations when requested after 2020. Outreach to small scale or hobby farms included holding information booths at farmer's markets and pamphlets left at farm supply stores. Outreach to key influencers (regional agrologists, representatives of agricultural industry groups, etc.) was also an important part of the communications plan.

Since 2011, the Regional District of Nanaimo (RDN) on Vancouver Island has run a surface water quality monitoring program known as the RDN Community Watershed Monitoring Network (CWMN). The CWMN is a program that was developed in partnership with ENV, local streamkeeper organizations, and private forestry. Data since 2011 were summarized in trend reports (Ecoscape, 2018; Ecoscape, 2021), and recommendations from these reports were used to determine where more stream monitoring was needed to investigate poor water quality and potential contaminant sources. These recommendations guided sites chosen for additional sampling in 2019 and 2021. The resulting data on pH, temperature, conductivity, turbidity, phosphorus, nitrogen species, dissolved oxygen (DO), *Escherichia coli*, and metals are important for understanding the effects of changing agricultural practices in conjunction with other industrial operations as per *AEM Code* guidelines. This report presents 2019 and 2021 water quality data for agricultural areas in the RDN relative to applicable current BC Water Quality Guidelines (WQGs), applicable Water Quality Objectives (WQOs) and the guidance document *Phosphorus Management in Vancouver Island Streams (MoE, 2014).*

In the RDN, numerous streams show evidence of groundwater and surface water interaction. In areas of high agricultural use, runoff and infiltration from agricultural sites may thus affect the water quality in nearby streams and aquifers, potentially contaminating surface and ground water sources with excess nutrients, bacteria, herbicides and pesticides. Contamination of aquifers has long-term implications for groundwater impacts and future aquifer uses. Agricultural runoff can also cause severe fouling of surface water bodies due to enhanced algal growth, limiting biological activity by occluding sunlight and consuming available dissolved oxygen (DO) as algae decompose (MOE, 1997).

The purpose of this report is to provide an analysis and summary of 2019 and 2021 baseline water quality monitoring results collected by ENV and the RDN at selected sites that are part of the RDN's Community Watershed Monitoring Network. These summarized baseline data, combined with future monitoring of the area, will help to determine if requirements under the *AEM Code* are contributing to improved water quality.

2. WATERSHED PROFILE AND HYDROLOGY

Several different watersheds were monitored as part of this study and are summarized below, preceded by the year in which they were sampled. All these streams eventually flow into the Pacific Ocean in the Strait of Georgia:

- 2019 - Annie Creek is a small creek between Qualicum River and Little Qualicum River, flowing over 1.24 km before draining into the ocean. This creek is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2019 - Grandon Creek flows along 5.1 km in the French Creek watershed before draining into the ocean. The creek is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2019 - Beach Creek is a small creek that runs through an urban area of the Town of Qualicum Beach in addition to a community park and a golf course. It is part of the French Creek water region and flows over 700 m until it enters the ocean. This creek is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2019 - French Creek drains an area of 68 km^2 as it flows through Parksville to the ocean from the South Vancouver Island Ranges. The creek is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2019 - Shelly Creek is a small creek in Parksville and is a tributary of the Englishman River. It flows 6.5 km before entering Englishman River 2 km above the ocean drainage. This creek is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2019 - Morison Creek is a small creek just north of Englishman River Regional Park. It is a tributary to the Englishman River 12 km upstream of the ocean drainage and flows over 3 km before entering Englishman River. This site is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2021- Morningstar Creek is a tributary to French Creek, flowing 6.97 km before emptying into the French Creek Estuary. This site is in the Coastal Western Hemlock biogeoclimatic zone.
- 2019, 2021 - Swayne Creek is a large tributary of Morison Creek, which is itself a tributary of Englishman River. Swayne Creek is 8.9 km long and is part of the Englishman River drainage area. This site is in the Coastal Western Hemlock biogeoclimatic zone.

- 2021 - The Millstone River is a river that flows through rural areas outside city limits as well as within the city limits of Nanaimo. It is 14 km long and flows from Brannen Lake through the downtown area of Nanaimo into the Nanaimo Inner Harbor. The watershed covers approximately 100 km^2, with 16 tributaries, 26 streams, and 8 lakes (City of Nanaimo, 2019). This site is in the Coastal Douglas-Fir biogeoclimatic zone
- 2021 - McGarrigle Creek is 6 km long and is a tributary of the Millstone River. This site is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2021 - Chase River is a river that originates from Mount Benson, flows through Chase River Estuary Park, and terminates into the Nanaimo River estuary. It is 12 km long covering 285 km^2 with the major tributary being Charcoal Creek. Harewood Creek and Cat Stream are also tributaries. This site is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2021 - Holden Creek is a creek just south of Nanaimo. It flows from Quennell Lake and Holden Lake into the Nanaimo River estuary. It covers 18 km^2 across 9 km, with very few tributaries. This site is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2021 - Beck Creek flows from Beck Lake to Nanaimo River estuary. It flows 4.7 km, with a drainage area of 13.9 km^2 as it runs parallel to Richards Creek in its upper reaches before emptying into the Nanaimo River Estuary. Richards Creek is a tributary to Beck Creek. This site is in the Coastal Douglas-Fir biogeoclimatic zone.
- 2021 - Richards Creek is a small creek that originates from Richard Lake and flows through Richards Marsh into Beck Creek. It has a very small drainage area, and flows across 5 km. This site is in the Coastal Douglas-Fir biogeoclimatic zone.

Nanoose creek was selected to act as a reference site for the 2021 sampling. The only influences on Nanoose Creek are limited forestry, low residential and road density, and very limited agricultural land use. There is no industry upstream.

The nearest climate station to the watersheds located in the City of Nanaimo for which climate normal data are available is at the Nanaimo Airport (elevation 28 m) (Environment Canada Climate Station 1025370), located approximately 44 km south-east of Parksville. Average daily temperatures between 1981 and 2010 ranged from 4.0°C in January to 18.0°C in August. Average total annual precipitation between 1981 and 2010 was 1188 mm (Figure 1). Temperatures at higher elevations in the watershed would be cooler than recorded at sea level. A larger portion of the annual total precipitation occurred as snowfall in the higher-elevation terrain of the watershed. Most of the precipitation (909 mm, or 78%) fell between October and March (Water Survey Canada, 2005).

Mean monthly air temperatures measured at the nearest Environment Canada weather station (Environment Canada Climate Station 1025370) ranged from 3.5°C in December to 17.6°C in July, with an average annual temperature of 9.7°C (Figure 1) based on 30-year climate normal data collected between 1981 and 2010. High rainfall between October and April may influence the classification of some agricultural areas within the region as high risk under the *AEM code*.

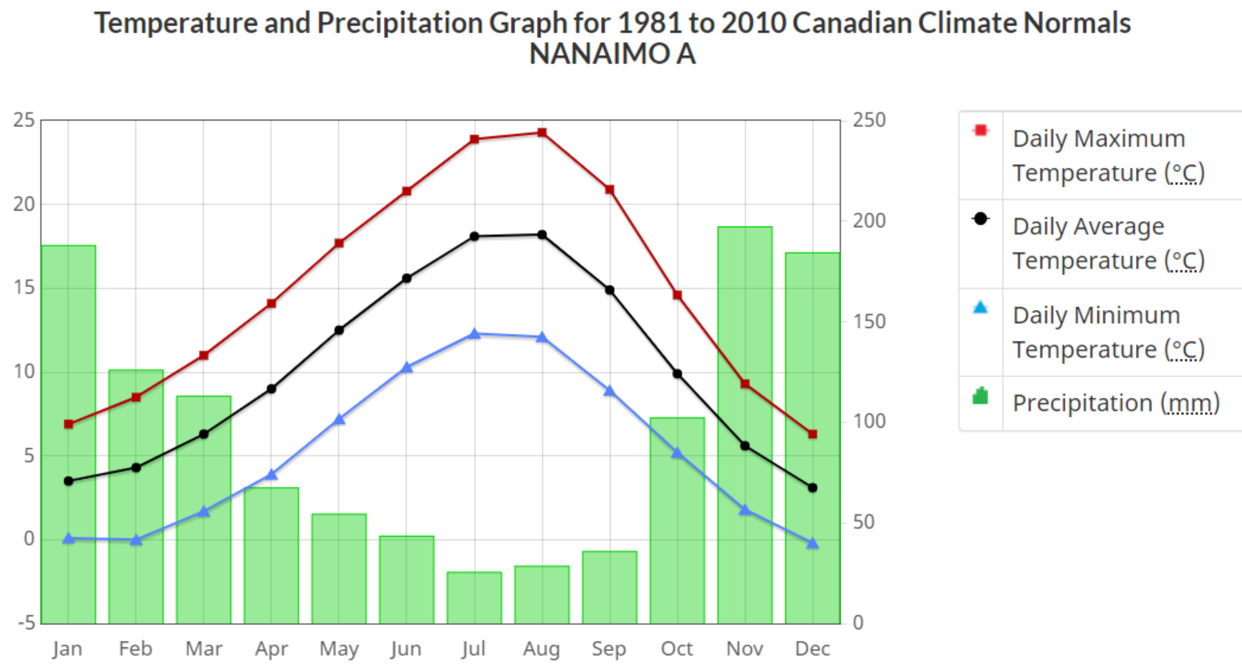

Figure 1: Climate data (1981 – 2010) for Nanaimo A (Environment Canada Climate Station 1025370) (Environment Canada, 2021).

3. WATER USES

Detailed research on water uses was conducted and reported below for 2021 sites as more comprehensive sampling occurred at these sites. Detailed water use analysis has not been completed for the 2019 sites, except for Swayne Creek which was sampled in both 2019 and 2021.

3.1 Water Licenses

Fifty-eight water licenses (14 for domestic use, 19 for private irrigation, 12 for general land improvement, ten for different conservation, two for non-power stream storage, two for lawn, fairway and garden irrigation, and one for locally provided waterworks) have been issued for waterbodies that were sampled in 2021 for this report (Table 1).

Table 1: Current water licenses by water body sampled in 2021 (BC Water Rights Database, 2021)

EMS ID in watershed	Watershed Name	License Type	Number of Licenses	Authorized uses
E318151	Morningstar Creek	Surface Water Surface Water Surface Water	2 1 1	Land Improve: General Lawn, Fairway & Garden: Watering Livestock & Animal
E294020	Nanoose Creek	Surface Water Surface Water	2 2	Irrigation: Private Domestic
E290478 **E290480** **E290291** **E306294**	Millstone River	Surface Water Surface Water Surface Water Surface Water Surface Water	14 1 1 1 2	Irrigation: Private Land Improve: General Conservation: Storage Lawn, Fairway & Garden Conservation: Construct Works
E290479	McGarrigle Creek	Surface Water Surface Water Surface Water	6 2 4	Domestic Conservation: Use of water Land Improve: General
E290485	Chase River	Surface Water Surface Water Surface Water Surface Water	1 1 2 2	Waterworks: Local Provider Stream Storage: Non-power Irrigation: Private Land Improve: General
E310147	Holden Creek	Surface Water	1	Irrigation: Private

3.2 Fisheries

Fisheries and fish presence in sites sampled were identified using Habitat Wizard (2022):

2019 sites: French Creek has populations of chinook salmon (*Oncorhynchus tshawytscha*), chum salmon *(O. keta*), coho (*O. kisutch*), and pink salmon (*O. gorbuscha*), as well as rainbow trout (*O. mykiss*) and cutthroat trout (*O. clarki*). In addition, invasive Atlantic salmon (*Salmo salar*) have also been observed in this stream. Grandon Creek and Beach Creek have coho salmon (*O. kisutch*) and cutthroat trout (*O. clarki*) present in the streams, while Beach Creek is also stocked with rainbow trout (*O. mykiss*) for fishing. Annie Creek is only populated by coho salmon (*O. kisutch*) and cutthroat trout (*O. clarki*). Swayne Creek and Morison Creek, in the same fish presence report, had observations of coho salmon (*O. kisutch*), cutthroat trout (*O. clarki*), steelhead (*O. mykiss irideus*) and three-spined stickleback (*Gasterosteus aculeatus*). Shelly Creek had reports of coho salmon, rainbow trout, cutthroat trout, sculpins, three-spine stickleback (MVIHES, 2020).

2021 sites: Millstone River has historically supported a diverse fish population. There have been strong efforts to protect the coho salmon (*O. kisutch*) population since 1998, when restoration and enrichment activities began (Lanarc Consultants Ltd, 1998). In addition to coho salmon, three-spined stickleback (*G. aculeatus*), steelhead (*O. mykiss irideus*), and cutthroat trout (*O. clarki*) have been observed in the river (Habitat Wizard, 2022). In addition to these fish species, crawfish are common in the river. The Chase River is a spawning channel for chinook (*O. tshawytscha*), chum *(O. keta*), coho (*O. kisutch*) and pink salmon (*O. gorbuscha*). It is also home to cutthroat trout (*O. clarki*), steelhead (*O. mykiss irideus*), lamprey (*Lampetra ayresii*), rainbow trout (*O. mykiss*), sculpins (*Cottus asper*), pumpkinseeds (*Lepomis gibbosus*), and stickleback (*G. aculeatus*) (Habitat Wizard, 2022). Holden Creek and Beck Creek have no major fishery, but both are spawning grounds for coho (*O. kisutch*) and chum salmon (*O. keta*), as well as supporting stickleback (*G. aculeatus*) and pumpkinseed (*Lepomis gibbosus*). Morningstar Creek is a spawning channel for coho (*O. kisutch*) but has no major fishery. Nanoose Creek has no major fisheries but is a spawning channel for coho (*O. kisutch*) and chum salmon (*O. keta*). Swayne Creek has no fisheries, but has coho salmon (*O. kisutch*), cutthroat trout (*O. clarki*), steelhead (*O. mykiss irideus*), and stickleback (*G. aculeatus*) (Habitat Wizard, 2022). McGarrigle Creek has no observed fish species or fisheries (Habitat Wizard, 2022).

3.3 Recreation

Historically and presently, recreational activities are enjoyed within the Millstone River watershed, Chase River watershed, Englishman River watershed, Nanaimo River watershed, and several other watersheds in the RDN. Though no reports were found specifically summarizing recreational uses, the streams in this study, due to their proximal locations in urban and rural areas, have been significantly utilised by humans. The larger streams are likely used for common activities such as fishing, swimming, and tubing.

3.4 Flora and Fauna

All sample sites fall within the coastal western hemlock or coastal Douglas-fir biogeoclimactic zones and can be expected to have similar terrestrial flora and fauna species across all sites sampled. These include flora typical to much of Vancouver Island, as well as common fauna. In addition to these common species, many threatened species have been observed, including Townsend Big-eared Bat (*Corynorhinus townsendii*), two subspecies of Peregrine Falcon (*Falco peregrinus anatum, Falco peregrinus pealei*), Red-legged frog (*Rana aurora*) and Dolly Varden (*Salvelinus malma*) (Hawkes, Gaboury, and Fenneman, 2013) (Habitat Wizard, 2022).

3.5 Designated Water Uses

Designated water uses are those identified for protection in a specific watershed or waterbody. As outlined by the water license table above, the designated water uses to be protected for the watersheds within the RDN considered in this study are aquatic life, wildlife, drinking water, irrigation, and recreation. Not all uses apply to each stream (see Licences

Table 1 above).

4. <u>INFLUENCES ON WATER QUALITY</u>

Large portions of all watersheds sampled in this study are privately held. Upper watershed lands within RDN Electoral Areas are largely owned by Mosaic Forest Management Ltd, but within municipal areas almost all sites are accessible via public lands such as roads and parks. There are no authorized direct discharges under the *Environmental Management Act* to any of the streams monitored in this report.

Historically, the most significant anthropogenic impact on water quality in the Regional District of Nanaimo was logging and, in specific areas, coal mining. Much of the shoreline around the City of

Nanaimo was altered by tailings from mining activity, and the runoff of the mines flowed into many of the watersheds in the Nanaimo area. The coal mines were closed in the early twentieth century, and logging became the primary large industry influencing upper watershed water quality in the regional district (City of Nanaimo, 2021). The impacts from mining declined as activity decreased but some effects are still measured in modern stream water quality assessments. Legacy mining impacts from coal mining include arsenic seepage into watersheds (City of Nanaimo, 2021). These effects are beyond the scope of this report.

The modern influences with the greatest impacts on sites surveyed in this report are rural and urban development, agricultural activity, and industry such as forestry. In rural and urban areas, stormwater runoff and impermeable surfaces (i.e., roadways) are typical contributors to water quality impacts, and usually come from multiple sources or properties (i.e., non-point source impacts). In agricultural areas, additional contributors to water quality impacts can include crop over-fertilization, high water use, and improper animal waste management. These influences informed which parameters were selected when planning the sampling for this report.

Lands within the Agricultural Land Reserve (ALR) are found in the lower portion of sampled watersheds, often directly adjacent to water bodies. Agricultural land use makes up 21% of the ALR land in the RDN (ALR land makes up 14% of the RDN's land area), with 20% of agricultural lands being cultivated field crops (BC Ministry of Agriculture, 2012). These values are based on agricultural land use inventory (ALUI) data; note these data were mostly collected for parceled land within the Agricultural Land Reserve (ALR), and it does not fully cover the watersheds surveyed in this study (BC Ministry of Agriculture, 2012).

Agricultural activity within the RDN include hay and grass, forage and pasture, berries, mixed vegetables, fruit trees, greenhouses, land-based agriculture, and raising livestock (cattle, small poultry, sheep, dairy, etc.) (RDN, 2012). Outside of the ALR, agricultural activity occurs as well, though to a significantly lesser degree. Many farm properties have limited riparian areas along the rivers and streams.

This study focuses on watersheds with known adjacent agricultural land use. Study watersheds are listed below with potential sources of water quality impacts, either from in field observations or land use mapping (Ecoscape; 2018, 2021):

- Morningstar Creek - stormwater runoff, golf course maintenance, livestock, soil distributor
- Swayne Creek – dominant land use is agricultural, low to subsurface summer flows
- Millstone River - dominant land use is agricultural in upper reaches, non-point source stormwater runoff, Brannen Lake recreation site
- McGarrigle Creek - dominant land use is domestic, agriculture, land-based aquaculture
- Chase River- no agriculture, dominant land use is residential (highly urbanized)
- Richards Creek - moderate agricultural activity, low to subsurface summer flows, runs directly adjacent to or through farm properties
- Holden Creek - dominant land use is agricultural, agricultural dam installed on the stream
- Beck Creek – moderate agricultural activity

5. STUDY DETAILS

In this study, the sites selected for 2019 and 2021 monitoring were recommended based on trends reported in the Ecoscape reports of 2018 and 2021, respectively. The sampling in 2019 primarily covered sites in the northern area of the RDN, while sites in 2021 were more south, including sites within the City of Nanaimo and further south (Table 2). Locations of sites sampled in 2021 are shown in Figure 2.

Discrete (or grab) water samples were collected by ENV and RDN in accordance with the B.C. Field Sampling Manual (MOE, 2013) and the B.C. Ministry of Environment, Lands and Parks Freshwater Biological Sampling Manual (Cavanagh, Nordin, & Warrington, 1996). Water samples were collected in laboratory-supplied sample bottles with appropriate preservatives if needed, packed on ice and shipped within appropriate hold times to ALS Laboratories in Vancouver, B.C. Water samples were analyzed in a laboratory for chloride, ammonia, nitrate, nitrate, total and Kjeldal nitrogen, total phosphate, turbidity, and *Escherichia coli* in 2021. In 2019, lab samples were only analyzed for chloride and total phosphorus. In 2021, parameters collected in situ using a handheld YSI Pro Quattro meter were temperature, pH, specific conductance, and dissolved oxygen (DO).

Englishman River and French Creek are two water bodies in the region that have site specific WQOs. It is standard practice for such WQOs to apply to the ecoregion of study, which encompasses all study sites surveyed in this report (Deniseger, *et al*., 2009). Thus, where applicable, data from this study were compared to the French Creek and Englishman River WQOs; for parameters that are not considered in site specific WQO, the BC Water Quality Guideline (WQG) was used.

In 2019 total phosphorus samples were collected monthly to compare to the ENV phosphorus guidance for Vancouver Island (MoE, 2014): May 22, June 24, July 24, August 26, and September 24. Dissolved chloride samples were collected at a frequency of five weekly samples in 30 days (5-in-30) from August 5 to August 26, 2019 (low-flow period).

In 2021, monthly samples for phosphorus, nitrogen species, turbidity, and *E. coli* were collected between May 26 and September 14, 2021; phosphorus was compared to the phosphorus guidance for Vancouver Island streams (MOE, 2014). Nutrients and metals samples were collected at a 5-in-30 frequency for the period between August 3 and August 31, 2021 (lowest flow), and between October 5 and November 2, 2021 (first fall flush). The 5-in-30 sampling allows for comparison of temperature, turbidity, and *E. coli* results to the applicable French Creek (Barlak & Phippen, 2014) and Englishman River WQOs (Barlak *et al.*, 2010) (Table 3). For parameters not included in the WQOs (nitrate and DO), data were compared to BC WQGs.

Table 2: RDN sample site coordinates.

EMS ID	Years sampled	Description	Latitude/Longitude
E288091	2019	Grandon Creek at Laburnum Road	49° 20' 29.5"N 124° 27' 50.7"W
E288090	2019	Grandon Creek West Crescent	49° 21' 24.4"N 124° 28' 2.3"W
E288092	2019	Beach Creek at Hemsworth Road	49° 20' 56.0"N 124° 25' 42.3"W
E288093	2019	Beach Creek at Memorial Golf Course	49° 21' 16.6"N 124° 26' 21.2"W
E243022	2019	French Creek at Barclay Bridge	49° 20' 39.1"N 124° 22' 18.1"W
E243021	2019	French Creek at Highway	49° 19' 23.2"N 124° 24' 51.8"W
E243024	2019	French Creek at Grafton Road	49° 17' 21.1"N 124° 25' 59.9"W
E290452	2019	Shelly Creek at Blower Rd	49° 18' 38.1"N 124° 17' 59.6"W
E287131	2019	Shelly Creek at Hamilton Rd	49° 18' 29.0"N 124° 18' 11.9"W
E248835	2019	Morison Creek Upstream of Englishman River	49° 16' 55.9"N 124° 18' 33.0"W
E240141	2019	Annie Creek	49° 23' 7.0"N 124° 35' 27.9"W
E318151	2021	Morningstar Creek	49°19'49.5"N 124°22'02.5"W
E308186	2019 2021	Swayne Creek	49°16'32.7"N 124°22'53.9"W
E294020	2021	Nanoose Creek at Matthew Crossing	49°15'35.8"N 124°14'25.8"W
E290485	2021	Chase River at Park Ave	49°08'47.3"N 123°56'37.8"W
E290479	2021	McGarrigle Creek at Jingle Pot Rd	49°11'41.2"N 124°02'21.5"W
E290478	2021	Millstone River at Biggs Rd	49°12'19.6"N 124°03'06.5"W
E290480	2021	Millstone River at East Wellington	49°10'50.9"N 123°59'52.5"W
E290481	2021	Millstone River at Barsby Park	49°10'24.7"N 123°56'46.8"W
E306294	2021	Millstone River at Jingle Pot Rd	49°11'40.9"N 124°02'22.7"W
E290487	2021	Beck Creek at Cedar Rd	49°07'28.5"N 123°54'33.5"W
E310147	2021	Holden Creek at Lazo Lane	49°07'02.7"N 123°50'26.9"W
E321395	2021	Richards Creek upstream Frames Rd	49°07'15.5"N 123°54'53.3"W

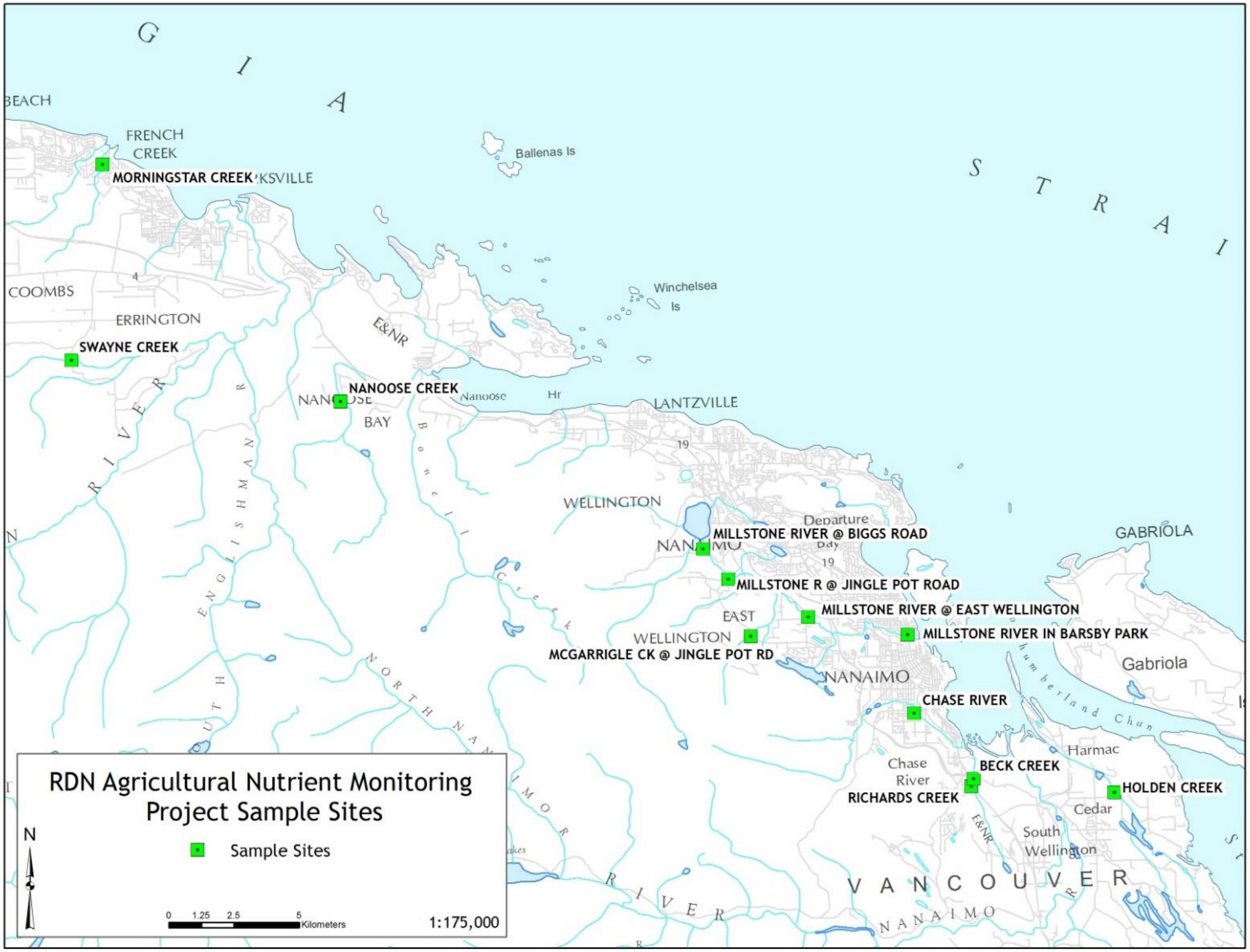

Figure 2: Location of 2021 water quality sampling sites from RDN nutrient and metals sampling. Due to limited relevant results, 2019 sample sites are not pictured.

Table 3: Applicable Water Quality Objectives for the Englishman River watershed (Barlak et al.*, 2010) and French Creek watershed (Barlak & Phippen, 2014).*

Variable	Watershed	Objective Value
Turbidity	Englishman	October to December: 5 NTU maximum January to September: 2 NTU maximum
	French Creek	October to December: 5 NTU maximum January to September: 2 NTU maximum
Temperature	Englishman	Short Term: ≤15ºC weekly average Long Term: ≤17ºC weekly average
	French Creek	Short Term: ≤15ºC weekly average Long Term: ≤17ºC weekly average
Escherichia coli	Englishman	October to November: ≤ 41 CFU/100mL 90th percentile December to September: ≤ 10 CFU/100mL 90th percentile
	French Creek	≤ 41 CFU/100mL 90th percentile
Dissolved Aluminum	Englishman	At any location in the river: 0.05 mg/L average (based on a minimum 5 weekly samples collected over a 30-day period) 0.10 mg/L maximum
	French Creek	0.05 mg/L average (based on a minimum 5 weekly samples collected over a 30-day period) 0.10 mg/L maximum

5.1 Quality Assurance / Quality Control

Quality assurance and quality control was verified by collecting replicate samples at 10% of sites. Replicate co-located samples are collected by filling two sample bottles in as close to the same time as possible (one right after the other) at a monitoring location, and then calculating the percent difference between the laboratory results reported for the various samples. The maximum acceptable percentage differences between replicate samples are 25%. However, this interpretation only holds true if the results are at least ten times the detectable limits for a given parameter, as the accuracy of a result close to the detectable limit shows more variability than results well above detectable limits. As well, some parameters (notably bacteriological indicators) are not homogeneous throughout the water column and therefore it is expected to see a higher degree of variability between replicate samples.

In 2021, fourteen sets of replicate samples were collected during the sampling program (two at Morningstar Creek (E318151), two at Millstone River at Biggs Rd (E290478), one at Millstone River at East Wellington (E290480), three at Chase River (E290485), one at Nanoose Creek (E294020), and one at Richards Creek (E321395)). In all replicate samples, percent mean differences of all parameters were found to be within acceptable limits as discussed above (Appendix A Table 13). Based on these samples, the data can be considered within acceptable limits for data quality.

In 2019, replicate samples were collected from 10% of sites, with 5 samples each for chlorine and total phosphorus. These samples were within acceptable limits for all sample days.

6. RESULTS AND DISCUSSION

Due to the limited sampling conducted in 2019, there is limited focus on these data in this report. The data collected for chloride in 2019 (see Appendix Table 11) did not exceed guidelines at any site and thus will not be discussed further. Turbidity and phosphorus data from 2019 (Appendix A Table 12) are reported in the applicable sections of this report below.

6.1 pH

pH is a measure of the concentration of free hydrogen ions (H+) in water. The concentration of hydrogen ions in water can range over 14 orders of magnitude, so pH is defined on a logarithmic scale between 0 and 14. A pH between 0 and less than 7 is acidic (the lower the number, the more acidic the water) and a pH greater than 7 is alkaline (the higher the number, the more basic the water). The aesthetic guideline for drinking water is a pH between 6.5 and 8.5 (McKean and Nagpal, 1991). The effectiveness of chlorine as a disinfectant is reduced outside of this range. The water quality guideline for pH for the protection of aquatic life in fresh water is no statistically significant change in pH when ambient pH is outside of the range of 6.5 to 9.0 pH units (McKean and Nagpal, 1991). Inside of this range, there is no restriction on change.

Only field pH data was collected for this study, as in situ monitoring with a properly calibrated instrument is considered the most accurate way to measure pH. Streams in Nanaimo generally had higher pH than streams north of Nanaimo, with the highest pH being observed at Millstone River at Barsby Park (E290481) and Chase River at Park Ave. (E290487) (Table 4). Generally, pH was highest in the summer months. All field pH values met the WQG.

Table 4: Field pH sampling results in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 26th to November 3rd, 2021.

EMS ID	Average of field pH (summer low flow)	Average of field pH (fall flush)	Average of field pH (all samples)	Total number of all samples
E290478	6.876	6.73	6.83143	14
E290479	7.112	6.968	7.12714	14
E290480	7.122	6.826	7.08	14
E290481	7.578	7.048	7.43214	14
E290485	7.252	6.96	7.21429	14
E290487	7.688	7.226	7.52571	14
E294020	6.854	7.006	6.94	14
E306294	7.102	6.856	6.97929	14
E308186	6.8425	6.856	6.95769	14
E310147	7.476	7.044	7.28857	14
E318151	7.022	7.276	7.20929	14
E321395	7.356	6.812	7.2442	14

6.2 Temperature

Water temperature alters the solubility of water for oxygen and other gases, pH, and conductivity, and the metabolic rates of aquatic organisms. Lower water temperatures allow for higher DO concentrations (Oliver and Fidler, 2001). The WQO for temperature in both the Englishman River and French Creek is a weekly average of ≤17°C in the short term at any location, and a weekly average of ≤15°C in the long term (5-10 years) to protect fish species that are present (Barlak *et al.*, 2010; Barlak & Phippen, 2014) (Table 3). As samples in this report were only taken weekly and monthly, the weekly averages could not be calculated. However, any recorded temperatures that are higher than the WQO demonstrate that there may be potential for an exceedance of the WQO.

Temperatures recorded had the potential to exceed the WQO in the period of June, July and August at all sites in 2021 except Swayne Creek (E308186), Morningstar Creek (E318151), and Nanoose Creek (E294020) (Figure 3). Cooler temperature sites may have had more groundwater influence or had more shade from direct daylight upstream of the sample site. Higher than average air temperatures affect the summer 2021 water temperatures due to a record-breaking heat wave that occurred during June 2021 on the west coast of North America. This heat dome caused air temperatures of up to 49°C in British Columbia from late June to early July, with air temperatures of up to 40°C in the RDN. This unprecedented event was an outlier from the climate norm in the RDN. Under average temperature trends, as long as refuges remain with average temperatures below the guideline, juvenile fish should be able to retreat to these areas during periods of elevated temperatures (Barlak & Epps, 2010; Barlak & Phippen, 2014).

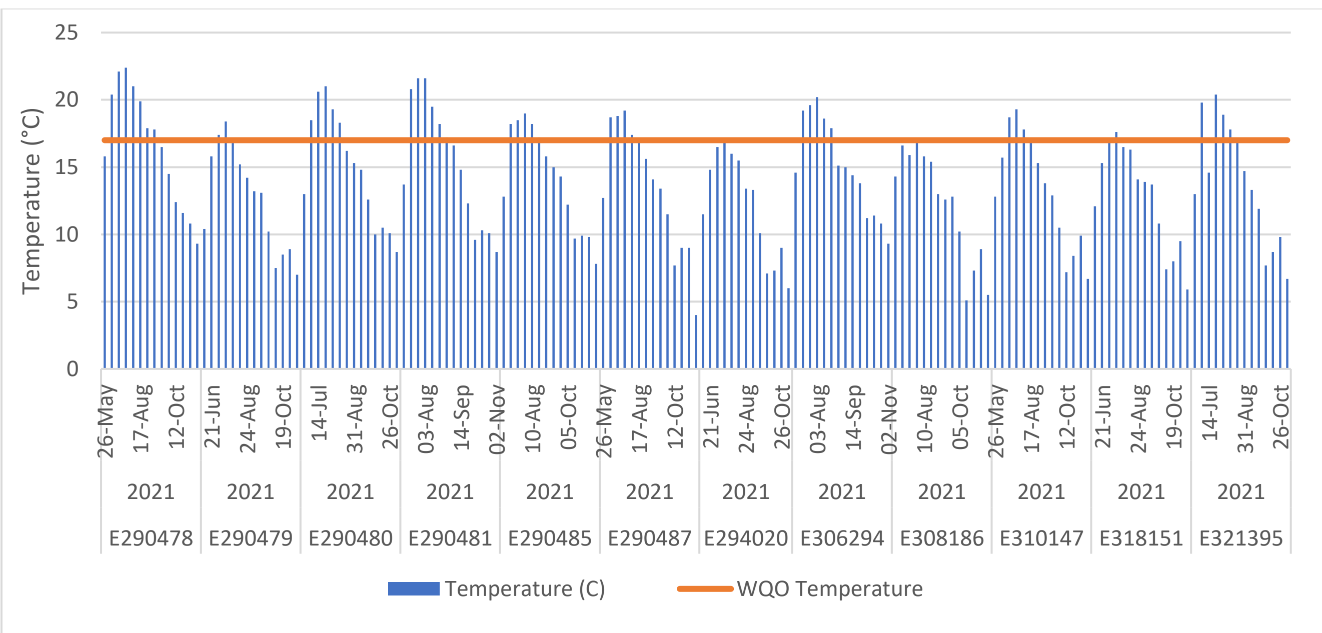

Figure 3: Summary of individual stream temperature measurements at Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 26 to November 2, 2021. The French Creek WQO for temperature is included for reference.

6.3 Conductivity

Conductivity refers to the ability of a substance to conduct an electric current. The conductivity of a water sample gives an indication of the concentrations of dissolved ions in the water. The more ions dissolved in a solution, the greater the electrical conductivity. As temperature affects the conductivity of water (a 1°C increase in temperature results in approximately a 2% increase in conductivity), specific conductance is used (rather than simply conductivity) as it is corrected to 25°C (Phippen, 2012). Coastal systems, with high annual rainfall values and typically short water retention times, generally have low specific conductance (<80 µS/cm), while interior watersheds generally have higher values (Phippen, 2012). Increased flows resulting from precipitation events or snowmelt tends to dilute the ions, resulting in decreased specific conductance levels with increased flow levels.

Low specific conductance was seen in Millstone at Biggs Rd (E290478), McGarrigle Creek (E290479), Millstone at Jingle Pot Rd (E306294), and Swayne Creek (E308186), with the minimum value being 42.6 µS/cm at McGarrigle Creek (E290479). In general, specific conductance was higher in summer low flow samples than in fall flush samples, due to lack of dilution in summer. The maximum value was 936 µS/cm at Morningstar Creek (E318151), and the other sites with highest specific conductance values were Beck Creek (E290487) and Richards Creek (E321395) (Table 5). Specific conductance at these sites is consistent with observed known water quality influences; Morningstar Creek and Beck Creek have high road influence while Richards Creek went subsurface in the summer, leading to an accumulation of ions in standing water.

Table 5: Summary of specific conductance sampling results in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 26 to November 2, 2021.

EMS Site	Average of Specific Conductance (µS/cm)	Max of Specific Conductance (µS/cm)	Min of Specific Conductance (µS/cm)
E290478	84.76	89.4	74.1
E290479	103.59	159.9	42.6
E290480	139.67	192.3	79.6
E290481	165.02	229.4	87.7
E290485	263.83	436.3	113.3
E290487	400.21	501.9	261.9
E294020	262.28	338.1	70.4
E306294	90.81	102.3	85
E308186	107.4	164.2	43.1
E310147	226.31	243.9	176.3
E318151	503.43	936	218.2
E321395	320.15	443.1	182.3

6.4 Turbidity

Turbidity is a measure of the clarity or cloudiness of water and is measured by the amount of light scattered by the particles in the water as nephelometric turbidity units (NTU). Elevated turbidity levels can decrease the efficiency of disinfection, allowing microbiological contaminants to enter the water system (Caux *et al*., 1997). To protect drinking water quality in watersheds with domestic licenses, applicable Englishman River WQOs are: between October to December (when turbid flows can occur), turbidity should not exceed 5 NTU; and, during the remainder of the year (clear flow periods), turbidity should not exceed 2 NTU (1 NTU above ambient levels) (Table 3) (Barlak *et al.*, 2010).

Turbidity is useful as an indicator of other potential contaminant issues in a stream which is why it is sampled regularly and used as in indicator in the RDN CWMN program. High turbidity can be associated with algal growth, sediment disturbance in streams, or runoff from land uses. Turbidity values collected in 2019 ranged from 0.08 NTU at French Creek (E243024) to 7.74 NTU at Morison Creek (E248835). Values from January to September had exceedances at Morison Creek, but no other exceedances were observed (see Appendix A Table 12).

Turbidity in 2021 had values ranging from 0.1 NTU at Nanoose Creek (E294020) to 36.3 NTU at Richards Creek (E321395). Values from January to September had exceedances at Millstone at Biggs Rd (E290478) in May, June, July, and August, Millstone at East Wellington (E290480) in October, Millstone in Barsby Park (E290481) in October, Beck Creek (E290487) in September, Millstone at Jingle Pot (E306294) in May, June, July, August, and September, Swayne Creek (E308186) in May, August, and September, Morningstar Creek (E318151) in May, September, and October, and Richards Creek (E321395) in July, August, and September (Figure 4).

Residential and rural development is associated with many potential sources of increased turbidity in watersheds including land disturbance, rainwater runoff, and, during low summer flows, nutrient-induced algal growth. While nutrients in residential areas are usually associated with lawn/garden fertilization, rural areas used for agriculture have several additional potential sources including animal wastes, crop fertilization and septic fields. In addition, land used for agriculture typically has reduced riparian vegetation and altered drainage patterns.

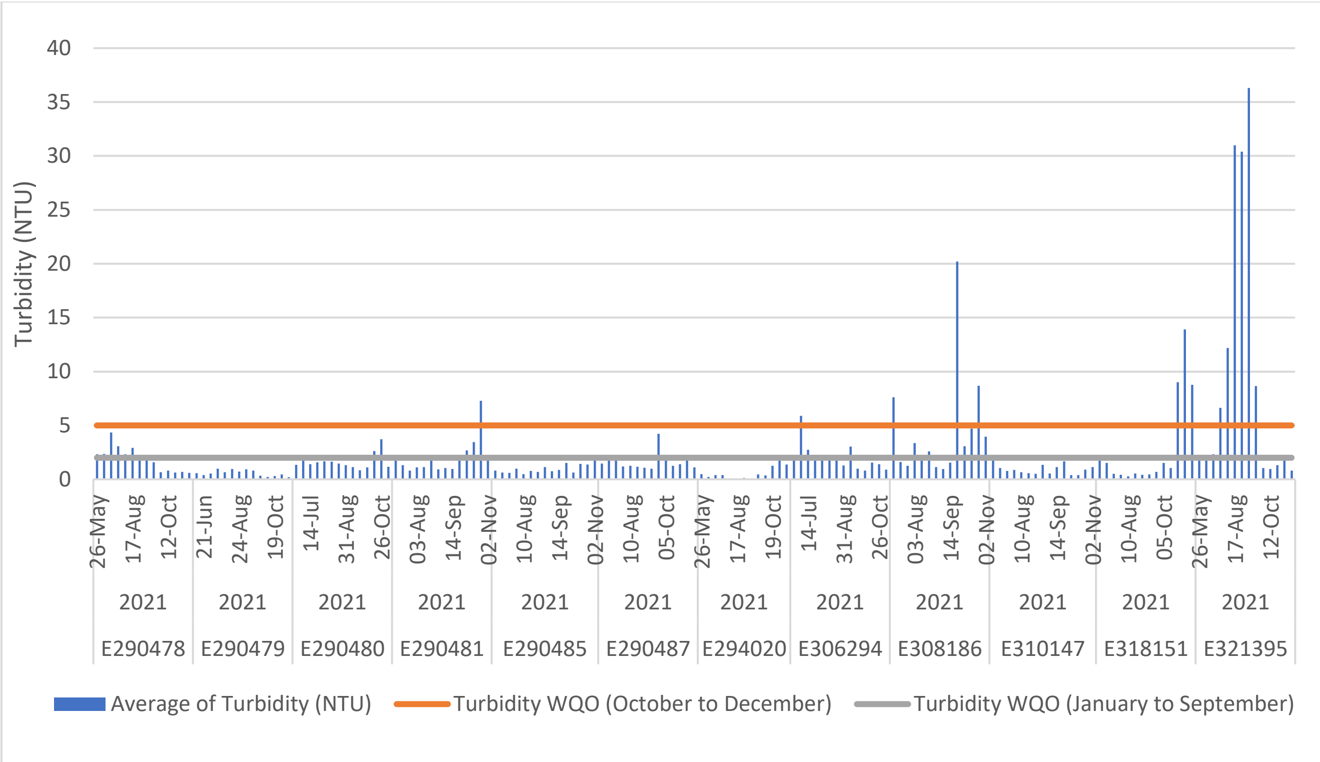

Figure 4: Summary of individual turbidity measurements at Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 26 to November 2, 2021. WQO are included for the period October to December and the period January to September.

6.5 Phosphorus

Phosphorus is usually the limiting factor in freshwater aquatic systems. Phosphorus is essential to primary productivity in streams, but levels even slightly higher than background can cause excessive algal growth and many associated impacts to the health of streams and their resources. In watersheds where drinking water is a priority, it is desirable that nutrient levels remain low to avoid algal blooms and foul-tasting water. Similarly, to protect aquatic life, nutrient levels should not be too high, or the resulting plant and algal growth can deplete oxygen levels when it dies and begins to decompose, as well as during periods of low productivity when plants consume oxygen (MOE, 2014).

Rainwater runoff and groundwater inflow from land development, agriculture (fertilizer and/or animal wastes), failing septic fields and treated sewage effluent discharges are leading sources of phosphorus in urban and rural residentially developed areas. The high rate of population growth on Vancouver Island and very low summer stream flows makes streams extremely sensitive to phosphorus pollution, thus it is vital to manage phosphorus inputs into streams (MOE, 2014). To address this challenge, a Vancouver Island phosphorus guidance document was developed to protect Vancouver Island streams using area specific data, with the intent of limiting and preventing excessive nutrient input and subsequent environmental impact (MOE, 2014). This document specifies that the May to September total phosphorus average, with samples collected monthly, should not exceed 5 µg/L (0.005 mg/L), and maximum total phosphorus should not exceed 10 µg/L (0.010 mg/L) in any one sample.

Total phosphorus data from 2019 showed average of May-Sept monthly samples were greater than the maximum guidance of 0.010 mg/L in all sites except French Creek at Grafton Road (E243024) (Figure 5). Agricultural related damming was discovered on Swayne Creek in 2019, affecting the water quality downstream. RDN provided some outreach and education to streamside landowners at the Swayne Creek site and, as a result, water quality in Swayne Creek has improved in subsequent years.

In 2021, the only sample site that did not exceed the maximum phosphorus guidance for Vancouver Island (MOE, 2014) is Nanoose Creek (E294020) (Figure 6), the reference station. All other sites sampled had exceedances of guidance, with the highest values being observed at McGarrigle Creek (E290479) and Richards Creek (E321395). Richards Creek's highest concentration was 0.7 mg/L in late August as a still pool with no flow. McGarrigle Creek had a maximum concentration of 0.86 mg/L in May 2021. Investigations into potential sources of nutrient inputs (agricultural practices and land-based aquaculture activities) in McGarrigle Creek were underway at the time of publication of this report. Average concentration of phosphorus across all sites also showed exceedances (Figure 7), with Nanoose Creek being the only site that did not exceed the guidance for average phosphorus concentration (5 µg/L or 0.005 mg/L).

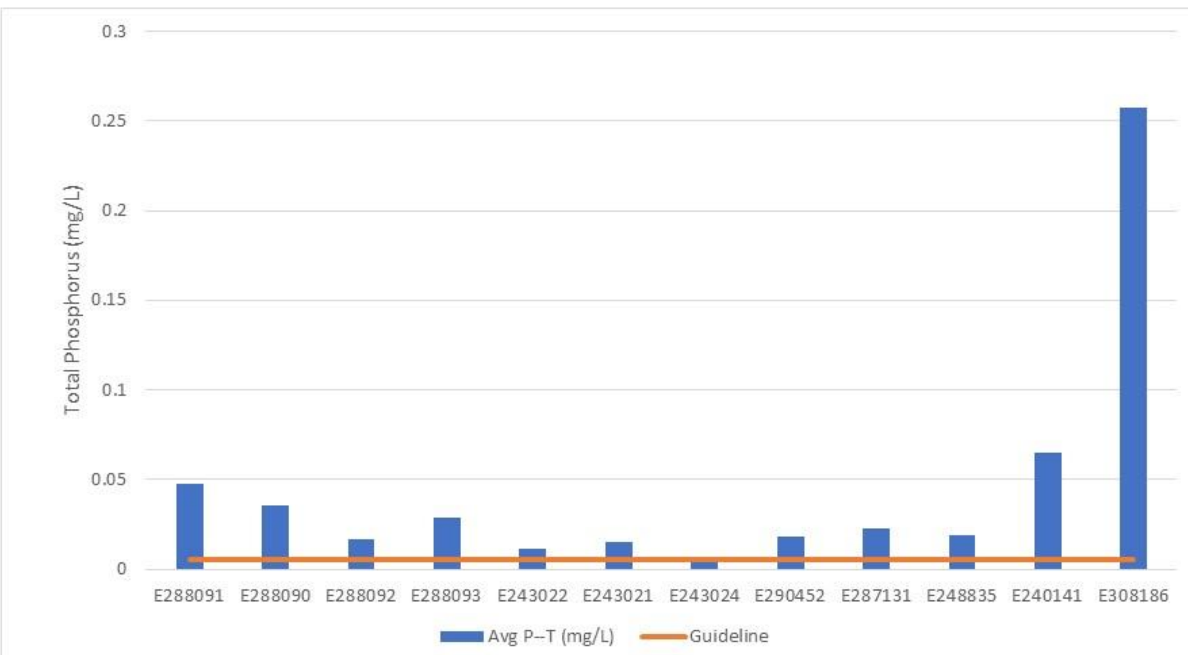

Figure 5: Average total phosphorus from May to September 2019 with samples collected monthly in Annie Creek (E240141), French Creek (E243021, E243022, E243024), Morison Creek (E248835), Shelly Creek (E287131, E290452), Grandon Creek (E288090, E288091), Beach Creek (E288092, E288093), and Swayne Creek (E308186) as well as summer low flow 5-in-30s. The guidance for average phosphorus of 5 µg/L(5 mg/L) for monthly samples between May and September 2019 is included.

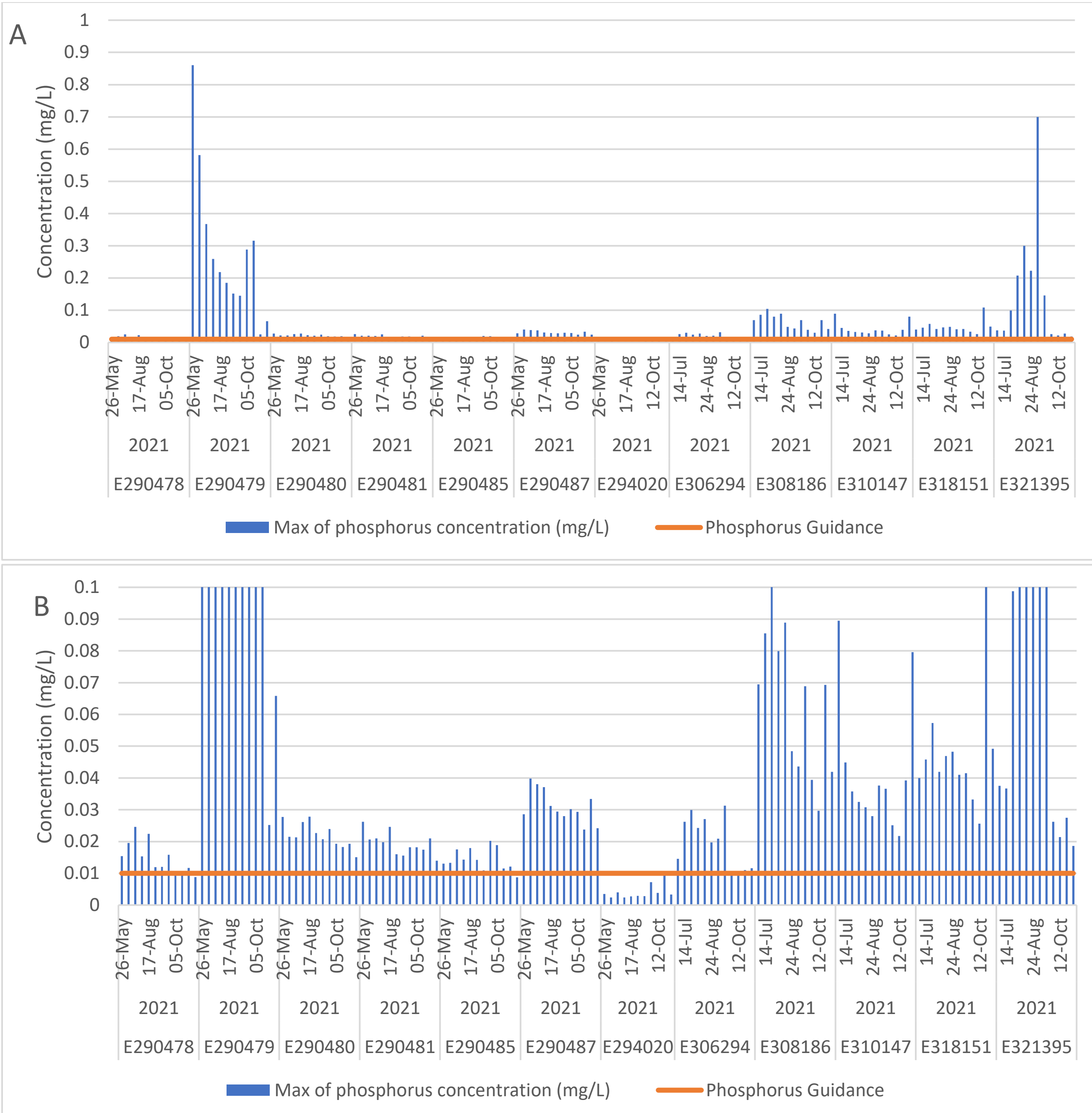

Figure 6: A: Summary of individual total phosphorus samples in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 26th to November 2nd, 2021. B: Summary of individual total phosphorus samples with a maximum concentration of 0.1 mg/L to show exceedances of the guidance of 0.010 mg/L. The maximum total phosphorus guidance value of 10 µg/L (0.010 mg/L) (applicable May through September only) is included.

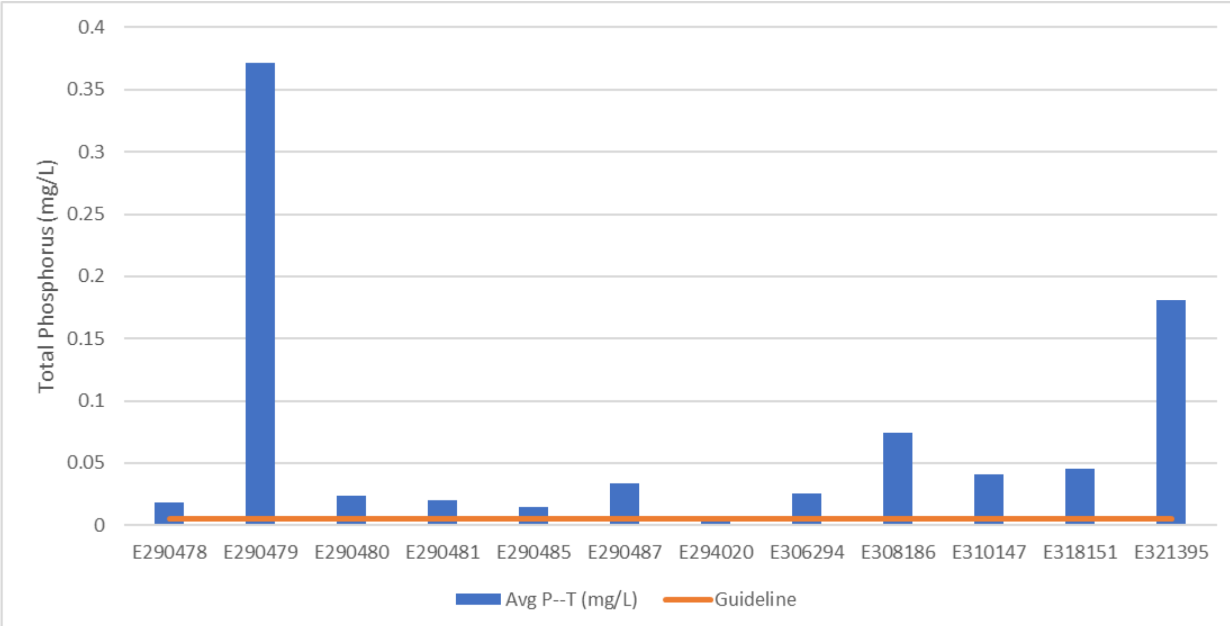

Figure 7: Average total phosphorus from May to September with samples collected monthly in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) as well as summer low flow 5-in-30s. The phosphorus guidance average value of 5 µg/L (5 mg/L) for monthly samples between May and September is included.

6.6 Nitrogen

For the protection of aquatic life, the BC WQG for dissolved nitrate is a maximum concentration of 32.8 mg/L in a single discrete sample and an average concentration of 3.0 mg/L from 5 samples in 30 days (Meays, 2009). Dissolved nitrate (NO_3) was one of several nitrogen forms analyzed as part of this study. In addition to nitrate, ammonia (NH_3) was also sampled. The BC WQG for ammonia is based on pH and temperature. Based on these parameters, the WQG for ammonia is 21.4 mg/L for a single sample and is 1.81 mg/L for the average of 5 samples in 30 days.

Nitrate is often a nutrient associated with grass fertilizers. Fertilizers for grasses and hay are largely composed of nitrate compounds, so farms with these crops often contribute to elevated levels in streams (Nordin & Pommen, 2001). Land-based aquaculture practices also produce nitrogen rich effluent (Nootong *et al.,* 2012).

Nitrate concentrations were low relative to WQGs at most sites, but they were consistently elevated at Holden Creek (E310147) with an exceedance in the summer low flow 5-in-30 average (Table 6). McGarrigle Creek (E290479), Morningstar Creek (E318151), and Chase River (E290485) had periods of elevated concentration, but the 5-in-30 averages were within WQG, and no discrete samples exceeded WQGs in either summer low flow or fall flush. The elevated nitrate levels in Holden Creek, McGarrigle Creek, and Morningstar Creek are likely due to upstream agriculture, aquaculture and golf course maintenance practices. Chase River has no significant agricultural practice upstream that influences its flow, so it is unknown what may be causing elevated levels. The likely cause is residential fertilizer use, especially on lawns where the fertilizers are primarily composed of nitrate.

Ammonia is a nutrient often associated with fertilizers. High ammonia can be seen in agriculture and aquaculture discharge and is often a nutrient leading to algal growth in streams. There are no exceedances of ammonia guidelines at any site sampled in 2021. Sampling at McGarrigle Creek (E290479) showed ammonia concentration values that were double the concentration of other sites. These high values could be associated with aquacultural activity seen upstream, thus outreach and further monitoring in the stream is recommended to determine the source of ammonia in the stream.

Table 6: Summary of dissolved nitrate (NO_3) concentrations measured in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 2 to November 2, 2021. Sites are arranged in order of sampling. Maximum and minimum values were from the period May 26 to November 2, 2021 and contained 16 samples. Summer low flow 5-in-30 sampling was from the period August 3 to August 31, 2021 and fall flush 5-in-30 sampling was from the period October 5, to November 2, 2021.

EMS Site:	Max of Dissolved NO_3 (mg/L)	Min of Dissolved NO_3 (mg/L)	Summer Low Flow NO_3 5-in-30 Average	Fall Flush NO_3 5-in-30 Average
	WQG: < 32.8 mg/L		WQG: < 3.0 mg/L	
E290478	0.142	0.003	0.003233333	0.04484
E290479	5.57	0.118	0.4755	0.6755
E290480	0.352	0.0116	0.01276	0.187166667
E290481	0.432	0.0616	0.0972	0.242
E290485	0.786	0.125	0.623571429	0.484833333
E290487	0.185	0.0307	0.11386	0.06924
E294020	0.193	0.0108	0.1238	0.02202
E306294	0.21	0.0075	0.03804	0.09866
E308186	0.978	0.003	0.0076	0.558333333
E310147	3.99	0.78	**3.734**	2.496
E318151	1.98	0.0782	0.22324	1.256
E321395	0.157	0.003	0.00364	0.08474

Table 7: Summary of dissolved ammonia concentrations in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 2 to November 2, 2021. Maximum values were from the period May 26 to November 2, 2021 and contained 16 samples. Summer low flow 5-in-30 sampling was from the period August 3 to August 31, 2021 and fall flush 5-in-30 sampling was from the period October 5, to November 2, 2021.

EMS Site:	Max of Dissolved NH_3 (mg/L)	Summer Low Flow NH_3 5-in-30 Average	Fall Flush NH_3 5-in-30 Average
	WQG: < 2.2 mg/L		
E290478	0.0126	0.00752	0.005575
E290479	0.0961	0.0101	0.084
E290480	0.0224	0.0116	0.00645
E290481	0.0157	0.01128	0.005
E290485	0.0271	0.01418	0.00845
E290487	0.0233	0.01404	0.010125
E294020	0.0061	0.00522	0.005
E306294	0.0228	0.01106	0.00525
E308186	0.0628	0.03	0.054125
E310147	0.0453	0.0071	0.00845
E318151	0.0463	0.01224	0.0139
E321395	0.0421	0.04592	0.012975

6.7 Dissolved Oxygen

Oxygen is the single most important component of surface water for self-purification processes and the maintenance of aquatic organisms which utilize aerobic respiration (MOE, 1997). The WQG for dissolved oxygen (DO) is expressed as an instantaneous minimum value of 5 mg/L O_2, and a 5-in-30 mean of 8 mg/L O_2. The dissolved oxygen concentration in water is directly related to water temperature, where cooler waters have higher concentrations of oxygen than warmer waters.

DO concentrations ranged from 2.42 mg/L at Morningstar Creek to 14.28 mg/L in Richards Creek during summer low flow (Figure 8). During fall flush, concentrations were 7.74 mg/L at Richards Creek to 15.04 mg/L in Nanoose Creek. Only the summer low flow had recorded concentrations below the short term acute WQG, observed for Swayne Creek (E306186), Millstone River at Biggs Rd (E290478), and Morningstar Creek (E318151) (Figure 8). Fall flush had no DO concentrations below the 5 mg/L short term acute guideline, but there were values below 5 mg/L in Richard Creek (Figure 9).

Swayne Creek (E306186), Millstone River at Biggs Rd (E290478), and Morningstar Creek (E318151), with low summer DO below 5 mg/L, were likely affected by the elevated summer temperature and/or low flows, as these same sites met WQG in the fall. Richards Creek, despite being subsurface with no flow, had higher DO than Swayne Creek. This was possibly due to groundwater influence but could also be caused by algal growth oxygenating the water; if this were the case, the DO would eventually decrease once algal decomposition processes started.

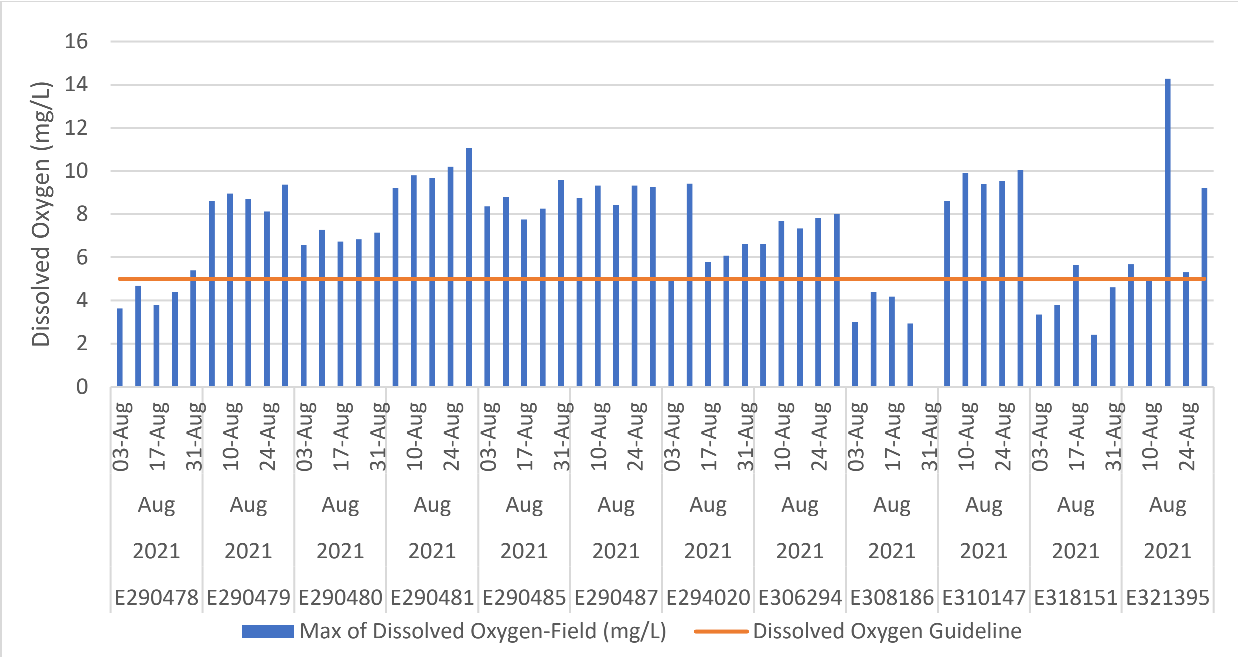

Figure 8: Summary of individual dissolved oxygen samples measured in summer low in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) between August 3 and August 31, 2021. Guideline for DO (5 mg/L) is a minimum value that samples should be above.

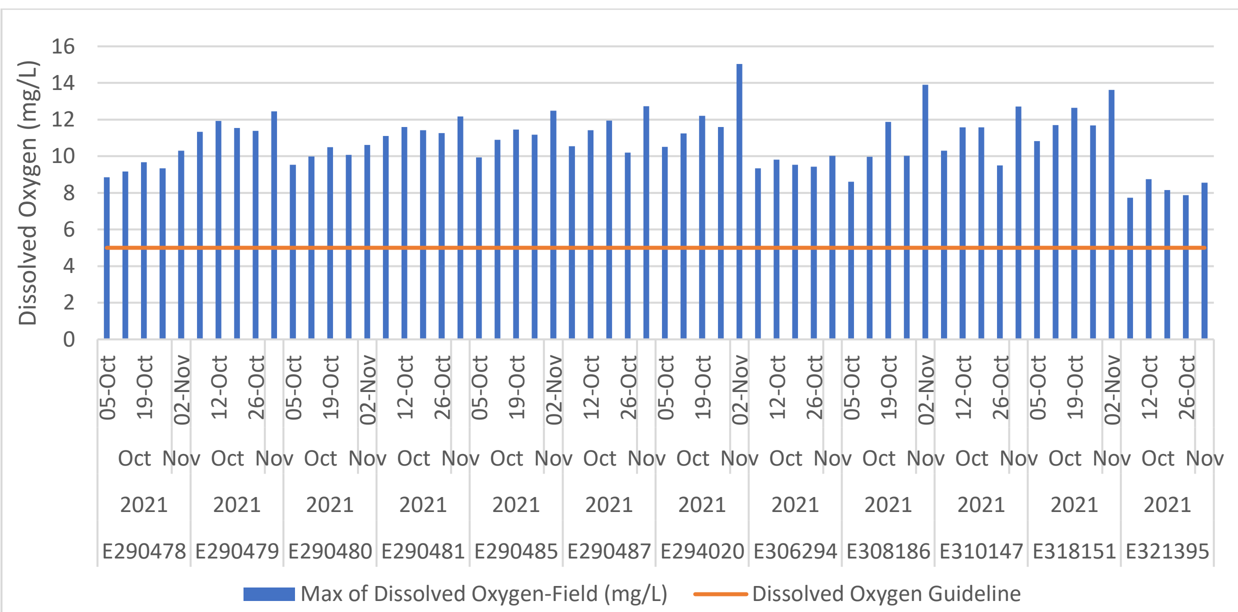

Figure 9: Summary of individual dissolved oxygen samples measured in fall flush in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) between October 5 to November 2, 2021. Guideline for DO (5 mg/L) is a minimum value that samples should be above.

6.8 Microbiological Indicators – *E. coli*

Fecal contamination of surface waters used for drinking and recreation can result in high risks to human health from pathogenic microbiological organisms as well as significant economic losses due to closure of beaches (Scott *et al*., 2002). The direct measurement and monitoring of pathogens in water, however, is difficult due to their low numbers, intermittent and generally unpredictable occurrence, and specific growth requirements (Krewski *et al.,* 2004; Ishii and Sadowsky, 2008). Studies have shown that *E. coli* is the main thermo-tolerant coliform species present in fecal samples (94%) of humans and other endotherms such as birds and mammals, (Tallon *et al*., 2005), and at contaminated bathing beaches (80%) (Davis *et al.*, 2005). The B.C.-approved water quality guidelines for microbiological indicators were developed in 1988 (Warrington, 1988) and include *E. coli* and enterococci; portions of these guidelines have been rescinded (ENV, 2020a) and replaced with summary documents for recreational and drinking water guidelines (ENV, 2021; ENV, 2020b). As small pieces of fecal matter in a sample can skew the overall results for a particular site, the 90th percentiles (for drinking water) and geometric means (for recreation) are generally used to determine if the water quality guideline is exceeded, as extreme values would have less effect on the data. The current objectives for *E. coli* in drinking water in Englishman River and French Creek are less than 10 CFU/100 mL in a mean of 5-in-30 samples from December to September, or a concentration of 41 CFU/100mL from October to November (Table 3). This objective considers background inputs from wildlife and is to protect domestic water intakes.

There are no objectives for recreational uses, so the BC WQG of ≤ 200 CFU/100 mL (geometric mean) (MOE, 2019; ENV, 2021) is used for comparison to samples for water sources that are not used for drinking water.

E. coli levels were elevated at most sites surveyed in both 2021 summer and fall samples, with the consistently highest value appearing at Chase River (E290485). In this study, individual *E. coli* concentrations ranged from just above detection limits (1 CFU/100mL) to 1810 CFU/100mL at Millstone River at East Wellington Rd. (E290480) (Table 8). The maximum values all occurred during the fall flush period in October. Summer low flow *E. coli* sampling ranged from 18 CFU/100mL at Nanoose Creek (E294020) to 1200 CFU/100mL at Chase River (E290485). This pattern continued in the fall samples, where the lowest maximum concentration was 42 CFU/100 mL at Nanoose Creek (E294020) and the highest was 1810 CFU/100 mL at Millstone River at East Wellington Rd. (E290480). All sites except Morningstar Creek (E318151), Nanoose Creek (E294020), McGarrigle Creek (E290479), and Holden Creek (E310147) exceeded the B.C. WQG for recreation (≤ 400 CFU/100mL in a single sample, (ENV, 2019)) in both summer low flow and fall flush. The Holden Creek site (E310147) had exceedances only in summer low flow.

The Englishman River WQOs applicable to these watersheds are for protection of water sources but represent the natural variability within the watershed. The objectives are that the maximum 90th percentile collected from December to September is 10 CFU/100 mL, and from October to November is 41 CFU/100 mL (Barlak *et al.*, 2010). The 90th percentile of all samples collected exceed these objectives except Nanoose Creek (E294020) in the fall flush sampling.

E. coli results confirm suspected anthropogenic impacts from dominant land uses in the study watersheds relative to the Nanoose Creek background site. Wildlife, agricultural activity, and other human activities can cause *E. coli* levels to rise. In Chase River, the high values are likely primarily influenced by stormwater runoff carrying fecal matter from pets and wildlife from Harewood Centennial Park, Colliery Dam Park, and residential properties (Habitat Wizard, 2022). In Swayne Creek (E308186), agricultural land use is dominant and thus the most likely source of high *E. coli* levels. In Millstone River at East Wellington Rd (E290480) and at Barsby Park (E290481), exceedances of B.C. WQG for *E. coli* were likely due to agriculture and parks being the dominant land use upstream.

E. coli levels observed in this report are of concern, as values were consistently over the WQG for recreational use regardless of time of year, and over the Englishman River drinking water WQO at all sites. This highlights the need for recreators to use caution with pets and children around these streams and water users to appropriately treat their water for domestic use. In smaller streams, there is lower likelihood of use for recreation activities. However, activity on a smaller scale may still occur in these streams. Microbial source tracking could be done in the future to help determine the sources of *E. coli* in the study area. In addition, public awareness and signs may be necessary to protect recreators.

Table 8: Summary of E. coli concentrations (CFU/100mL) in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during the period May 26 to November 2, 2021. Highlighted values exceed the guideline or objective associated with the column as follows: The single sample maximum WQG for recreation 400 CFU/100ml. Summer 90th percentile values are in exceedance if the value is greater than 10 CFU/100 mL and fall 90th percentile values are in exceedance if values are greater than 41 CFU/100 mL. The geometric mean maximum WQG for recreation is 200 CFU/100 mL.

			90th Percentile		Geometric Mean	
EMS Site	**Summer Max.**	**Fall Max.**	**Summer**	**Fall**	**Summer**	**Fall**
E290478	81	74	**78.5**	**79.6**	49.3	31.9
E290479	190	190	**246**	23.9	93.4	31.4
E290480	240	**1810**	**345**	**1339**	115.9	152.1
E290481	270	390	**635**	**366**	77.2	**207.0**
E290485	**1200**	**460**	**1038**	**1038**	**295.6**	42.5
E290487	160	70	**461**	**461**	71.3	33.9
E294020	18	42	**23.6**	**38.4**	6.3	15.3
E306294	150	270	**243**	**243**	121.0	100.0
E308186	230	**970**	**215**	**748**	43.8	186.1
E310147	290	83	**242.6**	**127.7**	93.1	19.2
E318151	22	260	**114**	**129**	8.0	79.4
E321395	260	260	**260**	**260**	56.2	75.9

6.9 Metals

Metals are an indicator of various influences on a water body and can have significant impacts on the organisms living in the streams. In urban areas, metals can be an indicator of road influence, as car wear can contribute to road runoff with higher metal content than runoff in less developed areas (MOE, 2008). In addition, fertilizers can be a source of metals such as cadmium, copper, and zinc (ENV, 2019).

Some total metal WQGs are dependent on other environmental factors such as pH, water temperature, or hardness. Only metals observed to be at or near levels of concern are discussed below.

Copper (Cu) WQGs are dependent on the specific chemistry of the water body and can only be calculated using the BC Biotic Ligand Model (BLM) online calculation. The BC BLM User's Manual provides clear instruction of how the calculation should be used to determine chronic and acute WQGs (ENV, 2019). Calculating a WQG using the full BC BLM requires 11 water chemistry parameters. To overcome the fact these parameters are not always routinely measured, a simplified version of the BC BLM was included in the software and requires only four water chemistry parameters which need to be measured with Cu: temperature, DO, pH, and hardness. The remaining seven parameters are estimated based on the criteria described in Cu WQGs Technical Report (ENV, 2019). The WQG for Cu is for aquatic life in freshwater, using dissolved Cu. For this study the Cu WQG is 0.304 µg/L based on the above parameters. This study uses total metals, so cannot be compared directly against guidelines for Cu. However, it can be used to indicate where further sampling of metals may be needed based on total Cu concentrations.

Manganese (Mn) is a metal often associated with road runoff, as Mn is a stabilizing agent in gasoline (MOE, 1988). To protect freshwater aquatic life from chronic effects, the average concentration of total Mn in mg/L should not exceed the value as given by the following relationship: Average Mn Concentration (mg/L) less than or equal to 0.0044 [H] + 0.605 (Reimer, 1999). The water quality guideline for long-term chronic sampling in this study is 1.16 mg/L based on an average water hardness of 126 mg/L in summer low flow, and 128 m/L in fall flush.

The Englishman River WQO for aluminum is that, at any location in the creek, dissolved aluminum should not exceed a maximum of 0.1 mg/L at any one time and the mean of 5 weekly samples in 30 days should not exceed 0.05 mg/L. This study uses total metals, so cannot be compared directly against guidelines for aluminum. However, it can be used to indicate where further sampling of metals may be needed based on total aluminum concentrations. Background aluminum levels observed in the development of the Englishman River WQO suggested some natural geological sources of dissolved aluminum on Vancouver Island are likely (Barlak *et al*., 2010).

Iron toxicity in freshwater is influenced by multiple factors, and often these factors can interact in antagonistic ways. The existing BC WQG for total iron in freshwater is that the maximum total iron concentration should not exceed 1.0 mg/L in a single sample to protect aquatic systems from detrimental effects of iron (MOE, 2008). On Vancouver Island, the streams can be influenced by natural iron deposits in addition to anthropogenic sources (MOE, 2008). The levels of iron shown in sampling are not always anthropogenic in nature, so metals sampling to identify sources may be needed if iron is consistently in exceedance.

Metals results of note for this study are:

- Average and maximum total copper results at all sites except Holden Creek (E310147), including background site Nanoose Creek (E294020), were higher than the dissolved copper guideline in both summer and fall (Table 9, Table 10). As the dissolved portion can be much lower than the total copper measured, the observed values suggests that further metals monitoring should be completed to identify if dissolved metals such as copper are of concern, particularly at sites mentioned below.

- Though some total aluminum levels were elevated more than others and likely indicative of inputs (natural or anthropogenic) in the summer, none were higher than the Englishman River Water Quality Objective for dissolved aluminum. Fall total aluminum 5 in 30 values were higher than the dissolved aluminum objective at seven of the sites. Like for copper, this points to a need for further metals monitoring to identify if dissolved aluminum is of concern.
- Morningstar Creek (E318151) had consistently elevated total copper through both summer low flow and fall flush sampling, as well as elevated total aluminum in the fall flush sampling. The high metals were likely due to road influences upstream of the sample site, and golf course maintenance which may include uses of fertilizers that contain metals.
- Richards Creek (E321395) also had consistent elevated iron, manganese, and copper through the summer low flow sampling. This was likely due to the stream becoming subsurface with no surface water flow, and evaporation increasing concentrations of nutrients and metals in the pool.
- Swayne Creek (E308186) had elevated total copper during both summer low flow and fall flush samples and elevated total aluminum during fall flush. This could be due to road influence, as copper discharge can be associated with brake pads from vehicles or could be from pesticide use in agricultural areas.

Table 9: Total metals concentrations (mg/L) measured in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during 2021 summer low flow 5-in-30s. Highlighted values exceed the provincial WQGs for the specified parameter.

	Iron (mg/L)		**Copper (µg/L)**		**Aluminium (mg/L)**		**Manganese (mg/L)**	
EMS Site	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**
E290478	0.55	0.420167	0.729	0.677	0.0656	0.04335	0.15	0.097717
E290479	0.148	0.121067	0.976	0.7898	0.0184	0.015967	0.0338	0.019613
E290480	0.552	0.5126	1.19	0.8148	0.0281	0.02504	0.0924	0.07754
E290481	0.229	0.2122	1.39	1.216	0.0484	0.02558	0.0492	0.0348
E290485	0.104	0.096129	1.985	1.51	0.0222	0.018743	0.0412	0.03087
E290487	0.339	0.268	0.778	0.6242	0.0158	0.01312	0.0754	0.06858
E294020	0.0222	0.01346	0.585	0.4696	0.00541	0.00483	0.0109	0.007504
E306294	0.714	0.6246	1.06	0.8394	0.036	0.02714	0.0658	0.05128
E308186	0.76	0.550833	1.18	0.9802	0.01455	0.01126	0.453	0.2759
E310147	0.152	0.1272	0.357	0.2726	0.0164	0.012678	0.1	0.07324
E318151	0.12	0.05646	4.42	2.422	0.0218	0.01093	0.0851	0.05352
E321395	**6.16**	**4.944**	1.22	0.9326	0.0551	0.03348	**4.93**	**3.498**

Table 10: Total metals concentrations (mg/L) measured in Millstone River at Biggs Rd. (E290478), McGarrigle Creek (E290479), Millstone River at East Wellington Rd. (E290480), Millstone River at Barsby Park (E290481), Chase River (E290485), Beck Creek (E290487), Nanoose Creek (E294020), Millstone River at Jingle Pot Rd. (E306294), Swayne Creek (E308186), Holden Creek (E310147), Morningstar Creek (E318151), and Richards Creek (E321395) during 2021 fall flush 5-in-30s. Highlighted values exceed the provincial WQGs for the specified parameter.

	Iron (mg/L)		Total Copper (µg/L)		Aluminium (mg/L)		Manganese (mg/L)	
EMS Site	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**
E290478	0.143	0.11178	0.961	0.812	0.0486	0.0267	0.016	0.01394
E290479	0.0727	0.057867	0.922	0.795333	0.0731	0.04622	0.00474	0.00303
E290480	0.255	0.181833	1.2	0.936	0.0734	0.066	0.0266	0.01713
E290481	0.403	0.2654	1.58	1.2564	0.212	0.10854	0.045	0.02966
E290485	0.214	0.194833	1.74	1.42483	0.139	0.0753	0.0352	0.02153
E290487	0.744	0.5466	0.818	0.6746	0.0623	0.03584	0.0791	0.0523
E294020	0.152	0.09842	1.04	0.7382	0.164	0.08534	0.00596	0.00284
E306294	0.228	0.1692	1.06	0.8808	0.0943	0.05306	0.0268	0.01854
E308186	0.558	0.413833	2.8	2.04667	0.7675	0.46517	0.0156	0.01171
E310147	0.361	0.1943	0.978	0.5288	0.0694	0.03742	0.138	0.04234
E318151	0.945	0.608167	5.86	4.40167	1.16	0.577683	0.121	0.04933
E321395	0.768	0.6288	1.19	1.0312	0.0539	0.0343	0.0541	0.04094

7. SUMMARY

Based on data collected during both study periods (2019 and 2021), there were water quality impacts of concern at all sites sampled except Nanoose Creek (2021 background site). This was consistent with the CWMN trend report conclusions (Ecoscape, 2018; Ecoscape, 2021) and the reasons sites were initially chosen for further investigation. Results from this study confirm the need for focused watershed education and awareness to urban and rural property owners in the RDN, particularly those living or conducting their livelihoods (e.g., farming) adjacent to streams. Enforcement of the AEM Code should also result in improvements in water quality near agricultural areas.

The 2019 sampling showed phosphorus guidance for Vancouver Island was exceeded at all sites with agricultural use areas upstream. The total chloride sampling from 2019 did not indicate any major concerns.

In 2021, Nanoose Creek, as the reference site, had limited human influence upstream of the sample site and generally good water quality. All other sites had high total phosphorus and *E. coli* levels, with extremely high phosphorus levels observed at McGarrigle Creek and very high *E. coli* levels observed at Millstone River, Chase River, and Swayne Creek. Elevated nitrate could be seen at Holden Creek, Chase River, and McGarrigle Creek and Morningstar Creek. Nitrate suggests influences from agricultural practices. Richards Creek had consistent nutrients and metals exceedances in summer when flows are lowest, likely due to concentration of contaminants from evaporation. Together, these results suggest that agricultural activity and road runoff are large contributors to negative impacts in the study area, contributing to the poor water quality in Millstone River, McGarrigle Creek, Swayne Creek, Holden Creek, Morningstar Creek, and Chase River.

As best management practices of agricultural fertilizers and livestock waste can greatly reduce nutrient and microbiological impacts to nearby waterbodies, recommendations from this study are:

- Continue further investigation of nutrient inputs at McGarrigle Creek to improve water quality at this site in the future. The very high levels of total phosphorus and elevated nitrate and ammonia observed at this site relative to other sites sampled suggest a single source contribution.
- Conduct sampling for dissolved metals to enable comparison to BC WQG at sites where elevated total copper and aluminum were observed.
- Conduct focused watershed awareness and best management practices education efforts to agricultural landowners adjacent to several sites, with McGarrigle Creek and Holden Creek being the highest priority. Richards Creek and Millstone River are also high priority sites, as well as properties along Morningstar Creek.
- Continue community education efforts around watershed awareness, rainwater (stormwater management) and non-point source contaminants.
- Collaborate with managers of parks and other recreation sites to increase signage and dog waste cleanup stations to reduce pet waste washing into streams.

These recommendations are in support of the AEM Code of Practice and will help reduce agricultural impacts on watersheds. There are explanations of what actions are required under the Code of Practice at the AEM website (AEM Code, 2019). Continued monitoring and investigation can help direct future outreach and education attempts. Future outreach should indicate any additional measures needed to manage agriculture and stormwater impacts on streams.

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APPENDIX A

Table 11: Chloride data from 2019 sampling.

EMS ID	Max of dissolved chloride (mg/L)
E240141	3.03
E243021	5.17
E243022	
E243024	
E248835	
E288090	11.9
E288091	
E288092	
E288093	
E308186	

Table 12: Turbidity values from 2019 sampling. Shows maximum and minimum of all sites sampled. Highlighted values are in exceedance of Englishman River WQOs.

EMS ID	Max of Turbidity (NTU)	Min of Turbidity (NTU)
E240141	3.07	1.46
E243021	2.07	0.2
E243022	3.36	0.24
E243024	0.76	0.08
E248835	**7.74**	0.29
E287131	1.81	0.24
E288090	1.93	0.1
E288091	3.97	1.19
E288092	3.36	0.49
E288093	3.41	1.29
E290452	3.54	0.26

Table 13: Comparison of ALS regular and replicate samples from 2021 sampling. Values highlighted are in exceedance of the acceptable percentage differences (25%).

Date	Site	Percent Variation
26-May-21	Morningstar	3.31
22-Jun-21	Millstone at Biggs Rd	10.73
14-Jul-21	Richards Creek	13.83
03-Aug-21	Swayne Creek	5.25
10-Aug-21	Millstone at Biggs Rd	3.45
17-Aug-21	Chase River	6.99
24-Aug-21	Chase River	5.53
31-Aug-21	McGarrigle Creek	5.52
14-Sep-21	Nanoose Creek	3.62
05-Oct-21	Chase River	4.42
12-Oct-21	Millstone at East Wellington	4.64
19-Oct-21	McGarrigle Creek	4.10
06-Oct-21	Swayne Creek	4.93
02-Nov-21	Morningstar	4.66