ENVIRONMENTAL QUALITY SERIES

Nooksack River Transboundary Report: August 2018 to September 2019 Data Summary

Julie Porter, Lyndsey Johnson, Deb Epps

November 2019

No. 2019-02

This is the second data summery report for the Nooksack Watershed Transboundary Partnership**.** The Ministry of Environment and Climate Change Strategy conducts water quality monitoring of freshwater and marine water through numerous programs to evaluate the condition of waterbodies in B.C. For additional information visit: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-monitoring/water-quality-monitoring-documents

ISBN:

Citation:
Porter, J.A. and L. A. Johnson. 2019. Nooksack River Transboundary Project, August 2018-September 2019 Data Summary Report. Environmental Quality Series. Prov. B.C., Surrey B.C.

Author's Affiliation:

B.C Ministry of Environment and Climate Change Strategy

Cover Photographs:
Fishtrap Creek at Echo Rd, credit: Lyndsey Johnson

Acknowledgements

We would like to thank the many people who contributed to this project's development and execution. Thank you to staff from the Washington State Department of Health, Washington State Department of Agriculture and Whatcom Conservation District who provided guidance related to sampling techniques and protocols used in Washington.

We are grateful to the Langley Environmental Partners Society (LEPS) and their staff who helped collect the aquatic ecosystem samples. Thank you also to Lisa Dreves and Pina Viola from LEPS.

We would like to acknowledge the authors of this summary report: Julie Porter, Environmental Impact Assessment Biologist, with senior reviews by Deb Epps, Section Head Provincial Water Quality, Lyndsey Johnson, Environmental Impact Assessment Biologist, and Jillian Tamblyn, Senior Environmental Impact Assessment Biologist. Jennifer Wilson, Compliance, and Michael Dykes, Spatial Data Analyst, also contributed.

EXECUTIVE SUMMARY

The Nooksack River is located south of the United States–Canada Border in the State of Washington and discharges primarily into Bellingham Bay through a wetland system. Bertrand Creek and Fishtrap Creek are two large sub-basins of the upper Nooksack River Watershed that straddle the international boundary. As part of the Nooksack Watershed Transboundary Project, both the B.C. Ministry of Environment & Climate Change Strategy (ENV) and Washington State (WA) Department of Ecology are conducting sampling programs to monitor and address the high concentrations of microbiological indicators influencing the closure of shellfish production in Portage Bay near the Lummi Reservation (and located within Bellingham Bay) in WA State. ENV is working on opportunities to reduce preventable sources of fecal coliform bacteria on the Canadian side of the border.

Since 2017, monthly water samples have been collected by the Monitoring, Assessment & Stewardship (MAS) section of the B.C. ENV and the Langley Environmental Partners Society (LEPS). In March 2018, a bacterial source tracking sampling program was initiated. Based on the review of data collected from 23 sample sites by both ENV and LEPS between August 2018 and July 2019, each of the four streams (Cave Creek, Bertrand Creek, Fishtrap Creek and Pepin Brook) sampled in the Nooksack River Watershed display various issues with fecal coliform and *E. coli* concentrations, including applicable water quality guideline exceedances.

The highest fecal and *E. coli* concentrations were observed in Spring and to a lesser degree in the Fall. In addition, some of results in the upper sites tended to be higher than sites located closer to the border. Preliminary results from the bacterial source tracking project indicate specific fecal sources, which are predominately roof bird, duck, dairy and human in all four creeks. A benchmark (goal) for the four border sampling sites was established through collaborative efforts between ENV and WA for *E. coli*. The border specific benchmark was set at 200 CFU/100 mL geometric mean for *E. coli*; all but the Cave Creek border site met this benchmark during the first round of 5-in-30 geometric mean sampling (refers to five consecutive weekly samples collected within 30 days).

While the primary focus of this project is on fecal concentrations, water samples are also analyzed for nutrients to provide additional information about the watershed. It appears there is a concern in nutrient data pertaining to phosphorus. Although no water quality guideline exists, literature suggests that 10 µg/L of phosphorus is acceptable, based on a mean of monthly samples collected between May and September. Every site sampled, with the exception of one site, had extremely high concentrations, sometimes thousands of times over the suggested limit. Phosphorus is another indicator of nutrient overload often linked to fertilizer. Excessive amounts of phosphorus can result in harm to aquatic life.

Our sampling programs are progressively identifying sources and sites of concern which have the potential to lead to a decrease in fecal contamination and an increase in public awareness and education. Continued sampling will further identify sources and provide a better understanding of links to rainstorm events, the timing of manure spreading and overall annual trends.

CONTENTS

FIGURES

TABLES

ACRONYMS

B.C.	British Columbia
CFU/mL	Colony Forming Units per millilitre
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
ENV	Ministry of Environment and Climate Change Strategy
HBPO	Human Boat Pump Out
LEPS	Langley Environmental Partnership Society
SOP	Standard Operation Procedures
TCG	Transboundary Technical Collaboration Group
URL	uniform resource locator (website address)
WA	State of Washington
WWTP	Waste Water Treatment Plant
WQTG	The Nooksack River Water Quality Task Group

1. PROJECT BACKGROUND

1.1 Introduction

This report provides an overview of water quality data collected between fall 2018 and summer of 2019, including Bacterial Source Tracking (BST). This report is the second annual summary in the three-year Nooksack River Transboundary project. The first summary report was released in April 2019 and reported on data from June 2017 to July 2018.

The Nooksack River is located south of the United States–Canada Border in the State of Washington and discharges primarily into Bellingham Bay through a wetland system. The watershed for this river spans both the United States and Canada (Figure 1). In recent years, this watershed has experienced a significant increase in urban and agricultural development, which has led to an overall decline in water quality and ecosystem health. At the mouth of the Nooksack River is the Lummi Indian Reservation. Since 1998, Lummi Nation shellfish beds in Portage Bay have been closed for harvesting up to six months of the year due to seasonally elevated fecal coliform bacteria levels in the marine water (British Columbia Ministry of Environment and Climate Change Strategy [B.C. ENV], 2018b). The closures typically last from April to June and from October to December, and May and November historically have the highest fecal coliform counts.

Bertrand Creek and Fishtrap Creek are two large sub-basins of the upper Nooksack River Watershed that straddle the international boundary. Pepin Brook flows into Fishtrap Creek south of the international border. About half the land areas of both Bertrand Creek and Fishtrap Creek Watersheds are in British Columbia (B.C.), Canada, and half are in the State of Washington (WA), United States. Both B.C. and WA are working to understand the sources of fecal coliform pollution and to share best practices to reduce these sources and improve water quality.

The Nooksack River Water Quality Task Group (WQTG) began meeting in late 2016 to better understand water quality conditions and identify opportunities to reduce preventable sources of fecal coliform pollution in the transboundary area of the watershed. Water quality improvement efforts support mutual public and environmental health goals within the lower Nooksack River system and benefit shellfish harvest recovery efforts in the Nooksack River's receiving waters of Portage Bay (Portage Bay Shellfish Protection District Committee, 2014).

In August 2018, the WQTG recommended establishing a multi-agency Transboundary Technical Collaboration Group (TCG) for three years (August 2018 to August 2021). The TCG aims to deliver bacteria pollution reduction activities, as outlined in the Three-Year Work Plan and Terms of Reference. One of the WQTG's recommendations for the TCG was to continue long- and short-term ambient sampling in freshwater areas and to continue source identification sampling, including water quality monitoring, to identify fecal coliform sources.

Fecal coliforms are a subset of total coliform bacteria. Typically found in the gut and feces of warm-blooded animals, they are a better indicator of animal or human waste than total coliforms (U.S. Environmental Protection Agency, 2012). *Escherichia coli* (*E. coli)* is a species of fecal coliform that is specific to fecal material from humans and other warm-blooded animals and is typically used by the U.S. Environmental Protection Agency as an indicator of the health risk from water contact during recreation. In B.C., *E. coli* is also the preferred indicator in freshwater environments (Warrington, 2001).

ENV has three sampling programs developed to monitor and address the fecal coliform exceedances influencing the closure of shellfish production in the Nooksack Watershed. They include regular monthly sampling, five weekly consecutive samples collected in 30 days (5 in 30), and BST sampling. These programs are described in more detail in the Methods section below. In addition, ENV is also involved in compliance activities, including promotion of best management practices as well as enforcement of unauthorized discharges and permit inspections.

British Columbia - Washington Nooksack River Transboundary Water Quality Project

Site Type

- EMS
- LEPS
- EC

Freshwater Atlas - Watershed

- Bertrand Creek
- Fishtrap Creek
- Watersheds

- Streams / Ditches / Drainage Channels
- Lake - Definite
- Lake - Indefinite
- Lake - Intermittent
- Reservoir - Definite
- Canal
- Tailing Pond

- Parcels with Livestock

Agriculture Structures

- Poly greenhouse
- Glass greenhouse
- Crop barn
- Farm

Cultivated Field Crops

- Cereals & Oilseeds
- Tree fruits
- Vines & berries
- Forage, pasture
- Vegetables
- Floriculture
- Specialty, Turf, Nut trees
- Nursery & Tree plantations
- Other

Coordinate System: NAD 1983 BC Environment Albers
Projection: Albers
Datum: North American 1983

Created by Innovation and Adapatation Services Branch
Created on 2019/05/09

Document Path: S:\Gis\Requests\Mapping\Nooksack_20180730\Nooksack20190313.mxd

N

0 1 2 3 4 Kilometers

0 0.5 1 1.5 2 Miles

British Columbia | Ministry of Agriculture

1.2 Land Use

In BC, the Nooksack River Watershed is located in the Fraser Valley Region, which receives upwards of 600 mm of rain annually from October 1 to April 1. Rain events in the seasons between Fall 2018 and Summer 2019 were seasonally average (Environment and Climate Change Canada, 2019).

The BC portion of the Nooksack Watershed is of mixed used including; industrial (compost, greenhouse, mushroom compost and on land finfish), residential, parkland and agriculture including raising livestock (horses, beef cattle, dairy cattle, sheep, goats, llamas, donkeys, game, mink and chickens), providing forage and pasture, operating nurseries and greenhouses, and growing trees, berries, vine crops, mushrooms and other field vegetables or flowers (B.C ENV, 2018b). The WA portion of the Nooksack Watershed is predominately comprised of dairy farms and berry fields.

Bertrand Creek, located in the Township of Langley, flows near berry farms, and industrial operations including mushroom facilities. Pepin Brook flows through farm land, but mostly through Aldergrove Regional Park before crossing into WA. Fishtrap Creek and its tributaries flow through mostly agriculture, specifically berry growing and the cattle industry.

Water uses in this region include irrigation, well water for drinking, and water for animals' consumption. Pepin Brook flows through a well used recreational park, where there is likely primary contact by domestic animals and humans.

1.3 Water Quality Sampling

The Monitoring, Assessment & Stewardship (MAS) section of the B.C. ENV has been collecting water samples from Bertrand Creek, Fishtrap Creek and Pepin Brook since June 2017. Prior to this, the Langley Environmental Partnership Society (LEPS) collected samples as per their contract with WA. When their contract ended December 2018, ENV took over some sample sites, based on high fecal coliform results and geographic location.

1.4 Compliance Activities

Building on the success of the previous Compliance Team inspections of 2017-2018, additional inspections were conducted in May of 2019. The sites chosen for inspection were based on previously planned inspections for specific sector activities permitted under the *Environmental Management Act* (EMA), as well as recommendations from the MAS group based on their findings through this project. Most of the inspections were located near Cave, Bertrand and Fishtrap Creeks and included hobby farms, chicken facilities and horse boarding businesses. Most of these properties were found to be complying. However, there was one property that had been receiving manure and stock piling it on the land adjacent to a tributary that enters Bertrand Creek upstream from site E273723 (near 16th Avenue). This property was inspected and found to be out of compliance, resulting in an order being issued under EMA. An order issued by the compliance section requires the landowner to rectify the non compliance issue (like improper manure storage). High fecal coliforms from this property may be affecting the exceedances at site E273723.

1.5 Report Objectives

The objective of this report is to provide an analytical summary of the sampling results for year two of this transboundary project. It will note any improvements, identify any trends and make recommendations to the existing monitoring programs through the adaptive management process. This report will also form the basis for discussions with our WA partners as well as help focus future compliance activities.

2. METHODS

2.1 Water Quality Sampling

Discrete (or grab) water samples were collected by ENV in accordance with the *B.C. Field Sampling Manual* (B.C. ENV, 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 specific to the parameter being tested. Samples were either collected monthly or five consecutive weekly samples collected within 30 days (i.e., 5-in-30 sampling).

Parameters collected *in situ* using a hand-held metre (YSI pro plus meter) included:

- pH,
- temperature,
- specific conductivity, and
- dissolved oxygen (DO) (mg/L and %).

Monthly water samples were analyzed for:

- General chemistry: total organic carbon, total suspended solids,
- Nutrients: ammonia, chloride, nitrate and nitrite, total Kjeldahl nitrogen, total nitrogen (N), total organic nitrogen, dissolved ortho-phosphate, phosphorus,
- Microbiological parameters: *E. coli* and fecal coliform bacteria

5-in-30 samples were only analyzed for microbiological parameters. Samples were delivered to ALS Laboratory in Burnaby for analysis on the same day they were collected. Quality assurance and quality control methods included replicate sampling (10% of samples, or 1 replicate sample, and travel blank per sampling event). Replicate samples that were collected for bacteriological indicators were incorporated into the seasonal geomean calculations, thus some of these geomeans may be based on four to six samples rather than the regular three (one per month). The relative percent differences were found to be highly variable in the bacteriological replicate samples.

Table 1: Summary of ENV water quality sampling events and number of samples collected

Sampling date	Cave Creek	Bertrand Creek	Pepin Brook	Fishtrap Creek	Total number of samples collected
August 13, 2019	1	5	5	3	14
September 9, 2018	1	5	5	3	14
October 16, 2018	1	5	4	5	15
November 06, 11, 20, 27, 2018	1	17	16	8	42
December 04, 2018	2	7	5	3	17
January 09, 2019	1	7	5	3	16
February 21, 2019	1	7	6	3	17
March 13, 2019	2	7	6	4	19
April 16, 2019	3	8	6	4	20
May 15, 2019	2	18	16	8	42
June 06, 2019	2	8	6	3	19
July 02, 09, 16, 23, 30, 2019	5	7	5	6	23
August 20, 2019	0	7	5	2	14
September 16, 2019	2	7	2	2	13
Total	24	115	92	57	288

2.2 Bacteriological Sampling

The BST program is a collaboration of both ENV and WA, based on the Whatcom County Water Quality Program Bacteria Monitoring QAPP (Douglas, 2017). Detection of fecal pollution by molecular source tracking (MST) targets a number of genetic markers from a limited number of gut microbes which are believed to originate from specific sources. A whole sample DNA sequencing (WSS) method using next generation DNA sequencing (NGS) platform was used to sequence all DNA obtained directly from fecal sources to provide a thorough analysis of the species present in the sample.

The sampling methodology consists of two parts: discrete water sampling and fecal samples, the latter to build a DNA reference library. The DNA reference library in an integral part for analysis. All fecal samples were collected within the Nooksack Watershed.

Discrete water samples were collected by ENV and rain events were targeted to get the maximum coliform possible. Four litre plastic bottles, supplied by ALS Labs, were filled up to 2 litres as required by Exact Scientific Services lab, located in WA State.

Water samples were analyzed for:

- Microbiological parameters: *E. coli* and fecal coliform bacteria,
- 16S DNA analysis (species type),
- Next Generation DNA analysis (species abundance).

Water samples for DNA analysis were selected based on a series of steps to determine their viability (Figure. 2). It was under the assumption that a certain number of fecal bacteria (CFU/100 mL) was needed to get robust DNA results. Therefore, if the sample had over 100 CFU/100 mL of *E. coli* or fecal coliform it would be analysed to identify species. If there were special circumstances such as over 500 CFU/100 mL the sample would also receive “shotgun” analysis to identify diversity and abundance.

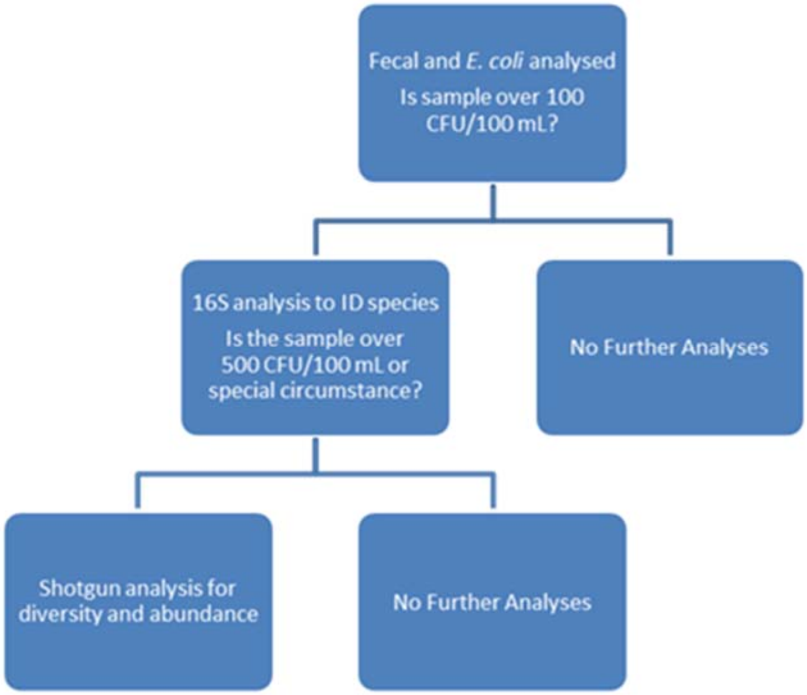

Figure 2: Flow chart of DNA analysis methods.

It is important to note that the DNA results graphed for each creek shows the species percent of the DNA that was identified in the fecal library, not a percentage of bacteria CFU counts. There are still many unidentified bacteria and coliforms in each sample. The amount of unidentified bacteria numbers will decrease as different fecal sample sources are added to the library. A summary of the BST sampling is provided in Table 2.

Table 2: Summary of ENV BST sampling

BST Sampling date	Cave Creek	Bertrand Creek	Pepin Brook	Fishtrap Creek	Total number of samples collected
November 17, 2018	0	3	3	3	9
December 05, 2018	0	3	3	3	9
December 11, 2018	0	2	4	0	6
January 22, 2019	0	4	3	3	10
February 01, 2019	1	6	4	1	12
February 20, 2019	2	5	5	1	13
March 07, 2019	2	2	3	0	7
Total	5	25	25	11	66

Fecal sampling protocol was based on a standard operating procedure (SOP) created by Whatcom County based on previous studies and guidance (Embertson et al, 2019). ENV adopted these methods and field testing kit to reduce variability and error. A field sampling kit consisting of a whirl bag, gloves, sterile spoon were used to obtain a sample. Each sample has a field sheet recording species and location of the sample. Samples were then frozen and collected by biologists from Trinity Western

University for DNA extraction.   These DNA samples were then delivered to Exact Laboratory by the TWU lab biologist. The fecal samples were then added to the fecal reference library along with samples from WA (Table 3).

Table 3: ENV and WA fecal reference library table

WA Scat Samples			BC Scat Samples
Beaver	**Duck**	**Racoon**	**Goat**
Beef (grass eating animals)	**Goat**	**Roof Bird (starling and crow)**	**Rabbit**
Chicken	**Goose**	**Seagull**	**Sheep**
Dairy Lagoon	**Horse**	**Sheep**	**Chicken**
Dairy Solids	**Human Boat Pump Out**	**Swan**	**Mink**
Deer	**Human WWTP (septic)**	**WWTP Water**	**Horse**
Dog	**Pig**		**Cow**

Some scat sample identifiers in the reference library are multi-species either because the scat is too hard to collect individually (crow and starling) or until more individual samples can be obtained and analysed. The Beef sample is also multi-species comprised of grass eating animals. The human fecal samples are categorized according to treatment methods: Human Boat Pump Out (HBPO), was collected from vessels pumping out their sewage systems, Human Waste Water Treatment Plant (WWTP) from septic systems and WWTP Water, collected from waste water before entering treatment. Canadian results that are labelled HBPO may be from recreational vehicles rather than vessels because there are no water craft use in the Nooksack Watershed; further research into the fecal library is needed.

3. WATER QUALITY GUIDELINES

B.C. ENV developed ambient water quality guidelines (WQG) to assess and manage the health, safety and sustainability of B.C.'s aquatic resources. These WQGs were established to protect designated uses such as aquatic life, wildlife, agriculture, drinking water sources and recreation. They include guidelines for microbiological indicators, which are types of bacteria used to detect and estimate the level of fecal contamination in water. Bacteria often enter surface waters via point and non-point sources, including wild and domestic animal feces as well as seepage from leaking or failing septic systems. In this summary report the WQG's are only used for comparison of the 5 in 30 sampling data as they allow for the proper geometric mean calculations as per the guidelines.

Fecal coliforms have been used extensively for many years as indicators to determine the sanitary quality of surface, recreational and shellfish-growing waters. However, more recent studies have shown that *E. coli* is the main thermo-tolerant coliform species present in fecal samples (94 percent) from humans and other endotherms, such as birds and mammals (Tallon, Magajna, Lofranco, & Leung, 2005). In addition, where fecal coliform concentrations are higher than those of *E. coli*, it's highly likely that non-fecal sources have contributed. Current B.C. WQGs are based on *E. coli* as the freshwater indicator and enterococci as the marine indicator for microbial contamination. However, the Environment and Climate Change Canada shellfish program and Washington State still use fecal coliforms as indicators of risk in marine water. Therefore, this study monitored both fecal coliforms and *E. coli* in order to provide appropriate resource management recommendations to both B.C. and WA decision makers.

Table 4 provides the relevant guidelines for *E. coli* and fecal coliforms used in this report. Note that the updated 2017 B.C. Recreational WQGs document archived the fecal coliform guideline for recreation (≤ 200 colony-forming units (CFU)/100 mL geometric mean, based on the 2001 B.C. ENV report [Warrington, 2001]) and identified *E. coli* as the preferred indicator (B.C. ENV, 2017). Also, note that the primary contact recreation fecal coliform criteria for Washington State is 100 CFU/100 mL, based on the geometric mean, with no more than 10% of the samples exceeding 200 CFU/100 mL (Washington State Department of Ecology, 2019).

Table 4: Applicable water quality guidelines.

ENV-approved water quality guidelines	***E. coli***	**Fecal coliform**
Primary recreation	≤ 200 CFU/100 mL (based on a geometric mean of a minimum of 5 samples collected weekly within 30 days); or < 400 CFU/100 mL (single-sample maximum concentration)	No B.C. guideline *<u>For comparative purposes:</u>* *Archived B.C. WQG = ≤ 200 CFU/100 mL geometric mean (based on a geometric mean of a minimum of 5 samples collected weekly within 30 days)* *Washington State Primary Contact Recreation Criteria: 100 CFU/100 mL (based on the geometric mean), and not more than 10% of the samples exceeding 200 CFU/100 mL.*
Irrigation crops eaten raw	77 CFU/100 mL (based on a geometric mean of a minimum of 5 samples collected weekly within 30 days)	≤ 200 CFU/100 mL (based on a geometric mean of a minimum of 5 samples collected weekly within 30 days)
General irrigation	≤ 1,000 CFU/100 mL (based on a geometric mean of a minimum of 5 samples collected weekly within 30 days)	≤ 1,000 CFU/100 mL (based on a geometric mean of a minimum of 5 samples collected weekly within 30 days)

4. RESULTS

The water quality data in this report was collected from a total of 23 sample sites from August 2018 to September 2019; the sample locations are described in Table 2. Typically, geometric means are calculated based on 5 consecutive weekly samples collected within a 30-day period; however, due to the lack of weekly data sets, in this report, we calculated the geometric means seasonally and used the monthly sampling results (n=3), with some months having an n of up to 6 as additional BST fecal results were used. While the WQG's were used as a basis of comparison for these seasonal geomeans, they are only shown graphically on the benchmark and 5 in 30 sampling data.

The data were grouped by season using the Equinox calendar:

- Winter: December 21 to March 20
- Spring: March 21 to June 21
- Summer: June 22 to September 22
- Fall: September 23 to December 20

The data results in this report are presented by watershed, moving west to east (Bertrand Creek, Pepin Brook and Fishtrap Creek). Within each watershed, the data are summarized by parameter (i.e., fecal coliforms, *E. coli,* then BST). Results above the WQGs are called exceedances. The data are followed by a discussion section that provides insight into the potential sources of contamination for each watershed. Recommendations, including any changes to future monitoring programs, are proposed at the end of the report.

Criteria for determining actual sites of concern (or "hotspots") included three qualifiers:

- high geometric means (over the guideline limits for recreation and irrigation) or over 400 CFU/100 mL,
- the number of times the sites exceeded the guidelines (above 50 percent of sample dates),
- extremely high maximum grab sample results (anything above 1,000 CFU/100 mL).

4.1 Bertrand Creek Results

The Bertrand Watershed drains an area of approximately 42.8 km^2 and is the largest creek system in the Canadian part of the Nooksack Watershed. Cave Creek is a 4 km long tributary to Bertrand Creek which joins Bertrand Creek approximately 250 m south of the border (Pearson, 1989) and therefore, water quality results are combined for both creeks, with the exception of the bacteriological source results. Bertrand Creek provides habitat for several species such as Nooksack dace and Salish sucker, and coho salmon (LEPS, 2019). Bertrand Creek's headwaters originates close to Fraser Highway, west of Aldergrove, and continues to flow through residential and urban areas. As the creek loops south, it flows through agricultural areas where Howes Creek (a tributary) joins to the main arm. Flow, water temperature, and dissolved oxygen lessen during summer months, with some sites on Howes Creek and Bertrand becoming ephemeral. The water in Bertrand Creek and its tributaries is highly influenced by farming practices and possible urban contamination such as reported incidents of homeless camps dumping their refuse into the headwater portion of Bertrand Creek in Aldergrove.

Using the WQG's for raw crops (200 CFU/100 mL) and irrigation (1000 CFU/100 mL) as a reference, there are several exceedances in different seasons and sites (Figure 3). Seasonally, fall 2018 had overall lower bacteriological concentrations than winter, spring and summer (except for Bertrand at 256th, North of

12th, E314990 (B-10). However, both spring and Summer of 2019 had more exceedances of the 200 CFU/100 mL raw crops WQG than fall and winter.

4.1.2 Fecal Coliform

The main sites of concern are E314990 and Howes Creek E206847 because their concentrations have been above 1000 CFU/100 mL. These sites are both located downstream of composting facilities. The remaining sites all show variability from season to season and site to site. All sites except E293977 had concentrations higher than 400 CFU/100 mL in Summer of 2019 (Figure 3).

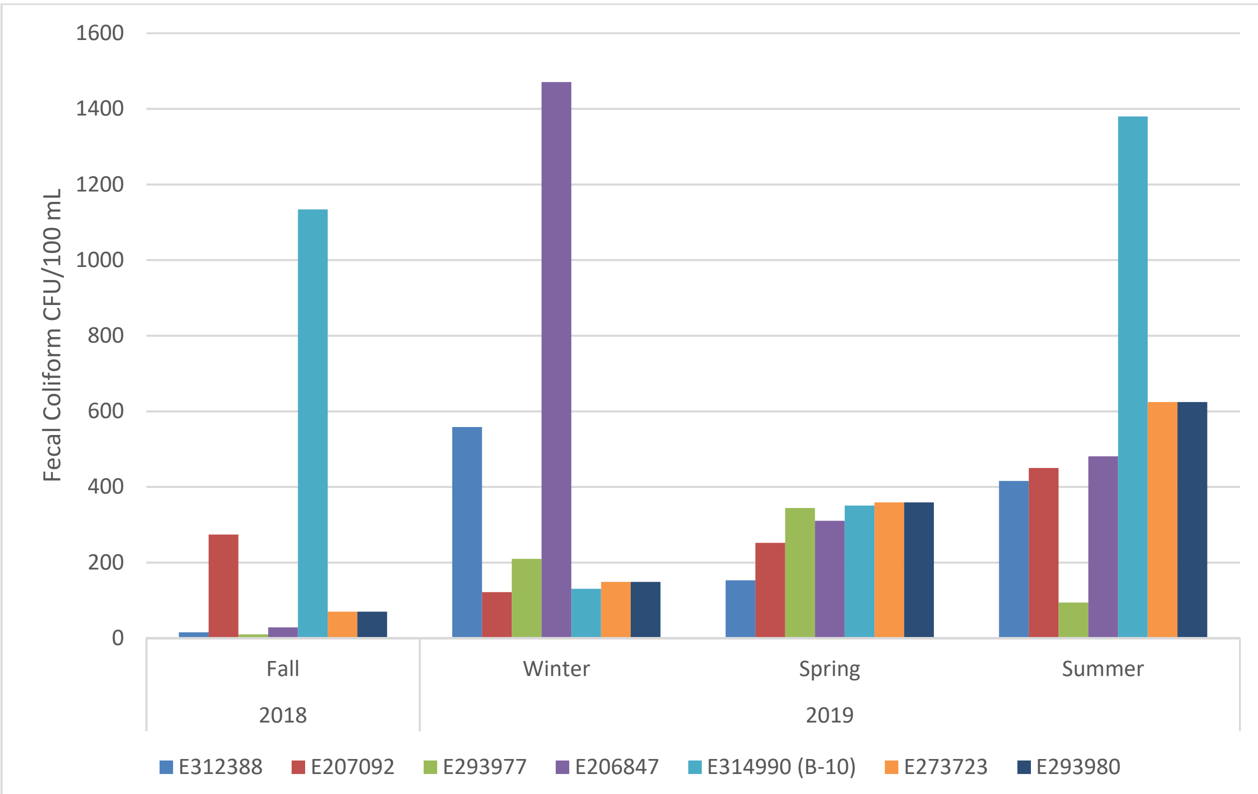

Figure 3: Bertrand Creek fecal coliform results by season and sample site

4.1.3 *E. coli*

The *E. coli* results follow the same patterns as the fecal coliform results, although with lower concentrations, as expected (Figure 4). These results confirm that sites E314990, E2306847 and E312388 are areas of fecal pollution and may need more compliance action.

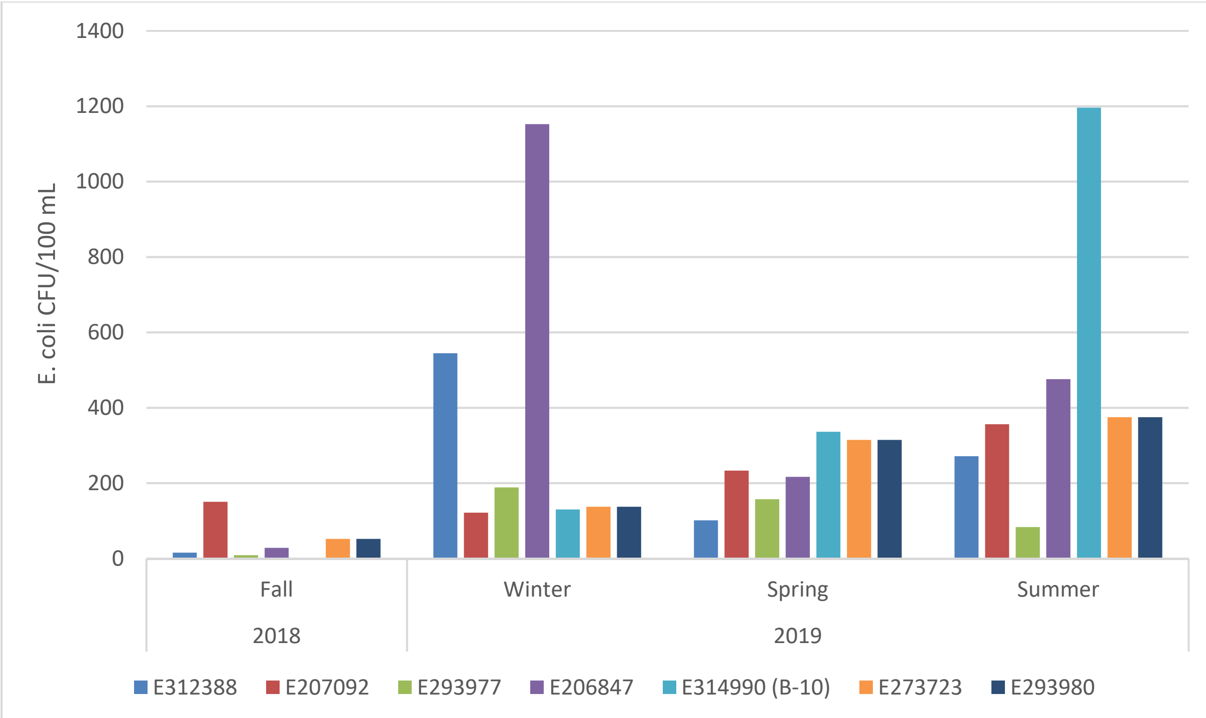

Figure 4: Bertrand Creek E. coli results by season and sample site. There was no E. coli data collected for site E314990 in Fall 2018.

4.1.4 Bacterial Source Tracking

The BST results are shown separately for each Cave Creek and Bertrand Creek in this report. Although these creeks eventually confluence across the border, the DNA results upstream for both may be from significantly different sources.

Cave Creek

There are only two sample sites on Cave Creek due to its small size. However, BST sampling was still conducted as the creek flows through agriculture and small hobby farms. The BST results included DNA from the following sources: Beef (cow), Dairy Lagoon, Dairy Solids, Duck, Human Boat Pump Out (HBPO), Human Waste Water Treatment Plant (WWTP), Roof bird, and WWTP Water (Figure 5). There is still some work to be done on source identification, as there is likely no human boat pump out in this system. It may reflect RV pump outs instead or septic systems.

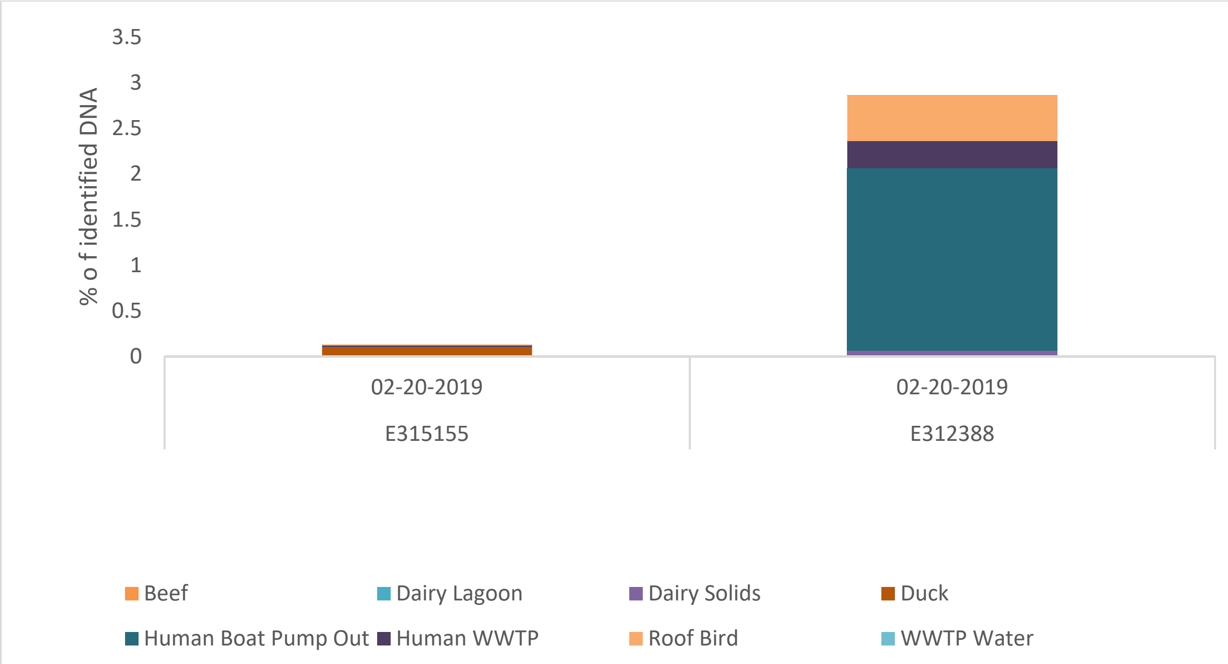

Figure 5: BST DNA results by species on Cave Creek. These percentages are based on the actual percent of DNA identified.

Site E315155 is located upstream from the border at 248th, the DNA results were mostly duck, with some Roof bird and Human WWTP. However, at the border site E312388, the top three species are HBPO, Roof Bird, and Human WTTP. As mentioned above the HBPO is not likely present in this watershed, and in fact the source of bacteria is likely from RV or holding tank units.

Bertrand Creek

The following species were detected at least once in the Bertrand Creek system: Beef (cow), Dairy Lagoon, Dairy Solids, Duck, Human Boat Pump Out, Human Waste Water Treatment Plant (WWTP), Roof Bird (crow, starling), and WWTP water (Figure 6).

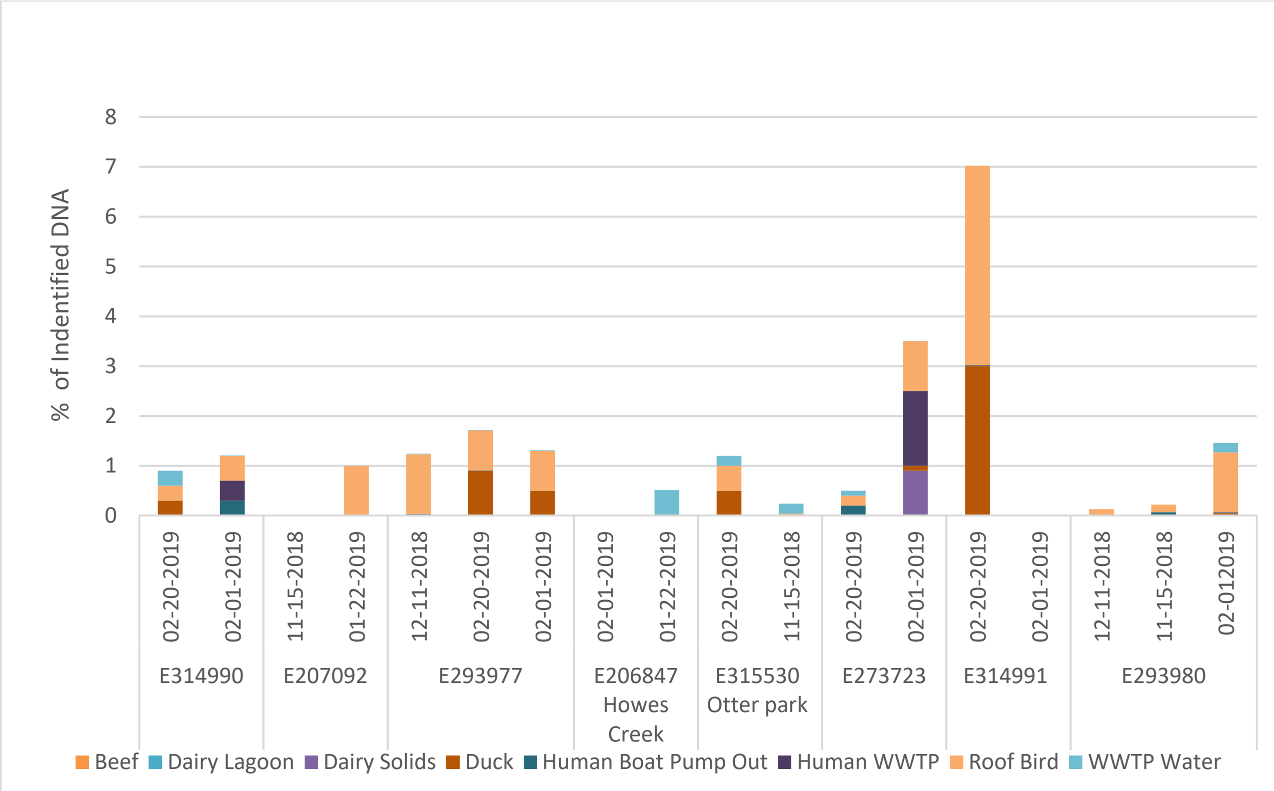

Figure 6: BST DNA results by species. These percentages are based on the actual percent of DNA identified.

The top three most prominent fecal sources in Bertrand Creek are Roof Bird, Duck, and Human WWTP. It is unlikely the contributions from Roof Bird and Duck can be controlled. However, the human sources, likely septic systems, could be addressed through collaboration with local health authorities and municipalities.

4.1.5 Nutrients and Physical Water Quality Results

Nutrient and physical parameter exceedances are shown in Appendix B. It is noted that continuous and high phosphorus results were recorded at every sampling event. Phosphorous is a cause for concern because its an indicator of nutrient loading, possibly from fertilizer application, manure and/or organic waste in sewage and industrial effluent. There are no stream WQG's for phosphorus, however, a draft report based on Vancouver Island Streams (similar to the Nooksack Watershed) suggests that May to September total phosphorous average, with samples collected monthly, should not exceed 5 µg/L, and maximum total phosphorous should not exceed 10 µg/L in any one sample (Nordin, 2019). According to this suggested guideline, phosphorus exceedances for a single sample of over 10 µg/L happens at least 98% of sampling events. The phosphorus maximum of 10 µg/L was used for comparison because of the lack of data for a monthly average; these results can be found in Appendix C. Phosphorus can be quite damaging to aquatic life due to decreased oxygen levels, and can cause eutrophication, creating unsightly algal blooms.

Nutrient sampling occurred seasonally, until summer of 2019. Nutrients are now being taken monthly during regular sampling.

As mentioned, phosphorus is in exceedance in every nutrient sample collected in Cave and Bertrand Creek. Of particular concern is that phosphorus results for Howes Creek E206847 were at least 1000 times over the suggested guideline of 10 g/L.

Cave Creek at the border site E312388 had two exceedances of the short term (acute) chloride irrigation guideline of 100 mg/L.

During the warm summer months, dissolved oxygen often drops below the instantaneous minimum of 5 mg/L, which is below the BC WQG for all life stages of fish, other than buried embryo/alevin; it is unlikely there is spawning in much of Bertrand and Cave Creek due to the silty substrate and therefore the guidelines for embryo/alevin would not apply. Lower dissolved oxygen concentrations occur because of the low flow and higher temperatures during the summer season, however as mentioned high phosphorus concentrations may be having an effect on DO.

4.2 Pepin Brook Results

Pepin Brook drains approximately 7.2 km^2 and is the smallest system in the Nooksack Watershed, mostly flowing through Aldergrove Regional Park. It provides habitat for species like lamprey, longnose dace, coho salmon, cutthroat, trout, rainbow trout and American shad as well as endangered species of Nooksack dace and Salish sucker (LEPS, 2019). There is a large composting facility that discharges its effluent into a tributary to Pepin Brook, which may directly affect the water quality in this system.

4.2.1 Fecal Coliform

As Figure 7 shows, there are still large exceedances from Site E309447, which is the Pepin Brook Tributary below a compost facility. All the remaining samples are less than 200 CFU/100 mL, with the exception of E208494 in the fall of 2018.

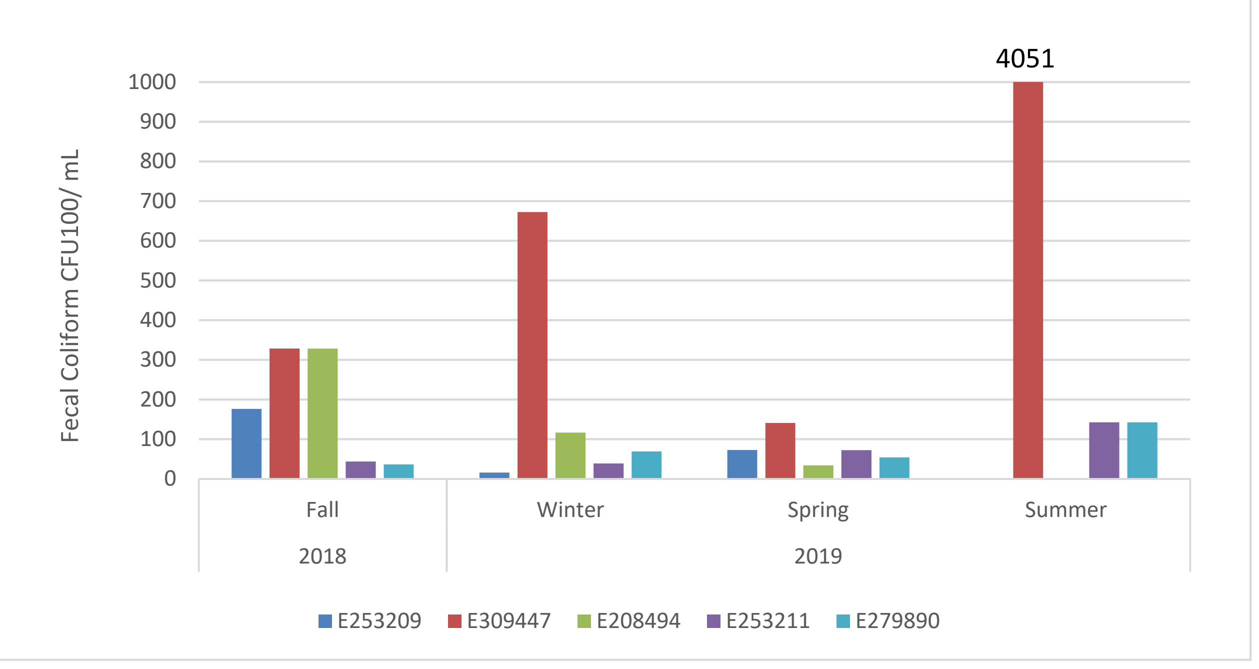

Figure 7: Pepin Brook Fecal Coliform results per season and sample site

4.2.2 *E. coli*

Figure 8 also shows a very high concentration for *E. coli* at site 306447 in summer and a slightly higher concentration in winter above 200 CFU/100 mL. All the remaining sites are below 200 CFU/100 mL for all seasons.

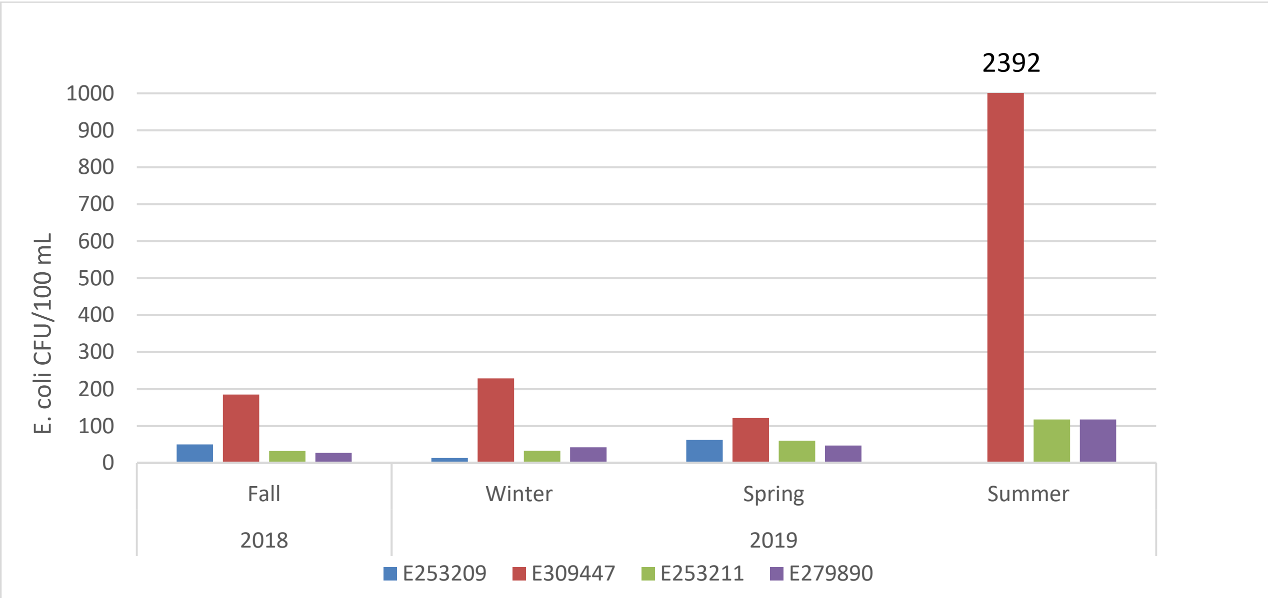

Figure 8. E. coli results per season and sample site

4.2.3 Bacterial Source Tracking

The species detected in Pepin Brook are: Beef, Dairy Lagoon, Dairy Solids, Duck, HBPO, Human WWTP, Roof Bird and WWTP Water (Figure 9). Roof Bird and Duck likely correlates to the numerous roof birds that perch at the compost facility in large numbers, scavenging the compost piles. WWTP water was also found in sites that have hobby farms near by, again a possible indicator of septic system failure.

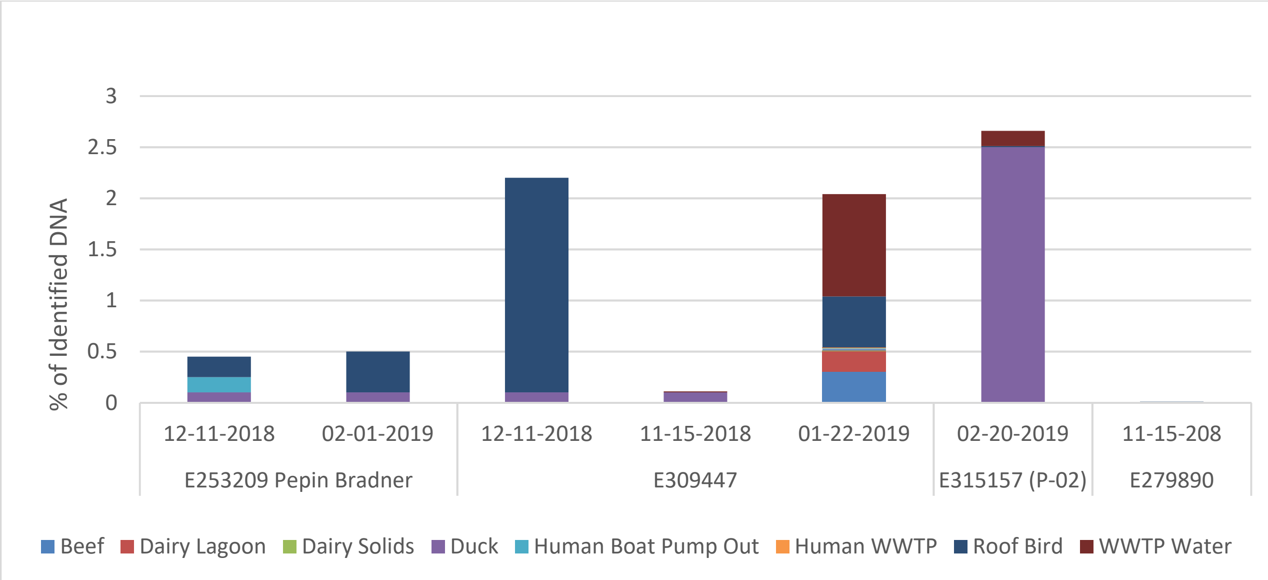

Figure 9: BST DNA results by specie shown in the legend. These percentages are based on the actual percent of DNA identified.

4.2.4 Nutrients and Physical Water Quality

As mentioned earlier, phosphorus was in exceedance in all sites but one, at E253211 located in Aldergrove Park. DO was found to be low during summer months, specifically at sites E208494, E253209, and E29890 most likely because of low flow, warm temperature and possible nutrient loading.

4.3 Fishtrap Creek Results

The Fishtrap Watershed drains approximately 30 km^2 before crossing the border into WA (City of Abbotsford, 2019). Fishtrap Creek also supports Nooksack dace and Salish sucker along with coho salmon. Most of the length of this creek is on or bordering agricultural lands including Dairy and berry growing. It is also important to note that Fishtrap Creek surface water feeds into the ground water aquifer that many Abbotsford citizens use for their drinking water.

4.3.1 Fecal Coliform

The fecal coliform results were relatively low (under 200 CFU/100 mL), with the exception of Waetcher Creek E310908 in Fall 2018 (Figure 10). A mushroom compost facility located at the headwater of Waetcher Creek had a pollution event resulting in extreme exceedance of WQG's in October 2018. It could be possible that another incident happened and was reflected in the Fall of 2018.

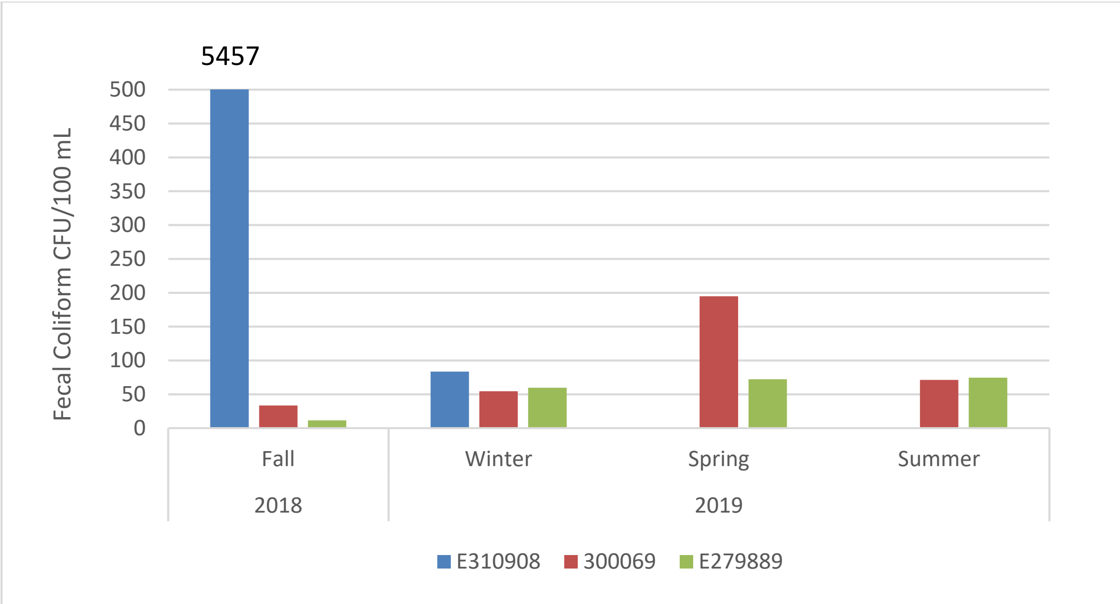

Figure 10: Fecal Coliform results by season and sample site. Spring and Summer results for site E310908 are missing because there was not enough sample data.

4.3.2 *E. coli*

The *E. coli* results are very close to the fecal coliforms with Waetcher Creek E210908 having a high number of *E. coli* and Fecal Coliforms, indicating that more of the coliforms are fecal in nature (Figure 11).

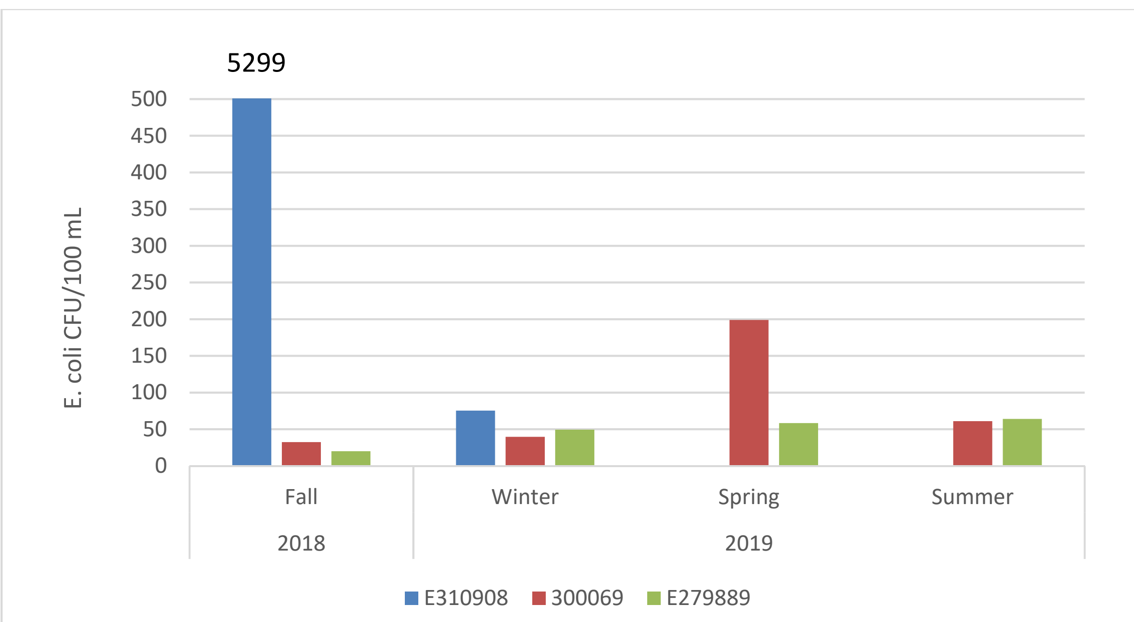

Figure 11: E. coli results per season and sample site. Spring and summer data for site E310908 is missing because there were not enough sample data.

4.3.3 Bacterial Source Tracking

Fishtrap Creek's DNA results differ from Bertrand Creek and Pepin Brook because of the greater influence of human DNA results rather than duck and roof bird. There was also indication of Beef, Dairy Lagoon, Dairy Solids, Duck, HBPO, Human WWTP, WWTP Water and Roof bird; the top three DNA results belong to Dairy Lagoon, Human WWTP and Dairy Solids. This finding indicates that dairy facilities and human waste systems need to be inspected in this area for failures or cross connections (Figure 12).

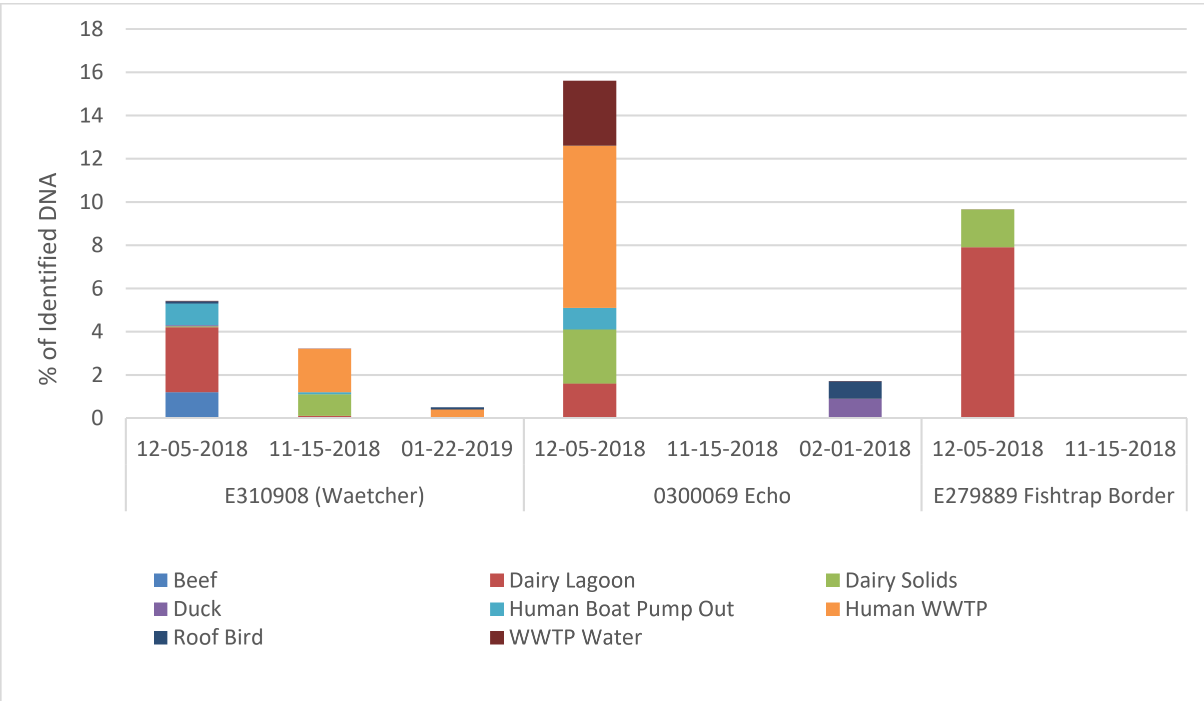

Figure 12: BST DNA results by species. These percentages are based on the actual percent of DNA identified.

4.3.4 Nutrients and Physical Water Quality

Like the other creeks in the Nooksack watershed, Fishtrap Creek also had exceedances of the maximum grab guideline of 10 µg/L of phosphorus at every site and sample event except one site at one time and low DO during summer months.

4.4 CAN/USA Border Benchmarks

In an effort to minimize Canada's contribution to fecal coliforms entering the USA, the technical working group established a benchmark goal for the four border sites of a maximum *E. coli* concentration of 200 CFL/100 mL based on the geometric mean of 5 samples collected weekly in 30 days.

The benchmark was created based on:

- Statistical analysis,
- Probability of achievability,
- BC Water Quality Guidelines.

Five consecutive weekly samples were taken between the dates of July 2, and July 30, 2019 to calculate the geometric means for both fecal coliform and *E. coli*. In general, concentrations were low, with the exception of Cave Creek which exceeded the benchmark of 200 CFU/100 mL (Figure 13); the high concentrations at Cave Creek may be attributed to fecal contributions from duck, roof bird and human which was identified from the BST work, leading us to assume that there maybe be faulty septic systems or illegal dumping.

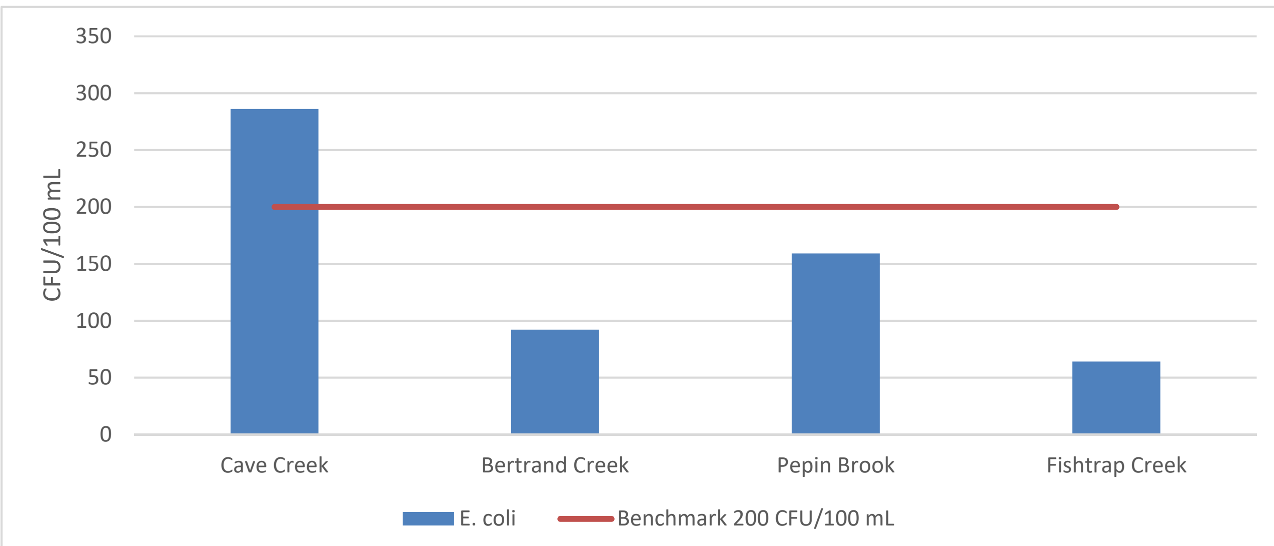

Figure 13: Border Benchmark geometric means for E. coli in July 2019.

The border site at Pepin Brook E279890 was part of the 5 in 30 sampling in fall of 2018 to identify sites of concern (more details in Section 4.4). Those results where also low, thus showing that this is not a site of concern.

4.5 Sampling at Sites of Concern

In an effort to determine and confirm previously identified hotspot sites and now sites of concern, two sets of 5-in-30 sampling was completed in fall 2018 and spring 2019 at seven locations (Figure 14). The following sites were labelled as hot spot sites based on monthly grab sample exceedance on a regular basis or at a site with historical extreme exceedances. These sites include E207092, E206847, E273723 and 300069 which often have high exceedance results that are not explained by weather or documented pollution incidents. Sites E279890 and E253211 are generally low, however they have historically had periodic and infrequent high concentrations, and therefore, were included in the 5-in-30 sampling to confirm consistent low numbers. Site E309447 often has high exceedances, but because of previous compliance and MAS efforts, the source has been located and it is currently being monitored and corrected by the facilities involved and ENV.

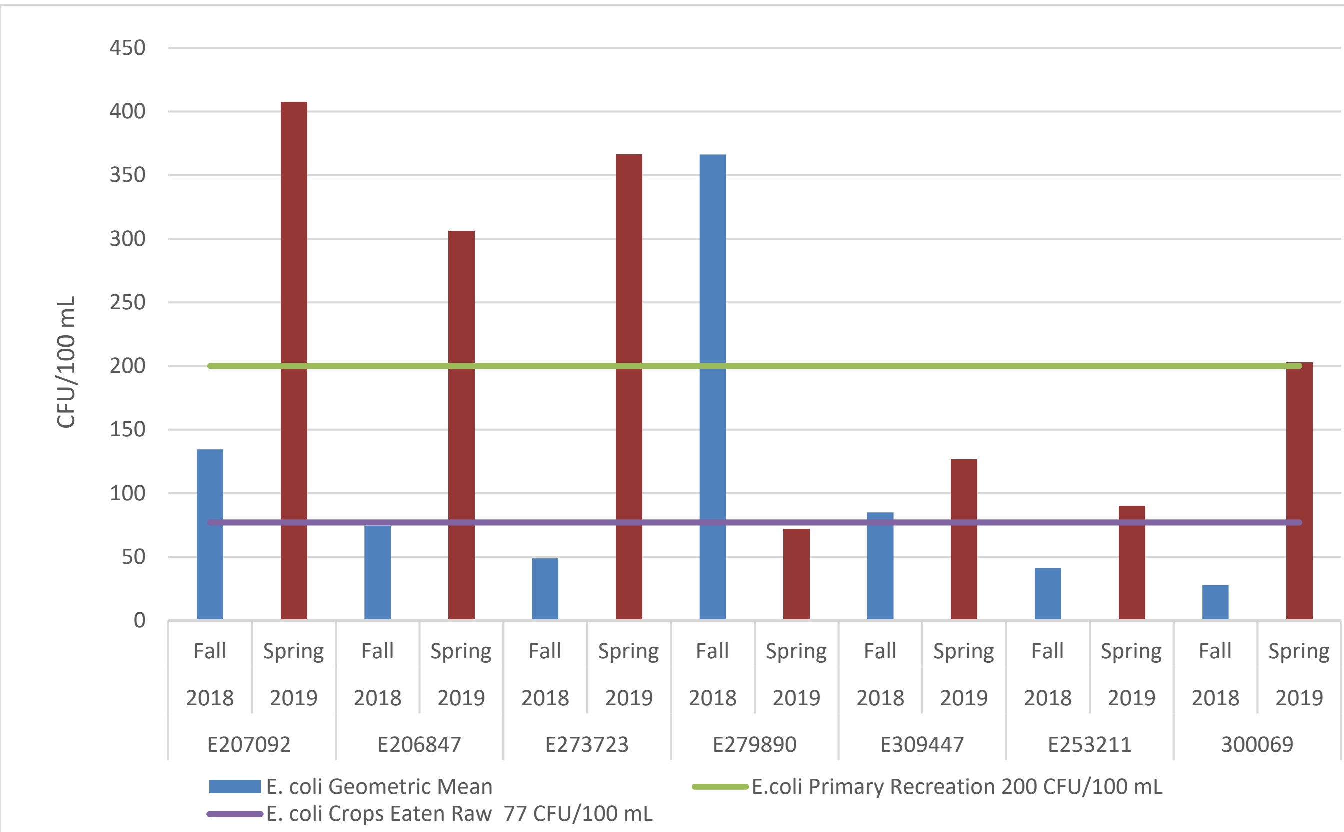

Figure 14: Sites of concern E. coli geometric means in fall and spring

The results show that in the spring of 2019, *E. coli* concentrations were higher than in fall, 2018 (with the exception of site E279890). During spring sampling, there happened to be higher than normal rainfall and therefore this, in addition to manure spreading may have caused higher concentrations. Sites E207092, E206847, E273723 and 300069 exceed both guidelines in both or either season, thus confirming their status as hotspot sites.

5. DISCUSSION

The water quality results in the Canadian portion of the Nooksack Watershed indicate that there are high concentrations of *E. coli*, fecal coliform and phosphorus in each of the four creeks sampled. The water quality results indicate contamination comes from run off, agricultural waste and human sewage. Due to compliance efforts and continued monthly monitoring and BST sampling, the sites of concern can be narrowed down for education and compliance action. We can identify what species may be responsible for the most fecal contamination at each site, thus concentrating efforts on issues we can control, such as sewage inspection. A more detailed discussion of each of these watersheds is provided below, starting with the uppermost sites working downstream to the border sites.

Bertrand Creek

Bertrand Creek, being the largest system, had the most sites in exceedance of fecal coliform guidelines. Of particular interest are sites E207092, E206847, E723723, and E314990, as they all have frequent and high bacterial exceedances. Site E206847 located at Howes Creek also has the highest phosphorus results, at times exceeding 100 times the suggested guideline of 10 µg/L. This makes sense if all the upstream sites are experiencing overages and compound once at the border. Unfortunately, DNA results show that half of fecal contaminants entering this system are from roof birds, and duck, thus out of our purview. However, there are instances of human fecal contamination at the upstream sites of concern like E207092 and E314990.

While the border site on Cave Creek does not have extreme exceedances, it is the only system that does not meet the border benchmark. The DNA results indicate the presence of duck and roof bird, and there is also an indication of human septic waste. This is the only area in the whole watershed where chloride exceeded water quality guidelines. It is suspected that because of high conductivity and chloride results there may be ground water influence. ENV is working with the groundwater department at the Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD) to further understand the connection between surface and ground water in the watershed.

Pepin Brook

Pepin Brook, which mainly runs through Aldergrove Regional Park is mostly low on fecal exceedances. The hotspot site for the second year in a row is E309447, a tributary to Pepin Brook and directly downstream of a large composting facility. The data shows that while other sites are low, this site is usually higher and at times has extreme exceedances such as in the summer of 2019. This facility is working with ENV to understand how to manage their effluent better. The DNA here is also predominantly roof bird and duck, although there is indication of WWTP water, which could indicate an issue in the local sewage pipes. The Pepin Border site was below the border benchmark as well.

Fishtrap Creek

Fishtrap Creek is mainly surrounded by berry fields and agriculture and its tributaries include Waetcher Creek. Throughout the last year, the bacteriological results have been low, with the exception of Waetcher Creek last fall. Phosphorus is high like in all other sites. However, the most concerning results in Fishtrap are from the DNA analysis conducted. Unlike its counterparts with high roof bird and duck contribution, the predominant fecal source here is human and cow. Dairy lagoon and solids account for almost 50% of identified DNA whereas human accounts for approximately 40%. The type of human input appears to be from septic tanks and sewage pipes. This is concerning as surface water from Fishtrap does enter the ground water aquifer used in many well systems in Abbotsford. The border site at Fishtrap Creek is below the benchmark guidelines and is not a concern at this time.

6. RECOMMENDATIONS

The sampling programs conducted thus far have produced meaningful results, like the re-opening of the spring shellfisher in Portage Bay (WA) and decreasing fecal contamination at border sites. Areas of concern and potential sources are now more identifiable then they were at the beginning of the project. Collaborative efforts between ENV teams and Washington state has been successful in identifying, responding to and educating the public when to comes to the reduction of fecal contamination.

Based on the analysis of the second year of results, the following recommendations for the next year in this project are:

- Re-assess sites of concern to either keep 5 in 30 sampling or add new sites;
- Continued 5 in 30 sampling for border sites: E279980 Bertrand, E279890 Pepin, E3012388 Cave and E279889 Fishtrap in fall and spring;
- Continued BST water sampling at 300069 and E309447 to expand and verify the findings;
- Collect more fecal samples to expand the fecal reference library and fill gaps of additional potential species;
- Present the results to local municipalities and Ministry of Health in order to discuss potential solutions on human sewage issues.

REFERENCES

B.C. Ministry of Environment, 2013. B.C. field sampling manual. Available at https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/laboratory-standards-quality-assurance/bc-field-sampling-manual

B.C. Ministry of Environment and Climate Change Strategy, 2017. B.C. recreational water quality guidelines: Guideline summary. Water Quality Guideline Series, WQG-02. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/recreational_water_quality_guidelines_bcenv.pdf

B.C. Ministry of Environment and Climate Change Strategy, 2018a. British Columbia approved water quality guidelines: Aquatic life, wildlife & agriculture, summary report. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf

B.C. Ministry of Environment and Climate Change Strategy, 2018b. Compliance Nooksack River watershed audit report, Environmental Management Act 2018. Available at https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/reporting/environmental-compliance/audit-reports/6270_nooksackwatershed_auditreport.pdf

B.C Ministry of Environment and Climate Change Strategy, 2019. Nooksack River Transboundary Water Quality Sampling Program June 2017- July 2018 Data Summary Report. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/monitoring-water-quality/south-coast-wq-docs/2019-04-29_nooksack_wq_report.pdf

Bratt, Calvin, 2019. Lynden Tribune. Available at https://www.lyndentribune.com/news/portage-bay-shellfish-beds-open/article_c2d8c1b2-5596-11e9-823f-e3f57456c95d.html

Brooks, Jenna; Schlenker, Casey; McLaughlin, Ryan; Harris, Meagan. 2019. Utilizing a Fecal Source Reference Catalog for Molecular Source Tracking Analysis for Improved Water Quality Management. Laboratory Report prepared for Ministry of Environment and Climate Change Strategy. Exact Scientific Services. Practical Informatics, LLC, Whatcom Conservation District.

Cavanagh, N., Nordin, R.N., and Warrington, P.D.,1996. Freshwater biological sampling manual. Water Management Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. Available at https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/freshwaterbio.pdf

City of Abbotsford. 2019. Website. Available at https://www.abbotsford.ca/city_hall/plan_for_200K/plan_for_200K_-_fishtrap_creek_ismp.htm#stage1

Douglas, Erika. 2017. Whatcom County Water Quality Program Bacteria Monitoring QAPP. Whatcom County Public Works, Natural Resources Division.

Emberston, Nichole. Harris, Meagan. Graham, Scarlett. McLaughlin, Ryan. Brooks, Jenna, Schlenker, Casey. Oostra, Kent. 2019. Development and Demonstration of a Fecal Source Reference Catalog and Methodology for Improved Molecular Source Tracking Analysis for Water Quality Management. Available at https://whatcomcd.org/sites/default/files/research/WSCC_DNAProject_FinalReport_071119_FINAL_Posted.pdf

Environment and Climate Change Canada. 2019. Abbotsford Weather Stats. Available at https://abbotsford.weatherstats.ca/charts/rain-monthly.html

Langley Environmental Partners Society. 2019. Website by Motiontide. Available at http://www.leps.bc.ca/stewardship/watersheds-of-langley/

Pearson, Mike. 1989. British Columbia Conservation Foundation. Fisheries Project Report No.76. Province of British Columbia Ministry of Fisheries. https://www.for.gov.bc.ca/hfd/library/documents/bib95170.pdf

Portage Bay Shellfish Protection District Advisory Committee, 2014. Portage Bay Shellfish Protection District Shellfish Recovery Plan. Available at https://www.whatcomcounty.us/DocumentCenter/View/3429/2014-Portage-Bay-Shellfish-Recovery-PlanPDF?bidId

Reiberger, Kevin. 2014. A Review of Microbial Indicators Used in Water Quality Monitoring Programs in British Columbia. Science and Information Branch, Water Stewardship Division, Ministry of Environment.

Tallon, P., Magajna, B., Lofranco, C., & Leung, K.T., 2005. Microbial indicators of faecal contamination in water: A current perspective. *Water, Air, and Soil Pollution, 166*, 139–166. Available at https://doi.org/10.1007/s11270-005-7905-4

Nordin, Rick. 2009. A Phosphorus Guideline for Vancouver Island Streams Draft. Prepared for British Columbia Ministry of Environment.

United States Environmental Protection Agency, 2012. Water: Monitoring and assessment, 5.11 Fecal bacteria. Available at https://archive.epa.gov/water/archive/web/html/vms511.html

Warrington, P.D., 2001. Water quality criteria for microbiological indicators: Overview report. B.C. Ministry of Water, Land and Air Protection, Victoria, B.C. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/microindicators-or.pdf

Washington State Department of Ecology, 2019. Updates to water quality standards. Available at https://ecology.wa.gov/Water-Shorelines/Water-quality/Freshwater/Surface-water-quality-standards/Updates-to-the-standards

APPENDIX A: RELATIVE PERCENT CALCULATION FOR COLIFORMS

Relative Percent Difference Calculations

Creek	Site	Sample Date	Sample Number	*E. coli* CFU/100 mL	Fecal Coliform CFU/100 mL	*E. coli* % Relative Difference	Fecal Coliform % Relative Difference
Bertrand	E207092	13-11-2018	L2195871-1	150	250	38	31
Bertrand	E207092	13-11-2018	L2195871-2	220	340		
Bertrand	E207092	11-06-2019	L2289485-1	108	108	33	55
Bertrand	E207092	11-06-2019	L2289485-2	150	190		
Bertrand	E293977	09-01-2019	L2218474-1	230	250	8	0
Bertrand	E293977	09-01-2019	L2218474-2	250	250		
Bertrand	E314991	21-02-2019	L2235588-1	70	70	25	60
Bertrand	E314991	21-02-2019	L2235588-2	90	130		
Bertrand	E273723	16-04-2019	L2243873-1	56	64	24	6
Bertrand	E273723	16-04-2019	L2243873-2	44	60		
Pepin	E253211	20-08-2019	L2332405-1	240	240	59	18
Pepin	E253211	20-08-2019	L2332405-2	130	200		
Pepin	E208494	18-09-2018	L2166447-1	54	54	51	35
Pepin	E208494	18-09-2018	L2166447-2	32	38		
Pepin	E253211	13-03-2019	L2243901-1	30	30	29	50
Pepin	E253211	13-03-2019	L2243901-2	40	50		
Fishtrap	0300069	16-10-2018	L2181962-1	14	14	0	0
Fishtrap	0300069	16-10-2018	L2181962-2	14	14		
Fishtrap	E315795	15-05-2019	L2274056-1	1400	1800	25	24
Fishtrap	E315795	15-05-2019	L2274056-2	1800	2300		
Cave/Bertrand	E312388	04-12-2018	L2205728-1	6	6	40	40
Cave/Bertrand	E312388	04-12-2018	L2205728-2	4	4		

Appendix B: Nutrient and Physical Water Quality Exceedance Results

B.1 Physical Parameter Exceedance Table

		Date	DO	pH	Total Suspended solids	Turbidity
WQG			For all Salmonid life stages: below 5 and above 11	6.5 – 9.0	Table 44. Changes from background noted below	Aquatic life change from background between 2, 5 and 8 NTU
Bertrand Creek	E293977	17-07-2018	1.4		39.6	
		18-09-2018	4.25			
		11-06-2019			62.10	23.30
		20-08-2019	3.5			
	E207092	17-07-2018	1.20			
		13-08-2018	4.16			
		61-07-2019	4.37			
		20-08-2019	4.40			61.90
	E206847	17-07-2018	0.90			
		18-09-2018	4.00			
		16-07-2019	2.82			
		20-08-2019			137	
	E293980	18-09-2018	2.70			
	E314991	15-05-2019	2.32			
		11-06-2019	1.35		47.30	
		16-07-2019	0.29		40.50	31.90
		20-08-2019	2.75		33.70	51.00
	E314990	21-02-2019			23.60	
		11-06-2019			41.10	
		16-07-2019	3.38			
		20-08-2019	4.15			
Cave Creek	E312388	16-07-2018	4.57			
		30-07-2019	4.60			
	E315155	16-09-2019	3.81			
Pepin Brook	E309447	17-07-2018	1.5			

		15-05-2019 29-05-2019			31.4 41.1	
	E208494	16-10-2018 06-11-2018 04-12-2018 06-07-2019 20-08-2019	4.75 4.65 4.77 4.84 4.89			
	E253209	16-10-2018 16-11-2018 09-01-2019	3.33 3.89	 9.58		
	E279890	23-07-2019	4.97			
	E253211	22-05-2019			101	45.5
Fishtrap Creek	0300069	16-10-2018 11-06-2019 16-07-2019 20-08-2019	3.51 4.89 4.93 4.17			
	E279889	02-07-2019 23-07-2019 30-07-2019	4.38 4.80 3.58			
	E310908	04-12-2018 05-12-2018				29.20 52.70
	E315795	20-08-2019	4.74			

B.2 Nutrient Exceedance Table

		Date	Chloride mg/L	Ammonia	Nitrate as N mg/L	Nitrite as N mg/L
WQG			Aquatic life short term (acute), Wildlife, Livestock: 600 mg/L Irrigation: 100 mg/L	Table 26C in WQGs	Short term (acute) wildlife and livestock: 100 mg/L	short term (acute)with chloride > 10: 0.60 mg/L as N
Bertrand Creek	E293977	17-07-2018 16-10-2018			3.25 3.59	
	E314991	09-01-2019			4.2	
Cave Creek	E312388	18-09-2018 16-10-2018	176 187			
Pepin Brook	E309447	18-09-2018			3.89	
Fishtrap Creek	E279889	17-07-2018			3.02	

Appendix C: Phosphorus Results

Site_ID	DATE_SAMPLED	Phosphorus (P)-Total mg/L	converted to ug/L as per WQG
E293977	18-09-2018	0.0115	11.5
E293977	16-10-2018	0.0249	24.9
E293977	09-01-2019	0.092	92
E293977	09-01-2019	0.0903	90.3
E293977	16-04-2019	0.0202	20.2
E293977	16-07-2019	0.0844	84.4
E293977	16-09-2019	0.385	385
E293980	18-09-2018	0.0315	31.5
E293980	16-10-2018	0.0195	19.5
E293980	06-11-2018	0.0664	66.4
E293980	04-12-2018	0.0184	18.4
E293980	13-03-2019	0.0841	84.1
E293980	16-07-2019	0.0264	26.4
E293980	20-08-2019	0.0238	23.8
E293980	16-09-2019	0.243	243
E273723	18-09-2018	0.0945	94.5
E273723	16-10-2018	0.0342	34.2
E273723	09-01-2019	0.0979	97.9
E273723	16-04-2019	0.155	155
E273723	16-04-2019	0.149	149
E273723	16-07-2019	0.0636	63.6
E273723	20-08-2019	0.0414	41.4
E273723	16-09-2019	0.303	303
E207092	18-09-2018	0.0675	67.5
E207092	16-10-2018	0.0513	51.3
E207092	16-04-2019	0.0582	58.2
E207092	16-07-2019	0.11	110
E207092	20-08-2019	0.239	239
E207092	16-09-2019	0.0795	79.5

E314291	16-10-2018	0.0387	38.7
E314291	21-02-2019	0.0177	17.7
0300069	16-04-2019	0.0301	30.1
0300069	16-07-2019	0.0294	29.4
0300069	20-08-2019	0.0512	51.2
300069	16-09-2019	0.0446	44.6
E279889	18-09-2018	0.0311	31.1
E279889	16-10-2018	0.0139	13.9
E279889	09-01-2019	0.147	147
E279889	16-04-2019	0.021	21
E279889	16-07-2019	0.0311	31.1
E279889	20-08-2019	0.024	24
E279889	16-09-2019	0.0567	56.7
E279889	16-09-2019	0.0544	54.4
E253209	18-09-2018	0.337	337
E253209	16-10-2018	0.09	90
E253209	09-01-2019	0.0541	54.1
E253209	16-04-2019	0.0872	87.2
E253209	16-07-2019	0.198	198
E253209	20-08-2019	0.178	178
E279890	18-09-2018	0.097	97
E279890	16-10-2018	0.0425	42.5
E279890	09-01-2019	0.0789	78.9
E279890	16-04-2019	0.0599	59.9
E279890	16-07-2019	0.17	170
E279890	20-08-2019	0.0757	75.7
E279890	16-09-2019	0.136	136
E253211	18-09-2018	0.056	56
E253211	16-10-2018	0.0359	35.9
E253211	09-01-2019	0.0592	59.2
E253211	16-04-2019	0.0555	55.5
E253211	16-07-2019	0.0905	90.5

E253211	20-08-2019	0.0795	79.5
E253211	20-08-2019	0.0828	82.8
E253211	20-08-2019	0.002	2
E253211	16-09-2019	0.132	132
E309447	18-09-2018	0.104	104
E309447	16-10-2018	0.0723	72.3
E309447	09-01-2019	0.257	257
E309447	16-04-2019	0.118	118
E309447	16-07-2019	0.0693	69.3
E309447	20-08-2019	0.0244	24.4
E309447	16-09-2019	1.02	1020
E208494	18-09-2018	0.0548	54.8
E208494	18-09-2018	0.0549	54.9
E208494	16-10-2018	0.0436	43.6
E208494	09-01-2019	0.0387	38.7
E208494	16-04-2019	0.0548	54.8
E208494	16-07-2019	0.0969	96.9
E208494	20-08-2019	0.0805	80.5
E310908	18-09-2018	0.1	100
E310908	09-01-2019	0.127	127
E310908	16-04-2019	0.0433	43.3
E310908	16-07-2019	0.0302	30.2
E310908	16-09-2019	0.0565	56.5
E206847	16-04-2019	3.63	3630
E206847	16-07-2019	4.67	4670
E206847	20-08-2019	5.44	5440
E206847	16-09-2019	1.99	1990
E312388	18-09-2018	0.122	122
E312388	16-10-2018	0.0788	78.8
E312388	09-01-2019	0.285	285
E312388	16-04-2019	0.243	243
E312388	16-07-2019	0.272	272

E312388	16-09-2019	0.173	173
E315155	16-04-2019	0.261	261
E315155	16-07-2019	0.212	212
E315155	20-08-2019	0.305	305
E315155	16-09-2019	0.108	108
E315156	16-04-2019	29.6	29600
E314991	09-01-2019	0.0955	95.5
E314991	16-04-2019	0.0579	57.9
E314991	16-07-2019	0.271	271
E314991	20-08-2019	0.442	442
E314991	16-09-2019	0.248	248
E314990	09-01-2019	0.0699	69.9
E314990	16-04-2019	0.0808	80.8
E314990	16-07-2019	0.0652	65.2
E314990	20-08-2019	0.116	116
E314990	16-09-2019	0.113	113
E315157	16-04-2019	0.118	118
E315157	16-07-2019	0.305	305
E315157	16-07-2019	0.118	118
E315157	20-08-2019	0.0959	95.9
E315157	16-09-2019	0.117	117
E315795	16-04-2019	0.021	21
E315795	16-07-2019	0.0205	20.5
E315795	20-08-2019	0.0096	9.6
E315795	16-09-2019	0.0495	49.5