Water Quality, Microbiology, and Invertebrate Analysis for the Beck Creek in Nanaimo, British Columbia

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Submitted to:

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1.0 Introduction and Background

1.1 Project Overview

The Vancouver Island University (VIU) Environmental Monitoring students carried out the Environmental Monitoring project for Beck Creek located south and slightly east of Nanaimo near Chase River and Cedar. Beck Creek is included in the water region 6 which is described as the Nanaimo River (Plewes R, Larrat H, Schleppe J 2018). The 3 VIU students carried out all field collection data and analysis under the supervision of Dr. Eric Demers faculty member of the Resource Management Officer Technology Program at VIU. There were two field sampling events, one during the low flow period on October 30 and one field sampling day in high flow period on November 20, 2019 . The reasoning for taking samples at two different times is to give a good representation of the stream health in different stages of flow (low vs high). The Environmental Monitoring class at VIU has been conducting water quality and invertebrate enumeration samples in the Beck creek since 2017. We chose to sample in the same 4 sites as previous years to continue analyzing the health of the creek/tributary (See Figure 2). A comparison of previous years' data and analysis will be compared in this final report to continue monitoring the impacts of restoration efforts, impacts from historical and current land use and water quality assessments.

1.2 Historical Review

The Nanaimo River Estuary is the largest estuary on Vancouver island. There are four major drainages out of the Nanaimo River Estuary, one being Beck Creek with a drainage area of 6.7㎢ (Government of British Columbia 2006). The Snuneymuxw First Nations people were the first known group to inhabit the land surrounding the Nanaimo River watershed (Government of British Columbia 2006). The land is of great importance to their traditional practices and spirituality (Government of British Columbia 2006). This land is still of great importance to the Snuneymuxw people and our research will help to create trend analysis of the Beck Creek tributary for past and future restoration projects.

In the late 1800s to the early 1900s the Nanaimo River was used for coal mining (Morgan 2015). There were two major collieries at that time, the Reserve Colliery; owned and operated by the Western Fuel Company (See Figure 1). The Fiddick Colliery, owned and operated by the Pacific Coast Mine company (See Figure 1). The Pacific Coast Coal Mine was in the process of getting approval to open a new colliery in between two flooded mines (Morgan 2015). The Southfield mine was in operation from (1883-1893) before flooding, north of the new colliery. The Alexandra Mine was operational from (1884-1901) before flooding, south of the new colliery. Around 1911 the new colliery between the two flooded mines began operation, before long a major tragedy occurred in 1915 (Morgan 2015). Many lives were taken from the flooding of the new colliery. Attempts were made to pump out the flooding water, but issues arose

when the Beck Creek channel had collapsed from the excess of water. By 1922 the Pacific Coast Coal Mine company went bankrupt and all mining in the area desist (Morgan 2015).

From 1991-1993 Department of Fisheries and Oceans researched the coho escapement of Beck Creek (Irvine et al.,1994). During their research they determined that Beck Creek enters the Nanaimo River Estuary south of the Chase River. Anadromous fish use these areas to migrate upstream for spawning. The migration patterns seem to vary each year during the study because there is a small beaver dam downstream that causes blockages near culverts that deter spawners from reaching higher up stream in Beck Creek (Irvine et al.,1994). The determining factor of whether the blockage deters salmon or not is the amount of rainfall in the fall. The more precipitation the higher the water flow, allowing the beaver dam debris to pass through the channel easily (Irvine et al.,1994). Over the three year span coho escapement raged from 410 individuals in 1991, 48 individuals in 1992 and 99 individuals in 1993 (Irvine et al.,1994).

In more recent efforts to analyse the Beck Creek for salmon habitat the Harbour City River Stewards helped in the restoration projected in July 2012 (Nanaimo News Bulletin 2012). It was determined that in 1995 the Beck Creek was moved and rebuilt to accommodate for the widening of the Island Highway. Over the years the salmon migration Beck Creek channel lacked the optimal spawning substrate and habitat (Nanaimo New Bulletin 2012). The Harbour City River Stewards helped in placing 26 tonnes of custom gravel to enhance the salmon spawning grounds in the creek. Before

dumping the gravel, over 1000 salmon and trout fry where collected and placed in a nearby pool during the restoration. The Harbour City River Stewards continue to count returning spawners in the Beck Creek every fall (Nanaimo News Bulletin 2012).

Figure 1: Nanaimo Coal Mining Collieries (1884-1922) (Morgan 2015)

Figure 2: Old Nanaimo Coal Mining Photos (Morgan 2015)

1.3 Current and Potential Environmental Concerns

The current and potential environmental concerns for the Beck Creek is particularly the agricultural, residential and industrial land use surrounding the Beck Creek (Plewes R, Larrat H, Schleppe J. 2018). The Beck Creek runs into the Nanaimo Estuary, Chase River, Beck lake and smaller tributaries. Residential and agricultural runoff is one of the main concerns that impact the water quality of the steam. Current environmental concerns is the traffic from the expansion of the Island highway, this causing fuel, oil and liquid material run off into the stream (Nanaimo News Bulletin 2012). The historical use of the land also rises concerns of acid mine drainage and coal mining waste (Morgan 2015). The Acid mine drainage is a major concern, as it was indicated by the conductivity levels we recorded in the water quality section. Eutrophication is a major concern for the stream due to the growing agricultural and residential runoff (Laplante et al., 2018). Eutrophication caused by human induced

waste building up excess nutrients in the stream. During our site assessment on October 16, 2019 we witnessed large amounts of garbage dumping along all 4 sites. Excess of liter causing blockages and pollution of the stream is another concern when monitoring the water quality and invertebrate enumeration. Some of the concerns from previous analysis is the increasing turbidity. Higher water temperatures, decreasing dissolved oxygen concentrations and the flow of Beck Creek (Plewes R, Larrat H, Schleppe J. 2018). All of the above measures can impact the overall health of the stream.

2.0 Project Objectives

The objectives for the Environmental Monitoring project is to continue field data collection and analysing results for current and future projects to maintain and restore the Beck Creek watershed. The Beck Creek watershed is only a small piece of a much larger watershed that inhabits an abundance of land and aquatic species within the Nanaimo River Region. It is our objective to aid in complying supporting data to contribute to the future restoration of this area. During our field data collection it was our objective to sample in the 4 main sites in (Figure 2) to correspond with previous VIU student reports on Beck Creek. Within the 4 sample sites we sampled water quality, hydrology, microbiology and invertebrate enumeration. All of these samples were analysed in the lab at Vancouver Island University and some water quality samples were sent to the Australian Laboratory Services (ALS) in Vancouver, British Columbia. All field sampling requirements, parameters and laboratory analysis will be discussed in

this report. It is our objective to maintain the integrity of our samples by assuring quality control and quality assurance measures are executed appropriately. Our final objective was to create a report that creates a continuation of related data from previous VIU student reports of Beck Creek, this will allow for future years to continue the efforts of monitoring the Beck Creek Watershed.

3.0 Environmental Sampling and Analytical Procedures

3.1 Sampling Program

3.1.1 Locations and Habitat Characteristics

Beck Creek flows into the Nanaimo River Estuary. Sites sampled during the assessment were established during the initial Beck Creek analysis in 2017 (Miller et al. 2017). This assessment aims to maintain the continuity of data obtained from Beck Creek in order to establish long-term trends in the creek's health. A total of four sampling sites were assessed (Figure 2). Sites 1 and 2 were accessed by a walking path originating at the S end of Frames Rd and a gravel road originating at the SE corner of Elaine Hamilton Park in Nanaimo. It should be noted that accessing Site 1 requires crossing the railway track located adjacent to Site 2.

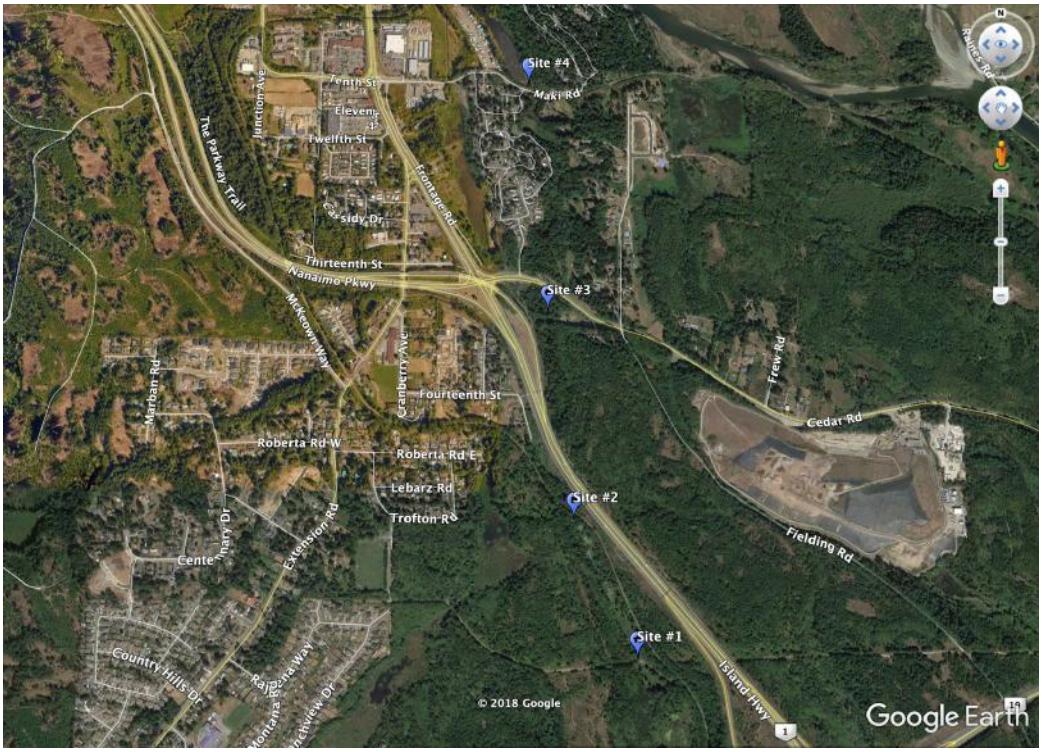

Figure 3: Beck Creek Sampling Sites

Starting furthest upstream, Site 1 is located at UTM 10U 433603 E, 5440523 N. Situated downstream of a culvert and gravel road, the monitoring site is open to almost full sun. Riparian vegetation consists of mainly grasses and bushes, located on steep slopes on either side of the water's edge. The flow was observed to be slow-moving, but water depth could not be ascertained on the initial visit as water visibility was obscured below approximately 30 cm of depth. Substrate was also unobserved but estimated to be an even mix of gravel and fine substrate with some woody debris (de Leplante et al. 2018).

Site 2 is roughly 500 m downstream of Site #1, just N of the culvert under the train track. Ponds are interspersed between Sites 2 and 3 The GPS position is UTM

10U 433409 E, 5440990 N. Site 2 has approximately 70% canopy cover. Both banks are again steeply sloped with moss and ferns as the predominant riparian vegetation and with Western red cedar (Thuja plicata), Douglas fir, and big leaf maple are the dominant tree species. Slippery uncovered soil and rocks are visible on either side of the creek. The flow is faster at Site 2 than Site 1 due to the lower water depth. Substrate consists of cobbles and gravel, with some fine substrate and deposits of large woody debris.

At UTM 10U 433346 E, 5441612 N, Site 3 is located SE of the intersection of Cedar Rd and the Trans Canada Highway. The most inaccessible of all the sites, Site 3 has high steep slopes covered in dead leaves and is closest to the Nanaimo landfill. There is little riparian vegetation, leaving exposed soil and the occasional fern. Dominant tree species at Site 3 include Western red cedar (T. plicata), big leaf maple, and Douglas fir. At Site 3 there is a large rectangular culvert upstream which adds to its higher flow rate. Rifles at the bottom edge of the site was sampled for invertebrates. Cobble and gravel substrate were intermixed with fines and large woody debris. During the site assessment, one coho (*Oncorhynchus kisutch*) salmon in spawning phase was observed. The parking lot near Site 3 had an accumulation of trash that was observed on the first sampling stint but was later cleared by the City of Nanaimo.

Site 4 was situated at the mouth of the Beck Creek and drains into the Nanaimo River Estuary at UTM 10U 433289 E, 5442348 N. Hydrology was measured from the outflow of the culvert underneath Maki Rd during the first sampling period. Due to an increase in high water flows, the second hydrology sampling stint was conducted in the

upper section of the culvert where access to the site was safe. Riparian vegetation consisted mostly of grass and shrubs that were intermixed with deciduous and coniferous trees like Garry oak, big leaf maple, and Douglas fir. Site 4 was exposed to full sun with about 10% canopy cover. Site 4 is also exposed to tidal inflows from the Strait of Georgia, which makes it the most unique sampling site in this assessment. Substrate was an even mix of cobbles and gravel, with a fair number of fine substrates and boulders.

Students that conducted assessments in 2017 and 2018 for Beck Creek recorded the substrate composition of the site. Substrate composition was not recorded in 2019 during the site assessments. See Table 1 for habitat characteristics of each site.

Table 1. Preliminary habitat characteristic assessment, October 30, 2019.

Site	Gradient	Canopy	Riparian Zone	Notes
1	<1%	Western Red Cedar (*T. plicata*) Red Alder (*Alnus rubra*) Big Leaf Maple (*Acer macrophyllum*)	Creeping Buttercup (*Ranunculus repens*) Common Tansy (*Tanacetum vulgare)* Salmon Berry (*Rubus spectabilis*) Common Snowberry (*Symphoricarpos albus*) Thimble Berry (*Rubus parviflorus*)	Adjacent to highway, railway, and walking trail In pond vegetation included duckweed and pondweed Substrate muddy and grassy Access: easy

2	<1%	Western Red Cedar (*T. plicata*) Douglas Fir (*Pseudotsuga menziesii*) Big Leaf Maple (*Acer macrophyllum*)	Oceanspray (*Holodiscus discolor*) Sword Fern (*Polystichum munitum*) Western Skunk Cabbage (*Lysichiton americanus*) Salal (*Gaultheria shallon*) Huckleberry (*Vaccinium*) Salmon Berry (*Rubus spectabilis*) Field Horsetail (*Equisetum arvense*)	Adjacent to highway, railway, walking trail, and residential area Substrate
3	<1%	Western Red Cedar (*T. plicata*) Big Leaf Maple (*Acer macrophyllum*) Douglas Fir (*Pseudotsuga menziesii*)	Sword Fern (*Polystichum munitum*) Trailing Blackberry (*Rubus ursinus*) Ocean Spray (*Holodiscus discolor*)	Adjacent to highway and road leading to Cedar, near landfill, and residential area
4	<1%	Garry Oak (*Quercus garryana*) Big Leaf Maple (*Acer macrophyllum*) Douglas Fir (*Pseudotsuga menziesii*)	Common Snowberry (*Symphoricarpos albus*) Trailing Blackberry (*Rubus ursinus*) Ocean Spray (*Holodiscus discolor*)	Adjacent to residential, campsites, and powerline

3.1.2 Sampling Frequency

Sampling was carried out by three VIU students that conducted two sampling events at four sites in the Beck Creek system. A low flow sampling event took place on October

30, 2019 and a high flow sampling event took place on November 20, 2019. Objectives for sampling activities varied between sites and are outlined in Table # below.

Table 2: Outline of field measurements from each site.
"A" denotes sampling that took place on October 30,2019 and "B" on November 20, 2019. Water quality samples from Site 4 were only analyzed at VIU laboratory whereas Sites 1, 2, and 3 were analyzed both at VIU laboratory and by ALS Laboratory

Site	Location (UTM 10U)	Hydrology	Water Quality	Microbiology	Invertebrates
1	433603 E 5440523 N	-	A (replicates) B (replicates)	A	-
2	433409 E 5440990 N	-	A (2 replicates) B (2 replicates)	A (2 replicates)	A (4 replicates)
3	433346 E 5441612 N	-	A (replicates) B (replicates)	A	A (4 replicates)
4	433289 E 5442348 N	A B	A B	A	-

3.2 Basic Hydrology

Hydrology was measured at Site #4 during both sampling events. The circular culvert at Site #4 provided a controlled and easily sampled location to measure the creek's discharge. Velocity was measured using a float, tape measure, and stopwatch. The stream cross-section was measured with a measuring tape. Discharge was

measured at low tide to ensure the influx of saltwater from the Nanaimo River Estuary during hightide did not affecting the results. Velocity and cross-section measurements were taken at the downstream end of the culvert for sampling event #1. During the second sampling event, velocity and cross-section measurements were taken at the upstream portion of the culvert, due to increased flow presenting danger to samplers at original downstream sampling location.

Area was calculated using calculations found on MathBitsNotebook.com for determining the segment of a circle (Roberts, 2014). Another method was laid out in the 2018 Beck Creek stream survey, but the calculations put forth could not be duplicated to provide accurate results in 2019. Using calculations is more precise than rough estimating the average depth of the culvert. Velocity was then calculated by taking the average time the float took to travel a specified distance, divided by that distance. Discharge was calculated by multiplying the velocity by the wetted area of the culvert. Table 3 outlines the results.

Table 3: Discharge results of Site 4

	30 October 2019	20 November 2019
Wetted Area	$0.34m^2$	$0.51m^2$
Velocity	1.06m/s	1.00m/s
Discharge	$0.36m^3/s$	$0.51m^3/s$

The second sampling event saw a 33% increase in stream flow. This is due to the significant rain event that took place earlier in the week.

3.3 Water Quality

3.3.1 Field Measurements

Dissolved Oxygen and water temperature readings are only accurate if recorded in the field. To accommodate this, an electronic probe was used in-situ to measure DO and water temperature at each sample site, during both sampling events. Figure 5 details Site 1's DO content of 3.5 in October and 5.1 in November, outlining its unsuitability as habitat for freshwater fish, as a minimum of 5.0 is required for survival for any stages beyond a buried embryo or alevin (BCMOECCS, 2019). For Sites 2-4, there was no significant variation between DO levels site to site or between sampling periods. With a minimum DO of 9.5 at Site 2 and a maximum DO of 11.4 at both Site 3 and Site 4, all sites downstream of Site 1 exceeded the recommended DO water quality guideline of 9.0 or greater for all stages of freshwater fish (BCMOECCS, 2019)

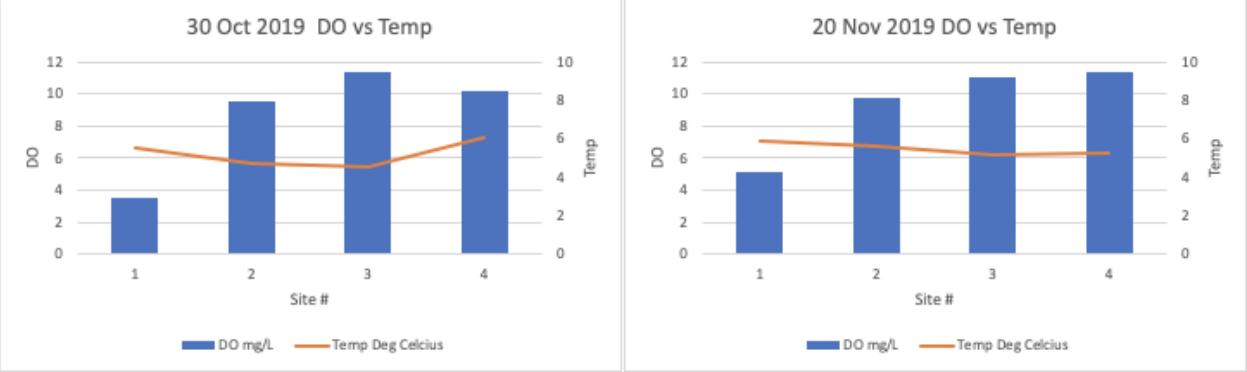

Figure 4: 2019 Temporal and Spatial comparison of DO and water temperature for Beck Creek

As seen in Figure 6, the DO in Site 1 varies greatly when compared with the sample sites further downstream. This trend has been steady for the past three years.

When considering the eutrophic nature of Beck Lake, the higher frequency of beaver dams closer to Site 1, and the increased flow of Beck Creek below Site 1, this result is expected. DO trendlines in 2017 and 2019 mirror each other with only one noticeable deviation in DO at Site 1 in November. 2018 did not have a significant rain event between sampling dates, which could account for the lower overall DO of that year (Laplante et al, 2018).

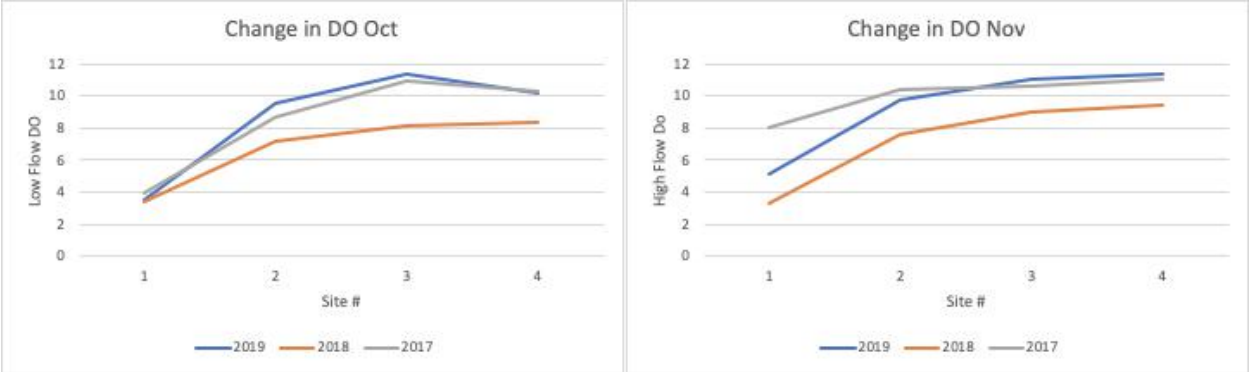

Figure 5: Change in DO of Beck Creek in October and November 2017-2019

The average water temperature of Beck Creek in October and November of 2019 was 5.2℃ and 5.5℃ respectively. Compared with average water temperatures from 2017 (7.85℃ in Oct and 6.75℃ in Nov) and 2018 (9.3℃ in Oct and 6.3℃ in Nov) in Figure 7, 2019 can be seen as having an overall colder water temperature, but no visible trend is apparent.

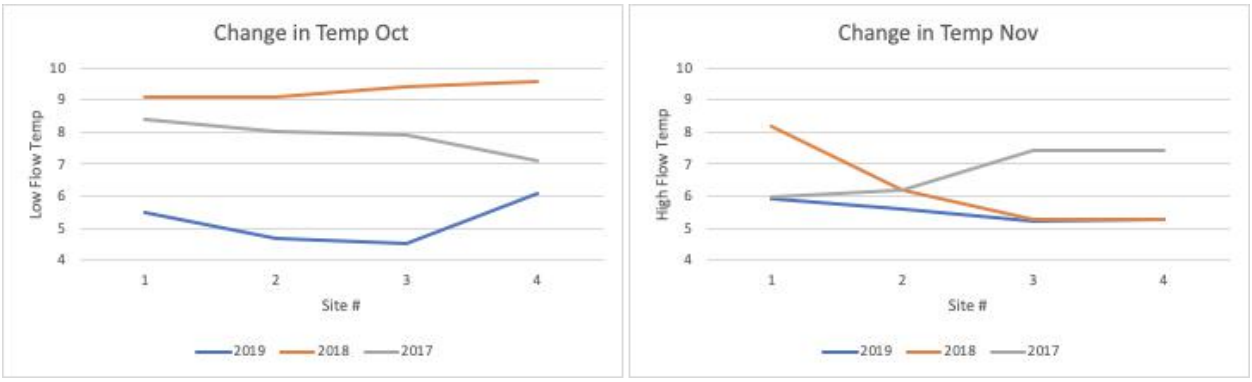

Figure 6: Change in water temperature of Beck Creek in October and November 2017-2019

3.3.2 Water Sample Collection

Water samples were collected in accordance to the Ambient Freshwater and Effluent Sample manual (BCMWLAP, 2013). Sampling began at the furthest downstream sampling site to ensure any sediment stirred up by sampling methods flows downstream away from the remaining unsampled sites. Site #4 had one sample per sampling event collected for VIU analysis. Site #3 had four samples collected per sampling event, one for VIU analysis, and three for ALS Laboratories analysis. Site #2 had 5 samples collected per sampling event: one for primary VIU analysis, a replicate for VIU analysis, and three for ALS Laboratories analysis. Site #1 again had four samples taken during each sampling event, one for VIU analysis and three for ALS Laboratories analysis. ALS Laboratory samples for total metals were preserved with supplied nitric acid. ALS Laboratory samples for total nutrients were preserved with supplied sulphuric acid. A trip blank was also used to test for environmental

contaminants in regards to nitrates and phosphates. Upon collection all water samples were kept in a cooler with ice packs until time for analysis.

3.3.3 VIU Laboratory Analyses

Samples collected for analysis at Vancouver Island University were transported to the lab within 24 hours of collection. At VIU, the samples were tested for pH, conductivity, turbidity, nitrates, phosphates, hardness, and alkalinity. Site #2 had two replicates taken per sampling event to analyze the accuracy of testing methods.

The pH for each sampling site during both sampling events, with the exception of Site 3 during the initial sampling event, fell within the water quality guidelines of 6.5-9.0. Site 3 had a pH of 6.4 at this time, which was 0.1 below the guideline (Figure 8). A noticeable trend was the increase in pH at each site from the initial to secondary sampling event. This loosely mirrors results from the 2018 study, but in 2017, pH levels marginally dropped from the first sampling event to the second. In regards to pH, these differences from October to November represent a significant change. While still within the water quality guidelines, an increase in pH should follow a trend of increasing conductivity and alkalinity. During this study, this was not the case. Alkalinity and conductivity in Beck Creek are many times above the normal expectancy, which could be a contributing factor to the pH deviation from normal trends.

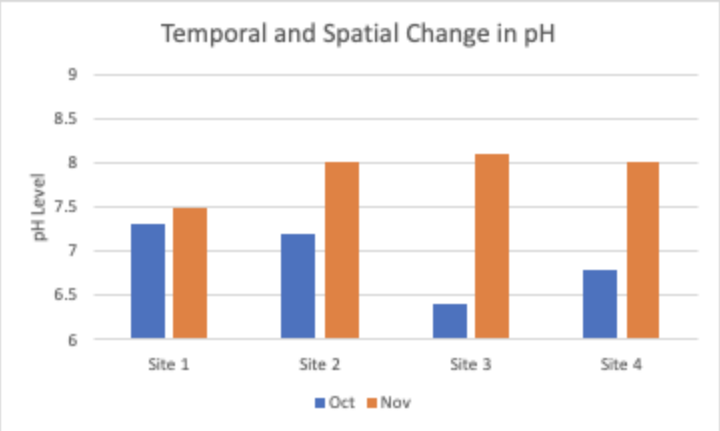

Figure 7: 2019 Temporal and Spatial pH Change of Beck Creek

Conductivity results for Beck Creek resemble those of interior BC lakes and streams (200-1000 µS/cm) as opposed to those that would normally be expected in BC coastal lakes and streams (<150 µS/cm) (Demers, 2019). During the initial sampling event, conductivity results varied from a high of 418 µS/cm in Site 1, to a low of 363 µS/cm in Site 3. Potential effluent leakage from the abandoned mines in the vicinity of Beck Creek could explain this increased level of conductivity. Conductivity was analyzed in the lab using the same equipment and methods for both sampling events. However, an anomaly occurred during the conductivity sampling or testing for the second sampling event. Results in November were in some cases over double what the October results were found to be. When compared to previous years studies and to the 2019 ALS Laboratory samples, it was decided that these results would not be used for analysis of the water course. Instead, the ALS Laboratory samples will be used in isolation for Sites 1-3.

The average turbidity in October and November were 1.6 NTU and 2.79 NTU respectively (Figure 9). Site 3 portrayed a higher turbidity than the remaining sites,

possibly due to its location near the highway with increased amount of garbage and vagrant activity than the other sites. Overall, Beck Creek has low turbidity with low variation, compared with the water quality guidelines of a maximum increase of 5 NTU if the background NTU is 8-50 (BCMOECCS, 2019).

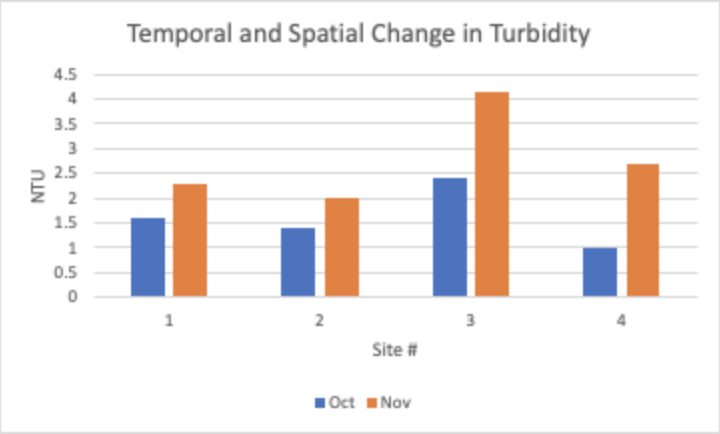

Figure 8: 2019 Temporal and Spatial Turbidity Change of Beck Creek

The water quality guideline for nitrates is 32.8 mg/L (BCMOECCS, 2019), although in BC coastal rivers and lakes, they tend to be <0.30 mg/L (Demers, 2019). As depicted in Figure 10, The highest concentration of nitrates found in Beck Creek was 0.03 mg/L of NO_3. This is well within the guidelines, but about 10x lower than would be expected of similar water courses. 2017 and 2018 reports indicate that nitrate levels have remained fairly steady since study of Beck Creek began. It is unclear what is responsible for the lower level of nitrates in Beck Creek, as the nearby old mines, train tracks, and agriculture land would be expected to leech nitrates into the watershed (Demers, 2019).

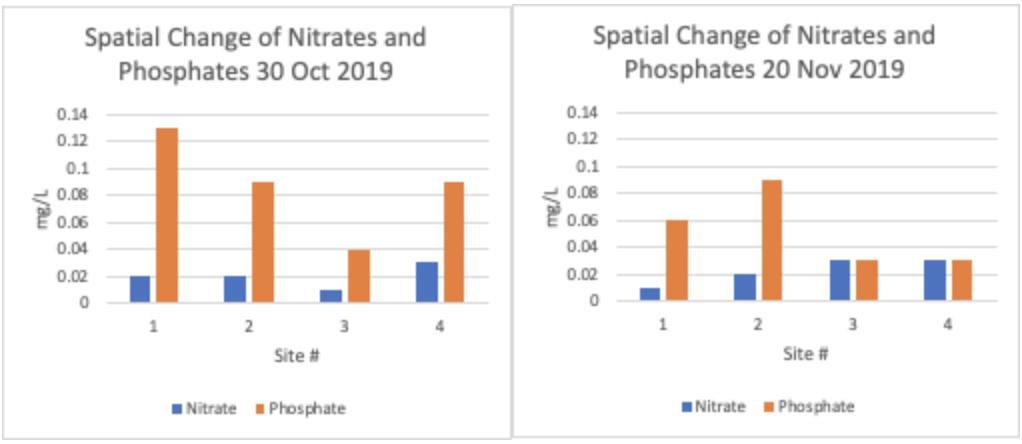

Figure 9: 2019 Temporal and Spatial comparison of Nitrates and Phosphates for Beck Creek

Phosphate is normally the most limiting freshwater nutrient. Levels exceeding 0.03 mg/L of PO_4 can cause eutrophication of waterbodies (Demers, 2019). High levels of phosphates are present throughout Beck Creek, with the highest levels being found in Site 1 and 2. Phosphate averages in Site 1 and 2 respectively were 0.95 and 0.9 mg/L. Phosphate levels dropped slightly moving downstream, with Site 3 displaying an average level of 0.035 mg/L and Site 4 resulting in average phosphate levels of 0.06 mg/L. Nitrate and Phosphate levels in 2019 do not differ significantly from the 2018 study results. However, both have dropped greatly from 2017. The increased phosphate levels follow expected patterns from water bodies adjacent to agriculture, residential, and industrial areas (Demers, 2019).

Hardness levels for Beck Creek neither definitely indicated hard or soft water. The water quality guidelines for soft water are <60 mg/L and hard water, >120 mg/L (BCMOELP, 1998). Seen in Figure 11, with the exception of the initial sample of Site 1 (136 mg/L) all sampled values fell in between the guidelines for soft and hard water.

This indicates a normal level, consistent with both the 2018 (Laplante et al) and the 2017 (Miller et al) study results.

Figure 10: 2019 Temporal and Spatial Hardness Comparison of Beck Creek

Alkalinity analysis indicated Beck Creek had a diminutive acid sensitivity throughout. The lowest value found during either sampling event was in Site 4 with a $CaCO_3$ level of 88.8 mg/L (Figure 12), over 4x the representational level of a watercourse with low acid sensitivity (BCMOE, 2017). Site 2 displayed the highest alkalinity during the initial sampling event with 172.8 mg/L (Figure 12).

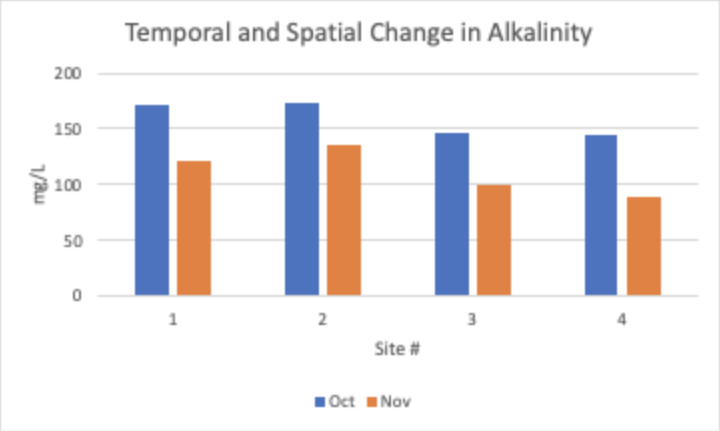

Figure 11: 2019 Temporal and Spatial Alkalinity Change of Beck Creek

3.3.4 ALS Laboratory Analyses

Water samples from sites 1-3 were sent to ALS Laboratories, located in Vancouver, BC. ALS Laboratories provided three bottles per sampling site, resulting in a total of 9 water samples being packaged and sent off for analysis. ALS Laboratories is a more comprehensive laboratory and was able to test for further parameters above and beyond those able to be tested for at VIU. They included total levels of various metals and additional conventional parameters.

Conductivity results from ALS Laboratories were used as the comparison data for Sites 1-3 in this report. Water samples from Site 4 were not sent to ALS Laboratories for analysis, and as such, the VIU sample data was used. Figure 13 depicts a gradual decrease in conductivity from Site 1 (426 µS/cm) to Site 4 (398 µS/cm) during the initial sampling event. This trend is replicated throughout the second sampling event. During November, there is also an overall lower conductivity than in October. This is potentially due to rain events occurring in between sampling events, diluting the conductivity concentration of the water.

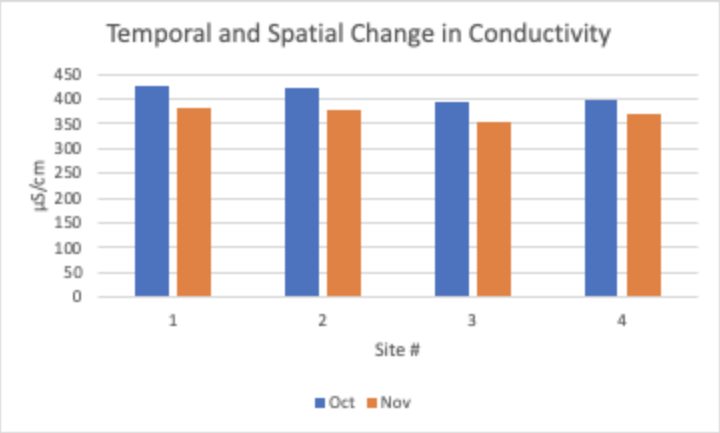

Figure 12: 2019 Temporal and Spatial Conductivity Change of Beck Creek

pH levels did not differ greatly from VIU analysis to ALS Laboratories analysis. The LDLs that ALS laboratories could achieve for nitrates and phosphates were 0.0010 and 0.0020 mg/L respectively. These LDLs are 10x lower than what the VIU laboratory equipment is capable of detecting. In addition, ALS Laboratories compares Total Nitrogen levels to Total Phosphorus levels, as opposed to the Nitrate:Phosphate comparison that could be conducted at VIU. As such, ALS Laboratories values for N:P Ratio will be used. Despite what the nitrates and phosphates sampled at VIU indicated, Beck Creek N:P ratios were inconsistent. Some sites saw increases from October to November, while others saw decreases. There was also no indication of a decrease or increase of the N:P ratio moving downstream, unless one took into account the average N:P ratios for each site. A third sampling event would aid in determining temporal and spatial N:P trends. On average, Site 1 was just slightly Nitrogen limited, while both Site 2 and 3 were Phosphorus limited.

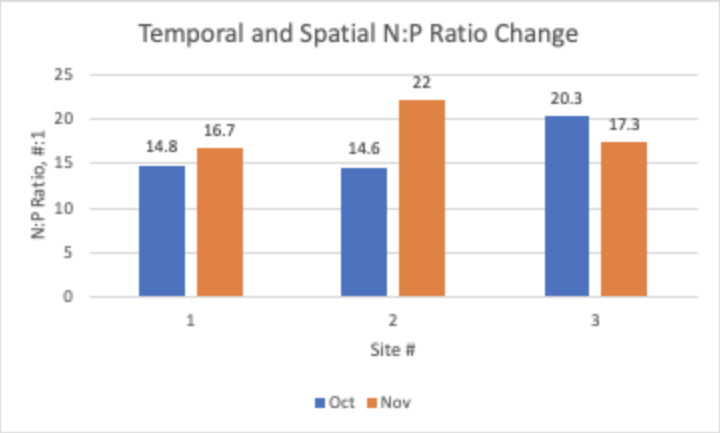

Figure 13: 2019 Temporal and Spatial N:P Ratio Change of Beck Creek

ALS laboratories metal analyses came back as either meeting water quality guidelines, or had LDLs too large to detect potential harmful levels.

3.3.5 Quality Assurance/ Quality Control Measures

Ensuring the integrity of field samples is of the utmost importance. To aid in the prevention of contamination, sampling methods strictly adhered to the methods outlined in the Ambient Freshwater and Effluent Sample manual (BCMWLAP, 2013). Results from VIU and ALS Laboratories were checked and cross-referenced between each other. Cross-referencing the data will readily detect errors and omissions. Trip blanks were used to detect environmental contaminants or faults in sampling methods. It is unknown where the trip blanks supplied by Dr. Eric Demers were acquired from, but both nitrate and phosphate levels found in the trip blanks mimicked those in the field samples.

3.3.6 Data Analyses, Comparison to Guidelines

Data from both ALS Laboratories and Vancouver Island University was compared with the water quality guidelines for freshwater aquatic life contained in 'Guidelines for Interpreting Water Quality Data in BC' (BCMWLAP, 1997). Comparisons identified abnormal parameter levels within the creek, which were used to determine stream health issues and the steps required to mediate them.

3.4 Microbiology

3.4.1 Water Sample Collection

Microbiology sampling only take place during the first sampling event on October 30, 2019. The microbiology sampling helped determine the presence or absence of total coliforms and fecal coliforms (*E. coli*). A total of five 100 mL samples, with a replicate sample from Site 2, was collected from each site using sterile 100 mL Whirl-Pak bags.

3.4.2 VIU Laboratory Analyses

Samples collected from Beck Creek were taken to Vancouver Island University laboratory for analysis and methods outlined in the *Total Coliforms and E. Coli Membrane Filtration Method* (US EPA 2003) were followed for microbiology sampling and analysis. All five 100 mL samples were filtered through a vacuum pump with a 47 µS membrane filter. Each sample was transferred into separate petri dishes that contained a m-ColiBlue24 broth saturated absorbent pad. The petri dish was incubated

for 24 hours at 35 °C ± 0.5°C and the number count was recorded as colony forming units (CFU) per 100 mL.

After water samples were analyzed at VIU lab, the number of fecal (*E. coli*) and non-fecal coliforms grown in petri dishes was recorded. Colours of the colonies formed included red, blue, and clear but only the red and blue. Images of the coliform plates can be found in the appendix. The blue coliforms indicate the presence of fecal coliform (*E. coli*) and red coliforms indicate the presence of non-fecal coliforms. Blue colonies counted from Site 1 and red colonies from Sites 1, 3, and 4 were counted by choosing 10 random squares due to the high amount of fecal (*E. coli*) and non-fecal coliforms. The average count per square for each individual dish was multiplied by the filtered area (908 mm^2) over the area of each square (9 mm^2). Calculations of fecal (*E. coli*) and non-fecal coliforms can be found in Figure 3. For the rest of the plate counts, the number of fecal (*E. coli*) and non-fecal coliforms was determined by counting each individual red or blue dot.

Results from 2017 and 2018 vary from the results indicated below. In 2017, the highest amount of fecal (*E coli*) coliforms was found at Site 3 and the highest amount of fecal (*E. coli*) coliforms in 2018 was at Site 4 replicate sample. In 2019, the highest amount of fecal (*E. coli*) coliforms was also found at Site 4. This beaver dam and stagnant water around and at this location may be a reason for the buildup of fecal (*E. coli*) coliforms. According to the *Guidelines for Interpreting Water Quality Data*

(BCMWLAP 1997), water from Beck Creek should not be consumed without treatment and Site 1 could be used for general irrigation.

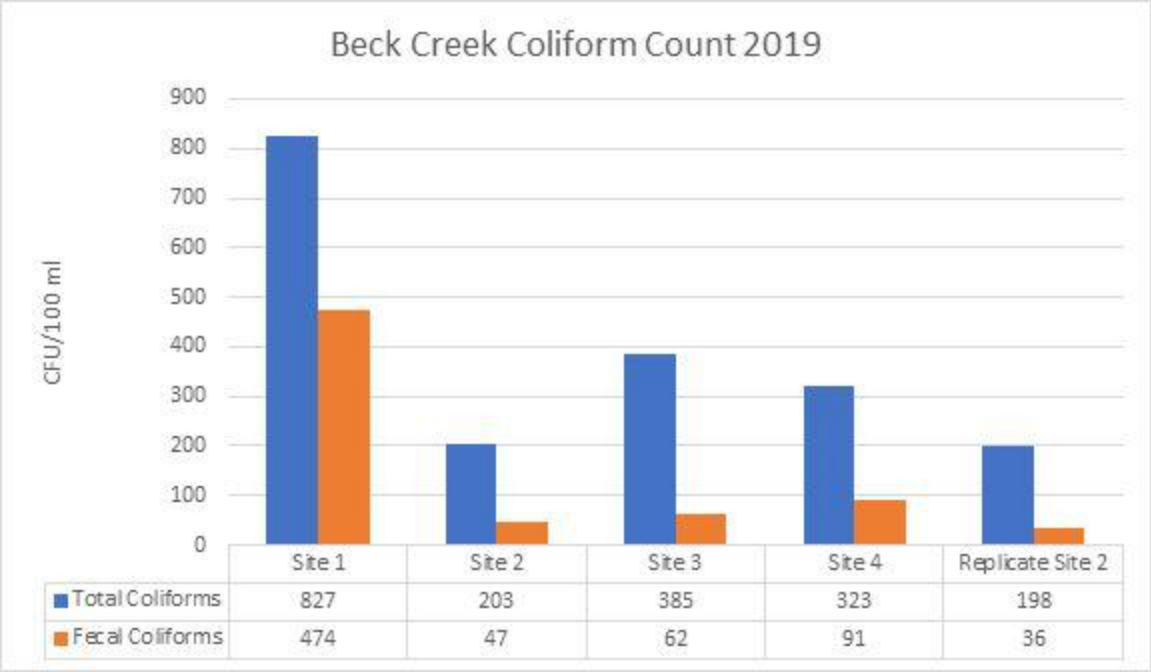

Figure 14: Total and fecal coliform counts taken during first sampling stint on October 30, 2019.

3.4.3 Quality Assurance/ Quality Control Measures

Proper sampling techniques and methods were carried out both in the field and in lab settings. Latex gloves were worn in the lab during analysis, and proper use of equipment was implemented, and the cleanliness of equipment was maintained during analysis for quality assurance. To ensure quality of samples, m-ColiBlue24 Broth will only be used if the product has received approval from the testing manufacturer. The replicate sample can be used as a duplicate sample from one of those chosen sites, this will show if consistency in sampling.

Microbiology testing was conducted during the first sampling set only at all four stations. 100-ml sterile Whirlpak bags will be used to collect the water sample. The bags were labeled prior to the sample collection. The sample bags were then taken back to the lab to be studied for chloroform. The samples were pumped through a sterile filter and placed onto sterile petri dishes containing a pad soaked in ColiBlue24 broth to promote bacterial growth. The petri dishes were then placed in an incubator at 37 degrees celsius overnight and removed the following morning. If Blue colonies appear on the petri dishes it is a sign the water sample contains fecal coliform. Quality Assurance was maintained throughout the testing by wearing gloves, using sanitized containers and proper storage. Quality Control was ensured by using sample blanks and one replicate throughout the analysis.

3.5 Stream Invertebrates Communities

3.5.1 Invertebrate Sample Collection

Stream invertebrate samples were collected from sites 2 and 3 (See Appendix) in the low flow period on October 30. We used the Streamkeepers Handbook refered to use by Dr. Eric Demers for field and lab protocol (Taccogna and Munro 1995). For the two sites we sampled, we took 4 replicate samples per site making a total of 8 invertebrate samples in the sampling areas of Beck Creek. A Hess sampler was used to collect the invertebrate samples by starting a sample set in the lower crest of a riffle moving upwards to the upper crest of the riffle. We used similar substrate composition in each sample site to allow for accurate sampling. Sterilized bottles were used to store

and transport samples. All invertebrate samples were kept alive in each sample bottle,stored in a cooler and transported to the lab for accurate identification of the invertebrates collected.

3.5.2 Laboratory and Data Analyses

The collected Invertebrates from sites 2 and 3 were analyzed in the lab on October 30. Each sample set and replicate was separated into groups based on the 3 pollution tolerance categories and further into family and order. During analysis in the lab an invertebrate survey field data sheet was filled out to record the number of species and taxa (See Appendix Tab D). The data sheet was then used to determine abundance and density, water quality assessments, diversity, predominant taxa, and an overall site assessment rating (See Appendix Tab D). The Shannon-Wiener Index of Diversity was then applied to determine the overall diversity of the stream for each of the two sites (See tables 3 and 4).

After lab analysis of the benthic invertebrates collected in the Beck Creek we calculated for the three categories of invertebrates, category 1 being (pollution Intolerant), category 2 somewhat pollution tolerant, and category 3 (pollution tolerant). These Categories indicate the species that are most abundant and pollution tolerance levels for each category of species. Using the Invertebrate Survey Field Data Sheets in Appendix D we determined that for site 2 we collected 199 species of invertebrates and 103 species of invertebrates for site 3. For site 2 the average site rating equaled 2.75 which is in the marginal to good category for overall site assessment. For site 3 the

average site rating equaled out to 3.25 which is in the Acceptable to Good category for overall site assessment for invertebrates (See Appendix Tab D). The difference is rating for site 2 and 3 is primarily due to the abundance of species within the EPT Index. The EPT Index describes the species that are most pollution intolerant. The greater number of specimen and diversity of taxa within this category indicate a healthier stream. To look closer at the ratio for each category compared to the total number of specimens for each site see (Figure 16). As you can see in the pie graphs below site 3 was composed of more Category 1 (pollution intolerant) species and in site 2 was composed of more Category 2 (somewhat pollution tolerant).

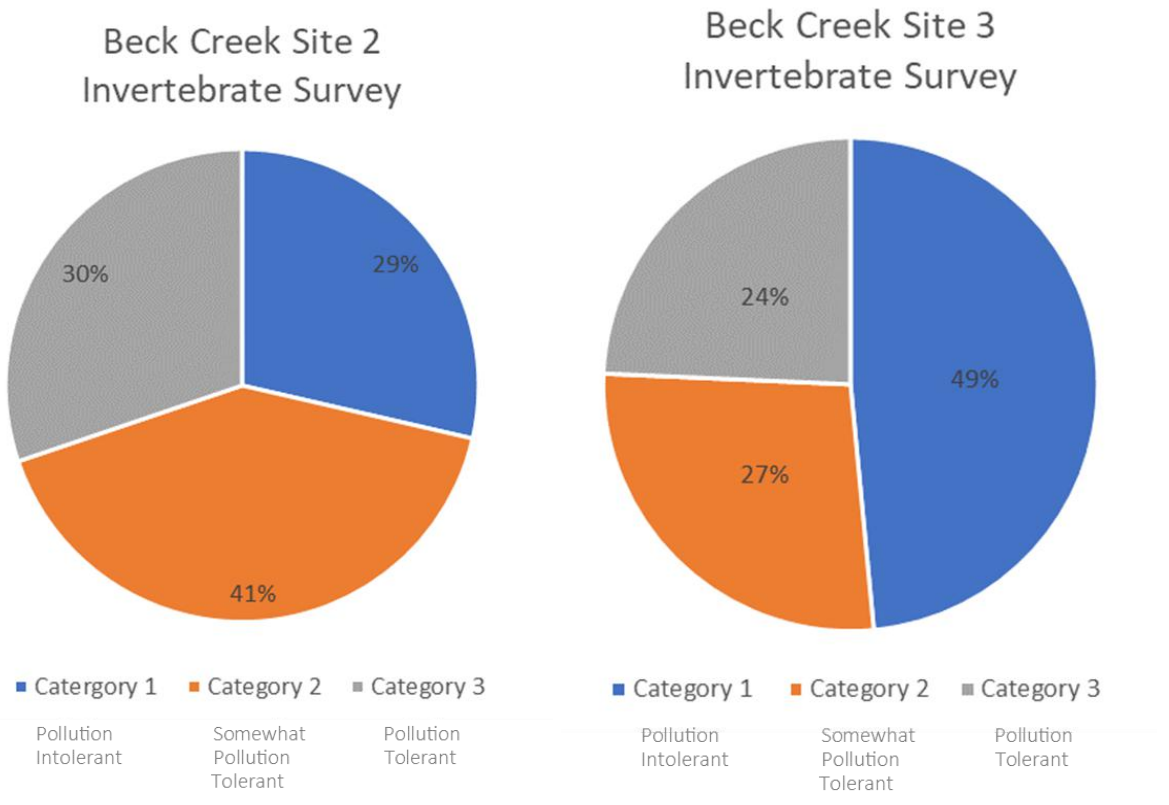

Figure 15 : Beck Creek Site 1 and 2 Invertebrate Categories

Next we used the Shannon Wiener index of diversity to calculate the level of diversity for site 2 and 3. In the Shannon Wiener index the calculations range from 0 being low diversity to 1 being high diversity. Our Shannon Wiener Diversity Index calculated to 0.689 for site 2 and 0.794 for site 3 (See Tables 3 and 4). The two values calculated for both site indicates a relatively high diversity in invertebrates within our site with site 2 being the lower of the two which is similar when we calculated the EPT Index. We also compared our index rating with the past reports from VIU students in 2017 and 2018. The index diversity ratings for both years was relatively low with an average of 0.4 except for site 2 in 2017 which was 0.69 (See Appendix Tab D).. This comparison shows us that the diversity of the Shannon Wiener Index has increased drastically in 2019.

Table 4: Shannon Wiener Invertebrate Diversity Index Site 2

Stream Invertebrate Sample - Beck Creek (Site 2)

Shannon-Weiner Diversity Index

Species (Common Name)	Number Counter/Species	*pi*(C/T)	ln(*pi*)	*pi**ln(*pi*)
Stonefly Nymph	57	0.286	-1.252	-0.358
Clam/Mussel	2	0.01	-4.605	-0.046
Cranefly Larva	8	0.04	-3.219	-0.129
Scud (Amphipod)	72	0.362	-1.016	-0.368
Aquatic Worm	46	0.231	-1.465	-0.338
Blackfly Larva	1	0.019	-3.963	-0.075
Midge Larva	13	0.005	-5.298	-0.026
TOTAL	199	0.998	-----	-1.34

$$H = \frac{-\sum_{i=1}^{S}(p_i \cdot \ln p_i)}{\ln S} =$$ -(-1.34)/ln(7)=0.689

Table 5: Shannon Wiener Invertebrate Diversity Index Site 3

Stream Invertebrate Sample - Beck Creek (Site 3)

Shannon-Weiner Diversity Index

Species (Common Name)	Number Counter/Species	*pi*(C/T)	ln(*pi*)	*pi**ln(*pi*)
Mayfly Nymph	15	0.1456	-1.9269	-0.281
Stonefly Nymph	35	0.3398	-1.079	-0.367
Alderfly Larva	3	0.029	-3.54	-0.103
Cranefly Larva	11	0.1067	-2.2378	-0.239
Crayfish	1	0.0097	-4.636	-0.045
Scud (Amphipod)	13	0.126	-2.071	-0.261
Aquatic Worm	15	0.1456	-1.9269	-0.217
Blackfly Larva	2	0.019	-3.963	-0.0753
Midge Larva	6	0.058	-2.847	-0.165
Water Mite	2	0.019	-3.963	-0.0753
TOTAL	103	0.998	-----	-1.8286

$$H = \frac{-\sum_{i=1}^{S}(p_i \cdot \ln p_i)}{\ln S} = \quad -(-1.8286)/\ln(10)=0.794$$

Lastly, it was important to get an overall comparison of the invertebrates collected and analyzed from the VIU students in 2017 and 2018 to understand how the 2019 monitoring projects reflects previous data. A bar graph was created to illustrate the comparison of the Invertebrate Survey average site ratings for all 3 years (See Figure 17). In 2017 for both sites 2 and 3 gave an average site rating of 1 which is ranked in the poor site rating category. In 2018 for both sites 2 and 3 gave an average site rating of 1.75 which is in poor to marginal site assessment category. For this year (2019) we calculated site 2 at 2.75 in the marginal to acceptable category and site 3 at 3.25 in the acceptable to good site assessment category. In the graph you can see the trend of the site assessment ratings increasing each year. This is an indicator that water quality

parameters are reflecting the increase in overall health of the stream by the presence of pollution intolerant species in abundance. Invertebrate sampling supplements water quality parameters well, because without good water quality we would not have good site assessment ratings or good Shannon Wiener Index ratings (Taccogna and Munro 1995).. Invertebrates play an important role in the stream ecosystem, they are part of the food chain and supply many organisms and aquatic life with food. Invertebrates also help clean the streams by consuming algae, fungi, bacteria and break down leaf liter to provide food for other species (Taccogna and Munro 1995).

Figure 16: Comparison of Invertebrate Average Site Assessment for 2017-2019

3.5.3 Quality Assurance/ Quality Control Measures

Quality assurance and quality control measures outlined in the Freshwater Biological Sampling Manual (Cavanagh, et al.) were followed while sampling and analyzing stream invertebrates. Assuring that no samples were contaminated during collection with proper and clean equipment being used in the field and lab. Replicates of samples from each sample at both sites were collected to ensure the quality of the samples collected. In the field we added extra stream water to the top of each sample before securing with a lid to keep the invertebrates alive and stored them in a cooler before transporting to the lab. We kept the invertebrates alive to maintain accurate sampling in the lab. In the lab we used large trays to analyse each sample bottle separately. We did this to ensure we collected and identified each invertebrate accurately for each replicate sample. We also made sure to analyse and identify all invertebrates for site 2 and then separately for site 3 so that we did not commingle the samples for each site. Additionally, data sheets were used to record specimens to ensure proper identification and calculation of invertebrates for each site.

4.0 Conclusion & Recommendations

4.1 Overall stream health

The greatest indicator of stream health for Beck Creek was the presence of salmonids at Site 3 during the second sampling event. Immediately downstream of Beck Lake is eutrophic, dotted with beaver dams and wetland habitat. The DO here provides poor habitat for fish survival. It is not until further downstream of Site 1 that water quality traits begin to improve. Beginning with Site 2, DO levels rise to almost 3x that which is found in Site 1. Moving downstream from Site 1, average N:P ratios did increase to above the recommended 16:1 ratio for optimal plant growth. It appears to be a trend within our sites of the Beck Creek that the overall health of the stream decreases going upstream towards site 1 and 2. This is mostly due to the lower levels in water quality for dissolved oxygen, conductivity, nitrogen and phosphates. This is most likely due to eutrophication in the Beck Lake diluting into the upper site 1 and 2. Another concern is the high conductivity levels in all of our sites specifically for sites 1 and 2, this is due to acid mine drainage from historical use of the area. Comparing 2019 results to the previous two years of reporting, the 2019 microbiology results were not consistent with 2017 and 2018 results. In the 2019 assessment, the greatest amount of fecal (E. coli) coliforms occurred at Site 1 and were significantly lower at Site 2, 3, and 4. Microbiology results are consistent with the findings of water quality suggesting that Site 1 is more eutrophic than the other three sites. Eutrophication at Site 1 may indicate impact from

urbanization, agricultural runoff, and impacts from wildlife living within the Beck Creek tributary. The invertebrate sampling in sites 2 and 3 indicated the change in overall quality from the lower site 3 and 4 and the upper sites 1 and 2. In Site 2 the EPT index was slightly lower than site 3 for overall site assessment. The invertebrate analysis shows that overall site 2 and 3 have increased for abundance and diversity in the last 3 years.

4.2 Recommendations for ongoing studies

A third sampling event every year would aid in establishing yearly and ongoing trends in stream health. As this is a fairly new study, data trends are just beginning to surface. Definite trends in stream health should not be derived until at least one or two more years of data have been collected. The unfamiliarity of scientists with the sampling locations and specific methods used to sample Beck Creek could contribute more readily to errors than later years once the study has been established. As well, the weather and water flow patterns seen in Beck Creek have as of yet to be confirmed as analogous. For on going study we recommend more sample sites towards Beck Lake which is south of site 1. Our analysis indicates that water quality issues are coming from further upstream past site 1. We also recommend more invertebrate samples specifically in site 1 to determine the abundance and diversity of organisms in that site. For all four of our sites we recommend more replicate samples for all parameters to get a more accurate analysis. Finally, we recommend a minnow trapping event in all four

sites to determine the presence or absence of fish species with in the Beck Creek. We recommend continuing monitoring the Beck Creek to generate trend analysis and health of the system each year.

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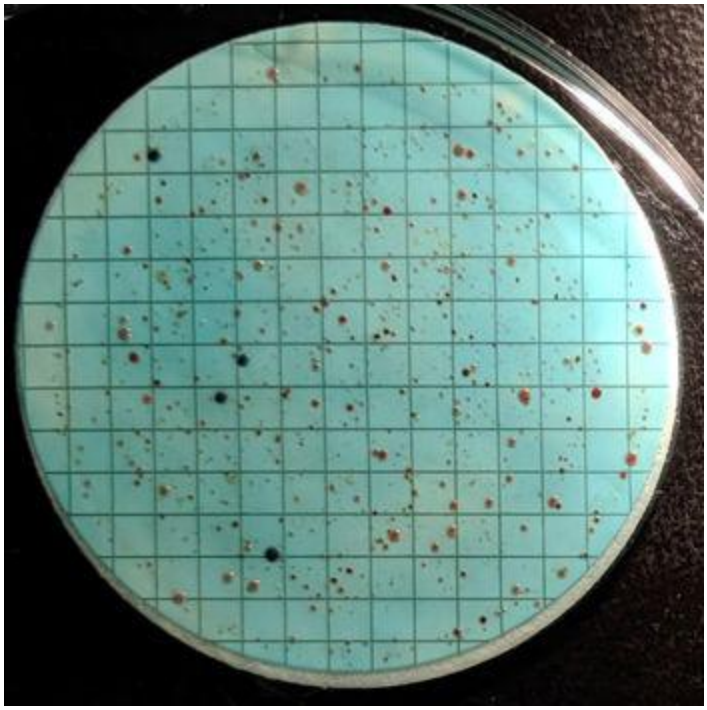
Appendix

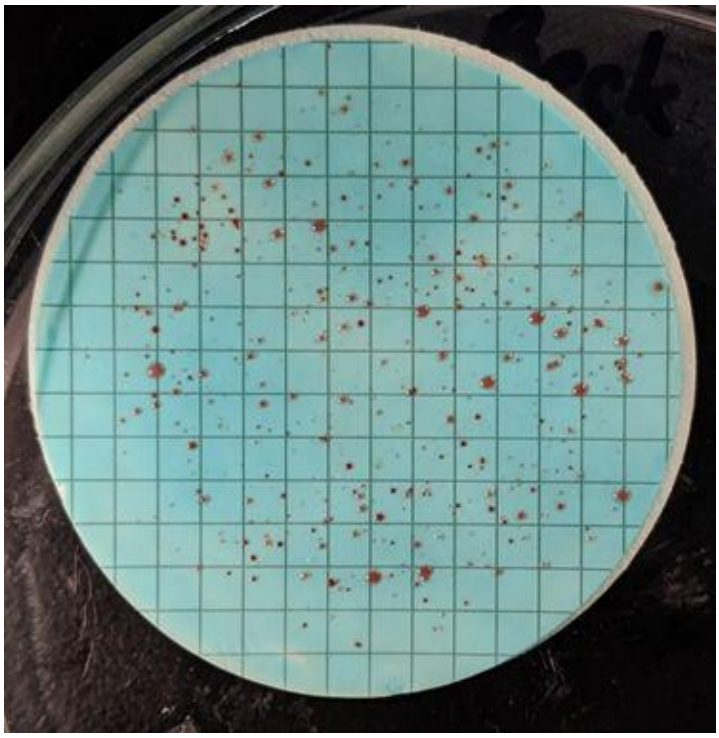
Parameters	Units	Site 1		Site 2		Site 2 Replicate		Site 3		Site 4		Trip Blank	
		30-Oct	20-Nov	30-Oct	20-Nov	30-Oct	20-Nov	30-Oct	20-Nov	30-Oct	20-Nov	30-Oct	20-Nov
DO	mg/L	3.5	5.1	9.5	9.7	9.5	9.7	11.4	11	10.2	11.4	-	-
Temperature	Deg Celcius	5.5	5.9	4.7	5.6	4.7	5.6	4.5	5.2	6.1	5.3	-	-
pH	pH Units	7.3	7.5	7.2	8	7.1	7.9	6.4	8.1	6.8	8	-	-
Conductivity	uS/cm	418	853	417	556	407	515	363	575	398	368	-	-
Turbidity	NTU	1.6	2.27	1.4	2.02	1.7	1.82	2.4	4.15	1	2.7	-	-
Nitrates NO3	mg/L	0.02	<0.01	0.02	0.02	<0.01	0.03	<0.01	0.03	0.03	0.03	0.01	0.03
Phosphates PO4	mg/L	0.13	0.06	0.09	0.09	0.09	0.05	0.04	0.03	0.09	0.03	0.02	0.09
Hardness CaCO3	mg/L	136	84	112	88	96	88	96	84	96	76	-	-
Alkalinity CaCO3	mg/L	171.6	120.8	172.8	136	170.4	111.6	145.6	100.4	144	88.8	-	-

Client Sample ID			BECK CREEK-STATION 1	BECK CREEK - STATION 1	BECK CREEK-STATION 2	BECK CREEK - STATION 2	BECK CREEK-STATION 3	BECK CREEK - STATION 3
Date Sampled			30-Oct-2019	20-Nov-2019	30-Oct-2019	20-Nov-2019	30-Oct-2019	20-Nov-2019
Time Sampled			9:00	9:00	9:00	9:00	9:00	9:00
ALS Sample ID			L2374854-1	L2386179-1	L2374854-2	L2386179-2	L2374854-3	L2386179-3
Parameter	Lowest Detection Limit	Units	Water	Water	Water	Water	Water	Water
Physical Tests (Water)								
Conductivity	2.0	uS/cm	426	381	424	377	395	352
Hardness (as CaCC	0.50	mg/L	92.2	84.6	90.4	84.1	89.6	82.3
pH	0.10	pH	7.58	7.82	7.82	7.97	8.02	7.99
Anions and Nutrients (Water)								
Ammonia, Total (a:	0.0050	mg/L	0.0663	0.0463	0.0269	0.0333	0.0094	0.0129
Nitrate (as N)	0.0050	mg/L	0.0136	0.0140	0.0128	<0.025	0.0161	0.0799
Nitrite (as N)	0.0010	mg/L	0.0029	0.0051	0.0022	<0.0050	0.0014	0.0023
Total Nitrogen	0.030	mg/L	0.527	0.560	0.466	0.729	0.448	0.529
Orthophosphate-Di	0.0010	mg/L	0.0141	0.0110	0.0108	0.0098	0.0077	0.0065
Phosphorus (P)-Tot	0.0020	mg/L	0.0355	0.0335	0.0319	0.0332	0.0221	0.0306
N:P	N/A	N/A	14.8	16.7	14.6	22.0	20.3	17.3
Total Metals (Water)								
Aluminum (Al)-Tot	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony (Sb)-Tot:	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	0.010	mg/L	0.053	0.042	0.045	0.044	0.037	0.036
Beryllium (Be)-Tot	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	0.10	mg/L	0.13	0.10	0.12	<0.10	0.11	<0.10
Cadmium (Cd)-Tot:	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total	0.050	mg/L	27.4	25.0	26.8	24.8	26.4	24.0
Chromium (Cr)-Tot	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	0.030	mg/L	0.735	0.869	0.564	0.894	0.390	0.682
Lead (Pb)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-T	0.10	mg/L	5.78	5.41	5.68	5.36	5.73	5.41
Manganese (Mn)-T	0.0050	mg/L	0.117	0.0929	0.0550	0.201	0.0216	0.0727
Molybdenum (Mo)-	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Tot	0.30	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Tota	2.0	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Tota	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total	0.10	mg/L	8.31	8.47	8.11	8.45	7.61	7.20
Silver (Ag)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total	2.0	mg/L	64.9	52.6	63.0	52.9	56.3	41.9
Strontium (Sr)-Tota	0.0050	mg/L	0.392	0.294	0.373	0.287	0.334	0.239
Thallium (Tl)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium (V)-Tot:	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Qualifier Legend								
HTC	Hardness was calculated from Total Ca and/or Mg concentrations and may be biased high (dissolved Ca/Mg results unavailable).							

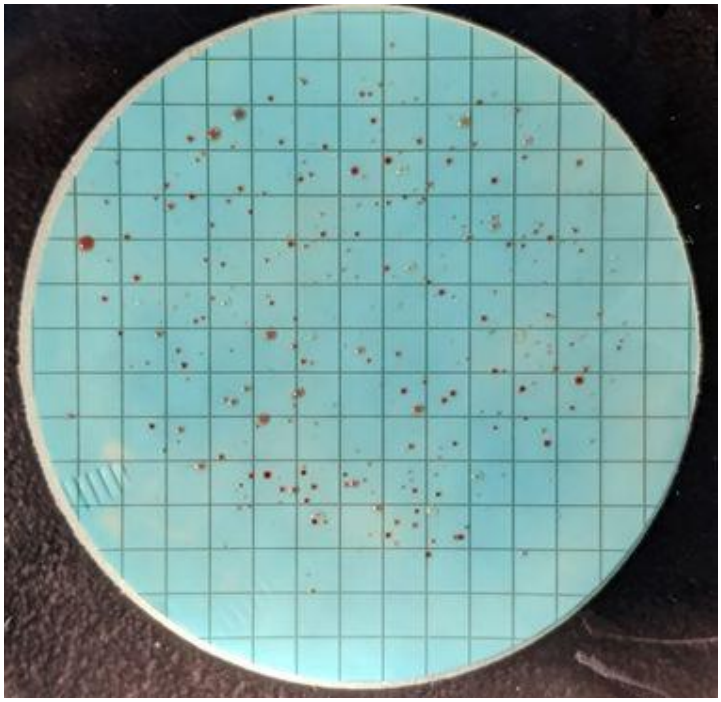
Site 1 Beck Creek coliform plate sampled October 30, 2019 Tab C



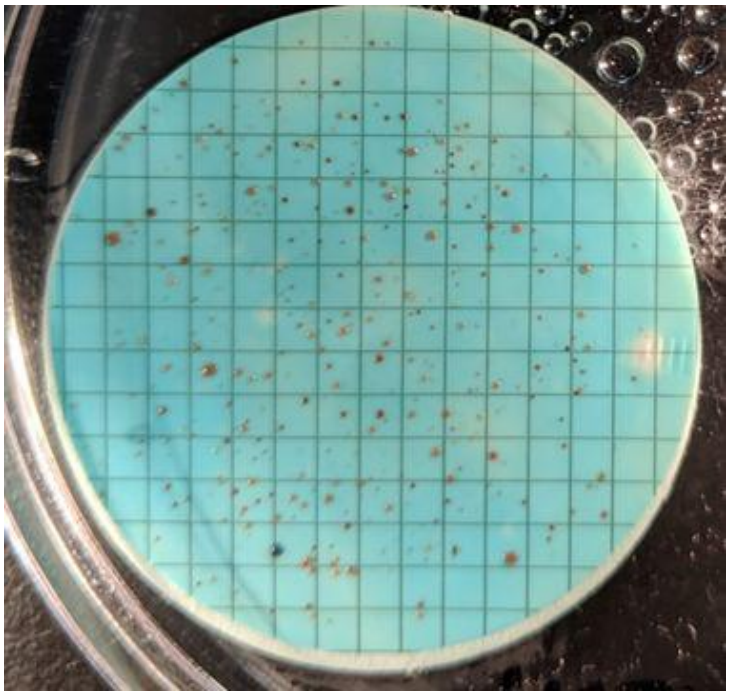
Site 2 Beck Creek coliform plate sampled October 30, 2019



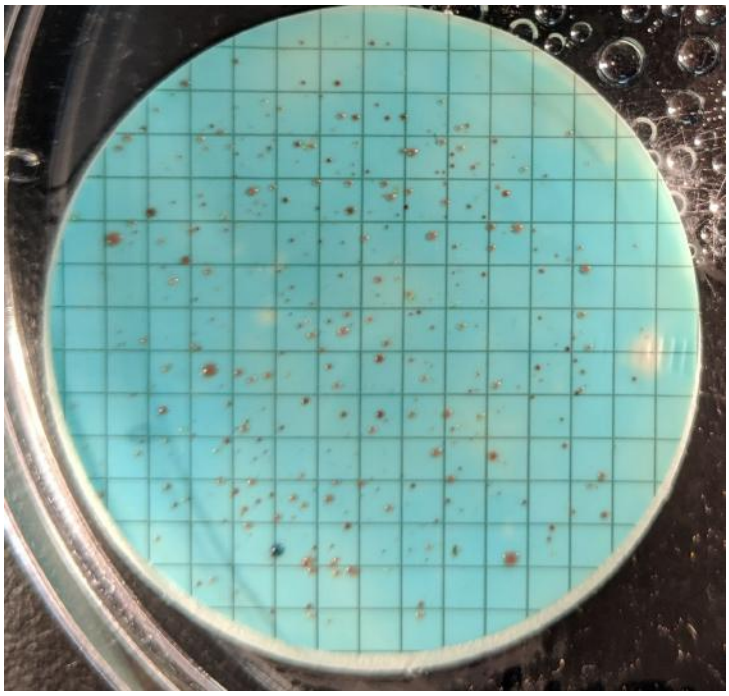
Site 3 Beck Creek coliform plate sampled October 30, 2019 Tab C



Site 4 Beck Creek coliform plate sampled October 30, 2019



Replicate sample site 2 Beck Creek coliform plate sampled October 30, 2019 Tab C



Invertebrate Comparisons 2017-2019

2017	Shannon-Wiener Index	EPT Index
Site 2	0.693	1 (Poor)
Site 3	0.421	1 (Poor)

2018	Shannon-Wiener Index	EPT Index
Site 2	0.44	1.75 (Poor)
Site 3	0.48	1.75 (Poor)

2019	Shannon-Wiener Index	EPT Index
Site 2	0.689	2.75 (Marginal)
Site 3	0.794	3.25 (Acceptable)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Beck Creek	Date:	30 October, 2019
Station Name:	Site 2	Flow status:	Low

Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates
Hess Sampler	4	0.09 x4 $0.36m^2$

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)		
	Stonefly Nymph (EPT)	57	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		57	2
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	2	1
	Cranefly Larva	8	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	72	1
	Watersnipe Larva		
Sub-Total		82	3
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	46	3
	Blackfly Larva	1	1
	Leech		
	Midge Larva (chironomid)	13	2
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		60	6
TOTAL		199	11

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 199

DENSITY: Invertebrate density per total area sampled:

199 ÷ 0.36 m^2 = 552.77 / m^2 (From page 1)

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (in Col. C): Amphipods (72)

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x __2__ + 2 x __3__ + __6__ = 18

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

__0__ + __0__ + __2__ = 2

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

__0__ + __0__ + __57__) / __199__ = 0.286

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 11

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

__72__ / __199__ = 0.362

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	3
EPT Index	2
EPT To Total Ratio	2
Predominant Taxon Ratio	4

Average Rating

Average of R1, R2, R3, R4

2.75

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:		Date:
Beck Creek		30 October, 2019
Station Name: Site 3		Flow status: Low
Sampler Used: Hess Sampler	Number of replicates 4	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 X 4= 0.36 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	15	3
	Stonefly Nymph (EPT)	35	3
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		50	6
Category 2 Somewhat Pollution Tolerant	Alderfly Larva	3	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	11	3
	Crayfish	1	1
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	13	2
	Watersnipe Larva		
Sub-Total		28	7
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	15	3
	Blackfly Larva	2	1
	Leech		
	Midge Larva (chironomid)	6	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		25	6
TOTAL		103	19

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 103

DENSITY: Invertebrate density per total area sampled:

103 ÷ 0.36 m^2 = 286.11 / m^2 (0.36 m^2 From page 1)

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (in Col. C): Stonefly Nymph (35)

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x _6__ + 2 x __7__ + __6___ = 36

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

__0___ + __3___ + __3___ = 6

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

_0___ + __15___ + __35__) / __103___ = 0.485

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 19

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

___35__ / ___103__ = 0.339

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	3
EPT To Total Ratio	2
Predominant Taxon Ratio	4

Average Rating
Average of R1, R2, R3, R4
3.25