Water Quality and Stream Invertebrate Assessment on Richards Creek, North Cowichan (BC)

Submitted to:
Dr. Eric Demers

Vancouver Island University

900 Fifth St. Nanaimo, BC, Canada V9R 5S5

Ph: (250) 753-3215; 2033

Submitted by:

Tylyn Der, Stephanie Govier, Hailey Quist, and Heidi Richardson

RMOT 306

Vancouver Island University Natural Resource Protection Dept.

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Executive Summary

An environmental monitoring project was conducted by four students in the Natural Resource Protection Program at Vancouver Island University (VIU) on Richards Creek in the Cowichan Valley, BC. Four stations were monitored that were established by previous projects. This project is a continuation of previous assessments completed by VIU and the Department of Fisheries and Oceans.

The objective of this stream survey was to assess current stream condition and contribute to existing data for monitoring long-term stream health. To conduct this assessment, sampling was completed during low water flow and high water flow events, on November 2, 2015, and November 24, 2015, respectively. Basic hydrology, water quality parameters, microbiology and stream invertebrate communities were analyzed in this project.

Water samples were analyzed ALS Environmental Laboratory in Vancouver, B.C. and by students in the Vancouver Island University Laboratory. The data was then compared to BC Water Quality Guidelines (RISC 1998). With the exception of dissolved oxygen, we found that all the nutrients and metals were below the applicable guidelines. In the microbiology samples, the high amount of fecal coliforms reflected the agriculture in the area. The invertebrate communities suggested that the stream is relatively healthy. All stations had a decent diversity of stream invertebrate taxa. During sampling, two Coho salmon (*Oncorhynchus kisutch*) were observed in the stream indicating the stream was capable of sustaining salmonid life.

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1.0 Introduction

1.1 Project Overview

This environmental monitoring project of Richards Creek, located in North Cowichan, BC, ran for four weeks from October 26 to November 25, 2015. Four third-year Bachelor of Natural Resource Management and Protection students from Vancouver Island University conducted this project under the direction of Dr. Eric Demers.

Richards Creek is a 10-km long creek located south of Crofton that runs from the Crofton Reservoir into the northeast end of Somenos Lake in Duncan (Appendix I, Figure 1). The creek varies in width from 2-18 m and has a gradient that fluctuates from <0.1-5.0%. Headwaters originate from Mount Richards and Maple Mountain and are fed into the stream via the Crofton Reservoir. The stream then flows through lowlands occupied by agriculture (Lanarc Consultants Limited 1999). The Crofton Reservoir is managed and maintained by the District of North Cowichan as a source of potable water. Water is discharged 60 m below the reservoir into Upper Richards Creek and is regulated by a 5 cm pipe. Due to this outflow, water leaving the lake has been recorded at lethal temperatures in the early summer months into a salmonid bearing stream. High temperatures are partially alleviated by groundwater springs feeding into the Upper Richards Creek, but the effect is limited during low-flowing summer months (Lanarc Consultants Limited 1999).

1.2 Historical Review

Agriculture has modified the lowland portion of the basin by farmers straightening the creek to flow along field edges and by removing important riparian vegetation on the creek banks.

Flooding of vegetable and hay fields in some areas extends up to 600 m wide, which is then drained back into Richards Creek. In other areas, the creek has been ditched as part of previous agriculture drainage improvements. Habitat compensation was undertaken in 1983 by the dredging of the less productive portion of Lower Richards Creek (Lanarc Consultants Limited 1999). Above Richards Trail on the Van Eeuwen farm, property fences were installed along the riparian corridor to prevent browsing, bank erosion, and in-stream cattle watering. A spawning population of up to 700 Coho salmon (*Oncorhynchus kisutch*) has been recorded in Richards Creek, as well as small populations of chum (*Oncorhynchus keta*), steelhead (*Oncorhynchus mykiss*), cutthroat (*Oncorhynchus clarkii*) and rainbow trout (*Oncorhynchus mykiss*). The productivity of populations has been limited by lack of appropriate spawning and rearing habitat (Madrone Environmental Services Limited 2015). Periodically, water has been withdrawn below Richards Trail for the use of crop watering, which has caused intermittent and reduced stream flow to minimal levels.

1.3 Potential Environmental Concerns

The high-density of agricultural land use, urban areas (particularly near bridges) and large amounts of water licences surrounding Richards Creek are an environmental concern. Ditching and watering of agricultural lands have lead to high-nutrient runoff into Richards Creek. In addition, loss of riparian vegetation due to cattle browsing and field widening has also contributed to high-nutrient runoff. Low flow due to summer water withdrawal from the Crofton Reservoir and decreased surface water flow has resulted in potentially lethal water temperatures and low dissolved oxygen content for salmonids and other aquatic life (Madrone Environmental Services Limited 2015; Lanarc Consultants Limited 1999). Urban areas are affected by disposal of garbage on steep banks near roadways that fall into the creek. This garbage mainly consists of spray paint canisters and fast food waste.

2.0 Project Objectives

The objective of this assessment was to contribute to six years of pre-existing data collected from VIU students and build a long-term assessment of overall stream health. To add to this data, water quality assessment and invertebrate sampling were conducted to determine potential and current environmental impacts on Richards Creek from neighbouring land use. Four set stations focused on monitoring hydrology, water quality, microbiology, and stream invertebrates. Laboratory analysis provided insight into current stream health. The District of North Cowichan, the Department of Fisheries and Oceans, and agriculture landowners will be interested in the results of this monitoring program.

3.0 Methods

3.1 Sampling Stations

3.1.1 Locations

The four sampling locations were based on the previous years of monitoring (Vancouver Island University 2014). These stations were originally selected for accessibility, habitat characteristics, nearby areas of concern for potential effluent sources, and safety of the crew. Residential areas or agricultural fields surrounded each station.

3.1.2 Habitat Characteristics

Station 1 was located on Escarpment Way, near Osborne Bay Road (Appendix I, Figure 2). The site was at the first bridge on this road, approximately 130 m from Osborne Bay Road. The site was overgrown with evergreens and thick brush of various species. The stream substrate consisted of cobble, with few large rocks dispersed throughout. The sampling site was shallow and had fast-moving water. There was residential housing near the creek and one agricultural field.

Station 2 was located at the end of Rice Road (Appendix I, Figure 3). A 25 m path on the left-hand side of a cul-de-sac was used to access the creek. The substrate of the creek consisted of large boulders, cobbles, and large woody debris. This station was in a gully, not near an agriculture field, and had a relatively large riparian buffer.

Station 3 was located at the bridge crossing of Richards Trail (Appendix I, Figure 4). For easier access, the station was located on the west side of the bridge. The substrate of the creek consisted of large cobbles but also had old cement slabs near the culvert/bridge from roadwork or farmers. Agriculture fields surrounded this station as well as a single tree-line of various tree and brush species.

Station 4 was located at the bridge crossing on Herd Road, near Coastal Animal Services (Appendix I, Figure 5). The station was located on the west side under the bridge. There was a cleared gravel area under the bridge and the water was deep with a low gradient. The substrate consisted of small cobbles. This site area was at the end of agriculture fields, had a relatively small riparian area, and duckweed was present during the first sampling event.

3.1.3 Sampling Frequency

Sampling occurred twice within a two-week space in between sampling events on November 2 and 24th. To produce the most representative results, the first water sampling event occurred during low flow, and the second sample event occurred during high flow.

Triplicate stream invertebrate samples were collected during the first sampling event at stations 1, 2 and 3. Microbiology water samples were also only collected during the first sampling event and were taken at all four sites. All other data, hydrology measurement and VIU and ALS Laboratory water samples, was collected during both sampling events and were taken at various sites. At station 1, VIU and ALS samples were collected, at station 2 only VIU samples were collected, at station 3 hydrology, VIU and ALS samples were collected and at station 4 VIU and ALS water samples were collected, including a replicate sample to be analyzed at VIU.

3.2 Basic Hydrology

Many of the water quality parameters discussed below are dependent on stream discharge for proper interpretation. Stream discharge was calculated once at station 3 and was determined by the float method. The float method consists of calculating the cross-sectional area (m^2) of the stream at a specific point, measuring the mean water velocity (m/s) and completing a simple calculation to determine discharge (m^3/s).

3.3 Water Quality

Most water quality parameters were measured during both sampling events. This was to compare the parameters between high and low flow events. The water quality parameters that were measured include water temperature (°C), dissolved oxygen (DO mg/L), conductivity (µS/cm), pH, turbidity (NTU), total alkalinity (mg/L as $CaCO_3$), hardness (mg/L as $CaCO_3$), nitrate (mg/L), and phosphate (mg/L). Water samples were also collected to determine total and fecal coliforms (CFU/100mL).

3.3.1 Field Measurements

Temperature and dissolved oxygen were measured on site using an electronic Oxyguard Handy Polaris DO Meter.

3.3.2 Water Sample Collection

Vancouver Island University water samples were collected in plastic water bottles from the university while ALS Laboratory water samples were collected in sterile glass and plastic containers provided by the company. The water samples for testing total and fecal coliforms were collected in sterile 100-mL Whirlpak bags. The water samples were kept in a refrigerator for a maximum of 4 days until they were analyzed in the lab.

3.3.3 VIU Laboratory Analyses

Turbidity, alkalinity, and hardness were all tested for at Vancouver Island University using their respective HACH kits. To measure nitrate and phosphate a DR 2800 HACH Spectrophotometer was used.

To determine total and fecal coliforms the "Total Coliforms and *E. coli* membrane Filtration Method" developed by the USEPA (2003) was followed. This method involved the filtration of a 100-mL sample through a 47- μm membrane filter, which was then placed onto a petri dish with an absorbent pad filled with m-ColiBlue 24 Broth. The dish was then incubated for 24 hours at 35^{o}C and red (non-fecal) and blue (fecal) colony forming units were counted.

3.3.4 ALS Laboratory Analyses

Samples were also submitted to ALS Laboratories in Vancouver, BC. This private lab provided analysis of general water quality parameters, nutrient analyses and a total metal scan. ALS water quality was conducted on station 1, 3 and 4.

3.3.5 Quality Assurance / Quality Control

To ensure data collected was accurate and precise both Quality Assurance and Quality Control measures were taken. The Ambient Freshwater and Effluent Sampling Manual produced by the Government of British Columbia (2003) was followed. In particular, gloves were always worn when handling and collecting samples in the lab, sample bottles were rinsed three times, samples were stored properly, and blank and replicate samples were taken, etc.

3.3.6 Data Analyses, Comparison to Guidelines

All data collected was compared to the Guidelines for Interpreting Water Quality Data prepared by the RISC (1998).

3.4 Stream Invertebrates Communities

Invertebrate communities of Richards Creek were sampled and analyzed for the first sampling event. The purpose of biological sampling was to get a general idea of ecosystem health.

Species were used to assess the pollutants in the stream by examining the predominant taxa, diversity, and abundance.

3.4.1 Invertebrate Sample Collection

Sampling was conducted once on November 2, 2015, during the low flow of Richards Creek at stations 1, 2, and 3. Three samples were taken for each station in similar habitats and substrates using the Hess sampler. Samples were placed in plastic containers, which were stored in the fridge until live lab analysis was completed at Vancouver Island University.

3.4.2 VIU Laboratory Analyses

The samples were analyzed in a lab within 48 hours. In the lab, we followed the Pacific Streamkeepers' procedures (Taccogna and Munro 1995). The invertebrates were identified to Order or Family and recorded using an invertebrate survey field data sheet for each station. The replicates for each station were taken into account collectively. Density, pollution tolerance index, EPT index and predominant taxon ration index was calculated to determine the overall site assessment rating. The Shannon-Weiner Index was calculated for each station to determine the species diversity in the community.

3.4.3 Quality Assurance / Quality Control

To ensure quality assurance three samples and a replicate were taken at each station to increase accuracy. As a team, we ensured gear was properly used and confirmed all invertebrates were collected into the lab sampling container. Proper sampling techniques included starting downstream and working upstream and collecting each sample independently to prevent the samples to be mixed with others. We accurately determined and noted the substrate type to correctly take the triplicate samples in similar areas. All containers were pre-labeled to ensure samples were put into the right container (DFO 2000). In the lab, we consulted an identification pamphlet to confirm proper identification of the invertebrates. To ensure quality control, data analysis was carefully calculated and verified.

4.0 Results and Discussion

4.1 General Field Conditions

Field observations and the discharge measurements for Richards Creek suggest that the water level was not at bank full during the first sampling event, but was during the second sampling event.

The average maximum air temperature for November was 9^{o}C, with an average minimum temperature of 0.3^{o}C. The average mean temperature for November was 4.7^{o}C (data for Nanaimo Airport retrieved from http://climate.weather.gc.ca/climateData). Total rainfall during the 10-day period prior to the early sampling event on November 2, 2015, was 61.7 mm. The 10-day period prior to the last sampling event on November 24, 2015, had a total precipitation amount of 44 mm.

4.2 Water Quality

4.2.1 Field Measurements

Water temperature averaged 10.0^{o}C and 4.6^{o}C during the early and late November sampling events, respectively (Table 1). The decrease in temperature corresponds with the decrease in air temperature during the same period. Dissolved oxygen was above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998) at all stations with the exception of station 4. Station 4 was well below the guideline with averages of 4.0 mg/L and 7.9 mg/L during the first and second sampling events, respectively (Table 1). These low levels suggest hypoxic conditions during both sampling events likely due to minimal water flow. The increase in dissolved oxygen in the second sampling event can be explained by the increase in stream discharge.

Table 1. Field measurements taken from four stations at Richards Creek on November 2 and 24, 2015. All measurements were taken within 5 cm below the surface with the exception of a lower measurement taken at station 4 to observe the effects of eutrophication near the surface.

Station	**Water Temperature (ºC)**	**Dissolved Oxygen (mg/L)**	**Discharge (m^3/s)**
	November 2, 2015		
1	10.1	12.5	N/A
2	9.4	12.1	N/A
3	9.4	11.8	0.13
4 (surface)	11.3	3.7	N/A
4 (bottom)	10.8	4.3	N/A
	November 24, 2015		
1	6.9	11.2	N/A
2	5.6	13.1	N/A
3	5.6	13.5	0.71
4 (surface)	4.2	8.1	N/A
4 (bottom)	4.3	7.7	N/A

4.2.2 VIU Laboratory Analysis

Conductivity and hardness both decreased from the first event to the second event as expected with the increase in discharge (Table 2). Conductivity decreased from an average of 179 µS/cm to 99 µS/cm and hardness decreased from 109.0 mg/L $CaCO_3$ to 48.8 mg/L $CaCO_3$. Water pH ranged from 7.0-8.9 over both sampling events with a general decrease in pH from upstream to downstream. For unexplainable reasons, water pH was abnormally high (8.6 and 8.9) at station 1 during both sampling events, although results were still within the guideline of 6.5-9 (RISC 1998).

Alkalinity changed from low acid sensitivity in the first event (22 mg/L $CaCO_3$) to moderate acid sensitivity in the second event (14 mg/L $CaCO_3$) (RISC 1998). Alkalinity remained relatively constant from upstream to downstream during the first sampling event, while it increased from upstream to downstream during the second sampling event. Turbidity increased from the first event to the second event with average amounts of 4.57 NTU and 2.60 NTU. This difference is explained by the increase in discharge from the first event to the second event.

Nitrate and phosphate were high in both sampling events, although both were higher in the first event. Nitrate had an average of 2.86 mg/L during the first event and 1.24 mg/L during the second event. During the first event phosphate was an average of 0.25 mg/L and during the second event, it was an average of 0.20 mg/L. Both nitrate and phosphate generally increased from upstream to downstream, which was anticipated by the obvious eutrophication of the lower stream during the first sampling event.

Table 2. Laboratory results for water samples taken from four stations on Richards Creek during November 2 and 24, 2015.

Station	Conductivity (µS/cm)	pH	Alkalinity (mg/L $CaCO_3$)	Turbidity (NTU)	Nitrate (mg/L)	Hardness (mg/L $CaCO_3$)	Phosphate (mg/L)
November 2, 2015							
1	152	8.6	31	2.44	3.02*	85.5	0.07
2	175	8.0	26	2.72	3.64*	119.7	0.07
3	163	8.2	30	5.51	1.49	102.6	0.36
4	227	7.5	28	8.60	4.12*	136.8	0.51
4 (replicate)	225	7.0	25	6.62	2.48*	119.7	0.46
24 November 2015							
1	75	8.9	8	2.21	0.88	42	0.13
2	94	8.5	13	1.69	1.52	47	0.07
3	100	8.1	16	2.57	1.33	48	0.15
4	133	7.5	19	4.67	1.16	59	0.56
4 (replicate)	124	7.2	21	3.16	1.30	57	0.35

*= over range

4.2.3 ALS Laboratory Analysis

Water quality results from ALS Laboratory were compared to the BC Provincial water quality guidelines for the protection of aquatic life (Table 3).

The conductivity measurements from ALS Laboratory were consistent with the field measurements obtained with the electronic probe. Conductivity increased from upstream to downstream sites during both sampling events. In addition, conductivity was lower during the last sampling event by an average of 14 µS/cm compared to 230 µS/cm in the first sampling event.

Total hardness and conductivity followed similar trends. There was a general increase from upstream to downstream stations and a slight decrease between sampling events. Total hardness decreased from the first event to the second event and averaged 82.9 mg/L of $CaCO_3$ (soft water) and 48.6 mg/L of $CaCO_3$ (hard water), respectively.

VIU lab measurements of pH ranged from 7-8.9 while the ALS Laboratory Results ranged from 6.81-7.56. At VIU, the pH during each sampling event decreased from station 1 to 4, while the ALS results did not show the same trend. This discrepancy possibly reflects improper calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis. However, both analyses showed Station 4 had the lowest pH during both sampling events and was approximately neutral.

During both sampling events, all nutrients were below applicable guidelines. Nitrate concentrations during the first sampling event were between 1.44 mg/L and 3.28 mg/L, and between 0.533 mg/L and 1.09 mg/L during the last sampling event. Station 4 consistently had the highest nitrate concentration during each sampling event.

Orthophosphate and phosphorus followed similar patterns, increasing downstream, with station 4 having the highest levels during each sampling event. Orthophosphate was above the detection limit (i.e. <0.001 mg/L) at all stations. The highest level (0.0958 mg/L) occurred at station 4 during the first sampling event, and the lowest level (0.0032 mg/L) occurred during the same sampling event at station 1. The highest level for phosphorus during each sampling event was at station 4 which were 0.139 mg/L (first event) and 0.159 mg/L (second event). Considering the high concentrations of both nitrate and phosphorus, these results suggest station 4 is the most eutrophic part of the stream that was sampled.

All metals were below detections limit or below applicable guidelines. It should be noted that total metal analysis measures the combined amount of metals dissolved in water and bound to particles. In general, dissolved metals are more bio-available than metals that are bound to particles. The dissolved fractions of total metals in water are often lower than 100%.

Table 3. ALS Laboratories water quality parameter analysis results taken from Richards Creek on November 2 and 24, 2015

	BC Water Quality Guidelines						
	BC Max	First Sampling – November 2nd 2015			Second Sampling – November 24th 2015		
Variable	mg/L	1	3	4	1	3	4
General/Physical							
Conductivity		199	217	274	108	139	177
Hardness (as CaCO3)		69.3	76.9	99.6	35.7	48.5	61.6
pH	6.5-9.0	7.2	7.56	6.81	7.37	7.52	7.09
Nutrients							
Ammonia, Total (as N)		0.0233	0.0106	0.0828	0.0131	0.0053	0.0889
Nitrate (as N)	200	1.72	1.44	3.28	0.533	0.811	1.09
Nitrite (as N)	0.06	0.0057	0.0032	0.0302	0.0011	0.0011	0.0166
Total Nitrogen		2.14	2.16	4.35	0.792	1.08	2.1
Orthophosphate-Dissolved (as P)		0.0032	0.0871	0.0958	0.0044	0.0222	0.0796
Phosphorus (P)-Total		0.0172	0.109	0.139	0.0112	0.0267	0.159
Total Metals							
Aluminum (Al)-Total	0.1	<0.20	0.37	0.4	<0.20	0.25	0.85
Antimony (Sb)-Total	0.02	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.005	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	5	0.018	0.017	0.023	0.01	0.013	0.018
Beryllium (Be)-Total	0.0053	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	1.2	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.00002	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total		21.3	21.9	30	11.3	15	18.4
Chromium (Cr)-Total	0.001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.11	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	1	0.435	0.461	0.673	0.212	0.259	0.926
Lead (Pb)-Total		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.87	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total		3.92	5.36	5.97	1.84	2.7	3.79
Manganese (Mn)-Total	1.1-1.6	0.0968	0.0273	0.0627	0.0277	0.0245	0.0527
Molybdenum (Mo)-Total	2	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.065	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total		<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total		<2.0	<2.0	2.3	<2.0	<2.0	<2.0
Selenium (Se)-Total	0.002	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total		6.46	7.57	7.03	4.1	4.94	5.79
Silver (Ag)-Total	0.0001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total		10.7	10.6	11.8	5.2	5.9	8.3
Strontium (Sr)-Total		0.0734	0.0955	0.125	0.0349	0.0529	0.0826
Thallium (Tl)-Total		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total		0.012	0.02	0.021	0.011	0.013	0.038
Vanadium (V)-Total		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.033	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0089

4.2.4 Microbiology

All water samples collected from Richards Creek contained fecal and non-fecal coliforms (Table 3). The total coliform numbers were low at stations 1 and 2 and significantly higher at stations 3 and 4. A possible explanation for this result is the higher levels of turbidity in the areas with higher coliform counts. Station 4 had 2-4 times a number of fecal coliforms as the three other stations. This may be due to the close proximity of station 4 to farm land and the lack of riparian buffer.

Table 3. Fecal and non-fecal coliform counts from water samples taken from Richards Creek, November 2, 2015.

Colony Units CFUs/100ml water	Station 1	Station 2	Station 3	Station 4
Fecal Coliform (Blue)	76	52	76	200
Non-Fecal Coliform (Red)	844	84	2040	1016
Total	920	136	2116	1216

4.2.5 Quality Assurance/ Quality Control

For the nitrate parameter measured, in the first event, four out of the five measurements were over range indicating that the amount that was found in the sample could be higher than what the machine was outputting. Ideally, the sample and the replicate should be comparable and there should not be a notable difference. In the replicate sample during the first sampling event at station 4, there was a substantial difference in the nitrate. The sample was 39.85% higher than the replicate. In the second sampling event, turbidity was 32.44% higher than the replicated and phosphate was 37.5% higher than the replicate. This could have occurred because station 4 had the most variability due to the high eutrophication, therefore, the depth the sample was taken could have a great effect.

4.3 Stream Invertebrate Communities

4.3.1 Total Density

Based on the Pacific Streamkeepers Handbook, a site assessment rating was given for each station out of a maximum rating of 4.00 based on the streams water quality and diversity (Taccogna and Munro 1995). Table 4 shows the invertebrate taxa found and site assessment results. Station 1 had the lowest site assessment rating; it was assessed as a 2.25 reflecting a "marginal" site and had an invertebrate density of 155/m^2 (Figure 1). Station 2 was 3.00 "acceptable" and had a density of 188/m^2 and Station 3 had the best site assessment rating assessed at 3.50 suggesting the site was "acceptable" to "good" and an invertebrate density of 419/m^2. Invertebrate Survey Field Data Sheets can be found in Appendix II.

4.3.2 Taxon Richness and Diversity

Shannon-Weiner Diversity Index was calculated to illustrate the species diversity in each of the areas. Station 1 had a diversity index of 0.564, station 2 had a diversity index of 0.731 and station 3 had a diversity index of 0.626. Station 2 had the highest diversity index indicating this area had the highest species richness. With more diversity there is a wider range of species therefore, there is less competition between species.

Factors that could affect the results from the sites include the substrate composition. Station 1 had a substrate that mostly consisted of mud, with little to no rocks. Station 2 had a cobble substrate with large woody debris. Station 3 had a substrate of cobble and large boulders with lots of cover and shade.

Table 4. Total abundance, diversity and site assessment rating of invertebrates found in Richards Creek from triplicate samples from three stations taken on November 2, 2015.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2	Station 3
Category 1 Pollution Intolerant	Caddisfly Larva	1		2
	Mayfly Nymph		15	28
	Stonefly Nymph	1	10	20
Category 2 Somewhat Pollution Tolerant	Aquatic Beetle		3	1
	Aquatic Sowbug			1
	Clam, Mussel		1	
	Cranefly Larva	3	13	4
	Scud (amphipod)	15	3	10
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	18	1	40
	Blackfly Larva	1		
	Midge Larva (chironomid)	3	5	6
	Pouch and Pond Snails			1
	Total Abundance	42	51	113
	Density (number/m^2)	155	188	419
	Site Assessment Rating	2.25	3	3.5

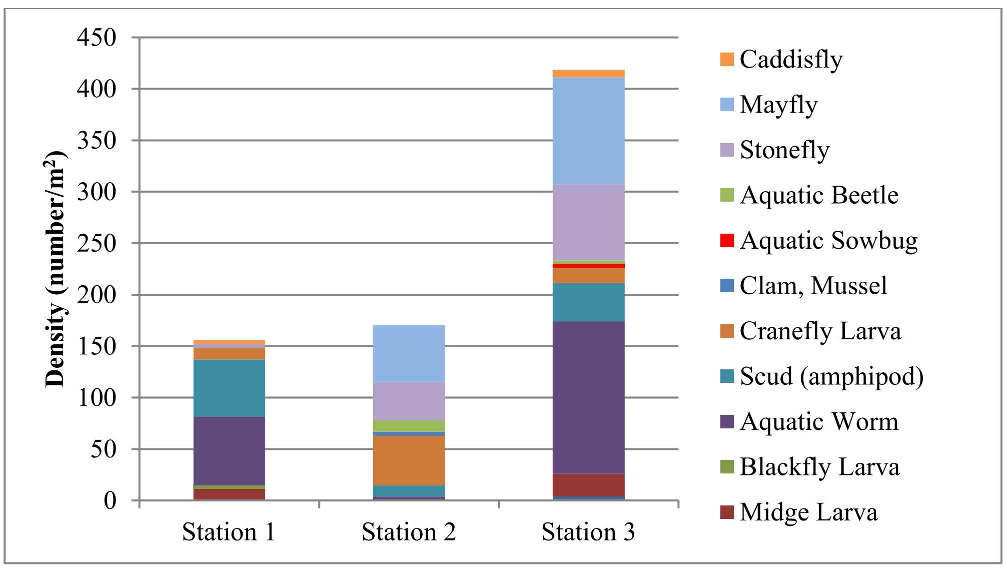

Figure 1. Density per metre^2 of taxa found in Richards Creek from triplicate samples from Stations 1, 2 and 3 taken on November 2, 2015.

5.0 Conclusions and Recommendations

After acquiring the data from the field and analyzing the results, we conclude that Richards Creek is relatively healthy. Most of the parameters were within the guidelines for a healthy stream, although the lower portion of the creek had less dissolved oxygen and more nitrate and phosphate resulting in decreased health. We have four recommendations for Richards Creek that may increase the health of this salmon-bearing stream. First, water removal and drainage should be more restrictive for agricultural purposes to prevent extremely low water flow and higher temperatures in the stream. Second, a larger riparian buffer should be established in the lower portions of the creek to prevent runoff and eutrophication in the lower portions of the stream. The positive effects of a riparian buffer were shown a station 2, which had the largest riparian buffer and the healthiest samples taken during each sampling event. Third, we recommend that landowners bordering the creek build proper fencing to prevent livestock from entertaining and contaminating the creek. Finally, to continue this ongoing project, monitoring should be conducted on an annual basis to monitor trends and changes and so the stream can remain healthy.

6.0 Acknowledgements

We would like to thank Fisheries and Oceans Canada and the Cowichan Valley Regional District for their continued support with this project. We would also like to thank Dr. Eric Demers and Ms. Sara Greenway for their guidance during the collected and analysis for water quality testing in the laboratory and the ALS Environmental Laboratory for their services for water parameter testing at a reduced rate. Also thank you to the Van Eeuwen Farm for allowing us to access the stream on their property. Special thanks to the Vancouver Island University Biology and Natural

Resource Protection department for the use of their equipment and past Natural Resource Protection students for their data for us to build on.

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8.0 Appendices

Appendix I. Map and photographs showing site locations and station conditions

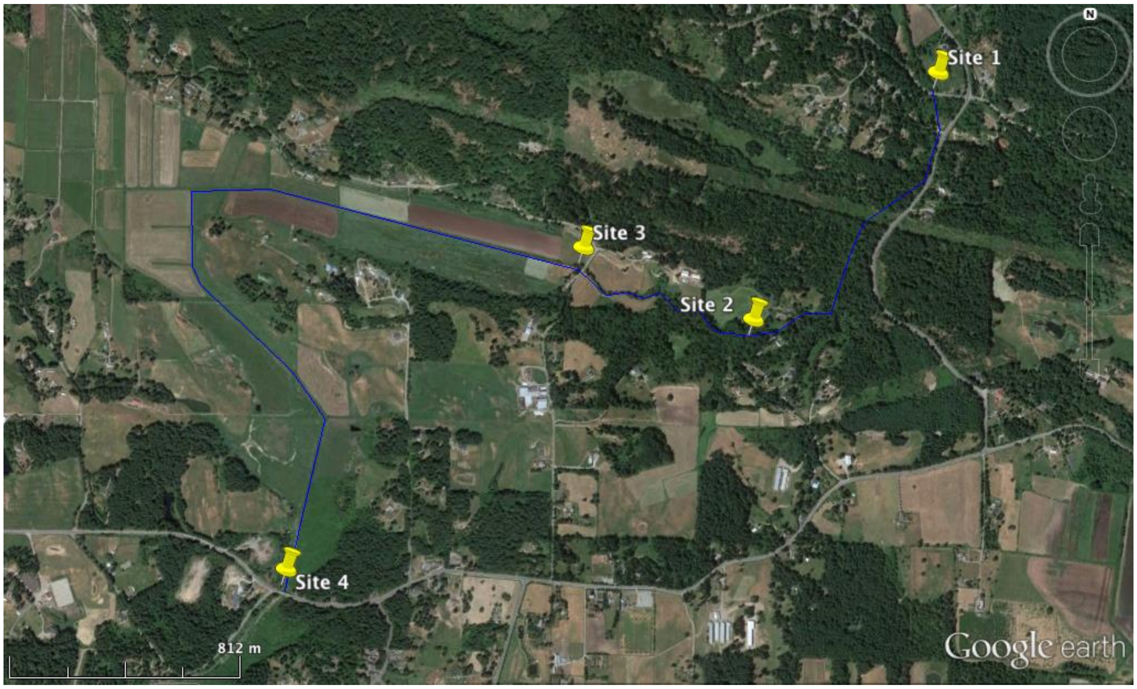

Figure 1. Overview of all sampling stations of Richards Creek (Google 2015).


Figure 2. Site conditions at sampling station 1 on Richards Creek at the Escarpment Way crossing (Heidi Richardson).

Figure 3. Site conditions at sampling station 2 off of Rice Road (Heidi Richardson).

Figure 4. Site conditions at sampling station 3 on Richards Trail Road (Heidi Richardson).

Figure 5. Site conditions at sampling station 4 on Herd Road (Heidi Richardson).

Appendix II: Invertebrate Survey Field Data Sheets. Samples collected at stations 1, 2 and 3 on Richards Creek on November 2, 2015.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: Nov 4/15
Station Name: 1		Flow status: low
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates: 3 x 0.09 = 0.27 m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 1	EPT4 1
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3 1	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 2	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	3	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	15	2
	Watersnipe Larva		
Sub-Total		C2 18	D2 3
Category 3	Aquatic Worm (oligochaete)	18	2
	Blackfly Larva	1	1
	Leech		
	Midge Larva (chironomid)	3	2
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 22	D3 5
TOTAL		CT 42	DT 10

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**. S1: 42

DENSITY: Invertebrate density per total area sampled

S1 42 ÷ 0.27 m^2 = S2: 155 /m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col C) S3: Aquatic Worms

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 + 5 = S4: 17

EPT INDEX: Total number of EPT taxa

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

EPT4 + EPT5 + EPT6: 1 + 0 + 1 = S5: 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	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT: (1 + 0 + 1) / 42 = S6: 0.047

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT** S7: 10

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col C for S3 / CT: 18 / 42 = S8: 0.42

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 3
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 3

Average Rating
Average of R1, R2, R3, R4
2.25

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: Nov. 4/15
Station Name: 2		Flow status: low
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates: 3x0.09m² = 0.27 m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 𝍸𝍸𝍸	EPT5 𝍷
	Stonefly Nymph (EPT)	EPT3 𝍸𝍸	EPT6 𝍷
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 25	D1 3
Category 2	Alderfly Larva		
	Aquatic Beetle	𝍷𝍷𝍷	𝍷
	Aquatic Sowbug		
	Clam, Mussel	𝍷	𝍷
	Cranefly Larva	𝍸𝍸𝍷𝍷𝍷	𝍷𝍷
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	𝍷𝍷𝍷	𝍷
	Watersnipe Larva		
Sub-Total		C2 20	D2 5
Category 3	Aquatic Worm (oligochaete)	𝍷	𝍷
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	𝍸	𝍷𝍷𝍷
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 6	D3 4
TOTAL		CT 51	DT 12

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT** — S1: 51

DENSITY: Invertebrate density per total area sampled.

S1: 51 ÷ 0.27 m^2 = S2: 188 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) — S3: Mayfly Nymph (15)

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 3 + 2 x 5 + 4 = S4: 23

EPT INDEX: Total number of EPT taxa

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

EPT4 + EPT5 + EPT6: 0 + 1 + 1 = S5: 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	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT: (0 + 15 + 10) / 51 = S6: 0.49

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7: 12

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

Good	Acceptable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT: 15 / 51 = S8: 0.29

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1: 4
EPT Index	R2: 2
EPT To Total Ratio	R3: 2
Predominant Taxon Ratio	R4: 4

Average Rating
Average of R4, R5, R6, R8
3

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Richards Creek		Date: Nov 4 /15
Station Name: 3		Flow status: low
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates: 3 x 0.09 m² = 0.27 m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 ||	EPT4 ||
	Mayfly Nymph (EPT)	EPT2 卌||| (28) 20	EPT5 ||
	Stonefly Nymph (EPT)	EPT3 卌卌卌卌	EPT6 |||
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 50	D1 7
	Alderfly Larva		
Category 2	Aquatic Beetle	|	|
	Aquatic Sowbug	|	|
	Clam, Mussel		
	Cranefly Larva	||||	|
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	卌卌	||
	Watersnipe Larva		
Sub-Total		C2 16	D2 5
	Aquatic Worm (oligochaete)	卌卌卌 (40)	|
Category 3	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	卌 |	||
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails	|	|
	True Bug Adult		
	Water Mite		
Sub-Total		C3 47	D3 4
TOTAL		CT 113	DT 16

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT** — S1: 113

DENSITY: Invertebrate density per total area sampled

S1: 113 ÷ 0.27 m^2 = S2: 419 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) — S3: Aquatic worms = 40

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 7 + 2 x 5 + 4 =
21 + 10 + 4

S4: 35

EPT INDEX: Total number of EPT taxa

Good	Accpetable	Marginal	Poor
>8	5-8	2-5	0-1

EPT4 + EPT5 + EPT6

2 + 2 + 3 =

S5: 7

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(2 + 28 + 20) / 113 =

S6: 0.531

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: — S7: 16

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S3) divided by CT.

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

40 / 113 =

S8: 6.354

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S4, S5, S6, S8), then calculate the average.

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 4
EPT Index	R2 3
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 4

Average Rating
Average of R4, R5, R6, R8

3.5