Water Quality, Invertebrate and Microbiology Analysis for Richards Creek, Duncan, British Columbia

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Final Report Submitted by:

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1.0 Executive Summary

University students in the R.M.O.T. Program at Vancouver Island University have undertaken a research project for a client, John Morgan, on the status of a stream in North Cowichan on Vancouver Island. Richard's Creek is located in-between Crofton and the small city of Duncan and has a length of about 9.2km. My partner, Scott Senkiw and I, Hayden Coopsie, will be conducting a few analyses within this stream to determine its overall health. Some of these analyses include water quality samples, microbiology samples to determine the amount of coliform, fecal and non-fecal. Stream invertebrates will also be sampled to accurately depict the health of the stream. Velocity and discharge measurements will be taken to determine if it is an ideal speed for fish to rear/spawn in. This study began on 28 October 2012 and lasted until 17 November 2012, where we wrapped up with the last of our water quality samples. Measurements were also taken in the field (pH, conductivity, temperature, dissolved oxygen) and the remaining parameters that we wanted to test were completed back at the VIU Lab (nitrate, phosphate, turbidity, alkalinity, hardness, microbiology). The stream invertebrates were sampled using a Hess sampler and catching in duplicate at three of our stations. The results that we obtained from water samples that were sent to Vancouver to an ALS Laboratory showed that there were no parameters that were above the guidelines for aquatic life to survive. The stream invertebrates, however, told us a different story. By examining the invertebrates back at the Lab at VIU, we

discovered that the stream is, unfortunately, not as healthy as we had predicted. It is "marginal" to "acceptable". One of our stations is adjacent agricultural lands, and may have a significant factor on the health of this stream. By conducting this report to our client, we now know that further monitoring must be completed on Richard's Creek, with emphasis around the agricultural land area and downstream towards the city of Duncan. If we work together to improve this creek, we can improve the life that is trying to thrive under the surface of Richard's Creek.

2.0 Acknowledgements

The authors (Scott Senkiw and myself, Hayden Coopsie) would like to thank the ALS Laboratory in Vancouver, BC, for their support in conducting our water quality analysis, without them, this would not have gone as smoothly and we achieved very informative data that we would not have received otherwise. We would also like to thank our client, John Morgan, for choosing Cowichan Valley Consulting Ltd., and sticking with us to the end. We are very thankful and looking forward to the positive aspects that Richard's Creek has to offer.

3.0 Introduction

Richards Creek is situated in the Somenos Basin, located approximately 15 minutes north of Duncan, British Columbia. Richards Creek is approximately 9.2 kilometres in length and flows south-westerly from Crofton Lake to Somenos Lake. It should also be noted that the Cowichan Valley Regional District (CVRD) regulates flow from the Crofton Lake reservoir into Richards Creek. Richards Creek is capable of providing year round spawning and rearing habitat for various salmonids. However, although this stream does have excellent fish rearing habitat, an

apparent downfall is the presence of an agricultural environment, combined with low gradient followed by a low summer water flow (Brooks B. et al., 2011).

In 2008, habitat restoration was conducted on Richards Creek involving summer flow augmentation; the project was followed through by DFO. The purpose of this habitat restoration was due to the apparent need for continued monitoring of water and habitat quality of Richards Creek. It is for this reason that Environmental Monitoring Students of Vancouver Island University have been conducting annual monitoring projects. This report documents a water quality and stream invertebrate assessment of Richards Creek conducted during the months of October and November, 2012.

Specific objectives for this assessment of Richards Creek included the following;

- Establish four water quality sampling stations
- Obtain field measurement of water quality at each station during two sampling events (October and November 2012)
- Water samples to be collected from each sampling station during two sampling events(October and November 2012)
- Collect stream invertebrates at three sampling stations during one sampling event (October and November 2012)

4.0 Methods

4.1 Study Site

This project was conducted on Richards Creek situated northeast of the City of Duncan, British Columbia (Fig. 1). Richards Creek flows from Crofton Lake southeasterly towards Richards

Trail. From there, it begins to flow southwesterly, flowing into the northeast portion of Somenos Lake. The upstream portion of Richards Creek flows through residential areas and riparian forest. The downstream portion meanders through agricultural lands. Flow influx from the Crofton lake reservoir is regulated by The Cowichan Valley Regional District (CVRD).

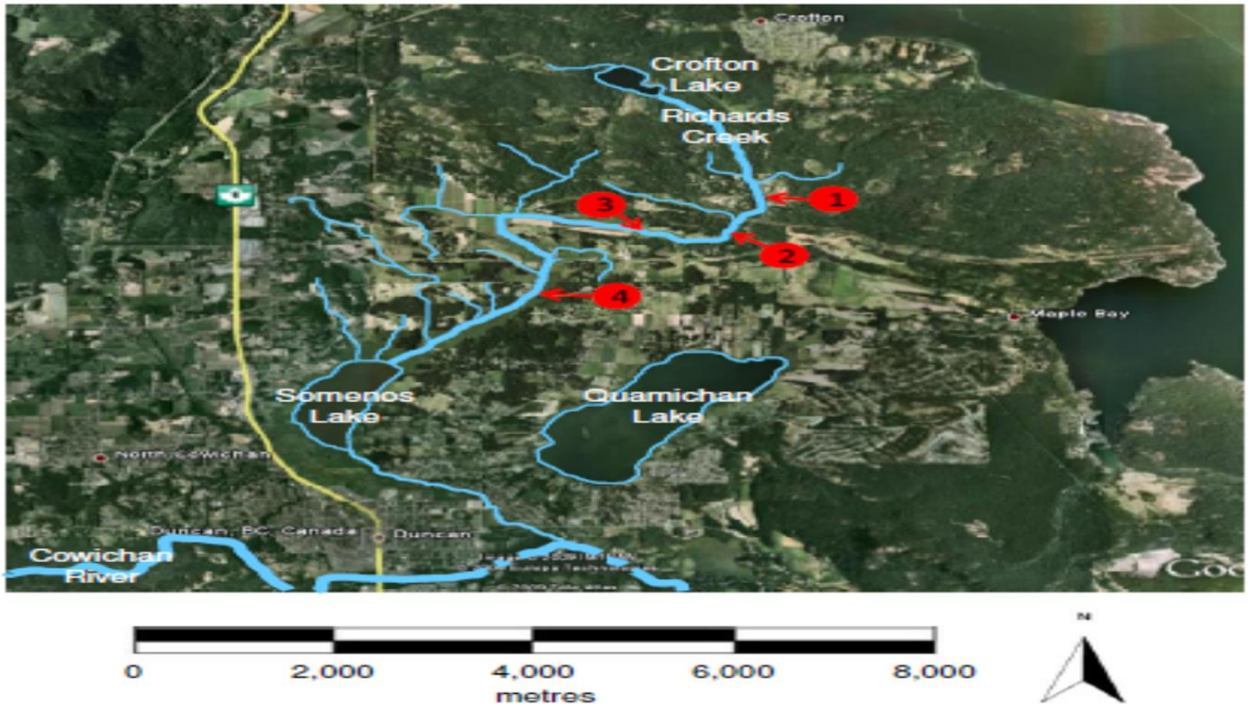


Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Richards Creek, during October-November 2012.

4.1.1 Sampling Stations

Four sampling stations were identified and established on Richards Creek during October, 2012 (Figure 3; Table 1). Each station's location was chosen to provide adequate covered based on the overall length of Richards Creek and to repeat sampling stations used by previous students and DFO. Stations selected were numbered from upstream (Station 1) to downstream, (Station 4). All stations could be accessed with ease and posed no apparent safety threats.

Site Description

Site 1- Located on a concrete culvert crossing on Escarpment Way. (~ 2.3 km downstream from Crofton Lake

Site 2- Located at the end of Rice Road and a short walking distance from the Cul-de-sac. (~1.2km downstream of Site 1)

Site 3- Located at culvert crossing on Richards Trail 1km north on Richard's Trail, after turning left off of Herd road.

Site 4- Locate at a roadway bridge on Herd Road and Mays (east) Road. (~2.0km north of Somenos Lake.

Table 1. UTM Coordinates (10u) for selected sites

Station	UTM Coordinates		Approximate Distance from Crofton Lake (km)	General Location
	Northing	Easting		
1	5409420	452560	2.3	Escarpment Way Crossing
2	5408622	452221	3.5	End of Rice Road
3	5408795	451331	4.2	Richards Trail Crossing
4	5407637	450282	7.2	Herd Road Crossing

4.1.2 Sampling Schedule

Field sampling was conducted on October 31 and November 17, 2012. During this study, samples were collected for the following; water quality analyses, stream invertebrates and microbiology. Sampling for invertebrates took place during the first sampling event only. This was due to the fact that sampling invertebrates during high flow would be unsafe and logistically difficult. Sampling for ALS was conducted at both sampling events at sites 1, 2 and 3.

4.2 Water Quality

4.2.1 Field Measurements

Water Quality sampling events were conducted on October 31 and November 17 2012. At each sampling station, the following measurements were obtained; Dissolved Oxygen (+/- 0.01mg/L), Water Temperature (+/- 0.01 C), Conductivity (+/- 1 µSiemens/cm), pH (nearest unit). Measurements were obtained using YSI multi-meter and probe.

4.2.2 Water Sampling

For each sampling even, two sets of water samples were collected. One set was to be analyzed at Vancouver Island University; the other was to be sent to ALS Laboratory in Vancouver, British Columbia.

Water Samples to undergo analyses at VIU were collected from all stations and the methodology is as follows; a clean, pre-labelled 500ml Nalgene bottle was rinsed three times and then used to collect water (Table 2). A replicate sample was taken at site 2. Quality Assurance and Quality Control are of the essence and examples such as given below are provided throughout this report. All water samples were obtained while wading upstream in the thalweg (with the exception of

site four as it was too deep). The bottles were plunged in a manner that would inhibit the entry of surface scum and care was taken not to disturb the stream bed. All samples were promptly placed in a cooler and transported to VIU for analyses within 48 hours.

Samples for analyses at ALS Laboratory were collected from sites 1, 2 and 3 during both sampling events. At each station, water samples were collected in three sterile, in some cases acid washed bottles supplied by the lab (Table 2). When filling the bottles, the same care and procedure was followed as mentioned above. Samples for analysis of nutrients were preserved with laboratory supplied sulphuric acid. Samples for analysis of metals were preserved with nitric acid. All bottles were inversed multiple times to ensure adequate mixing. Samples were transported to Vancouver Island University stored in a cooler with ice packs. Once on site, samples were stored in a refrigerator at 4 degrees Celsius until departure for ALS Laboratory.

A Field Blank was carried into the field during both sampling events for analyses at Vancouver Island University. The Field Blank, containing distilled water was carried into the field and subject to the conditions of the sampling bottles. For example, opening and closing for same instances and periods of time.

Table 2. Sampling Containers and preservatives used for water quality

Water Quality Parameters	**|Container**	**Preservative**	**Lab conducting Analyses**

• **Nitrate** • **Phosphate** • **pH** • **Conductivity** • **Alkalinity** • **Hardness** • **Turbidity** • **Dissolved Oxygen** • **Temperature** • **Coliforms**	**500 ml Nalgene Bottle**	**N/A**	**VIU**
• **pH** • **Conductivity** • **Hardness** • **Turbidity**	**1 L Plastic**	**N/A**	**ALS**
Total Metals	**250ml Plastic**	**Nitric Acid**	**ALS**
Anions, Nutrients	**250ml Amber Glass**	**Sulphuric Acid**	**ALS**

4.2.3 VIU Lab Analyses

Water samples to be analyzed at Vancouver Island University were analyzed for the following:

- Turbidity;
- Alkalinity;
- Hardness;
- Nitrate;
- Orthophosphate

Turbidity (TSS) was measured to nearest 1 mg/L using a HACH Spectrophotometer

Alkalinity (CaCO3) measured to nearest 0.1 mg/L using HACH digital titration method

Hardness (CaCO3) measured to nearest 1mg/L using HACH Test Kit

Nitrate measured to nearest 0.01 mg/L using HACH Spectrophotometer

Orthophosphate measured to nearest 0.01 mg/L using HACH Spectrophotometer

4.2.4 ALS Lab Analyses

Water samples to be submitted for analyses at ALS Laboratory were collected in compliance with instruction provided by ALS with due diligence. As well the following analyses were processed as per standard analytical procedures:

- Conductivity
- Hardness
- pH
- Turbidity (Total Suspended Solids)
- Anions and nutrients
- Total Metals

4.2.5 Quality Assurance / Quality Control

From the beginning to the end of the study, measures were taken to safeguard against potential contamination of all samples collected was minimized. Such practices include using pre-cleaned and rinsed containers, adhering to instructions regarding the preservation of samples prescribed by the outsourced analytical laboratory and ensuring all containers are properly labelled and legible. As well replicate samples and the inclusion of Field Blanks aided in identifying possible widespread contamination resulting from container (dirty caps or subsequent field procedure).

4.2.6 Data Analyses- Comparison with Applicable Guidelines

For the purpose of this report, water quality results once compiled, were compared with the applicable water quality guidelines for the well-being of freshwater life. The BC Water Quality

Guidelines are the maximum allowable concentration (for potential acute effects) and the 30-day average concentration (for potential chronic effects) (BCMWLAP 1998a, 1998b).

4.3 Microbiology

Water samples were collected at each sampling station on the first sampling event (October 31, 2012. At each of these stations, a sterile, pre-labelled "Whirl-Pak" (120ml) bag was used to collect a sample. Each was collected facing upstream and plunged to avoid surface scum. All samples were promptly placed in a cooler with ice packs and transported to Vancouver Island University within 48 hours. Once in the lab, water samples were tested for total coliforms and fecal coliforms (E.coli).

In this study, the m-coliBlue24 membrane filtration method was utilized. A 100ml sample from each site was measured using a graduated cylinder and then filtered through a membrane filter with marked grid-lines with a vacuum system. The filter was then transferred to a 100-mm Petri Dish containing an absorbent pad which was pre saturated with m-coliBlue24 broth. The membrane filters were then incubated until colonies became visible. The filters could then be examined under a dissecting scope at 16X magnification. A Red or Blue colony indicates a positive result. However, only Blue colonies specifically represent fecal coliforms. White or translucent colonies represent a total coliform negative result. All colonies present and counted on the filter were expressed as (CFU's) Colony Forming Units per 100ml of water.

4.4 Stream Invertebrates

4.4.1 Sampling Stations

Samples of stream invertebrates were collected from stations 1, 2 and 3 (Figure 1) on November 04, 2012. These sampling stations were selected based on safety, hydrological characteristics, substrate, and space for replicate samples. During the sampling period, all sites consisted of shallow riffles with predominantly gravel and sand substrate.

4.4.2 Sampling of Invertebrates

At each station (Sites 1, 2 and 3) duplicate samples were obtained using a Hess Sampler. Each site was approached by walking up from downstream. This negates the possibility of unnecessarily disturbing the stream bed and/or having invertebrates washed downstream and unaccounted for. Once the sampler was firmly placed into the stream bed, larger stones and cobble were held underwater near the intake and scrubbed to remove any attached invertebrates. These stones, now deemed devoid of invertebrates were placed downstream of the sampler. The remaining substrate was agitated to further dislodge the invertebrates.

Any invertebrates collected were within the container attached via threads at the end of the conical net. The net was carefully inspected for any remaining invertebrates. The sample was then placed in a separate container and mixed with ethanol to achieve an approximate 70% blend. The samples were stored in a cooler until transport to Vancouver Island University.

4.4.3 VIU Lab Analysis

The duplicate samples obtained from each station were combined into a single, composite sampler per station. The contents of all the invertebrate sample containers were poured into a large Pyrex dish. Invertebrates were then sorted into taxonomic groups with the aid of a dissecting scope and dichotomous key obtained from within the lab. The number of distinct subgroups within each broad taxonomic group was recorded on an Invertebrate Survey Field Data Sheet created by Pacific Streamkeepers.

5.0 Results and Discussion

5.1 General Field Conditions

Discharge and velocity measurements show an increase during the November sampling versus the sampling conducted in October (Figure 2). These measurements were measured at sites 1 thru 3, excluding site 4 as the creek in that area was stagnant; due to the complexity of the area, we deemed it unsafe to conduct further examination. In regards to our discharge and velocity measurements, site 2 will depict an accurate portrayal of how the two sampling events differed in relation to the flow and discharge of Richard's Creek. Water levels were, on average, 0.144 and 0.223m during the October and November sampling events, respectively. Calculations using mathematical formulae learnt in FISH 307 (Environmental Hydrology) at Vancouver Island University (M. Noyon, class hand-out) had an outcome of 0.085 and 0.244m^3 on 28 October and 17 November, 2012, respectively. With respect to the information above, we can conclude that as you travel further down Richard's Creek from Crofton Lake, you can see an increase in both water velocity and rate of discharge. Once you reach the agricultural land, however, the water

begins to decrease in speed. We predict that this is due to the level of agricultural activity in the area, as well as the minimal slope gradient in the immediate area.

During this sampling project, the weather conditions were cloudy with no precipitation, other than a few 5-10 minute minimal showers. Air temperature ranged from 9-11^{o}C. The average air temperatures 10 days before each sampling event were 10.4^{o}C for the October event and 8.5^{o}C for the November event (data collected from http://www.theweathernetwork.com). October and November received 84 and 141mm of precipitation, respectively (data taken from http://www.farmzone.com). November had an increase of precipitation resulting in a higher water flow and discharge, as we predicted.

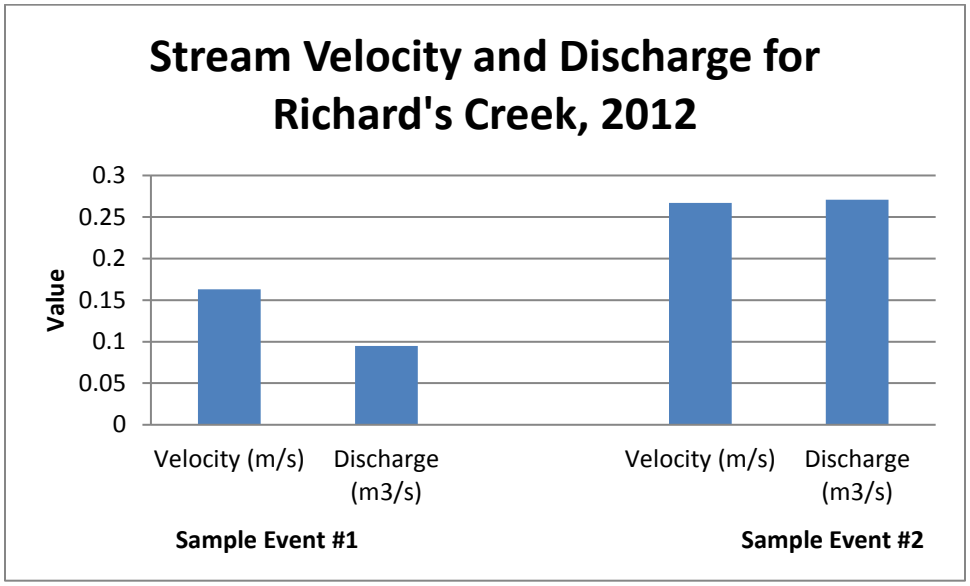


Figure 2: Average velocity (m/s) and discharge (m^3/s) measurements were taken during both sampling events at sites 1-3. Sample Event #1 represents the sampling on 28 of October 2012 and Sample Event #2 represents the sampling on 17 of November 2012.

5.2 Water Quality

5.2.1 Field Measurements and VIU Lab Analyses

Water temperature averaged 9.3°C and 7.6°C during the sampling events of October and November, respectively (Figure 3). The water temperature and the air temperature mirrored each other during our study of Richard's Creek, with the air temperature cooling as the water temperature cooled. While conducting the temperature measurements during the October sampling event, the temperature decreased the further downstream we sampled. As for the November sampling event, the same occurred as the previous sampling event, but site 2 and 3 differed in temperature by 0.01°C (Table 3).

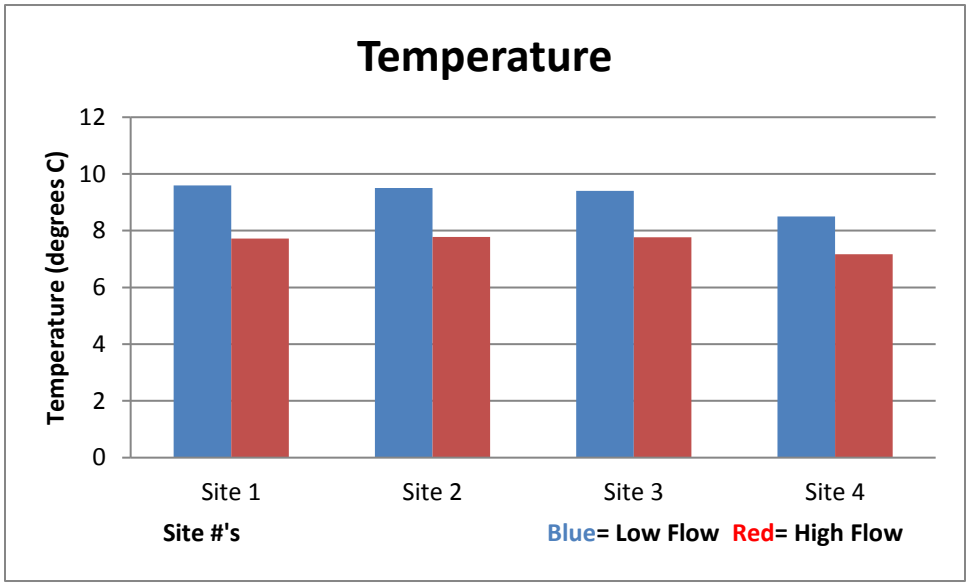


Figure 3: Temperature parameters were taken from all sample sites via field measurements during both sampling events.

During the November sampling event, all dissolved oxygen results were shown to be above the minimum guideline of 9.0mg/L for juvenile fishes, except for station 4, which had a dissolved oxygen rating of 4.9mg/L. Dissolved oxygen concentrations for the October sampling event

ranged from 45.5% (site 4) to 101.1%. We concluded that site 4 had such a low dissolved oxygen concentration due to the lack of moving water, and the presence of a high eutrophic environment.

Conductivity ranged from 122 to 188µS/cm during the November sampling event and increased from upstream to downstream as we predicted would happen (station 1 down to station 4) (Table 3). The October event revealed all measurements to be less than 142µS/cm, with the same upstream to downstream results mentioned above. The pH levels from the 1st sampling event ranged from 7.0 up to 7.6, with 7.6 being the further downstream (located under Herd Road Bridge). However, during the 2nd sampling event, pH values from sites 1-3 ranged from 7.27 to 7.63. The site under the Herd Road Bridge yielded a pH value of 5.10, which may be represented by the high carbon dioxide levels in the water due to the eutrophic nature of Richard's Creek in that area.

During both sampling events, with the exception of site 2 in October showing a slight decline, Alkalinity increased in value from upstream to downstream sites (Table 4). Hardness also showed values that increased the further downstream the water flowed. During the November sampling (high flow), the hardness of the water increased at site 4. With regards to site 4 just mentioned, Hardness levels for October and November sampling events stayed the same, however, Alkalinity values were increased on November 17th. Overall, the Alkalinity total was above 20mg/L, with exception to site 2 during low flow that measured 17.2mg/L, suggesting a "low acid sensitivity". Total hardness was generally below 70mg/L, with site 4 at high flow measuring 85.5mg/L, indicating relatively "soft water" defined under the "BC Water Quality Guidelines" given out in the RMOT 306 course.

Table 3: Field measurements taken from our four sample sites during 28 October 2012 and 17 November 2012.

Station	**Temperature (°C)**	**Dissolved Oxygen (mg/L or % saturation)**	**Conductivity (µS/cm)**	**pH**
28 October 2012				
1	9.6	97.7%	89	7.0
2	9.5	101.0%	112	7.4
3	9.4	99.8%	141	7.5
4	8.5	45.5%	142	7.6
17 November 2012				
1	7.72	9.41mg/L	122	7.63
2	7.78	10.1mg/L	142	7.27
3	7.77	9.95mg/L	151	7.43
4	7.17	4.9mg/L	188	5.1

Our values obtained for Total Suspended Solids (TSS) were quite low for both sampling events, with values ranging from 1.25 to 5.38 (Table 4). The first sampling event showed site 4 to have the highest TSS value, while the second sampling event yielded a higher value at site 2.

During both sampling events, our phosphorus levels generally increased the further downstream we sampled (Table 4). However, during the high flow at site 3, the phosphorus levels dropped

considerably from 0.53mg/L to 0.26mg/L. Other than the drop in phosphorus levels at site 3, more phosphorus was present on 18 November 2012 than on 28 October 2012. The highest concentration of phosphorus during the high flow was at site 4 at 0.69mg/L, while site 3 had the highest concentration during the low flow stage at 0.53mg/L. These phosphorus levels were in such a manner due to the nutrient-enriched waters of Richard's Creek.

Nitrate concentrations did increase in value as we sampled downstream, however, site 1 had the lowest October sampling level of 0.12mg/L, and site 4 had the most at 0.87mg/L (Table 4). During our November sampling events, we found that the level of nitrates dropped, but they were closer in value to our other sites. Site 2, however, had a higher low level than high flow with a value of 0.43 and 0.35mg/L, respectively. Nitrate concentration values ranged from 0.12mg/L to 0.87mg/L observed during the October sampling event alone. 0.35 to 0.53mg/L was the range for the November sampling event.

The water quality results contained a duplicate that was collected at site 2, and with this added sample, we concluded that most samples had values that were +/- 20.1% (Table 4). The major difference that we came up with was for phosphorus in that the October sampling differed by 86.3%, while the November sampling event only differed by 43.9%. Results from the field blanks and the trip blanks yielded values that were low or near the minimum detection limits. The field blanks and trip blanks were used to examine whether any contamination was occurring with our water samples via transport back to the lab, and our conclusion stated that no contamination occurred.

Table 4: VIU Lab results for water samples taken from four stations on Richard's Creek during 28 October and 17 November 2012. Duplicate samples (Samples 2A and 2B) were taken from station 2. Trip blanks were not analyzed (shown by N/A); field blanks were analyzed for Phosphorus and Nitrate.

Station	**Total Hardness (mg/L $CaCO_3$)**	**Total Alkalinity (mg/L $CaCO_3$)**	**Total Suspended Solids (mg/L)**	**Phosphorus (mg/L)**	**Nitrate (mg/L)**
28 October 2012					
1	51.3	20	1.25	0.24	0.12
2 (Sample A)	68.4	17.2	1.38	0.51	0.43
2 (Sample B)	68.4	14.8	1.38	0.07	0.35
3	68.4	19.6	2.34	0.53	0.62
4	68.4	21.6	3.12	0.46	0.87
Trip Blank	N/A	N/A	N/A	N/A	N/A
Field Blank	N/A	N/A	N/A	0.16	0.03
17 November 2012					
1	51.3	20.8	3.6	0.44	0.39
2 (Sample A)	68.4	24.8	5.38	0.57	0.35
2 (Sample B)	68.4	23.6	5.21	0.32	0.50
3	68.4	31.6	2.87	0.26	0.42
4	85.5	36.4	1.76	0.69	0.53
Trip Blank	N/A	N/A	N/A	N/A	N/A
Field Blank	N/A	N/A	N/A	0.01	0.04

5.2.2. ALS Lab Analyses

The water quality results were compared to the BC Water Guidelines for the protection of aquatic life (Table 5).

The conductivity measurements from the ALS Lab were consistent with the field measurements that we obtained with the electronic probe meter. The October sampling event (using four separate probe meters for separate parameters) differed by <9%, while the November sampling event (using the YSI probe, one meter) differed by <3%. During both sampling events, the conductivity levels increased from upstream to downstream stations. In addition, conductivity was higher during the November sampling event by approximately 10.5%.

Likewise for the hardness values, the measurements from the ALS Lab were consistent with the VIU Lab results. The ALS Lab results for the October sampling were 24.6% higher than the VIU Lab results, and 21.4% higher for the November sampling event.

The pH measurements were more close together for the ALS Lab results ranging from 7.56-7.80. October sampling events yielded a range from 7.59-7.72, while the November samples ranged from 7.56-7.67. Field measurements were a little less than the Lab measurements with a range of 7.0-7.63, with regards to site 4, which had a pH level of 5.1 during the November sampling event. Field measurements may have been slightly less due to the probe not being correctly calibrated, or some other unknown factor.

All anion and nutrient levels were well below the applicable guidelines. However, it is noted that during the October and November sampling events, the phosphorus levels rose to mesotrophic and eutrophic levels, respectively, while it was an oligotrophic environment further upstream.

All total metal concentrations at stations 1-4 were below the applicable water guidelines during both of our sampling events; however, it is worth noting that the copper levels at site 1 during the November sampling yielded 0.022mg/L, while the others were <0.010mg/L, which is not of concern.

It is known that the total metal analyses measure the amount of dissolved metals that are combined in water and bound to particles. Dissolved metals can combine to things much easier than metals that are attached to particles. If all the total metals were to come together in the water, it would usually be less than 100%.

With the combination of field measurements, ALS Lab results and VIU Lab results shows us that site 4 of Richard's Creek is in much poorer shape that the sites situated upstream. This is based on the substantial drop in pH value at site 4, as well as the drop in other parameters that were measured in Richard's Creek.

Table 5: Lab results (ALS Lab) for water samples taken from 3 of the 4 stations on Richard's Creek during 28 October and 17 November 2012. None of the parameters exceeded the recommended guideline for aquatic life. The blue and red text are shown to help match up the element with the correct value.

28 October 2012 – ALS Results

	97.7	123	153
Physical Tests			
	37.9	46.3	57.8
Conductivity			
	7.60	7.59	7.72
Hardness (as CaCO3)			
pH			

	<0.0050	<0.0050	0.0261
Anions and Nutrients			
	0.217	0.333	0.467
Ammonia, Total (as N)			
	0.0016	0.0018	0.0058
Nitrate (as N)			
	<0.0010	<0.0010	0.132
Nitrite (as N)			
	0.0120	0.0126	0.154
Orthophosphate-Dissolved (as P)			

Phosphorus (P)-Total			
	<0.20	<0.20	<0.20
Total Metals			
Aluminum (Al)-Total	<0.20	<0.20	<0.20
Antimony (Sb)-Total	<0.20	<0.20	<0.20
Arsenic (As)-Total	<0.010	<0.010	0.011
Barium (Ba)-Total	<0.0050	<0.0050	<0.0050
Beryllium (Be)-Total	<0.20	<0.20	<0.20
Bismuth (Bi)-Total	<0.10	<0.10	<0.10
Boron (B)-Total	<0.010	<0.010	<0.010
Cadmium (Cd)-Total	11.6	13.9	16.5
Calcium (Ca)-Total	<0.010	<0.010	<0.010
Chromium (Cr)-Total	<0.010	<0.010	<0.010
Cobalt (Co)-Total	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.262	0.267	0.336
Iron (Fe)-Total	<0.050	<0.050	<0.050
Lead (Pb)-Total	<0.010	<0.010	<0.010
Lithium (Li)-Total	2.13	2.81	4.01
Magnesium (Mg)-Total	0.0372	0.0314	0.0188
Manganese (Mn)-Total	<0.030	<0.030	<0.030
Molybdenum (Mo)-Total	<0.050	<0.050	<0.050
Nickel (Ni)-Total	<0.30	<0.30	<0.30
Phosphorus (P)-Total	<2.0	<2.0	<2.0
Potassium (K)-Total	<0.20	<0.20	<0.20
Selenium (Se)-Total	3.32	4.62	5.42
Silicon (Si)-Total	<0.010	<0.010	<0.010
Silver (Ag)-Total	5.3	6.7	8.4
Sodium (Na)-Total	0.0383	0.0487	0.0696
Strontium (Sr)-Total	<0.20	<0.20	<0.20
Thallium (Tl)-Total	<0.030	<0.030	<0.030
Tin (Sn)-Total	<0.010	<0.010	0.010
Titanium (Ti)-Total	<0.030	<0.030	<0.030
Vanadium (V)-Total	<0.0050	<0.0050	<0.0050
Zinc (Zn)-Total			

17 November 2012- ALS Results

	118	138	148
Physical Tests	41.8	50.4	55.1
Conductivity	7.56	7.67	7.58
Hardness (as CaCO3)			
pH			
	0.0065	0.0062	0.0067
Anions and Nutrients	0.299	0.299	0.357
Ammonia, Total (as N)	<0.0010	<0.0010	<0.0010
Nitrate (as N)	<0.0010	<0.0010	0.0437
Nitrite (as N)	0.0144	0.0190	0.0728
Orthophosphate-Dissolved (as P)			
Phosphorus (P)-Total			
	0.42	0.55	0.39
Total Metals	<0.20	<0.20	<0.20
Aluminum (Al)-Total	<0.20	<0.20	<0.20
Antimony (Sb)-Total	0.013	0.016	0.014
Arsenic (As)-Total	<0.0050	<0.0050	<0.0050
Barium (Ba)-Total	<0.20	<0.20	<0.20
Beryllium (Be)-Total	<0.10	<0.10	<0.10
Bismuth (Bi)-Total	<0.010	<0.010	<0.010
Boron (B)-Total	13.1	16.0	16.7
Cadmium (Cd)-Total	<0.010	<0.010	<0.010
Calcium (Ca)-Total	<0.010	<0.010	<0.010
Chromium (Cr)-Total	0.022	<0.010	<0.010
Cobalt (Co)-Total	0.433	0.638	0.476
Copper (Cu)-Total	<0.050	<0.050	<0.050
Iron (Fe)-Total	<0.010	<0.010	<0.010
Lead (Pb)-Total	2.17	2.56	3.24
Lithium (Li)-Total	0.0495	0.0521	0.0412
Magnesium (Mg)-Total	<0.030	<0.030	<0.030
Manganese (Mn)-Total	<0.050	<0.050	<0.050
Molybdenum (Mo)-Total	<0.30	<0.30	<0.30
Nickel (Ni)-Total	<2.0	<2.0	<2.0
Phosphorus (P)-Total	<0.20	<0.20	<0.20
Potassium (K)-Total	5.06	5.53	5.59
Selenium (Se)-Total	<0.010	<0.010	<0.010
Silicon (Si)-Total	6.9	7.0	6.9
Silver (Ag)-Total	0.0422	0.0490	0.0612
Sodium (Na)-Total	<0.20	<0.20	<0.20
Strontium (Sr)-Total	<0.030	<0.030	<0.030
Thallium (Tl)-Total	0.022	0.025	0.019
Tin (Sn)-Total	<0.030	<0.030	<0.030
Titanium (Ti)-Total	<0.0050	<0.0050	<0.0050
Vanadium (V)-Total			
Zinc (Zn)-Total			

5.3 Microbiology

All of the samples that were collected for Coliform from Richard's Creek contained some Coliform bacteria (Table 6). Total Coliform levels ranged from 166 CFU/100mL at station 2 to 797 CFU/100mL at station 1. The percentage of total Coliform made up of *E. Coli* bacteria was <4% for stations 1 and 2, while station 3 had 20.5% *E. Coli* bacteria. The higher total fecal Coliform at station 3 was as predicted as this is where the agricultural environment begins. Higher total Coliform was located at station 1, which does not typically happen, as Coliform usually builds up as you go further downstream, not upstream. The same results were discovered by the RMOT class of 2009 (Brown L., et al. 2009).

Table 6: Total Coliform and *E. Coli* counts sampled from 3 stations on Richard's Creek (station 4 was not sampled) during 28 October 2012. All values are expressed as CFU (Colony Forming Units) per 100mL. No microbiology samples were taken on 17 November 2012.

Station	**Total Coliform (CFU)**	***E. Coli***	***% E. Coli***
1	797	30	3.8%
2	312	10	3.2%
3	166	34	20.5%

5.4 Stream Invertebrates

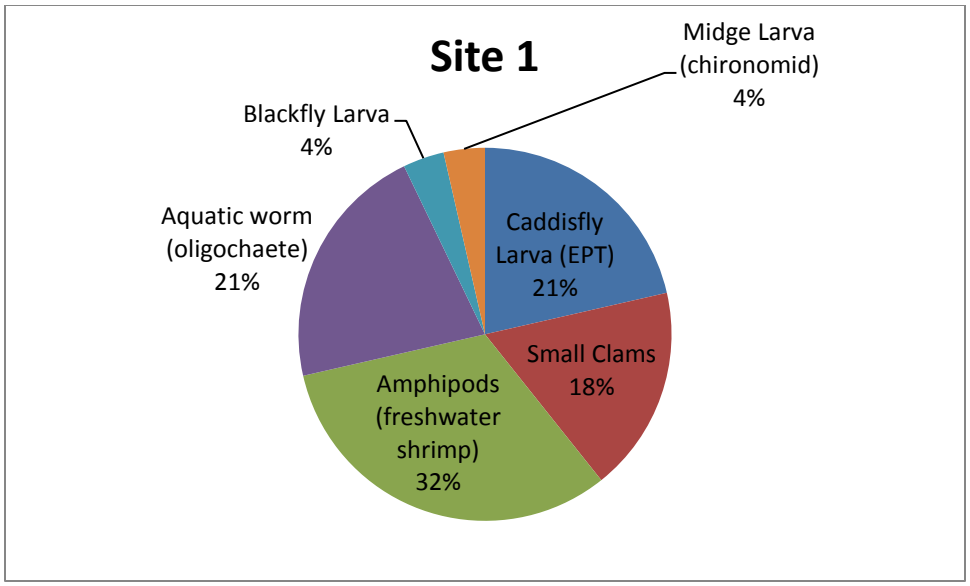
A total of 114 stream invertebrates representing 6 taxonomic groups were counted at 3 stations on Richard's Creek on 31 October 2012 (Table 7; Figure 4; Appendix 2). Invertebrate density was located at station 2 with 70 bugs, while stations 1 and 3 had 28 and 16 invertebrates, respectively. The range per m^2 was between 155 and 388 invertebrates. Station 1 was dominated

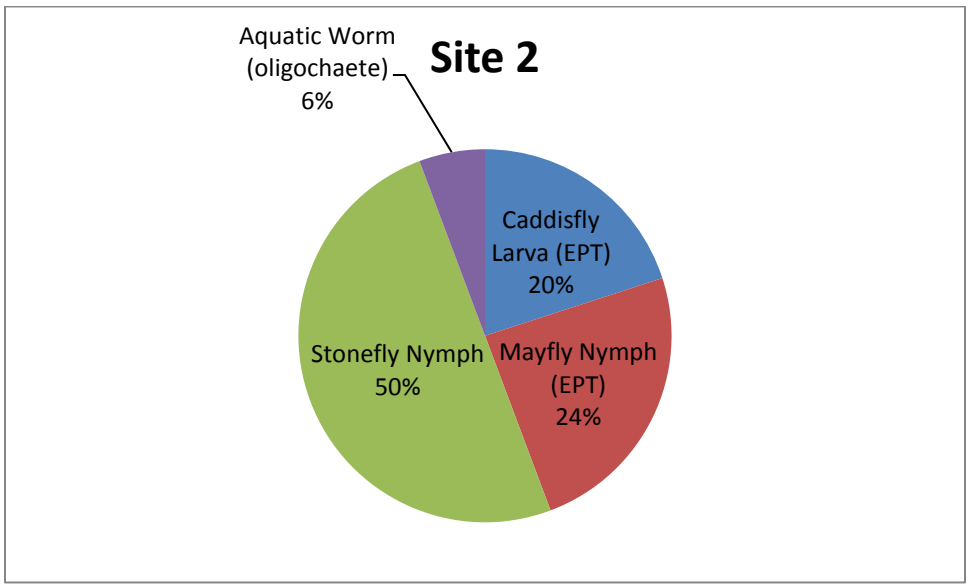
by amphipods, while stations 2 and 3 had their dominant invertebrates of stone fly nymphs and chironomids, respectively.

Site assessment ratings ranged from 1.75 to 2.50 showing "marginal" for site 1 and "acceptable for sites 2 and 3. These ratings are based on the invertebrate diversity and community in the stream. The EPT Taxa that represents this stream ranged from 21%-94%, with the majority being at site 2. Site 1 had the lowest amount of EPT invertebrates.

Table 7: Abundance and diversity of invertebrates taken in duplicate at three stations on Richard's Creek during 31 October 2012. The overall site assessment is included for each station (out of 4.00). Invertebrate Survey Data Sheets are included in Appendix 2. No stream invertebrates were sampled on 17 November 2012.

Pollution Tolerance	**Invertebrate Taxa**	**Station 1**	**Station 2**	**Station 3**
Category 1: Pollution Intolerant	Caddisfly Larva	6	14	1
	Mayfly Nymph	0	17	0
	Stonefly Nymph	0	35	4
Category 2: Somewhat Pollution Intolerant	Clam, Mussel	5	0	0
	Amphipod	9	0	0
Category 3: Pollution Tolerant	Aquatic Worm (Oligochaete)	6	4	4
	Midge Larva (chironomid)	1	0	7
	Blackfly Larva	1	0	0


Site 1
Midge Larva (chironomid) 4%
Blackfly Larva 4%
Aquatic worm (oligochaete) 21%
Caddisfly Larva (EPT) 21%
Small Clams 18%
Amphipods (freshwater shrimp) 32%


Site 2
Aquatic Worm (oligochaete) 6%
Caddisfly Larva (EPT) 20%
Stonefly Nymph 50%
Mayfly Nymph (EPT) 24%

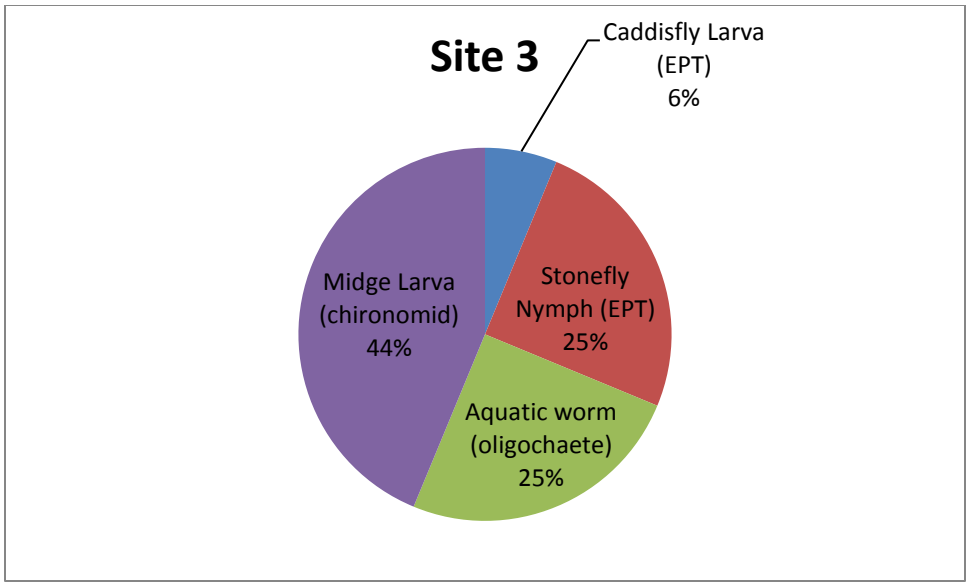


Figure 4: Percentage of stream invertebrates captured from duplicate samples taken at three stations on Richard's Creek during 31 October 2012. Data is summarized in Table ? and Invertebrate Field Data Sheets are in Appendix 2.

6.0 Conclusions and Recommendations

While undergoing this study on Richard's Creek, we have spent countless hours collecting samples, catching invertebrates and wading through flowing waters. In conclusion to our study, we believe that Richard's Creek is not in a "poor" state, but it is also not seeing a "healthy" environment. More monitoring must be done on Richard's Creek to determine what is causing this stream to decline, and more work should be done to determine how the agricultural land near station 3 has been effecting the creek, and to figure out some remediation work to combat this pollution. Richard's Creek has major potential; we just need to be there for her.

7.0 References

Brown L., McDonald T., Rochetta M., and Dr. Demers E. 2009. Water Quality and Stream Invertebrate Assessment for Richard's Creek, BC, Fall, 2008, Vancouver Island University.

Noyon M. FISH 307: Stream Parameters. Class Handout. 10 October 2012.

8.0 Appendices

APPENDIX 1. Photographs showing the site and where samples were conducted on Richard's Creek during October 2012 (courtesy of Scott Senkiw).

Photo 1: Richard's Creek at the Escarpment Way Crossing (Station 1; Invertebrates sampled here).

APPENDIX 1 (continued)

Photo 2: Station 1 at the area where the Water Quality/Microbiology samples were taken.

Photo 3: Richard's Creek at the end of Rice Road (station 2).

APPENDIX 1 (continued)

Photo 4: Richard's Creek at station 3; adjacent to agricultural lands.

Photo 5: Richard's Creek at Station 4, located right underneath the Herd Road Bridge crossing.

APPENDIX 1 (continued)

Photo 6: Station 4 with a view upstream towards the agricultural lands; station 3 is located ~2km upstream.

APPENDIX 2: Invertebrate Survey Field Data Sheet completed for duplicate stream invertebrate sample collections at Stations 1, 2 and 3 on Richard's Creek during 31 October 2012.