DEPARTURE BAY CREEK WATER QUALITY AND FRESHWATER INVERTEBRATE ANALYSIS

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EXECUTIVE SUMMARY

This report has been prepared as a part of the East Vancouver Island stream assessment series that was undertaken by Vancouver Island University. This report is focused on Departure Creek in Nanaimo, BC. Departure Creek is a short and narrow creek situated in the Departure Bay urban neighborhood and is affected by residential and commercial influence. Departure Creek is contributed to by 2 tributaries, Joseph Creek and Keighley Creek, and outflows into the Northwest corner of Departure Bay.

The purpose of this survey and report was to assess previously established sites, over two sampling events, for its water quality, hydrology, nutrients, metal content, and aquatic invertebrates. The data collected over the two sampling events can help determine Departure Creek's general stream health and ability to support aquatic life. The parameters tested were compared to the Guidelines for Interpreting Water Quality Data, prepared by the Ministry of Environment and various supporting agencies, to identify any points of concern in the Departure Creek ecosystem (Resource Inventory Committee, 1998). The purpose of utilizing two sampling events was to observe the changes that occurred between each event and determine how it affect parameters. To aid as an indicator of stream health, aquatic invertebrates were sampled during the first sampling event. Macroinvertebrate sampling occurred at two predetermined stations during the first sampling event to evaluate Departure Creek's taxa richness and diversity. These invertebrates were live captured using a Hess Sampler. Water samples were collected at all four stations to observe trends between stations to understand the general stream health of Departure Creek. These samples were analyzed by

the research team at the Vancouver Island University Lab and other samples were sent to Australia Laboratory Services Ltd. (ALS) in Burnaby, BC. The Vancouver Island University lab was able to test for general water quality parameters and ALS was also able to test for general water quality parameters as well as metal content and nutrient levels. Compiled data and precise results were critical in assessing the general stream health of Departure Creek.

Coliforms were sample for at all sites to determine the potential presence of pathogens in the water of Departure Creek. The coliform content of Departure Creek exponentially increased as it travels downstream, and this resulted in a significant but not harmful coliform count.

Analysis of general water quality parameters at the Vancouver Island lab determined that there was a high alkalinity level and a medium to high hardness level. ALS lab results were all below guideline maximums. Macroinvertebrate samples showed that there was minimal pollution sensitive species present, and this could indicate that a pollution was present. Departure creek is an integral part of the local ecosystem and the community. Further monitoring of the stream's health should continue to identify potential factors causing adverse effects and mitigate these factors when necessary.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION AND BACKGROUND

An environmental monitoring project for Departure Creek located in Nanaimo, BC was carried out by 4 third year Resource Management and Protection (RMAP) students in their third year of the Bachelor of the Natural Resource Protection (BNRP) Degree at Vancouver Island University. The goal of the project was to analyze water quality and freshwater invertebrates within the stream. This new data will be used in correlation with data from Departure Creek collected in previous years by students in the BNRP Degree. Departure Creek is 3 kilometres long and originates as two separate tributaries, Keighley creek and Joseph creek (Team Watersmart, 2015). There were 4 stations on the stream that were sampled. The farthest upstream sampling station was located at Neyland Road, and the most downstream sampling station was located next to Departure Road, downstream of station 1 (See Figure 1 and Figure 2).

Figure 1: Map showing Station #1 to #4 along Departure Creek (Map modified by Eric Demers, originally from the Regional District of Nanaimo, 2003.).

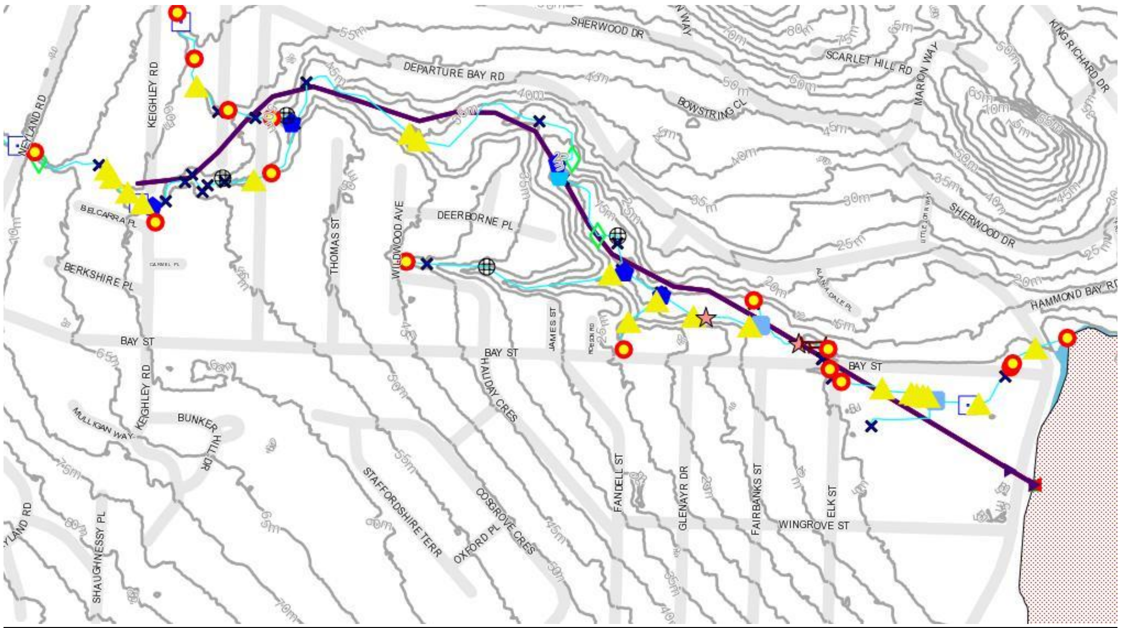

Figure 2: Topographical map of Departure creek (City of Nanaimo 2015).

Departure Creek flows through a developed residential area and has had much human activity encroaching on its sensitive riparian areas (Team Watersmart, 2015). The creek is used as a drainage system for most of the Departure Bay neighbourhood. Storm water is diverted into the creek where it flows into Departure Bay. This area also has some cultural significance to the local First Nations, who used to use the creek to support food gathering, shelter, and culture (Team Watersmart, 2015). It still remains as an area of cultural significance today.

There are several factors which could cause some environmental impacts to the area. During the first visit to the stream, one of the first things observed was the sign of pollution. Refuse, such as shopping carts, fast food packages, and plastic bags were observed in areas of the stream. Some of the refuse could be leaching toxins into the water system. The largest potential impact to the stream is the storm water runoff. Normally, the flow in the stream is low.

Because storm water is diverted into the creek, waters can rise rapidly, thus increasing the flow dramatically, thereby potentially causing bank erosion, and adding excess nutrients to the water. The runoff from the storm water could potentially have an adverse effect on stream biota, due to effluent introduction into the stream from the runoff. The lower reach of the stream will have Coho and Pink salmon spawn in the waters in mid to late fall which makes the overall health of this stream important on economical, ecological and cultural levels.

2. PROJECT OBJECTIVES

The objective of the proposed project is to replicate and continue an environmental monitoring project on Departure Creek, which has been completed by the Vancouver Island University RMOT 306 class from 2010 to 2014. The objective of this annual monitoring project is to sample and analyze various aspects of Departure Creek from four predetermined stations, along an approximate 1,700 meter section of creek, from Neyland Road to the outflow at Departure Bay. The aspects of Departure Creek that will be sampled and analyzed are water quality, hydrology, microbiology, and stream invertebrates. Details on the samplings and analyses will be explained in the following section of this proposal. Because Departure Creek is located in a densely populated area of Nanaimo, it is in turn very susceptible to the effects of residential effluence on watersheds. By completing this project it will give a general idea of Departure Creek's environmental condition. Through the comparison of the data obtained from previous years, it will also determine if there has been any significant changes in the creek's condition. Organizations and groups, such as the Department of Fisheries and Oceans Canada (DFO), the City of Nanaimo, the Regional District of Nanaimo (RDN), and the Nanaimo & Area

Land Trust (NALT), support and are interested in the monitoring of Departure Creek; therefore, it is also part of the project objective to continue to provide these groups with the project results, so they have an up to date idea of the general environmental condition of Departure Creek.

3. PROPOSED ENVIRONMENTAL SAMPLING AND ANALYTICAL PROCEDURES

3.1. Project Sampling

The project sampling has been broken down into four predetermined locations, in which all the sampling will occur. These locations were predetermined, as this is an annually replicated study and the samples are taken from the same stations to maintain consistency. These areas of Departure Creek are under significant public scrutiny; therefore precautions will be taken to respect the public in this area, such as whilst taking samples at the bank, and spending minimal time in the water. Below is a list of the four sampling stations, along with details of their specific locations. All four locations can also be seen on a map in Figure 1.

- Station #1 is located the farthest from the outflow of Departure Creek into Departure Bay, approximately 1,700 meters upstream (see Figure 3). This is immediately upstream of Neyland Road where it crosses Departure Creek. This Station was also given an approximate UTM coordinate of 5451108 meters north and 428056 meter east.

Figure 3: Sample Station #1 Overhead view of site (Photograph taken by Gavin Francis on October 21, 2015).

- Station #2 is located approximately 1,300 meters from the outflow of Departure Creek (see Figure 4). This station is actually located on a tributary of Departure Creek which is named Joseph Creek. The station is situated immediately upstream of Newton Street where is crosses Joseph Creek. The approximate UTM coordinate for this location is 5451137 meters north and 428356 meters east.

Figure 4: Sample Station #2 Overview of site (Photograph taken by Gavin Francis on October 21, 2015).

- Station #3 is located approximately 300 meters from the outflow of Departure Creek (see Figure 5). This station is located on Departure creek within Woodstream Park. Specifically this station is located directly upstream of the bridge where Woodstream Park's trail crosses Departure Creek. The approximate UTM coordinate for this station is 5450879 meters north and 428971 meters east.

Figure 5: Sample Station # 3 Overview of site upstream of Woodstream Park trail bridge (Photograph taken by Gavin Francis on October 21, 2015).

- Station #4 is located closest to the outflow of Departure Creek into Departure Bay, which is approximately 70 meters upstream from the outflow (see Figure 6). This station is located just upstream of the Departure Bay Road pedestrian foot bridge, which crosses Departure Creek. In this case, the station will be accessed from Bay Street. The approximate UTM coordinates for this station are 5450842 meters north and 429334 meters east.

Figure 6: Sample Station #4 Overview looking upstream from Departure Bay Rd pedestrian foot bridge (Photograph taken by Gavin Francis on October 21, 2015).

3.2. Sampling Frequency

The sampling occurring at all four stations will be completed during two sampling events. These two sampling events will include all samples taken in regards to water quality, hydrology, microbiology, and stream invertebrates. The dates of these two separate events will be determined upon project approval. Water quality samples will be taken at all four stations mentioned above and during both sampling events. The hydrology portion of this project will consist of one sample taken at one station, but during both sampling events. In regards to microbiology, a sample will be taken at all four stations; however, this will only occur during the first sampling event. The stream invertebrate samples will be taken at stations 1 and 2, but will only take place during the first sampling event.

3.3. Hydrology

The urban area of Nanaimo that Departure Creek is located in presents several characteristics that contribute to the hydrology of the creek. Rainfall runoff from the streets of the urban area drain into Departure Creek and increase its susceptibility to flash flooding. Leaf litter, tree fall, and domestic waste in the area occasionally causes blockage in culverts and canalizing regions of the watershed, which can reduce water flow. The watercourse has been altered by the addition of a retaining wall on private property along the watercourse. This changed the natural drainage of the creek. The flow of the creek will greatly increase during rainfall and greatly decrease in seasons of drought. Basic flow and discharge measurements of Departure Creek were collected during 2 sampling events: the first sampling event during low flow, being between October 31st and November 4th, 2015, and the second sampling event was during high flow during November 21st -25th, 2015. It was collected by the Float Method. The Float Method involves the measurement of the cross-sectional area of the creek and measuring the speed of the current with a small floating object, which was a 2 inch Ping-Pong ball for this study.

3.4. Water Quality

Water quality was tested twice during this study, the first sampling event during low flow between October 31st and November 4th, 2015, and the second sampling event occurred during high flow between November 21st -25th, 2015. The collected samples were stored in a fridge at approximately 4 Degrees Celsius, before in-lab sample analysis. The following parameters were tested in Departure Creek: conductivity (µs/cm), dissolved oxygen (DO% and DO mg/L), pH, hardness (mg/L $CaCO_3$), alkalinity (mg/L $CaCO_3$), turbidity/total suspended solids, coliform filtration and incubation, phosphate and nitrate. Temperature, dissolved oxygen, pH, and conductivity were tested in the field using an YSI Probe.

The samples were analyzed at a Lab at Vancouver Island University for the parameters listed. Analysis of the samples was in coordination with Australian Laboratory Services (ALS), a private analytical laboratory at 8081 Lougheed Highway, Burnaby, BC. ALS will test samples collected from Departure Creek for general water quality parameters, nutrient analyses, and total metal scans, which can detect approximately 30 different metals.

To ensure that the quality and integrity of the samples were maintained throughout the study, all members of the research team received a refresher briefing on the Ambient Freshwater and Effluent Sampling Manual (AFESM), designed by the Ministry of Environment of British Columbia. Checklists for the procedures listed above were, in turn, provided to the research team and were followed throughout the study. The samples were handled in accordance with the guidelines prescribed in AFESM to ensure quality. This included proper sample handling, proper rinsing of containers and equipment with distilled water before and after use, as well as the use of gloves for the duration of sample collection and handling. To ensure quality control, 1 trip blank and 1 field blank were brought to every sampling station. 1 duplicate was sampled from each station to ensure accuracy and increase integrity.

Data recorded during this study was subsequently analyzed and compared with the AFESM guidelines for drinking water, as well was the guidelines for aquatic life. The data collected in the study was also analyzed and compared with data collected from Departure Creek from previous years.

3.5. Microbiology

Microbiology samples were collected from Departure Creek for coliform analysis, and there was only one sampling event. Using 100ml Whirlpak bags, samples of water from the 4 stations were collected to test for coliform presence and abundance. These bags were filled to 100ml, tied closed and labelled before being stored in a fridge, which then awaited lab analysis. Sample collection and handling was done in accordance with the United States Environmental Protection Agency's (USEPA) guidelines on how to sample fecal bacteria.

Analysis of the microbiology samples was completed using the Total Coliforms and *E. COLI* Membrane Filtration Method outlined by USEPA. This method was conducted by filtering the 100ml bags through a 47mm filter. The filter was then placed into a 50mm petri dish that contained an absorbent pad that has been covered with m-ColiBlue24 Broth. The petri dish was then incubated at 35 Degrees Celsius ± 0.5 Degrees Celsius for 24 hours. After 24 hours, coliform colonies were present in the petri dish where the total coliforms were counted. The blue coliform colonies are fecal-coliforms and the red coliform colonies are non-coliforms.

For quality Assurance, gloves were worn, all equipment was rinsed, and samples were handled in accordance with the AFESM. Quality control for microbiology analysis at Vancouver Island University includes an inoculated blank. This blank was made by filtering 100ml distilled water, prior to testing samples from Departure Creek, through the 47mm filter, and then placing it in the 50mm petri dish with m-ColiBlue24 Broth. Then it was left to incubate in the same fridge that housed the samples for 24 hours. This petri dish was analyzed to see if any coliforms cultivated using the equipment, effectively testing the sterility of equipment.

3.6. Stream Invertebrate Communities

Stream invertebrate sampling occurred between October 31st and November 4th, 2015, during the first sampling period. Invertebrate sampling took place at Station 1, Station 2 and Station 3 on Departure Creek in Nanaimo, BC. Sampling was conducted by using a Hess Sampler and scrapping rocks inside the Hess Sampler to dislodge any invertebrates into the sampler's catch. Flow was too low for the employment of the Hess sampler, and so a Kick Sampler was employed in its place. To use the Kick Sampler, the sampler was placed downstream, and the substrate above it was scraped to release the invertebrates into the sampler. The sample areas at each station had similar substrate to maintain continuity in the sampling. The invertebrates collected were preserved in alcohol for later analysis in the lab. There were several large invertebrate collected, and the samples were collected live and analyzed approximately 24 hours later.

Invertebrate Sample Analysis was conducted at the lab at Vancouver Island University for enumeration testing. The samples were analyzed and data was entered onto Stream Invertebrate Survey Data Sheets to test for species abundance, species density and diversity, overall site assessment rating, pollution tolerance index, EPT index and EPT to total ration index.

For quality control, there were 3 replicates taken at each sampling station. Sampling began downstream and moved upstream to preserve the integrity of the substrate before being sampled. Sampling was conducted in accordance with AFESM guidelines.

4. HEALTH AND SAFETY PLAN

Safety was the highest importance for all group members. This section elaborates on the safety precautions taken by individual members as well as a larger safety mentality in general.

Upon first arrival the team agreed on a muster point in case of an emergency. The muster point for the team was the parking lot of the "7-Eleven" gas station located near site 4. (UTM: IOU- 5450786, - 0429344). In a unlikely event that compromises the safety of the 7-Evleven parking lot, the team agreed on the shores of Departure Bay as a secondary muster point (UTM: IOU 5450763, 0429368). All group members had each other's contact information as well as quick access to emergency numbers such as 911, the Provincial Health Hotline (811) and the Poison Control Hotline (1-800-567-8911). A member of the group will always checked in with Mr. Demers via text message prior to sampling or if he couldn't not be reached another individual known to the group was contacted and once again when sampling for the particular day was completed. Samples were only taken from Departure Creek during full daylight hours with the entire team present. When working, all team members will wore the appropriate gear for the weather. All members had waterproof, slip resistant Canadian Safety Association (CSA) approved footwear and was wearing them in the field. Upon arrival at each site the team collaborated to perform a site flow hazard assessment to determine the flashiness of the site. Flashiness is the level of response of a stream to a precipitation. Streams with high flashiness are susceptible to drastic increases in water levels over a short period of time if the flow was deemed too high for a particular site, the team would postpone sampling in that site until precipitation levels dropped. During the group's initial tour they noticed significant vegetation growth, particularly at site 4. The team will brought garden sears on their next visit to trim away what was needed to access the site safely.

The team noted the individual hazards that occurred at each site. Sites 1, 2 and 4 are located off of roadways. The team was constantly be aware of the traffic and its hazards. This is especially true for site 4, which was located in a relatively high traffic area near Departure Bay Road compared to sites 1 and 2 was located off of less-used residential roads. Each site possessed its own unique hazards as well as shared communal ones. Refer to table 1 for a complete list of potential hazards and their degrees of risk.

Table 1: Departure Creek Site Access and Potential Hazards

Site Location	Site 1	Site 2	Site 3	Site 4
Access	Great	Okay	Very Good	Poor
Embankment	Safe	Multiple loose boulders covered in leaf litter	Good	Overgrown with blackberries brambles
Substrate	Sand, Gravel, Cobble	Boulders, Gravel	Cobble, Sand	Sand, Boulders, Cobble
Water Depth as of Oct 21, 2015	Shallow	Very shallow	Shallow	Intermediate
Water flow Rate as of Oct 21, 2015	Low	Very Low	Low	Moderate
Hazards	Traffic, Tree Snag, Slope Potentially Slippery When Wet	Traffic, Erosion Due to Bamboo, Steep Gradient With Loose Footing, High Tree Coverage Could Result in Falling Branches in Wind Storm	Multiple Dead Trees, Potential Human Danger, Moderate Traffic Area for Domestic Dogs, Significant Leaf Litter	Higher Traffic Area, Urban Litter- Broken Glass, Potential for Needles etc.
Personal Safety Risk	Very Low	Low	Very low	Moderate

5. RESULTS

5.1. VIU Laboratory Analyses Results

In addition to the water quality parameters measured by ALS, the general parameters from every site were measured in a laboratory at VIU. Refer to Table 2 and 3 for full list of result from both events (3-NOV-15 and 24- NOV-15).

Table 2. Laboratory Analysis for Water Quality Parameters of VIU Samples from All Stations during Sampling Event 1

Stations	Temperature (°C)	DO (mg/L)	Turbidity (NTU)	pH	Conductivity (In µS)	Alkalinity ($CaCO_3$ mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Hardness ($CaCO_3$ mg/L)
1	11.6	9.9	1.97	7.7	192	48	1.11	0.17	153.9
2	10.3	10.9	1.42	7.4	166	44	1.7	0.05	102.6
3	10.6	12	0.49	7.8	280	66	2.53	0.1	102.6
4	10.9	10.7	0.51	8	360	75	0.58	0.06	153.9
Replicate	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Trip Blank	n/a	n/a	n/a	n/a	n/a	n/a	0.04	0.07	n/a

Table 3. Laboratory Analysis for Water Quality Parameters of VIU Samples from all Stations during Sampling Event 2

Stations	Temperature (°C)	DO (mg/L)	Turbidity (NTU)	pH	Conductivity (In µS)	Alkalinity ($CaCO_3$ mg/L)	Nitrate (mg/L)	Phosphate (mg/L)	Hardness ($CaCO_3$ mg/L)
1	9.7	11.5	0.73	7.5	170	33	3.56	0.12	119.7
2	7.6	12.0	1.46	7.4	144	29	2.44	0.09	85.5
3	8.0	11.7	0.7	7.4	213	47	0.44	0.09	119.7
4	7.9	11.7	0.97	7.6	270	71	3.07	0.2	119.7
Replicate	n/a	n/a	1.43	7.6	176	42	3.99	0.15	102.6
Trip Blank	n/a	n/a	n/a	n/a	n/a	n/a	0.04	0.11	n/a

Turbidity levels did fluctuate between events. With the exception of site 1, all turbidity levels increased.

pH levels remained nearly constant. The pH ranges between the two events were 7.4-8.

The conductivity of the Departure Creek shared the same patterns during both sampling events with site 2 having the lowest readings (166µS, Event 1and 144µS/cm, Event 2), 4 being the highest (360/cm, Event 1 and 270/cm, Event 2). Site 1 had the 2nd lowest levels, placing site 3 with second highest conductivity levels. This can logically explained. Conductivity levels increase downstream because of the saltwater influence with its concentration of Ions (NaCl) as outflow meets the ocean. It's noteworthy to mention all conductivity levels were higher in the first sampling event.

The alkalinity result indicates Departure Creek has low acid sensitivity. The patterns were the same in both events. However the first sampling event yielded higher measurements in all stations (First event; 44-75mg/L CaCo3. Second event; 29-71mg/L) these result are positive and indicate Departure Creek has the ability to maintain a stable pH if any acidic effluents were to leach in by residential and commercial activities.

Departure Creek showed high levels of Nitrate. In a typical watercourse the nitrate level is <0.3 mg/L (Dr. E Demers. Environmental Monitoring Professor at Vancouver Island University, Pers. Comm., 2015). The first sampling event yield levels ranging from 0.58-2.53 Mg. The second event produced even higher levels of concentration, with ranges from 0.44- >3.99 mg/L. The abnormally high levels of nitrate can be linked with high certainty to fertilizers used by the local residents and commercial activities. Many homes with gardens were located near the creek. A golf course located further upstream has likely leached Nitrate into the creek. It is reasonable to assume that the concentration of Nitrate in the second event is a result of heavy rains in between sampling events that resulted in higher flushing rates of Nitrate into the Departure Creek.

The observed low levels of Phosphate; the average between both events was 0.11 mg/L PO43- highest level was 0.17 mg/L PO43- that was from site 1 during the first sampling event. The lowest was site 2, from event one with 0.05 mg/L PO43-. No clear trends were observed among neither sites nor sampling events.

Departure Creek had interesting harness results. The first event ranged from 102.6-153.9 mg/L CaCO3. The second sampling event resulted in ranges from 85.5-119.7 mg/L CaCO3. The Departure Creek results showed most sites fell in the intermediary range in between the between soft and hard guidelines. Soft water is considered to be < 60mg/L. High water is >120mg/L. During the first sampling event sites 1 and 4 were both recorded at 153.9 mg/L CaCO3. Which is officially considered hard water. These results were conducted using the high range test, which is less accurate than the low range. This is why there were identical results among stations. The high range testing method had to be used because the conductivity levels fell within the high range. There was no clear trend of hardness. However, Site 2 seemed to have the lowest level hardness in both events, however hardness in Site 2 decreased from 102 to 85.5 mg/L $CaCO_3$.

Coliform colonies were only taken during event 1. Site 3 had the lowest amount of fecal coliform with only 15% (284) total amount of fecal Coliform Forming Units (CFU)/100ml. Site 1 was on the other end of the spectrum which produced the highest amount of fecal coliforms with 688 CFU/100ml making 30% of the coliforms (see Table 4). None of the samples passed the water quality criteria for drinking water or livestock use. The guideline maximum is 0 CFU for drinking water and 200 CFU for general livestock use, however; these levels are not harmful to aquatic life. CFU levels among the sites were relatively consistent. The presence of both local, domestic, and wildlife animals located upstream and at sites are almost certainly the cause of these results.

Table 4: Coliform Fecal Analysis Show Total Coliforms and Fecal Coliform Colonies per Station at Departure Creek during Sampling Event 1 on 3-NOV-15.

Site	Total Coliforms (per 100ml)	Fecal Coliforms (per 100ml)	% Fecal
1	2260	688	30
2	1856	484	26
3	1900	284	15
4	3148	928	29

5.2. ALS Results

During both sampling events on the 3rd and 24th of November, 2015, 3 samples were collected from station 1, the upper most station, and station 4, the lower most station. These samples were sent to Australian Lab Services (ALS), where they performed nutrient, metal and general parameter analysis. The analyses conducted by ALS were utilized more sophisticated technology and more time consuming analysis than the RMOT 306 course could afford to utilize on its own. ALS results were compared to the BC Guidelines for Intercepting Water Quality.

The results of ALS's analysis showed that there was significant change in some parameters and little change in others (see table 5). Average nitrogen levels between Station 1 and 4 rose between the first and second sampling event from 1.62 mg/L total nitrogen to 1.865 mg/L. This rise did not have much impact on the environment as the guideline maximum is 200 mg/L, but it was significant change that was likely caused by the recent rainfall in the area. Because of this nitrogen increase and the decrease of phosphorus, the total nitrogen to total phosphate had increased meaning Departure Creek is phosphorus limited. The ALS findings showed no parameters over guideline maximums or under minimums for aquatic life, suggesting that Departure Creek should be able to support aquatic life. Results from ALS were critical in determining Departure Creek's general stream health.

Table 5: ALS Lab Analysis Results of the Samples Taken from Departure Creek on November 3rd, and 24th, 2015.

		Sampling Date					
		03 Nov 15		24 Nov 15			
Parameters	**Units**	**Station 1**	**Station 4**	**Station 1**	**Station 4**	**Lowest Detection Limit**	**BC Water Guideline**
Physical Tests (Water)							
Conductivity	uS/cm	241	480	220	275	2	
Hardness (as CaCO3)	mg/L	92.8	110	78.6	87.6	0.5	
pH	pH	7.86	8.01	7.92	8.04	0.1	6.5-9.0

Anions and Nutrients (Water)							
Ammonia, Total (as N)	mg/L	<0.0050	0.0102	<0.0050	0.0063	0.005	
Nitrate (as N)	mg/L	1.45	1.46	1.93	1.59	0.005	200
Nitrite (as N)	mg/L	0.0014	0.0026	<0.0010	0.0018	0.001	0.06
Total Nitrogen	mg/L	1.56	1.68	2.01	1.72	0.03	
Orthophosphate-Dissolved (as P)	mg/L	0.0125	0.0105	0.0101	0.0044	0.001	
Phosphorus (P)-Total	mg/L	0.0143	0.0141	0.015	0.0113	0.002	
Nitrogen: Phosphorus Ratio	TN:TP	109.0909	119.1489	134	152.2124		
Total Metals (Water)							
Aluminum (Al)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	0.2	0.1
Antimony (Sb)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	0.2	0.02
Arsenic (As)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	0.2	0.005
Barium (Ba)-Total	mg/L	<0.010	0.014	<0.010	0.012	0.01	5
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	0.005	0.0053
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	0.2	
Boron (B)-Total	mg/L	<0.10	0.12	<0.10	<0.10	0.1	1.2
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	
Calcium (Ca)-Total	mg/L	23.7	26.9	20.5	23.3	0.05	
Chromium (Cr)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	0.001
Cobalt (Co)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	0.11
Copper (Cu)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	
Iron (Fe)-Total	mg/L	0.128	0.125	0.142	0.126	0.03	1
Lead (Pb)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	0.05	
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	0.87
Magnesium (Mg)-Total	mg/L	8.19	10.5	6.67	7.16	0.1	
Manganese (Mn)-Total	mg/L	0.0071	0.0127	0.0103	0.0125	0.005	
Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	0.03	2
Nickel (Ni)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	0.05	
Phosphorus (P)-Total	mg/L	<0.30	<0.30	<0.30	<0.30	0.3	0.1
Potassium (K)-Total	mg/L	<2.0	2.5	<2.0	<2.0	2	
Selenium (Se)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	0.2	0.002
Silicon (Si)-Total	mg/L	9.07	8.1	8.24	7.37	0.05	
Silver (Ag)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	
Sodium (Na)-Total	mg/L	9.1	52.8	10.6	19.4	2	
Strontium (Sr)-Total	mg/L	0.0919	0.127	0.0823	0.0987	0.005	
Thallium (Tl)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	0.2	0.002
Tin (Sn)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	0.03	
Titanium (Ti)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	0.01	
Vanadium (V)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	0.03	
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	0.0059	<0.0050	0.005	0.033

5.3. Invertebrates Analysis

Invertebrates were obtained from sites 1 and 4 using a Hess sampler and transported to VIU inside of a cooler. The group analyzed the total invertebrate density per metre squared, percentage of pollution tolerant species and the amount of taxa that were present. Micro invertebrates were not examined for the stream survey and will not be included in the report.

Station 4 was very close to the ocean and the stream invertebrates are affected by the rising tides as opposed to station1 which is far upstream and the rising tide has no effect on stream invertebrates collected. Hess samplers were used to sample 0.36m squared and the group collected 4 samples at each station, sampling a total area of 1.44m squared in both sites. After analysis it was determined that station 1 had an invertebrate density of 81.25 invertebrates per metre squared and Station 4 had a higher invertebrate density of 175 invertebrates per metre squared. Station 4 likely had higher density from the saltwater that flowed into the stream contained extra nutrients and a higher water level which could increase the total invertebrate density but could lower the diversity, because some species would be unable to survive the saltwater. Station 1 (See Table 6) had 14% of invertebrates captured being pollution intolerant, 20% of invertebrates captured being pollution tolerant, 77% of invertebrates captured being somewhat pollution tolerant (see Figure 7). Station 4 (see Table 7) had only 1% of invertebrates captured being pollution intolerant, 4% being pollution tolerant and 95% being somewhat pollution tolerant (see Figure 8).

Table 6: Station 1 Stream Invertebrate Sampling Results

Pollution Tolerance	Common Name	Number Counted	Number of Taxa	% of Catch
Pollution intolerant	Mayfly nymph	17	2	14%
Somewhat pollution tolerant	Aquatic beetle	2	1	2%
Somewhat pollution tolerant	Aquatic sowbug	1	1	1%
Somewhat pollution tolerant	Cranefly larva	1	1	1%
Somewhat pollution tolerant	Scud (amphipod)	73	3	62%
Pollution tolerant	Aquatic worm (oligochaete)	20	2	17%
Pollution tolerant	Planarian (flatworm)	3	1	3%

Table 7: Station 4 Invertebrate Sampling Results

Pollution Tolerance	Common name	Number counted	Number of taxa	% of catch
Pollution intolerant	Stonefly nymph	3	1	1%
Somewhat pollution tolerant	Aquatic sowbug	10	1	4%
Somewhat pollution tolerant	Clam	5	1	2%
Somewhat pollution tolerant	Scud (amphipod)	225	4	89%
Pollution tolerant	Aquatic worm (oligochaete)	3	1	1%
Pollution tolerant	Pouch and pond snails	6	2	3%

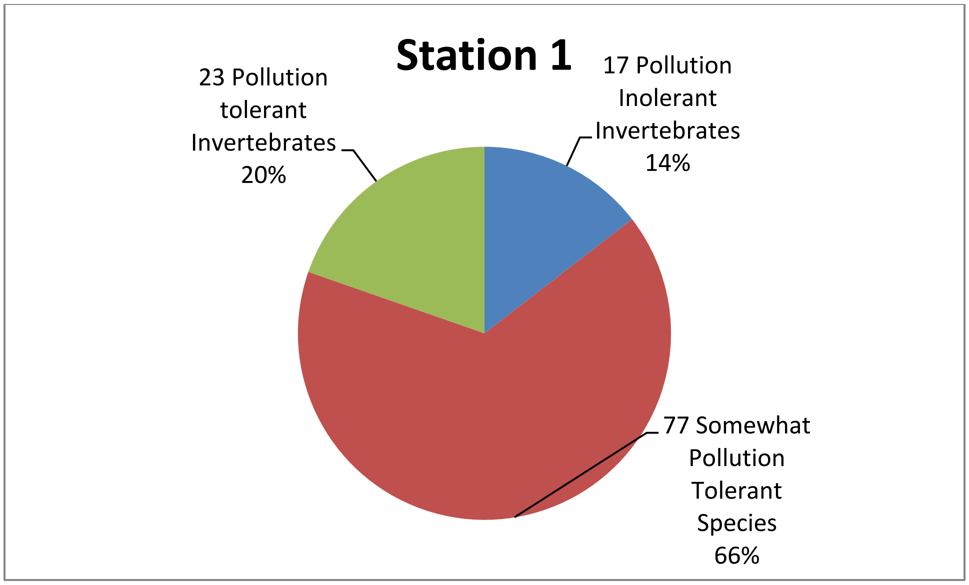

Figure 7: Degree of Invertebrate Species, with Varying Pollution Tolerance, Present at Station 1

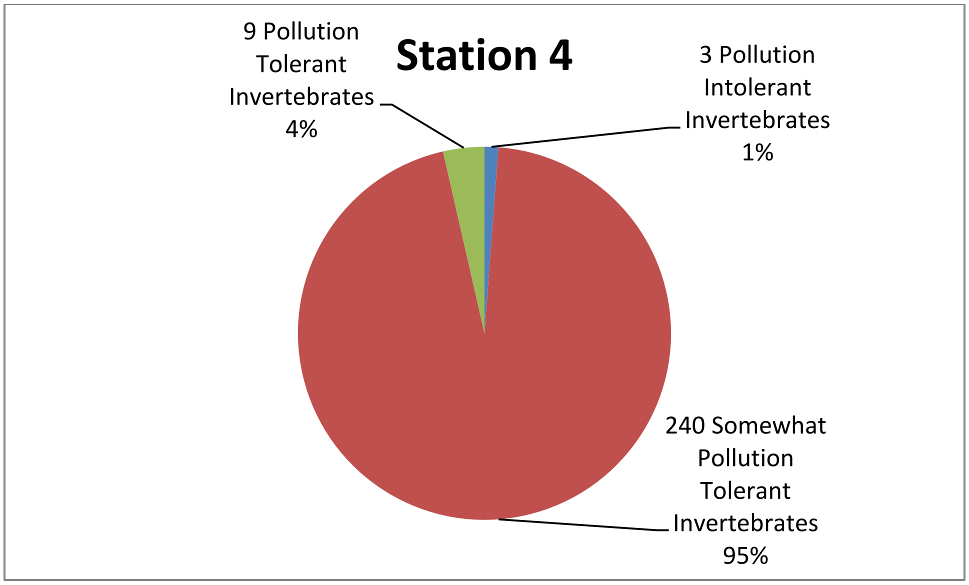

Figure 8: Degree of Invertebrate Species, with Varying Pollution Tolerance, Present at Station 4

There was limited diversity of taxa collected from stations 2 and 4, 11 taxa were observed in the samples from station 1 and 10 taxa were observed in the samples from station 4. The Dominant invertebrate species in the stream were scuds, and made up 81 % of the total catch from both sites. In comparison to previous years research projects it appeared that the amount of pollution sensitive invertebrates were extremely low. In the 2014 research project the majority of invertebrates that were collected were sensitive to pollution, in comparison the 2015 results showed that the somewhat pollution tolerant species were thriving while the intolerant species were mostly absent from the stream. A Shannon-Weiner Diversity Index score was calculated for both stations resulting in a score of .72 for Station 1 and .35 for Station 4. Station 1 had a significantly high score indicating that it has a higher species diversity. Station 4 had a lower species diversity and this could be the result of the tidal water influence making the area less desirable for certain aquatic species.

The population levels in the stream for invertebrates appears to be at a healthy level, but Saltwater has been assumed to have been a factor as to which species of invertebrates could survive in station 4. Sensitive invertebrates such as stonefly nymphs would have trouble surviving in higher salt water content. The lack of pollution intolerant species from both sampling stations is an indicator that the stream has suffered some environmental impacts.

5.4. Basic Hydrology

After completing hydrology samples during sampling events 1 and 2, it was determined that the discharge was 0.01068 m^3/s (or 1.068 cm^3/s) higher during sampling event 2. During sampling event 1, the discharge calculated was 0.0344 m^3/s, whereas the discharge during sampling event 2 was 0.04508 m^3/s. Sampling event 1 occurred on November 3rd, while sampling event 2 occurred on November 24th. With significant rainfall occurring in between events, this is likely the cause for the increase in discharge. See Table 8 below to see a direct comparison between the discharge levels of both sampling events.

Table 8: Discharge levels at Departure Creek at both Sampling Events

Sampling Event	Cross-Sectional Area (m^2)	Velocity (m/s)	Discharge (m^3/s)
Event 1	0.014995	0.2295	0.03440 = 3.440 cm^3/s
Event 2	0.161000	0.2800	0.04508 = 4.508 cm^3/s

Temperate ranges among sites did not fluctuate greatly in the first event (see Table 2). The difference between the coolest and warmest site was slightly over 1°C (10.3°C -11.6°C). Event 2 generated a larger range of results. In sampling Event 2, Site 1 demonstrated to be the warmest with a reading of 9.7°C; the opposite end of the transect (Site 4) produced the coolest of the entire survey with a temperature of 7.9°C (see Table 3). When examining the data between events and sites a trend becomes apparent. The coolest reading in Event 1 was warmer than warmest reading in Event 2. The atmospheric temperatures in the Nanaimo area dropped significantly in between the events as the days drew closer to the winter season. The 1.8°C difference between the top and the bottom of the transect could be due the cooler, seawater influence has Site 4, especially during high tide.

Departure Creek's Dissolved Oxygen (DO) levels were at a healthy level and well above the minimum limit for aquatic invertebrates (4.0 mg/L) (Resource Inventory Committee, 1998). The sites' ranges from the first event was from 9.9-12.0 mg /L with an average of 10.88 mg/L. Event

2’s levels were even higher, with a range of 11.5-12.0 mg/L and an average of 11.73 mg/L. There was no apparent trend in DO levels among sites but higher DO levels in Event 2 was likely caused by the increase of rainfall prior to Event 2. Rainfalls result in higher and faster stream flow, which can increase the amount of DO in a stream (Dr. J Morgan, Professor at Vancouver Island University, Pers. Comm., Sept 2014).

5.5. Quality Assurance & Quality Control

Throughout our project on Departure Creek quality control and quality assurance played a vital role in ensuring we obtained accurate and applicable data. In terms of quality control all water quality samples were taken in pre-rinsed or sanitized bottles to avoid any contamination to the samples. Also another quality control method utilized was the use of a replicate sample at station 1, although due to a technical error our replicate sample during the first sampling event was compromised. Almost all water quality parameters sampled at station 1 during the second sampling event showed very little to no variation between the original sample and the replicate. Although turbidity showed a significance increase between the original sample and the replicate, increasing from 0.73 NTU to 1.43 NTU. This was likely cause from disturbances in the creek by taking the previous water samples. Another parameter that showed a significant change was water hardness, the original sample being 119.7 mg/L $CACO_3$ and the replicate being 102.6 mg/L $CACO_3$. It is uncertain what caused the significant decrease in hardness from the original sample to the replicate sample, although it does indicate that possible contamination occurred either in the field sampling or lab analysis of the samples.

In regards to quality assurance, this is an annually replicated monitoring project. All methods and procedures are replicated to the best of the monitoring team's ability to assure all parameters tested are applicable, and can be compared sufficiently to the previous year's results.

6. Conclusion and Recommendations

After testing the parameters mentioned in this report it was determined that the water quality of Departure Creek in Nanaimo, BC, was of fair health. The creek was capable of supporting aquatic life but there were indicators that there may be some factors negatively impacting the stream. The parameters analyzed, including inorganic parameters, nutrient levels, metal levels and coliform content were all below guideline maximums. Some parameters such as hardness were high but was still within tolerable levels. Invertebrate sampling findings suggest that due to the low catch of pollution sensitive invertebrates, there is potentially a pollutant or confounding factor that is affecting aquatic life. Macroinvertebrate species diversity decreased between Station 1 and Station 4, and this could also indicate s factor that is decreasing diversity. Further research could determine the presence of pollution and the point or not point source of its origin.

ALS sample was a great resource for determining the general stream health of Departure Creek. ALS analysis results showed no parameters above maximum guidelines or below minimum guidelines. Their results showed that nitrogen levels increase as the water travels further downstream and this is like caused by the residential and commercial nutrient influence in the area. There results showed that the stream was in fair health.

This was an annual project that will likely carry in further into the future, and there are some considerations to be taken into account for future research. Station 2 near Keighley Creek had significantly low water levels that could drop even lower during times of drought. This could make sampling difficult or impossible. To compensate for this, a backup location should be established further downstream on the same tributary or where the tributary meets Departure Creek. An additional station could be placed on the Joseph Creek tributary to better understand where some of the higher numbers of nutrients that accumulate downstream originate from. Another point to recommend is that the sampling of Station 4 should be conducted at the same low tide level to prevent tidal water contaminating samples. Because Departure Creek is an area that the public heavily scrutinizes, bringing information pamphlets detail the purpose for the research could alleviate any issue with public interaction. These factors could improve the efficiency of further research and prevent unnecessary data

Acknowledgements

This report would not have been possible without the help of certain individuals and organizations. The authors would like to dedicate this section to identify and thank these groups and persons for their contributions. Firstly they would like to City of Nanaimo and Fisheries Oceans Canada (also known as Department of Fisheries and Oceans) for their financial support. Their funding covered the costs for the ALS samples. ALS is the third organization that we would like to thank. Their laboratory was able to test for metals and nutrients that we could not. We would also like to thank the VIU science department for loaning the equipment necessary for this stream survey, both in the field and in the laboratory. Sarah Greenway's contributions in the lab, specifically assisting in coliform colonies were greatly appreciated by the Departure Creek and her thanks are owed. We would like to express our gratitude to Ms. Jocelyn Dickson for her editing critique, and assistance in the completion of this report. Finally, a special thanks is given to Dr. Eric Demers for his knowledge, expertise and guidance throughout this entire project.

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Appendix

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Departure Creek		Date: Nov 4th, 2015
Station Name: #1		Flow status:
Sampler Used: Hess	Number of replicates 4	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates 0.36m² 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 17	EPT5 2
	Stonefly Nymph (EPT)	EPT3	EPT6
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 17	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle	2	1
	Aquatic Sowbug	1	1
	Clam, Mussel		
	Cranefly Larva	1	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	73	3
	Watersnipe Larva		
Sub-Total		C2 77	D2 6
Category 3	Aquatic Worm (oligochaete)	20	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)	3	1
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 23	D3 3
TOTAL		CT 117	DT 11

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 117

DENSITY: Invertebrate density per total area sampled:

S1 117 ÷ ~~0.36~~ 1,44 m^2 = S2 ~~325~~ 81,25 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 Scud 73

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 2 (6) + 2 x 6 (8) + 3 = S4 17

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

____ + 2 + ____ = S5 2

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

(____ + 17 + ____) / 117 = S6 0.1453

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 11

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

73 / 117 = S8 0.6239

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 1
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

Average Rating
Average of R4, R5, R6, R8
1.75

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Departure creek		Date: Nov 4, 2015
Station Name: #4		Flow status: low
Sampler Used: Hess	Number of replicates: 4	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 0.36 m^2 m^2

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	EPT5
	Stonefly Nymph (EPT)	EPT3 3	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 3	D1 1
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug	10	1
	Clam, Mussel	5	1
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	225	4
	Watersnipe Larva		
Sub-Total		C2 240	D2 6
Category 3	Aquatic Worm (oligochaete)	3	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails	6	2
	True Bug Adult		
	Water Mite		
Sub-Total		C3 9	D3 3
TOTAL		CT 252	DT 10

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 252

DENSITY: Invertebrate density per total area sampled: 1.44

S1 252 ÷ ~~0.36~~ m² = S2 ~~700~~ 175 / m²

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 Amphipod (225)

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 1 (3) + 2 x 6 (12) + 3 (3) = S4 18. 18

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 0 + 1 = S5 1

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

(0 + 0 + 3) / 252 S6 0.0119

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

225 / 252 S8 0.89

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 1
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 1

Average Rating
Average of R4, R5, R6, R8 1.5