DATA REPORT

Water Quality and Stream Invertebrate Assessment

for Departure Creek, Nanaimo, BC,

(Fall 2010)

Report prepared by:

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Table of Contents

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on Departure Creek, Nanaimo, BC, during November 2010.

This study was undertaken by 3rd year undergraduate students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU), offered as part of the Bachelor of Natural Resources Protection (Doug Gow and Kate Parsons). Students worked under the supervision of the course instructor, Dr. Eric Demers (Vancouver Island University). This report was compiled by Dr. Eric Demers based on a student group report.

VIU students contributed approximately 35 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 10 hours for project management and report compilation.

Logistical support was provided by the Fisheries and Oceans Canada (DFO) and the Nanaimo and Area Land Trust. Funding for field expenses and analytical processing of water samples was provided by the Living Rivers - Georgia Basin / Vancouver Island program, and Fisheries and Oceans Canada. ALS Laboratory (Burnaby, BC) provided reduced rates on their analytical services for this project.

2. Introduction

Departure Creek is located in the neighborhood of Departure Bay in Nanaimo, BC. It is approximately 3 km in length and it drains an urban watershed area of approximately 3 km² (City of Nanaimo, 1998).

Restoration and habitat enhancement have been conducted within the creek since 1995, especially within Woodstream and Centennial Parks (City of Nanaimo, 1998). The Nanaimo Area Land Trust (NALT) has been a major contributor to stream stewardship in the area.

This report documents a water quality and stream invertebrate assessment conducted on Departure Creek, Nanaimo, BC, during November 2010.

Specific objectives for this study of Departure Creek included:

- establish 4 water quality sampling stations;
- obtain field measurements of water quality at the 4 sampling stations during two sampling events (early and late November 2010);
- obtain water samples from each sampling station during two sampling events (early and late November 2010) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 2 sampling stations during one sampling event (early November 2010) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Departure Creek which is located in the neighbourhood of Departure Bay in Nanaimo, BC (Figure 1). The creek originates from two tributaries, Joseph Creek and Keighly Creek, and it discharges in the Strait of Georgia at Departure Bay. Water flows through an underground stormwater network in the upstream portion of watershed. The open portion of Departure Creek has an average gradient of 3%.

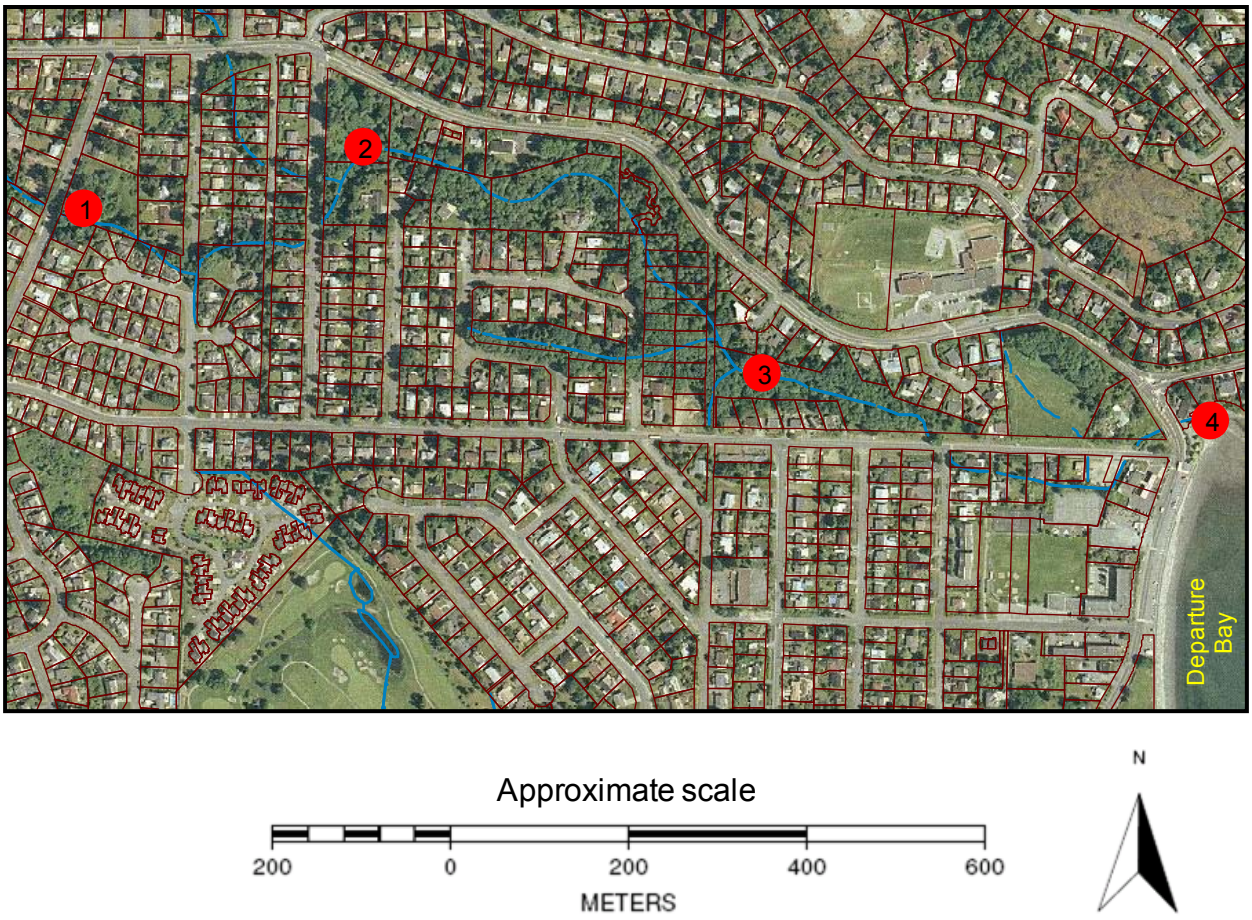

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on Departure Creek, during November 2010. Departure Creek is outlined in blue. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map and aerial photo (taken in 2003) were obtained from the City of Nanaimo's CityMap. Map scale is approximated.

3.1.1. Sampling Stations

Four stations were established on Departure Creek, during November 2010 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of Departure Creek. Stations were numbered from the upstream end to the downstream end of the creek. All stations were easily accessed via foot paths or road crossings. Stations 1 and 2 were located downstream of the Neyland Road and Newton Street crossings, respectively. Station 3 was located within Woodstream Park. Station 4 was located just downstream of the Departure Bay Road crossing, just upstream of the discharge in Departure Bay.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on Departure Creek, during November 2010.

Station	Northing	Easting	Distance from Departure Bay (m)	General Location
1	5451086	0428081	1,700	Immediately downstream of Neyland Rd
2	5451159	0428412	1,300	Approx. 150 m downstream of Newton St.
3	5450929	0428842	600	In Woodstream Park
4	5450857	0429394	5	Departure Bay waterfront

3.1.2. Sampling Schedule

Field sampling was conducted on 3 and 24 November 2010. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment. Table 2 lists the specific activities conducted at each station during each sampling event. Microbiology and stream invertebrate assessments were only completed during the early November event. Photographs showing site conditions and sampling activities are included in Appendix 1.

3.2. Water Quality

3.2.1. Field Measurements

Water quality sampling events were conducted on 3 and 24 November 2010. At each sampling station, field measurements of water temperature (to the nearest 0.01 ^{o}C), dissolved oxygen (to the nearest 0.01 mg/L), conductivity (to the nearest 1 µSiemens/cm) and pH (to the nearest 0.01 pH unit) were obtained with a YSI 556 MPS electronic probe. The electronic probe was placed directly in the channel water.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on Departure Creek, during November 2010. The symbols "A" or "B" indicate whether samples / measurements were taken during the early or late November sampling events, respectively.

Station	Water Quality				Stream Invertebrates
	Field Measurements	VIU Analyses	ALS Lab Analyses	Microbiology	
1	A, B	A, B	A, B	A	---
2	A, B	A, B	A, B	A	A
3	A [1], B [1]	A, B	A, B	A	A
4	A, B	A, B	A, B	A	---

Note: [1] Basic hydrological measurements were taken at station 3 during both sampling events.

Basic hydrological measurements were taken at station 3 during both sampling events. Water velocity (in m/s) was measured using a Swoffer Model 2100 Current Velocity Meter. The sensor was submerged at a depth 40% up from the creek bed. Stream wetted width was measured with a metered tape to the nearest 0.1 m, and wetted depths were measured with a meter stick to the nearest 0.01 m. Total cross-sectional area (in m^2) was calculated as the sum of the areas of cross-section polygons. Stream discharge (in m^3/s) was obtained as the product of mean water column velocity and cross sectional area.

3.2.2. Water Sampling

During each sampling event, two sets of water samples were collected for laboratory analyses: one set was transported for analysis at Vancouver Island University (VIU), and another set was shipped for analysis by ALS Laboratory, in Burnaby, BC.

Water samples for analysis at VIU were collected from all stations (Table 2). At each station, a clean pre-labelled 500-ml plastic bottle was rinsed 3 times and then used to collect a water sample (Table 3). Samples were obtained while standing on the stream bank or within the stream channel by immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. All water samples were kept in a cooler and stored at approximately 4^oC. Laboratory analyses were conducted at VIU within 48 hours of sampling.

Samples for analysis by ALS Laboratory were collected from all stations during both sampling events (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). All samples were obtained while standing on the stream bank or within the stream channel by directly immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inversed five times

for adequate mixing. All water samples were stored in a cooler on site, and shipped with ice packs within 48 hours for laboratory analyses at ALS Laboratory.

Table 3. Sampling containers and preservatives used for water quality samples taken at Departure Creek during November 2010. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Burnaby, BC.

Analytical Parameters	Container	Preservative	Analysed by
Total alkalinity, turbidity	500 ml plastic	None	VIU
Conductivity, pH, total hardness	1 L plastic	None	ALS Laboratory
Nutrients	250 ml amber glass	Sulphuric acid	ALS Laboratory
Total metals	250 ml plastic	Nitric acid	ALS Laboratory

3.2.3. VIU Laboratory Analyses

Water samples transported to Vancouver Island University were analysed for total alkalinity and turbidity. Total alkalinity (as $CaCO_3$) was measured to the nearest 0.1 mg/L using the HACH AL-DT digital titration method. Turbidity was measured to the nearest 1 FAU (Formazin attenuation units) using a HACH DR2000 Spectrophotometer (Method 8006).

3.2.4. ALS Laboratory Analyses

Water samples submitted for external analyses were processed as per ALS Laboratory standard analytical procedures. The analytes were: conductivity, total hardness, pH, nutrients (ammonia, nitrite, nitrate, orthophosphate and total phosphorus), and total metals (31 metals).

3.2.5. Quality Assurance / Quality Control

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers.

3.2.6. Data Analyses – Comparison with Applicable Guidelines

Water quality results were compared with the applicable provincial water quality guidelines for the protection 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). All guidelines were obtained from the BC Ministry of Environment, Water Protection Division (http://www.env.gov.bc.ca/wat/wq/).

It is important to note that for some metal parameters, analytical detection limits were above applicable guidelines. These include aluminium, antimony, arsenic, cadmium, chromium,

cobalt, copper, lead, nickel, selenium, silver, thallium and vanadium. For these metals, measured values reported to be below method detection limits cannot be assumed to be below the applicable guidelines.

3.3. Microbiology

3.3.1. Field Sampling

Water samples for total and fecal coliform enumeration were collected from each sampling station on 3 November 2010 (Table 2). At each station, a sterile pre-labelled 120-ml Whirl-Pak® bag was used to collect a 100-ml water sample by directly immersing the bag by hand just below the water surface while facing upstream. All samples were stored in a cooler with ice packs and transported within 48 hours to Vancouver Island University for laboratory analysis.

3.3.2. Laboratory Analyses

In the laboratory, water samples were tested for total coliform and fecal coliform (*Escherichia coli* or *E. coli*) using the m-coliBlue24 membrane filtration method (Millipore Corporation). A 25-ml volume of sample water was filtered through a 47-µm membrane filter (marked with 3-mm gridlines) using a vacuum pump. The filtration apparatus was then rinsed with approximately 5 ml of sterile water. A filtration blank was also completed with 25 ml of sterile water using the same filtration procedures. Each membrane filter (including the blank) was then transferred to a Petri plate containing an absorbent pad saturated with m-ColiBlue24 broth. All membrane filters were incubated at 37°C for 20 hours (until bacterial colonies were clearly visible).

Upon completion of the incubation period, membrane filters were then examined for bacterial colonies under a dissection microscope (16X magnification). A red or blue colony represents a total coliform "positive" result (Table 4). A blue colony specifically represents an *E. coli* "positive" result. A clear or white colony represents a total coliform negative result.

All colonies present on a membrane filter were counted and expressed as CFU (colony forming units) per 100-ml of sample water.

Table 4. Possible outcomes of the m-coliBlue24 membrane filtration method.

Bacteria Type	Positive Result	Negative Result
Total coliform	Red or blue colony	Clear or white colony No colony
E. coli	Blue colony only	Non-blue colony

3.4. Stream Invertebrates

3.4.1. Sampling Stations

Stream invertebrate samples were collected from stations 2 and 3 on 3 November 2010 (Table 1; Figure 1). The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples, safety and site access. At the time of sampling, all stations consisted of shallow riffles (water depth ~10-25 cm), with water velocity of ~0.25-0.50 m/s, and primarily sand and gravel substrate.

3.4.2. Invertebrate Sampling

At each station, three replicate samples (triplicates) were obtained using a Hess sampler and procedures as per the Pacific Streamkeepers procedures (Taccogna and Munro, 1995). Each site was approached by walking from downstream. The cylindrical, 34-cm diameter Hess sampler was hand-pressed into the substrate to isolate a circular 0.09-m^2 sampling area. All stones and debris 5 cm or larger within the sampling area were held under water in front of the collecting net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the collecting net was then transferred in a 125-ml plastic sample jar. The net was carefully inspected to ensure all content was transferred into the sample jar. Samples were stored in a cooler and transported to Vancouver Island University, where laboratory analyses were completed within 24 hours of sampling.

3.4.3. VIU Laboratory Analyses

Laboratory procedures and identification also followed the Pacific Streamkeepers procedures (Taccogna and Munro, 1995). The triplicate samples from each station were combined into a single composite sample per station. The contents of all invertebrate sample jars from a station were poured into a shallow white tray. Invertebrates were sorted into apparent taxonomic groups. Identification to the appropriate taxonomic level (as prescribed by the Pacific Streamkeepers procedures) was confirmed using a dissecting microscope. The number of invertebrates and the number of distinguishable subgroups within each broad taxonomic group were recorded on a Pacific Streamkeeper Invertebrate Survey Field Data Sheet. From these records, various useful metrics were calculated for each station, including: total density (number per m^2), total number of taxonomic groups, predominant taxonomic group, Pollution Tolerance Index, EPT (Ephemeroptera-Plecoptera-Trichoptera) Index, EPT to Total Ratio Index, Predominant Taxon Ratio Index, and overall Site Assessment Rating.

4. Results

The discharge measurement (Table 5) and field observations for Departure Creek suggest that water level was not at bankfull during both sampling events (0.063-0.077 m^3/s).

Table 5. Field measurements and laboratory results (VIU Laboratory) for water samples taken from four stations on Departure Creek during November 2010. Discharge measurements were collected at station 3 during both sampling events.

		Field Measurements				VIU Laboratory	
Station	**Discharge (m^3/s)**	**Temperature (^oC)**	**Dissolved Oxygen (mg/L)**	**Conductivity (µS/cm)**	**pH**	**Total Alkalinity (mg/L $CaCO_3$)**	**Turbidity (FAU)**
			3 November 2010				
1		12.61	9.88	212	6.79	56.8	5
2		11.87	10.20	268	6.93	79.6	6
3	0.063	11.42	10.49	262	6.82	76.4	2
4		11.18	10.17	277	6.77	78.8	2
			24 November 2010				
1		8.90	10.99	253	6.40	62.0	8
2		7.06	11.55	272	6.91	79.2	3
3	0.077	5.62	12.19	277	7.82	74.8	2
4		5.25	12.20	337	7.13	75.0	1

Average air temperature during the 10-day period prior to each sampling event was 9.4^{o}C and 0.4 ^{o}C for the early and late November sampling events, respectively (data for Nanaimo Airport retrieved from http://climate.weatheroffice.gc.ca). Total rainfall during the 10-day period prior to the early November sampling event was 39 mm. Total precipitation during the 10-day period prior to the late November sampling event included 24 mm of rain and 32 cm of snow, with 24 cm of snow on 19 November 2010. Since most of the water flow in Departure Creek originates as stormwater runoff, stormflow from rainfall events likely progresses through the watershed rapidly (i.e., within 1-2 days).

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 11.8^{o}C and 6.7^{o}C during the early and late November sampling events, respectively (Table 5). The decrease in water temperature reflected a concurrent decrease in air temperature between sampling events. During both sampling events, there was a gradual decrease in water temperature with distance downstream. During both sampling events,

all dissolved oxygen levels were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC, 1998). Overall, dissolved oxygen concentrations were >93% saturation.

Conductivity ranged from 212 to 337 µS/cm and generally increased as expected from upstream to downstream in Departure Creek (Table 5). Conductivity increased by an average of 30 µS/cm within station between sampling events. Water pH ranged from 6.40 to 7.82 during this study, and there was an average increase of 0.24 pH units between sampling events.

Total alkalinity averaged 72.9 and 72.8 mg/L during the early and late November sampling events, respectively (Table 5). Total hardness was relatively constant among sampling stations with the exception of station 1 where total hardness was slightly lower. Total alkalinity was well above 20 mg/L during both sampling events, indicating "low acid sensitivity" as defined by RISC (1998).

Turbidity ranged averaged 3.8 and 3.5 FAU during the early and late November sampling events, respectively (Table 5).

4.1.2. ALS Laboratory Analyses

Water quality results from ALS Laboratories were compared to the BC Provincial water quality guidelines for the protection of aquatic life (Table 6).

The conductivity measurements from ALS Laboratories were consistent with the field measurements obtained with the electronic probe and differed by <6%.

Total hardness followed similar trends as total alkalinity, and averaged 86.8 and 86.5 mg/L during the early and late November sampling events, respectively. Total hardness was between 60 and 120 mg/L during both sampling events, indicating "moderate hardness" as defined by RISC (1998).

Field measurements of pH (range: 6.40-7.82) were generally lower and more variable than the ALS Laboratories results (range: 7.92-8.29). This discrepancy possibly reflects differencial calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis.

All nutrient levels were below applicable guidelines and/or below detection limits. Total ammonia was below or near detection limit (i.e., 0.008 mg/L or less) during both sampling events. Nitrate concentrations decreased between the early (average: 1.46 mg/L) and late November sampling events (average: 1.18 mg/L). The highest nitrate levels were observed at station 1 during both sampling events (1.67 and 1.37 mg/L, respectively). Nitrite levels were below or near detection limit during this study (i.e., 0.0015 mg/L or less).

Table 6. Laboratory results (ALS Laboratory) for water samples taken from 4 stations on Departure Creek during 3 and 24 November 2010. All values are expressed in mg/L unless specified otherwise. The values enclosed in boxes exceeded at least one of the applicable water quality guidelines. See additional notes on the next page.

	BC Water Quality Guidelines [a]		3 November 2010				24 November 2010			
	BC Max	BC 30-day Mean								
Variable	mg/L	mg/L	1	2	3	4	1	2	3	4
General/Physical										
Conductivity (µS/cm)			215	273	269	273	254	273	277	319
Hardness, Total			79.1	90.3	87.9	90.0	79.3	91.9	86.7	88.1
pH (pH units)	6.5 - 9.0		8.17	8.29	8.28	7.92	7.98	8.07	8.09	8.00
Nutrients										
Ammonia-N	2.94 [b]	0.57 [b]	0.0053	0.0070	<0.0050	0.0086	0.0052	0.0080	<0.0050	0.0074
Nitrate (as N)	31.3	3	1.67	1.35	1.34	1.46	1.37	1.09	1.12	1.12
Nitrite (as N)	0.06 [c]	0.02 [c]	0.0010	0.0012	0.0011	0.0012	<0.0010	0.0015	<0.0010	<0.0010
Ortho Phosphate (as P)			0.0071	0.0071	0.0071	0.0079	0.0058	0.0060	0.0052	0.0054
Total Phosphorus			0.0098	0.0141	0.014	0.0137	0.0112	0.0107	0.0092	0.0104
Total Metals										
Aluminum (Al) [m]	0.10 [d]	0.05 [d]	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony (Sb) [m]	0.02		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [m]	0.005		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1	<0.010	0.016	0.013	0.013	<0.010	0.012	0.011	0.010
Berylium (Be)	0.0053		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [m]	0.00003 [e]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)			21.2	24.2	23.4	24.0	21.0	24.4	23.1	22.9
Chromium (Cr) [m]	0.001 [f]		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [m]	0.11	0.004	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [m]	0.009 [g]	0.002 [g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	1.0		0.123	0.163	0.119	0.153	0.313	0.132	0.088	0.118
Lead (Pb) [m]	0.061 [h]	0.006 [h]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)			6.34	7.29	7.13	7.28	6.51	7.49	7.06	7.49
Manganese (Mn)	1.41 [i]	0.95 [i]	0.017	0.021	0.010	0.016	0.019	0.025	0.009	0.015
Molybdenum (Mo)	2	1	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [m]	0.025 [j]		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)			<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [m]		0.002	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)			7.59	7.27	7.25	7.51	7.44	7.66	7.54	7.70
Silver (Ag) [m]	0.0001 [k]	0.00005 [k]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)			13.0	21.9	22.4	24.1	17.8	19.5	22.1	29.2
Strontium (Sr)			0.089	0.107	0.103	0.106	0.085	0.098	0.093	0.096
Thallium (Tl) [m]	0.0003		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium (V) [m]	0.006		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [l]	0.0075 [l]	0.0056	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Table 6. (Continued)

NOTES:

Results are expressed as mg/L except for pH and conductivity.
"<" means less than the detection limit.

[a] BC Water Quality Guidelines (WQG) compiled from
http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html
http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

[b] Total ammonia guideline is dependent on water temperature and pH of tested water.

[c] Nitrite guideline is for chloride concentration < 2 mg/L.

[d] Aluminum guidelines for pH ≥ 6.5.

[e] The maximum cadmium guideline is $0.001 * 10^{\{0.86 [\log(\text{hardness})] - 3.2\}}$ mg/L.

[f] Chromium guideline is for the more toxic Chromium VI.

[g] The maximum copper guideline is 0.001 * [0.094(hardness) + 2] mg/L.
The 30-day mean copper guideline is for hardness < 50 mg/L.

[h] The maximum lead guideline is $0.001 * e^{\{1.273 [\ln(\text{hardness})] - 1.46\}}$ mg/L.
The 30-day mean lead guideline is $0.001 * [3.31 + e^{\{1.273 [\ln(\text{hardness})] - 4.704\}}]$ mg/L.

[i] The maximum manganese guideline is 0.01102 * (hardness) + 0.54 mg/L.
The 30-day mean manganese guideline is 0.0044 * (hardness) + 0.605 mg/L.

[j] Nickel guideline is for hardness < 60 mg/L.

[k] Silver guidelines are for hardness < 100 mg/L.

[l] Zinc guidelines are for hardness < 90 mg/L.

[m] Analytical detection limits were above applicable guidelines for these metals.

Orthophosphate ranged from 0.0052 to 0.0079 mg/L during this study, and there was an average decrease of 0.0017 mg/L between sampling events. Similarly, total phosphorus ranged from 0.0092 to 0.0141 mg/L during this study, and there was an average decrease of 0.0025 mg/L between sampling events. Overall, total phosphorus levels were mainly within or near the moderate range typical of "mesotrophic" waters (0.010-0.025 mg/L) waters as defined by RISC (1998).

All metal concentrations were below the applicable water quality guidelines and/or below detection limits.

4.2. Microbiology

All samples collected from Departure Creek contained some coliform bacteria (Table 7). Total coliform counts increased from upstream to downstream, with a range of 807-1,452 CFU / 100 ml. The proportion of total coliform made up of *E. coli* bacteria also generally increased with distance downstream (range: 25-58%).

The filtration blank completed with sterile water did not produce any bacterial colonies.

Table 7. Total coliform and *E. coli* counts from water samples taken at five stations on Departure Creek on 3 November 2010. All values are expressed as number of bacteria per 100 ml. No samples were collected on 24 November 2010.

Station	Total Coliform	*E. coli*	% *E. coli*
1	807	202	25.0%
2	847	363	42.9%
3	928	323	34.8%
4	1452	847	58.3%
Filtration blank	0	0	–

4.3. Stream Invertebrates

A total of 164 stream invertebrates representing 11 broad taxonomic groups were counted at two stations on Departure Creek on 3 November 2010 (Table 8; Figure 2; Appendix 2). Animal density ranged from 237-370 animals/m^2. Overall, mayfly nymphs, aquatic worms and caddisfly larvae were the most common taxonomic group encountered.

Site assessment ratings ranged were 2.25 at station 2 and 3.50 at station 3, suggesting "marginal" and "acceptable" invertebrate community diversity, respectively. The low to moderate representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa: 23-62% of total abundance) indicates generally "marginal" environmental conditions.

Table 8. Abundance and density of stream invertebrates obtained from triplicate samples taken on 3 November 2010 at two stations on Departure Creek. Overall site assessment ratings are also provided for each station (out of a maximum rating of 4.00). Invertebrate Survey Field Data Sheets are included in Appendix 2. No samples were collected on 24 November 2010.

Pollution Tolerance	Invertebrate Taxa	Station 2	Station 3
Category 1 Pollution Intolerant	Caddisfly Larva	7	21
	Mayfly Nymph	8	25
	Stonefly Nymph	0	16
Category 2 Somewhat Pollution Intolerant	Aquatic Sowbug	4	0
	Cranefly Larva	0	5
	Scud (Amphipod)	11	1
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	31	22
	Blackfly Larva	0	8
	Leech	2	0
	Planarian (flatworm)	1	0
	Water Mite	0	2
	Total Abundance	64	100
	Density (number / m^2)	237	370
	Site Assessment Rating	2.25	3.50

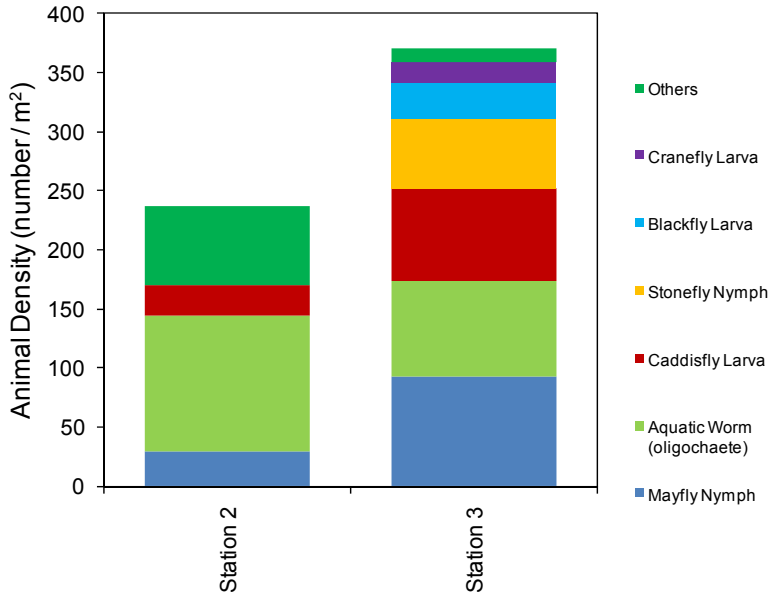

Figure 2. Density of stream invertebrates obtained from triplicate samples taken on 3 November 2010 at two stations on Departure Creek. The "Other" category includes water mite, scud, aquatic sowbug, leech and planarian in decreasing order of abundance. Data are summarized in Table 8 and Invertebrate Survey Field Data Sheets are included in Appendix 2.

5. Acknowledgements

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7. Appendices

APPENDIX 1. Photographs showing site conditions at each sampling station on Departure Creek.

Photo 1. Upstream view of Departure Creek near station 1 on 24 October 2010.

Photo 2. Upstream view of Departure Creek near station 2 on 24 October 2010.

APPENDIX 1. (Continued)

Photo 3. Upstream view of Departure Creek near station 3 on 24 November 2010.

Photo 4. Downstream view of the Departure Creek near station 4 on 24 November 2010.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for triplicate stream invertebrate samples collected at stations 2 and 3 on Departure Creek during 3 November 2010.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Departure Creek		Date:	3 November 2010
Station Name:	**Station 2**		Flow status:	Moderate
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Hess	3	0.09 x 3 =	0.27	m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)	7	1
	Mayfly Nymph (EPT)	8	1
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		15	2
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug	4	1
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	11	2
	Watersnipe Larva		
Sub-Total		15	3
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	31	3
	Blackfly Larva		
	Leech	2	1
	Midge Larva (chironomid)		
	Planarian (flatworm)	1	1
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		34	5
TOTAL		64	10

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 64

DENSITY: Invertebrate density per square metre:

64 ÷ 0.27 = 237

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Aquatic Worm (oligochaete)

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 + 2 x 3 + 5 = 17

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 1 + 0 = 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	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(7 + 8 + 0) / 64 = 0.23

SECTION 3 - DIVERSITY

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

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

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

Col. C for S3 / CT

31 / 64 = 0.48

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	3
EPT Index	2
EPT To Total Ratio	1
Predominant Taxon Ratio	3

Average Rating
2.25

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Departure Creek		Date: 3 November 2010
Station Name:	**Station 3**		Flow status: Moderate
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates	0.09 x 3 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)	21	2
	Mayfly Nymph (EPT)	25	3
	Stonefly Nymph (EPT)	16	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		62	7
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	5	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	1	1
	Watersnipe Larva		
Sub-Total		6	2
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	22	2
	Blackfly Larva	8	1
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	1
Sub-Total		32	4
TOTAL		100	13

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 100

DENSITY: Invertebrate density per square metre:

100 ÷ 0.27 = 370

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C): Mayfly Nymph (EPT)

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 2 + 4 = 29

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

2 + 3 + 2 = 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	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(21 + 25 + 16) / 100 = 0.62

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 13

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

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

Col. C for S3 / CT

25 / 100 = 0.25

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	4
EPT Index	3
EPT To Total Ratio	3
Predominant Taxon Ratio	4

Average Rating
3.50