Water Quality Analysis and Invertebrate Inventory for Departure Creek, Nanaimo BC

(Fall 2016)

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EXECUTIVE SUMMARY

This report was compiled to present the results of an environmental monitoring assessment that was conducted by four 3rd year Bachelor of Applied Science in Natural Resource Protection students from Vancouver Island University. The assessment examined various water quality parameters in the Departure Creek of Nanaimo, British Columbia. The project was conducted as part of a long term environmental monitoring project that assesses stream health under the direction of Dr. Eric Demers, RPBio. The data collected has been used and compared with previous years to determine trends in stream health. The project will compile field assessments of the riparian zone adjacent to the creek, water quality and hydrology of the creek, microbiologic analysis, and invertebrate inventory.

Departure Creek travels through an area of built up residential and commercial zoning, through park area and under roads. The stream passes through a number of culverts before it reaches Departure Bay. It is believed that the surrounding area has an effect on the quality of water. The first sampling also took place during an increased rain fall event that caused increase discharge through the stream system. This also had a drastic effect on the quality of the water during the first water quality sampling event, evidence of which displayed both in testing conducted in the Vancouver Island University lab in Nanaimo, BC. by program students, but also in independent testing conducted by ALS Environmental in Burnaby, BC. Continued monitoring of Departure Creek is highly recommended to ensure the security of habitat for species native to coastal British Columbia.

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INTRODUCTION

Project Overview

Departure Creek, a stream that winds through several neighbourhoods in Nanaimo, British Columbia, was assessed in detail for multiple water quality parameters and inventoried for invertebrates. This survey was conducted by four Bachelor of Natural Resource Protection students from Vancouver Island University: Callie Bouchard, Daniel Della Vedova, Hilary Blackman and Kevin Smith. These students prepared and conducted the project for Dr. Eric Demers RPBio, professor of RMOT 306 Environmental Monitoring. The examination of the stream took place between October and November 2016, which included assessments in the field at Departure Creek and in a lab at the Vancouver Island University earth sciences building 370.

This project compiled assessments of the riparian zone adjacent to the creek, water quality and hydrology of the creek, as well as microbiological analysis and invertebrate inventory. These assessments were conducted in four sites that were established in 2006 to facilitate a monitoring program. Completion of this task involved visiting the four sites during three field sessions. Sample examination was conducted by students during the laboratory analyses at VIU, and additional laboratory analyses by ALS in Burnaby, BC. The purpose of conducting this work was to report the findings to organizations with a vested interest in the stream and its productivity for the purpose of providing productive habitat for salmon. These organizations include Fisheries and Oceans Canada (DFO), British Columbia Conservation Foundation (BCCF), the City of Nanaimo, Regional District of Nanaimo (RDN), the Neighbourhood Association and the Nanaimo and Area Land Trust (NALT).

The data collected is to be compared to previous results from 2006- 2015 in order to continually monitor the quality of the water within Departure Creek as it remains an important spawning area for pink salmon (*Oncorhynchus gorbuscha*) and coho salmon (*Oncorhynchus*

kisutch). This report will provide background information about Departure Creek, explain the project objectives, outline the methods used, provide the results for each analysis, and conclude with recommendations. The study also provided an opportunity for students of the aforementioned program an opportunity to hone and build upon existing monitoring competencies, and to cultivate their appreciation and understanding of environmental monitoring techniques utilized in the natural resource management sector.

HISTORICAL INFORMATION

Departure Creek originates from the tributaries of Joseph Creek and Keighly Creek, extending through several neighbourhoods in Nanaimo before reaching a terminal end in Departure Bay (RDN 2014). This creek resides on Snuneymuxw First Nation Traditional Territory. The Snuneymuxw First Nation used Departure Creek for various cultural practices including bathing and food gathering. This site remains important to the Snuneymuxw people (RDN 2014). There are many stakeholders in this stream, as it is a productive habitat for pink salmon (*Oncorhynchus gorbuscha*) and coho salmon (*Oncorhynchus kisutch*) (RDN 2014). Departure Creek was assigned watershed code 920-400300 by the Ministry of Environment (MOE 2016a). There are no current water licenses available for water extraction or deposition in this stream to date. (MOE 2016b).

ENVIRONMENTAL CONCERNS

An initial survey of the site area was conducted and it was established that Departure Creek was characterized by many gentle glides, some riffles and pools, and lush vegetation, including a number of native species and numerous invasive species. Departure Creek provides an essential wildlife corridor in a built up municipality with effective riparian areas that ensure protection from erosion. The prominence of invasive plant species is a concern with regard to the

riparian area. The landform possesses cut banks and woody debris including salmonid habitat rehabilitation in some areas. The creek has little change in gradient, which is desirable for pink salmon (*Oncorhynchus gorbuscha*) movement; however, the creek passes through several culverts as the water moves toward the Strait of Georgia. The flow rate downstream of the culverts was deemed a concern, as these areas saw extreme acceleration of water during high-flow times. With regard to the analyses conducted, the main purpose was to determine the extent to which the urban environment influences Departure Creek. This creek is completely surrounded by urban development from origin to ocean. Runoff from roads, commercial, and private property is a concern. There was some evidence of dumping, and areas that exhibited litter.

OBJECTIVES

The primary objective for conducting a survey of Departure Creek in Nanaimo, BC was to determine the state of the water quality, as well as to test for the presence of possible pollutants. This was especially vital information, as the creek is salmon bearing. This was to be executed by monitoring the creek at four separate established stations, the goal being to complete an overall analysis of the existing environmental conditions. Hydrology tests were to be conducted at one site during low flow, and one site during high flow to determine if there are any changes in water quality during periods of heavy rain. As this creek runs through residential areas, microbiology testing was to be completed to establish the presence or absence of coliforms. Samples of macroinvertebrates were collected from station two during the first sampling event, as the health of a stream can be indicated by the presence or absence of certain invertebrate species.

SAMPLING AND ANALYSIS PROCEDURES

Sample Sites

Four locations were designated in 2006 by the original monitoring group for the monitoring program that would act as representatives of the stream system. These locations were spread out in areas that had very different stream characteristics; however, all are relatively easy to access and adjacent to a roadway. The sample site locations are shown in Figure 2 in the Appendix. Sites are organized with the first site placed near the beginning of the stream system and was referenced as Site 1 through 4.

The first site, "Site 1", was located at the intersection of Neyland Road at UTM coordinate 10U 0429312 5450829 (see Figure 3 in Appendix). The access to this site was a steep slope beside the downstream end of the Neyland Road culvert. This site was close to the road and simple to access. The site conditions consisted of a slope of 5%, a riparian area featuring 1.5m of stacked boulders lining the bank (man-made) and some overhanging shrubs. The substrate composition was predominantly gravelled, and the creek depth was low with a fast rate of flow. The only safety concern at this site was unstable footing. The surrounding land use was residential. Environmental issues noted at Site 1 included a large road culvert that greatly accelerated flow, causing a fast cascade of water. This may have caused increased erosion immediately downstream of the culvert.

Residence #3038 had PVC pipe extending from their property into the riparian area downstream of Site 1, demonstrating the extent of urban runoff into this creek. Site 1 was also laden with invasive plant species of Daphne (*Daphne laureola*), English Ivy (*Hedera helix*) and Holly (Aquifoliaceae) (E-flora BC 2013). Additionally, there was a storm drain entering the culvert from Neyland Road which could deposit road debris and other sediment. The measurements of Site 1-4 are recorded in Table 1.

Table 1. Stream Measurements Taken at Sites 1-4 on Departure Creek.

	Site 1	Site 2	Site 3	Site 4
Wetted Width (m)	2.31	4.11	4.80	1.91
Wetted Depth (m)	$\bar{x}$ 0.12	$\bar{x}$ 0.13	$\bar{x}$ 0.07	$\bar{x}$ 0.29
Bankfull Width (m)	3.18	5.16	6.10	2.44
Bankfull Depth (m)	$\bar{x}$ 0.67	$\bar{x}$ 0.64	$\bar{x}$ 0.61	$\bar{x}$ 0.54

"Site 2" on Departure Creek was located downstream of the crossing of Newton Street at UTM coordinate 10U 0428857 5450901 (see Figure 4 in the Appendix). The access to this site was down a steep bank off Newton Street, approximately 50m downstream of the road culvert. The conditions at Site 2 included a slope of 6% and a riparian area consisting of overhanging Sword Ferns (*Polystichum munitum*), Big Leaf Maple (*Acer macrophyllum*), Yellow Cedar (*Cupressus nootkatensis*), and undercut banks. The creek bottom composition was mainly gravel and cobble. Joseph Creek entered Departure Creek at this site, causing a small tributary. The only safety concern at Site 2 was the steep bank used for access. There was an appropriate site for sampling both water quality and aquatic invertebrates upstream from the Joseph Creek confluence. The surrounding land use was residential. Environmental issues discovered included the presence of an illegal urban dumpsite at roadside and invasive species including Daphne, English Ivy, and Yellow Archangel (*Lamium galeobdolon*) in the riparian area. There was also evidence of soil erosion in the riparian area, as indicated in Table 1.

"Site 3" on Departure Creek was located in Woodstream Park off of Bay Street at UTM coordinate 10U 0428392 5451129 (see Figure 5 in Appendix). This site was approximately 150m

off of Bay Street, in a large gully accessed through a public-access park trail. The stream runs adjacent to this footpath. Site conditions observed were a slope of 5%, and riparian area including in-stream cover with large woody debris and a deep pool. The substrate composition consisted of fines, gravel, cobble and boulders. The water was fast flowing and shallow. A slippery bank at the sample site was noted to be a potential hazard, as well as signs of recent fallen branches which could be dangerous in high winds. There was an appropriate site for water quality beside a pair of large logs crossing the creek. The land use at Site 3 was a municipal park, immediately backing onto residences. Environmental issues identified included the presence of invasive species of Daphne and English Ivy and Holly. There was also a very popular public trail running parallel to the creek which could contribute to erosion. The site measurements are indicated on Table 1.

"Site 4" on Departure Creek, the final site, was located near the intersection of Bay Street and Departure Bay Road at the downstream end of the Bay Street culvert at UTM 10U 0428075 5451095 (see Figure 6 in Appendix). This site was selected to avoid the tidal zone that introduces salt water into the Departure Bay Road culvert. Site conditions included a 10% slope and riparian zone with bankside shrub cover. The creek bottom composition at Site 4 included fines and boulders. The creek was fast flowing, likely due to the slope, and cascaded over boulders. Again, slippery conditions were a working hazard. There was an appropriate site to sample water quality 5m downstream of the Bay Street culvert. The surrounding land use was both commercial and residential; however, a key environmental concern at Site 4 was the presence of invasive plant species. The site was shrouded by Himalayan Blackberry (*Rubus armeniacus*) and also contains Yellow Flag Iris (*Iris pseudacorus*), and Morning Glory (*Convolvulus arvensis*) (E-Flora BC 2013). Measurements are displayed on Table 1. This site

was characterized by a limited area for vegetation as large portions of the area were characterized by concrete, culvert, grates, bridges, sidewalks and buildings. It is also adjacent to a gas station.

Water Quality

Water samples were collected from Sites 1-4 during two sampling events: November 2, 2016 and November 23, 2016. All sample sites were approached from downstream and water quality samples were taken midstream for quality assurance purposes. All water quality samples were stored in a cooler to preserve the samples for analysis.

A collection of nine samples, three from Sites 1, 3, and 4, were sent to ALS Labs in Burnaby, BC for analysis. These samples were collected in pre-rinsed and pre-labeled containers for quality assurance (Figure 7 in the Appendix). A 1 litre white plastic bottle obtained from ALS Labs was filled to the shoulder at Sites 1, 3, and 4, with no preservatives added. This sample was sent to test the general water parameters. A 250 ml white plastic bottle obtained from ALS Labs was filled to the shoulder at Sites 1, 3, and 4, and premeasured Nitric Acid (HNO_3) was added as a preservative. This sample was sent to test for the total metals in the water. A 250 ml amber glass bottle obtained from ALS Labs was filled to the shoulder at Sites 1, 3, and 4, and premeasured Sulphuric Acid (H_2SO_4) was added as a preservative. This sample was sent to test for the available nutrient levels. The results of these analyses were compared against the BC Ministry of Environment guidelines for interpreting water quality data.

One plastic bottle was filled with water from each site, and then brought to the lab at Vancouver Island University (VIU) to be analyzed. Water quality analysis at the VIU lab occurred on the same dates that the samples were obtained, (November 2, 2016 and November 23, 2016) to minimize the time between sampling and analysis. A replicate sample was taken

(Figure. 7 in the Appendix) and one trip-blank was taken at each sampling event, totalling two trip-blank samples, in order to ensure a high level of quality control. Bottles used for analysis at VIU were pre-labeled, rinsed three times and filled with clean hands to avoid contamination and provide quality assurance. Water quality parameters tested for in the field were taken with an Oxyguard Handy Polaris electronic probe. These parameters included:

- Temperature (degrees Celsius)
- Dissolved Oxygen (mg/l)
- Conductivity (µS/cm)

The water quality parameters tested for at the VIU lab included:

- pH
- Hardness (mg/l as $CaCO_3$)
- Alkalinity (mg/l as $CaCO_3$)
- Phosphate (mg/l as PO_4^{3-})
- Nitrate (mg/l as NO_3^-)
- Conductivity (µS/cm)
- Dissolved oxygen (% and mg/l)
- Turbidity (NTU).

Both pH and conductivity were measured at the VIU lab using modern electronic probes. Alkalinity was measured using a HACH AL-DT digital titration method, while turbidity was measured with a HACH 2100 Portable Turbidimeter. Hardness measurements were obtained using a HACH HA-71A test kit while nitrate and phosphate were measured with a HACH DR2800 Spectrophotometer. The results of these analyses were compared against the BC Ministry of Environment guidelines for interpreting water quality data.

Microbiology

Microbiology samples were collected at Sites 1-4 during the November 2, 2016 sampling event, and analyzed at Vancouver Island University the day of collection (November 2, 2016). These samples were collected using sterile 100 ml Whirl-Pak plastic bags. Nitrile gloves were used during collection to remove any possibility of contamination and assure quality. Analysis was completed at the lab using the Total Coliforms and *E. Coli* Membrane Filtration Method. The 100 ml samples were filtered onto bacterial plates and m-ColiBlue24 Broth was added. After a 24 hour incubation period, non-fecal and fecal colonies were counted. Presence and abundance of either Colony Forming Unit (CFU), were compared to the BC Ministry of Environment guidelines for interpreting water quality data.

Hydrology

Hydrology measurements of velocity and discharge were taken at Site 2 on November 2, 2016 and at Site 4 on November 23, 2016. Wetted width was measured with a surveying measuring tape. Wetted depth was measured using a metre stick, and taken at three locations across stream to attain an average depth. Flow velocity (m/s) was measured by timing a float ball over a set distance. This was replicated three times to attain an average flow velocity and for quality control. A correctional factor of k=0.85 was applied to the average flow velocity to account for surface velocity. Discharge (m^3/s) was then calculated using: Q (m^3/s) = Area (m^2) ● Velocity (m/s). Velocity was acquired using a buoyant float and timed.

Stream Invertebrates

Sampling for invertebrates was only done at Site 2 (the Newton Street Site), during the first sampling event. This site was selected because the water at Site 1 was too high and flowing too fast, Site 3 was deemed unacceptable due to the presence of pink salmon (*Oncorhynchus*

gorbuscha) and coho salmon (*Oncorhynchus kisutch*) that use the gravel and fines for spawning habitat, and Site 4 had considerable salt-water influence.

The sample site consisted of small gravel and fines and the invertebrates were sampled using a Hess Sampler. During sampling, five replicate samples were taken to ensure quality control. The first of the four samples was taken furthest downstream and each subsequent sample was taken further upstream, to avoid dislodgement of any invertebrates present. The samples were kept in five separate and labeled jars; no ethanol was added to the samples, as keeping the invertebrates alive made the task of sorting in the lab simpler. In the lab, the invertebrates were counted under a microscope (Figure 8 in Appendix) to determine taxa richness and suspected water pollution, as indicated by presence or absence of certain invertebrates. The quantity and variety of taxa helped to assess the overall stream conditions from the perspective of the benthic communities present. To ensure the correct representation of data, invertebrates were counted by three members of the team and calculations were repeated three times to ensure accuracy. Data analysis followed Pacific Streamkeepers procedures and the data was entered into the Shannon-Weiner Diversity Index for interpretation.

RESULTS AND DISCUSSION

Field Conditions

During the first sampling event on November 2, 2016, there was a substantial amount of rainfall. This increased the flow of the creek, resulting in a decreased ability to sample for invertebrates and an increase in the difficulty of collecting all samples. The second sampling event on November 23, 2016 was a clear, sunny day; therefore, the creek water levels were reduced back to normal flow and sampling was much simpler.

Hydrology

On the first sampling event, November 2, 2016, the discharge of Departure Creek was 2.44 m^3/s. This reflects the high level of precipitation at the time. Discharge on the second event, November 23, 2016, was reduced to 0.56 m^3/s. This was likely due to less precipitation. These results demonstrate the tendency for Departure Creek to quickly react to precipitation and drainage entering the water system.

Table 2. Discharge (m^3/s) results from 2 sampling events in Departure Creek, Nanaimo BC.

Sampling Event	Site	Discharge m^3/s
November 2, 2016	2	2.44
November 23, 2016	2	0.56

Quality Control and Assurance

In order to ensure quality assurance all bottles and containers used to collect samples were pre-labelled before going out into the field. While taking water samples, all sites were approached from downstream, and samples were taken from the midstream area avoiding the surface and bottom. The bottles used to collect samples for analysis at ALS were pre-rinsed, filled with clean hands, and stored in a cooler prior to transport to the lab. The bottles used to collects samples for analysis at VIU were rinsed three times on-site, filled with clean hands, and stored in a cooler until analysis took place that same day. To ensure a high level of quality control and reproducibility, trip blanks were taken into the field during each sampling event, and replicates were taken of both water samples and invertebrate samples.

Water Quality: Field Results

In the field, the Oxyguard Handy Polaris Electronic Probe was used to acquire three water quality parameters in order to determine stream health. These parameters included

temperature (degrees Celsius), Dissolved Oxygen (mg/l), and Conductivity (µS/cm). The measurements taken on both sampling events can be seen below in Tables 3 and 4.

Table 3. Water Quality Measurements Taken November 2nd, 2016

	Site 1	Site 2	Site 3	Site 4
Dissolved Oxygen (mg/L)	12.2	12.3	12.4	11.3
Conductivity (µS/cm)	0.04	0.01	0.01	0.06
Temperature (Celsius)	10.8	10.9	11	11

Table 4. Water Quality Measurements Taken November 23rd, 2016

	Site 1	Site 2	Site 3	Site 4
Dissolved Oxygen (mg/L)	10.7	11.2	10.7	11.1
Conductivity (µS/cm)	0.0982	0.1241	0.1245	0.1179
Temperature (Celsius)	11	10.5	10.2	10.2

The first sampling series took place during a higher than average rainfall event and caused some abnormal fluctuations to the sampling data (Figure 9 in Appendix). There were increased levels of turbidity and soil disruption from the high flow rate. Increased water disturbance was causing additional oxygen to be input into the system. In addition, the increased flow permitted ions to be flushed out of the system, which caused a significant drop in conductivity. Finally, the temperature remained relatively stable during both events.

ALS Laboratory Analyses

Laboratory analyses were received from the ALS testing facilities for both the November 2, 2016 and the November 23, 2016. Water samples from Sites 1, 3, and 4 were taken on both occasions. The data for the Departure Creek sampling events was individually compared to the BC Water Quality Guidelines (Water Protection and Sustainability Branch). Twenty-six water quality parameters were identified and the ALS data was graded into three categories. The categories were distinguished by green, orange, and red font; green indicating below the water quality guidelines, red as above, and orange indicating that the lab was able to detect a minimal detectable amount that was higher than the water quality guidelines. Three of the twenty-six water quality parameters did not have maximum allowable amounts: hardness, phosphorus, and calcium. Instead these parameters measure how soft or hard, how eutrophic, and how sensitive to acid the water is, respectively.

The first ALS sampling event had aluminum levels that exceeded the BC Water Quality guidelines at all three of the sampling locations with levels ranging from 0.77 mg/L-1.70 mg/L. The maximum allowable amount for water systems with a pH higher than 6.5, is 0.01 mg/L. In the second sampling event, the levels of aluminum in the water decreased to a minimum detectable limit of below 0.2 mg/L, which is still above the water quality guidelines. Iron levels were also high in the first sampling event, with water from the third and fourth sites coming in above the 1 mg/L parameter at 2.19 mg/L and 1.47 mg/L. Iron levels at the first site were under the guideline at 0.834 mg/L. The second sampling event on November 23, 2016 brought the third and fourth sampling locations under the 1 mg/L limit at 0.171 mg/L and 0.284 mg/L. The first sampling location, again, had the lowest level of iron at 0.153 mg/L. Higher flow rates from the first sampling session are believed to be the cause of the higher levels of aluminum and iron. It is also believed that the higher rate of flow and rainfall during the first sampling period resulted in

runoff from the road, residential, commercial, and city properties being washing into Departure Creek. High phosphorus levels during the first sampling event indicated that the water samples were eutrophic, while phosphorus levels during the second sampling event indicated that the water was oligotrophic at the first and third sampling site and mesotrophic at the fourth sampling site. High levels of phosphorus levels are likely a result of residential and commercial fertilizer that often contains phosphorus to increase nutrient levels.

The Nanaimo Golf Club is located less than 1km from Departure Creek and is likely a source of phosphorus is in the water system. Phosphorus can also come from detergent, human and animal waste, and decaying plants; since there was significant evidence of illegal disposal of yard waste in the area, this may be an alternate source of the phosphorus. Faulty and old septic systems can also result in the leaching of phosphorus into a water system, however, due to the non-rural nature of the residential community around Departure Creek, it is unlikely that many of the houses in this area operate with septic systems, and instead, likely use the city sewage system (Environment Canada). The first and second sampling events both showed levels of calcium that indicated that Departure Creek had low acid sensitivity. At the first sample site on the first sampling event the calcium level was 6.8 g/L, making it moderately acid sensitive; however, the other sites and dates all had levels above 8 mg/L. High levels of calcium increase the creek's ability to handle acid leaching into the system. Calcium increases the pH making the water more alkaline and more capable of having excess acidity added without the acidification of the watercourse. When the two dates are compared, the November 23, 2016 data seems to represent a healthier ecosystem with an increased ability to handle acidification, as well as having lower rates of phosphorus, decreasing the overly nutrient rich levels that can lead to eutrophic conditions, and lower rates of aluminum and iron. The rainfall and resulting runoff from the

roads, residential, municipal, and commercial presence in the area results in chemicals and compounds coursing through Departure Creek, which are often above the BC Water Quality Guidelines. With Departure Creek's susceptibility to flashy waters and the heavy rainfall for long periods of the year, it is likely that Departure Creek is consistently filled with subprime compounds and minerals that have adverse effects on the local flora and fauna. The ALS laboratory results, pertaining to the BC Water Quality Guidelines are visible in Figure 10 and Figure 11 located in the Appendix.

VIU Laboratory Analyses

Sampling for analyses in the Vancouver Island University Laboratory was conducted on November 2, 2016 and November 23, 2016 and laboratory analyses were conduct later in the day in Building 370 at the Nanaimo campus. Water samples were taken from four sites along Departure Creek and will be referred to as Site 1 through Site 4. Analysis was conducted for the following areas: conductivity, pH, turbidity, alkalinity, hardness, nitrate, and phosphate.

Unlike the ALS Laboratory results which generally decreased from the first sampling event to second event, the data collected in the Vancouver Island University generally increased between the first and second sampling event. This is because many of the parameters tested for in the Vancouver Island University lab relate closely to the increased calcium levels in the ALS results between the first and second sampling events that increased Departure Creek's ability to neutralize acid in the watercourse. These parameters include: conductivity, alkalinity, and hardness and these three parameters increased along with Calcium. All are known to reduce acidity and it is believed that the increase in calcium is directly related to the increase in the other three parameters. The pH of the system, however, was similar for both sampling events. The turbidity decreased during the second sampling event, which was a result of the heavy rain and

flashy, increased flow that was present during the first sampling event. The high rate of flow caused particles in the stream to become stirred up and mobile; this, along with runoff from the vicinity, resulted in a higher level of turbidity. The nitrate and phosphate were compared separately as they were observed to have much lower levels, between 0.04 mg/L and 1.16 mg/L. Phosphate levels decreased between the first and second sampling events across all four sites, directly comparable to the phosphorus levels detected by the ALS sampling. The phosphate levels are connected to the runoff from the rain event and likely came from fertilizers, detergents, and sewage. Nitrate levels decreased at Site 1 and Site 2 between the first and second sampling event following the pattern of the phosphate levels. At Site 3 and Site 4 however, the nitrate levels increased between the first and second sampling events. Reasons for this could be varied: it is possible that nitrate levels were higher at Site 3 and Site 4 because they are further downstream and more nitrate had built up in the water system as it culminates downstream. However, this was not the case for the other parameters so it is more unlikely. It is more likely that there is an influx or source of nitrates closer to sites 3 and 4 that are causing the nitrate to build up when the velocity is lowered. Nitrates come from untreated sewage and are often found in fertilizers. Site 3 is a known spawning location for Pink Salmon (*Oncorhynchus gorbuscha*) and coho salmon (*Oncorhynchus kisutch*), as well as a location of dog and black-tailed deer (*Odocoileus hemionus*) activity, which could increase fecal and urine counts in the water. Site 3 is also the closest site to the Nanaimo Golf Club, which has the potential to leach nitrogen rich fertilizers into the stream. Results of the laboratory analysis completed at Vancouver Island University can be viewed in Figure 12 and Figure 13 located in the Appendix.

Microbiology

On the date of the first sampling event, November 2, 2016, and the days prior to sampling, the Nanaimo area was experiencing some extreme storm weather. This resulted in a significantly high flow in Departure Creek along with higher levels of turbidity. The turbulent waters stirred up the creek beds, which is believed to have resulted in higher amounts of coliforms present within the water column. The microbiology samples that were tested for the presence or absence of coliforms were left to incubate in the lab for 24 hours. After this time, it was noted that there was a large amount of Colony Forming Units present on each sheet. In order to portray accurate results, the colonies were counted using the sub-plate count method of selecting 10 random squares on the plate, applying the formula [average count per square x (908 mm^2/9 mm^2)], and then extrapolating the count for the whole plate. The total coliforms were represented by combining both the final red and blue counts, fecal coliforms were represented by the final count of blue colonies, and the non-fecal coliforms were represented by the final count of clear/cream coloured colonies. The results of each site can be seen below in Table 5.

Table 5. Microbiology Results from Sites 1-4 on Departure Creek

	Site 1	**Site 2**	**Site 3**	**Site 4**
Total Coliform (CFU/100ml)	1271	696	716	605
Fecal Coliform (CFU/100ml)	666	333	393	373
Non-Fecal Coliform (CFU/100ml)	393	535	535	474

Invertebrate Inventory

Invertebrate data was collected and examined using the Pacific Streamkeepers guidelines created by the Department of Fisheries and Oceans. The invertebrates were first counted and sorted into categories according to the level of pollution tolerance to estimate the health of the creek (Figure 1). In order to establish the EPT Index, insects within the Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) were counted, as the members within these Orders all require clean water. The results of entering the species into the appropriate sections (Figures 14 and 15 in Appendix) showed that the presence of particular invertebrates indicated that Departure Creek has good pollution tolerance level and an acceptable EPT index. The EPT total ratio index is rated as poor due to the small amount of different taxons found; however, there is a good predominant taxon ratio due to the abundance of Amphipods. Departure Creek was given an overall rating of 3 and deemed acceptable for invertebrate life. In order to accurately calculate the species diversity of Departure Creek, the Shannon-Weiner Diversity Index was used. The calculations shown in Table 6 enabled the use of the Shannon-Weiner Diversity Index Formula, {H = -(-1.8788)/ln(10), H = 0.8150, H = 0.82, H = 82%} and outline how the creek received an overall species diversity rating of 82%.

Table 6. Shannon-Weiner Diversity Index Calculations

Species	**C**	**pi(C/T)**	**ln(pi)**	**pi*ln(pi)**
Caddisfly Larva	2	0.0339	-3.3843	-0.1147
Mayfly Nymph	3	0.0508	-2.9701	-0.1514
Stonefly Nymph	6	0.1017	-2.2857	-0.2324
Aquatic Sowbug	2	0.0339	-3.3843	-0.1147

Cranefly Larva	1	0.0169	-4.0801	-0.0690
Amphipod	17	0.2881	-1.2444	-0.3585
Aquatic Worm	14	0.2373	-1.4384	-0.3413
Blackfly Larva	2	0.0339	-3.3843	-0.1147
Midge Larva	11	0.1864	-1.6799	-0.3131
Planarian	1	0.0169	-4.0801	-0.0690
	59	**0.9998**	**------**	**-1.8788**

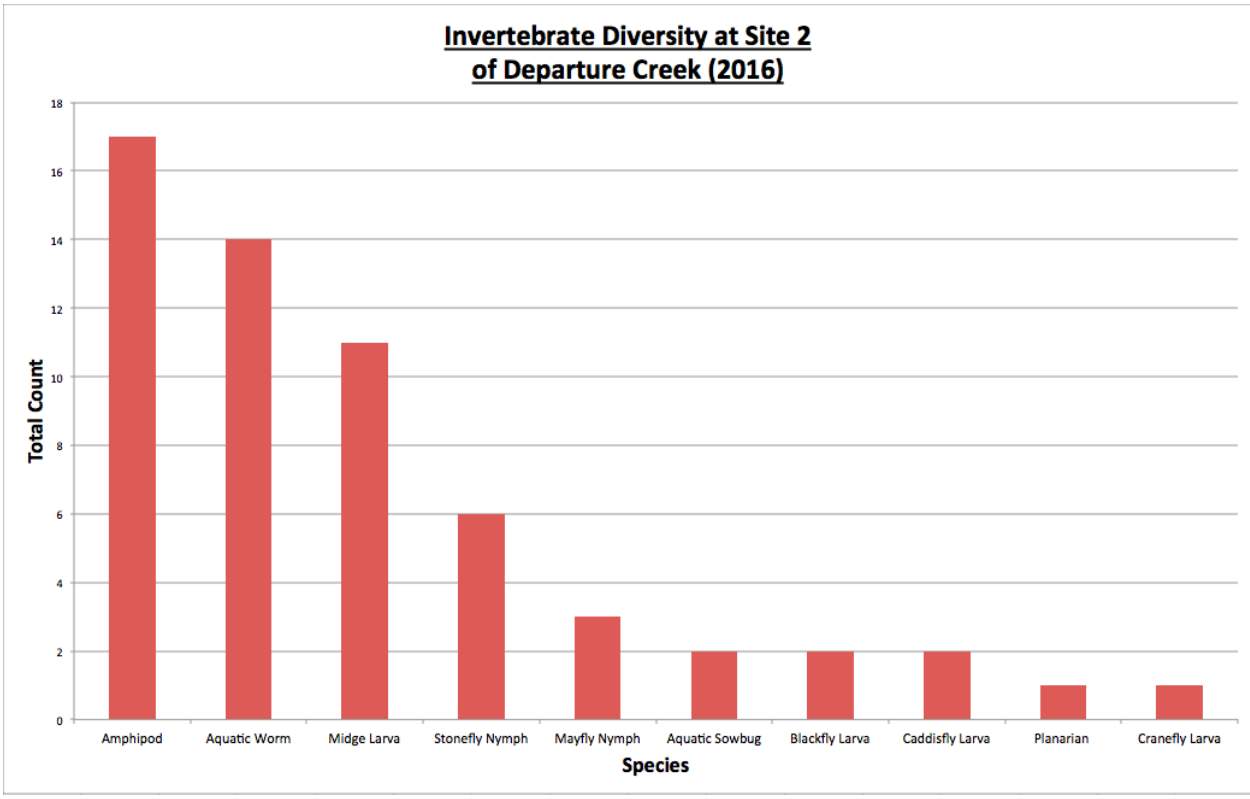

Figure 1. Graph Demonstrating Invertebrate Diversity at Site 2 of Departure Creek

CONCLUSION AND RECOMMENDATIONS

It was found that there was a significant decrease in water quality during high flow events. This is most noticeable at culverts within the stream system, as noted at Site 1, where a rain event caused acceleration of water flow. A direct correlation could be drawn between increased stream system discharge and an increase in acidification, higher turbidity, and high levels of coliforms within the creek. The phosphorous level was also considered to be eutrophic by the ALS lab (>0.025 mg/L) during the rainfall event.

These results lead us to the conclusion that the surrounding urban environment has an effect on Departure Creek. These effects can be reduced by ensuring that houses near the riparian area refrain from installing drainage pipes that lead from their property directly into the creek, as well as removing drainage pipes that divert water from storm drains along the roads into the creek.

The final recommendations are to disrupt the heavy flow at locations where culverts enter the creek. This could be made possible by the installation of permanent large woody debris or other structures. The removal of invasive species in the riparian areas and the subsequent planting of native species could improve the areas surrounding the creek as a wildlife corridor. The dumping of garden waste could be monitored and fined by local enforcement agencies to increase the suitability of the area as habitat for local species and to slow the spread of invasive and exotic plants. Further work could be done to determine whether high phosphate and nitrate counts are the direct result of fertilizers from the Nanaimo Golf Club. Any residences with septic tanks in the area could be flagged as possible sources of phosphate and nitrate as well.

ACKNOWLEDGEMENTS

We, the 2016 Departure Creek Environmental Monitoring crew would like to extend our thanks and acknowledgement to these individuals and organizations who assisted in making this assessment possible. First, to Dr. Eric Demers for his instruction into the techniques and procedures for conducting stream assessments. The Department of Fisheries and Oceans Canada for providing funding to Vancouver Island University so that reliable water quality analysis by ALS could be conducted. To ALS for giving our program access to accurate water quality testing at a reduced rate for this not for profit research project. To Sarah Greenway for her assistance in the laboratory during the Vancouver Island University Lab analysis. And finally, to Dr. John Morgan, for providing our first introduction to hydrological surveys.

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APPENDIX

Figure 2 - Site Map of Departure Creek

Figure 3. - Site 1 Panorama

Figure 4. - Site 2 Panorama

Figure 5. - Site 3 Panorama

Figure 6. - Site 4 Panorama

Figure 7. - Sampling Kit

Figure 8. - Free Swimming Caddisfly Larva under microscope

Figure 9. Site 1 Rain Event

			DEPARTURE CREEK-STATION 1	DEPARTURE CREEK-STATION 3	DEPARTURE CREEK-STATION 4	
			2-Nov-2016	2-Nov-2016	2-Nov-2016	
			9:00	9:00	9:00	
			L1853599-13	L1853599-14	L1853599-15	
Parameter	Lowest Detection Limit	Units	Water	Water	Water	Water Quality Guideline
pH	0.10	pH2	7.39	7.37	7.33	6.5-9
Hardness (as Ca	0.50	mg/L	21.7	32.3	33.1	< 60 Soft Water
Ammonia, Total	0.0050	mg/L	0.0115	0.0075	0.0092	14.2, 14.2, 15.9
Nitrate (as N)	0.0050	mg/L	0.399	0.396	0.649	3
Nitrite (as N)	0.0010	mg/L	0.0027	0.0024	0.0035	0.06
Phosphorus (P)-	0.0020	mg/L	0.0454	0.0486	0.0524	>0.025 Eutrophic
Aluminum (Al)-T	0.20	mg/L	0.77	1.70	1.04	0.1 when pH >6.5
Antimony (Sb)-T	0.20	mg/L	<0.20	<0.20	<0.20	0.02
Arsenic (As)-Tot	0.20	mg/L	<0.20	<0.20	<0.20	0.005
Barium (Ba)-Tot	0.010	mg/L	<0.010	0.017	0.012	5
Beryllium (Be)-T	0.0050	mg/L	<0.0050	<0.0050	<0.0050	0.0053
Boron (B)-Total	0.10	mg/L	<0.10	<0.10	<0.10	1.2
Cadmium (Cd)-T	0.010	mg/L	<0.010	<0.010	<0.010	0.0109, 0.0166, 0.0171
Calcium (Ca)-To	0.050	mg/L	6.18	9.09	9.08	4-8 Moderate Acid Sensitivity, >8 Low Acid Sensitivity
Chromium (Cr)-T	0.010	mg/L	<0.010	<0.010	<0.010	0.001
Cobalt (Co)-Tot	0.010	mg/L	<0.010	<0.010	<0.010	0.11
Copper (Cu)-Tot	0.010	mg/L	<0.010	<0.010	<0.010	0.000404, 0.00504, 0.00511
Iron (Fe)-Total	0.030	mg/L	0.834	2.19	1.47	1
Lead (Pb)-Total	0.050	mg/L	<0.050	<0.050	<0.050	0.0071, 0.0119, 0.0123
Lithium (Li)-Tot	0.010	mg/L	<0.010	<0.010	<0.010	0.87
Manganese (Mn)	0.0050	mg/L	0.0575	0.131	0.0909	0.779, 0.192, 0.905
Molybdenum (M	0.030	mg/L	<0.030	<0.030	<0.030	2
Nickel (Ni)-Total	0.050	mg/L	<0.050	<0.050	<0.050	0.025
Selenium (Se)-T	0.20	mg/L	<0.20	<0.20	<0.20	0.002
Silver (Ag)-Tota	0.010	mg/L	<0.010	<0.010	<0.010	0.0001
Zinc (Zn)-Total	0.0050	mg/L	0.0188	0.0260	0.0170	0.033 when hardness <90 mg/L

Figure 10. ALS Laboratory Analysis November 2,2016 sampling event

Client Sample ID			DEPARTURE CREEK - STATION 1	DEPARTURE CREEK - STATION 3	DEPARTURE CREEK - STATION 4		
Date Sampled			23-Nov-2016	23-Nov-2016	23-Nov-2016		
Time Sampled			9:00	9:00	9:00		
ALS Sample ID			L1862835-13	L1862835-14	L1862835-15		
Parameter	Lowest Detection Limit	Units	Water	Water	Water	Water Quality Guideline	
pH	0.10	pH	7.74	8.03	8.00	6.5-9	
Hardness (as Ca	0.50	mg/L	51.6	63.3	64.1	<60 Soft Water >120 Hard Water	
Ammonia, Total	0.0050	mg/L	0.0057	<0.0050	0.0072	1.83, 1.12, 1.13	
Nitrate (as N)	0.0050	mg/L	1.20	1.07	1.13	3	
Nitrite (as N)	0.0010	mg/L	<0.0010	0.0011	0.0014	0.0600	
Phosphorus (P)-	0.0020	mg/L	0.0094	0.0079	0.0105	<0.01 Oligotrophic 0.01-0.025 Mesotrophic	
Aluminum (Al)-T	0.20	mg/L	<0.20	<0.20	<0.20	.01 when pH >6.5	
Antimony (Sb)-T	0.20	mg/L	<0.20	<0.20	<0.20	0.02	
Arsenic (As)-Tot	0.20	mg/L	<0.20	<0.20	<0.20	0.005	
Barium (Ba)-Tot	0.010	mg/L	<0.010	0.011	0.011	5.000	
Beryllium (Be)-T	0.0050	mg/L	<0.0050	<0.0050	<0.0050	0.0053	
Boron (B)-Total	0.10	mg/L	<0.10	<0.10	<0.10	1.2	
Cadmium (Cd)-T	0.010	mg/L	<0.010	<0.010	<0.010	.0000187, .0000223, 0.000226	
Calcium (Ca)-To	0.050	mg/L	14.4	17.6	17.8	>8 Low Acid Sensitivity	
Chromium (Cr)-T	0.010	mg/L	<0.010	<0.010	<0.010	0.001	
Cobalt (Co)-Tota	0.010	mg/L	<0.010	<0.010	<0.010	0.11	
Copper (Cu)-Tot	0.010	mg/L	<0.010	<0.010	<0.010	.00685, .00797, .00803	
Iron (Fe)-Total	0.030	mg/L	0.153	0.171	0.284	1.000	
Lead (Pb)-Total	0.050	mg/L	<0.050	<0.050	<0.050	.0219, .0285, .0290	
Lithium (Li)-Tota	0.010	mg/L	<0.010	<0.010	<0.010	0.87	
Manganese (Mn)	0.0050	mg/L	0.0240	0.0147	0.0250	1.109, 1.238, 1.246	
Molybdenum (Mo	0.030	mg/L	<0.030	<0.030	<0.030	2	
Nickel (Ni)-Total	0.050	mg/L	<0.050	<0.050	<0.050	hardness <60mg/L .065 when hardness 60-120 mg/L	
Selenium (Se)-T	0.20	mg/L	<0.20	<0.20	<0.20	0.002	
Silver (Ag)-Tota	0.010	mg/L	<0.010	<0.010	<0.010	0.0001	
Zinc (Zn)-Total	0.0050	mg/L	0.0105	<0.0050	0.0058	0.033	

Figure 11. ALS Laboratory Analysis November 23, 2016 Sampling Event

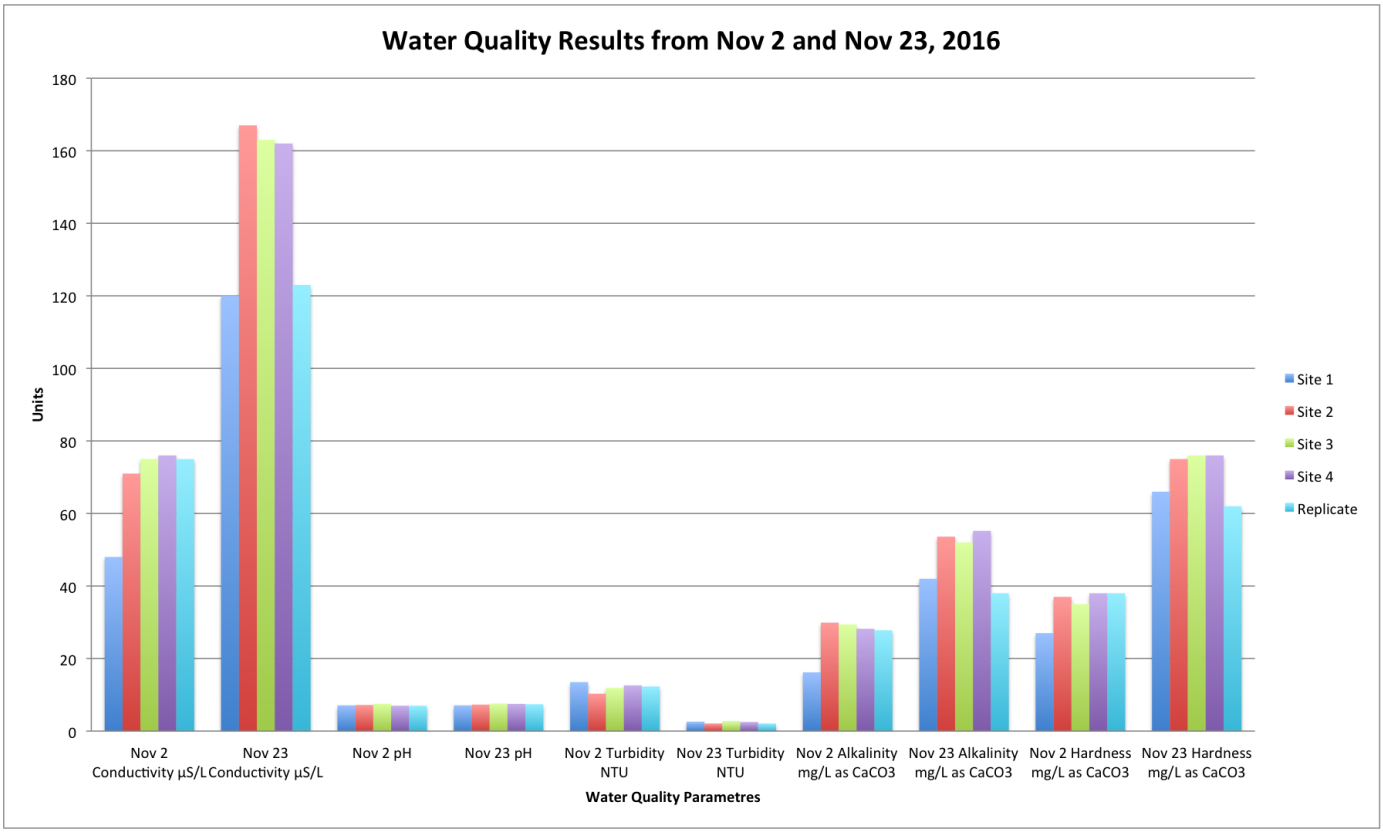

Figure 12. VIU Laboratory Analysis November 2, 2016 vs. November 23, 2016

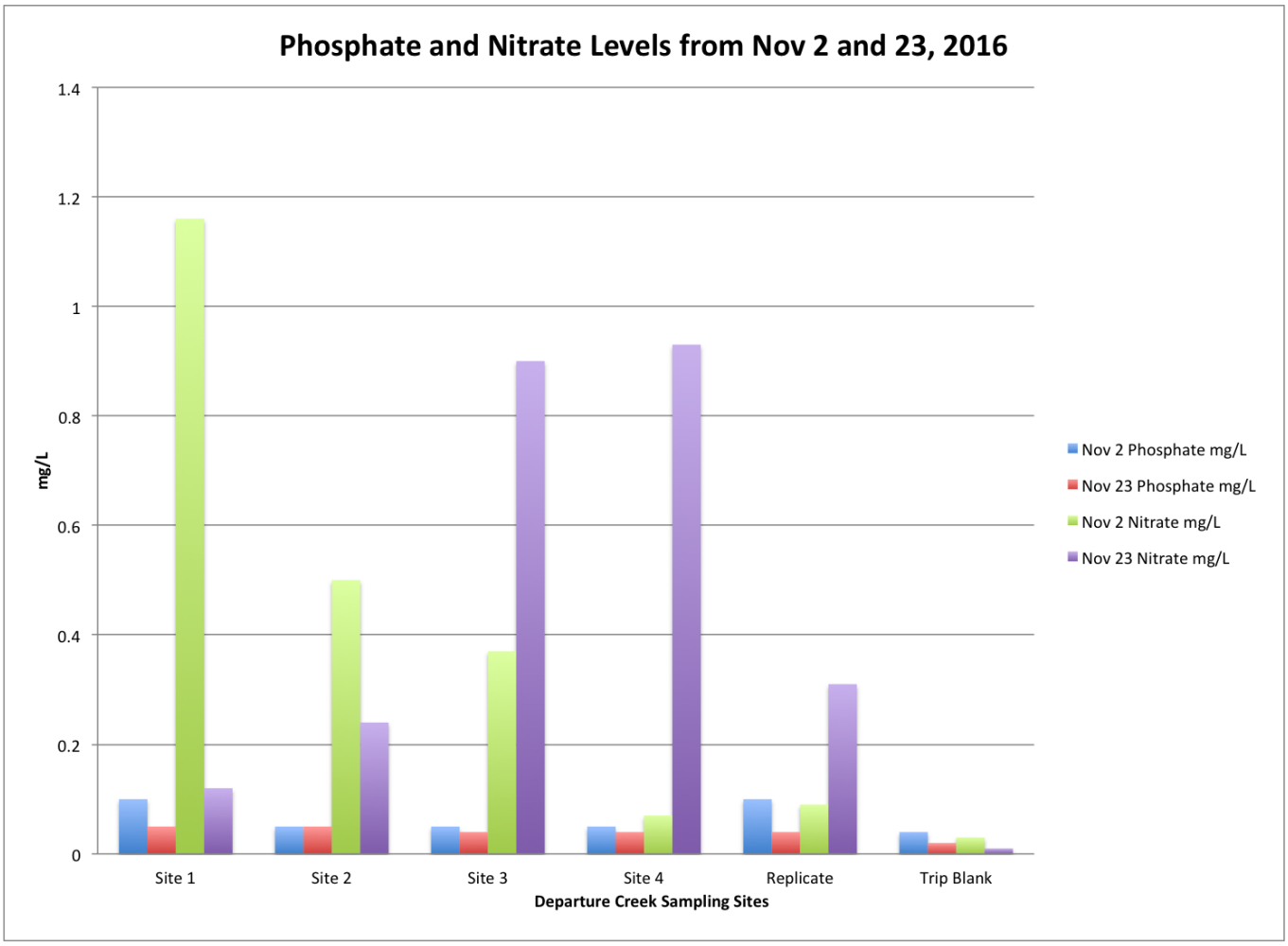

Figure 13. VIU Laboratory Analysis Phosphate and Nitrate Levels from Nov 2, 2016 vs. Nov 23, 2016

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Departure Creek	Date:	November 2. 2016
Station Name:	Station 2	Flow status:	High

Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates
Hess	5	0.09 x 5 = 0.45m^2

Column A	Column B	Column C	Column D
Pollution Tolerance	**Common Name**	**Number Counted**	**Number of Taxa**
Category 1	Caddisfly Larva (EPT)	EPT1 2	EPT4 2
	Mayfly Nymph (EPT)	EPT2 3	EPT5 2
	Stonefly Nymph (EPT)	EPT3 6	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 11	D1 6
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug	2	1
Somewhat Pollution Tolerant	Clam, Mussel		
	Cranefly Larva	1	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	17	1
	Watersnipe Larva		
Sub-Total		C2 20	D2 3
Category 3	Aquatic Worm (oligochaete)	14	2
	Blackfly Larva	2	1
	Leech		
Pollution Tolerant	Midge Larva (chironomid)	11	2
	Planarian (flatworm)	1	1
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 28	D 36
TOTAL		CT 59	DT 15

Figure 14. Invertebrate Data Sheet Page 1 of 2

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1
59

DENSITY: Invertebrate density per total area sampled:

59	/	0.45m^2	=	S2: 26.55/ m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C)

S3
Amphipoda

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 6 + 2 x 3 + 6 =

S4
30

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

2 + 2 + 2 =

S5
6

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

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

(EPT1 + EPT2 + EPT3) / CT

(2 + 3 + 6 / 59=

S6
0.19

SECTION 3 - DIVERSITY

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

S7
15

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

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

Col. C for S3 / CT

17 / 59 =

S8
0.29

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	3
EPT To Total Ratio	1
Predominant Taxon Ratio	4

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

Figure 15. Invertebrate Data Sheet Page 2 of 2