Data Report

Water Quality and Stream Invertebrate Assessment for the Millstone River, Nanaimo, BC (Fall 2012)

RMOT 306 Environmental Monitoring

Vancouver Island University

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Table of Contents

Table of Contents

Page

List of Figures

List of Tables

Executive Summary

During the fall semester of 2012 students from Vancouver Island University (VIU) enrolled in the Bachelor of Natural Resource Protection degree conducted an environmental monitoring project on the Millstone River and Benson Creek. The purpose of this project was to assess the health of the system in terms of water quality including microbiology, hydrology and benthic invertebrates. Additionally this project will provide continuing monitoring data that can be used as reference and comparison for future reports. Field data and water samples were collected, once in October to assess low flow conditions and once in November to assess high flow conditions. Water samples were analyzed in the laboratory at VIU, as well separate samples being sent to ALS Laboratories in Burnaby BC. Microbiology and benthic invertebrates were both tested only during the first sampling event at three of six sites. These samples were analyzed in the VIU lab. Information gathered in this project was analyzed against the *BC Water Quality Guidelines* as well as previous monitoring reports. Benthic invertebrates showed an improvement in site quality, from the previous year, in the high reaches of the river and in the lower section (site 5) showed a definite decline in quality. Microbiology conversely showed much higher levels in the upper portions of the river and an improvement in the lower sites compared to the previous year's report. General water quality showed most parameters within BC Water Quality Guidelines. Aluminum was the only parameter that was found to have elevated levels. Site 5 had well above the guideline limit in both sampling events and site 1 was above limits in the second sampling event. However there are still some metals that have guideline limits well below the detectable limits of these tests.

Acknowledgements

The authors would like to acknowledge Dr. John Morgan and Sarah Greenway from Vancouver Island University (VIU) for organizing materials, lab bookings, analysis equipment and liaising with ALS Laboratories; in addition the RMOT and Biology Departments at VIU for providing laboratory equipment and resources. In addition, thanks to Fisheries and Oceans Canada and the BC Conservation Foundation for their continued support to encourage students in the monitoring of the Millstone River. It is great to know students attending Vancouver Island University are acknowledged for their hard work. ALS Laboratory provided reduced rates on some of the analytical services provided to this Environmental Monitoring project and course.

1.0 Introduction

1.1 Project Overview

A water quality and stream invertebrate assessment was conducted on the Millstone River and Benson Creek located in Nanaimo, BC. The assessment was conducted by Vancouver Island University (VIU) Bachelor of Natural Resource Protection (BNRP) students, under the supervision of Dr. John Morgan, the instructor of the Environmental Monitoring (RMOT 306) course at VIU. This assessment is in continuation of previous assessments completed by BNRP students on the Millstone River and Benson Creek since 2007.

1.2 Historical Review

The Millstone River watershed encompasses 93.2 km^2 and is composed of 26 streams and 8 lakes. Benson Creek, Brannen Lake, and the Millstone River are the main drainage network for the watershed. Benson Creek flows out of Lucid Lake for 12 km into Brannen Lake in a northerly direction. It flows mainly through forested lands, mainly on the VIU woodlot, as well as private rural properties. The Millstone River drains Brannen Lake in a southeast direction flowing for 14 km through agricultural fields, urban and industrial areas, as well as a 35 hectare (ha) park in the heart of the City of Nanaimo before flowing into Departure Bay in the Strait of Georgia (City of Nanaimo, 2008; Cook and Baldwin, 1994; McNeill et al. 2012).

Over the last 35 years there have been significant attempts to enhance the salmon habitat on the Millstone River. The Deadman Falls located in Bowen Park was an impassable barrier until 2007 when an 800 meter (m) side-channel was constructed to allow fish species, particularly Coho salmon (*Oncorhynchus kisutch*), to navigate around the falls and access suitable habitat above. Aside from the sizable waterfalls located in Bowen Park, around which a fish bypass channel was built, the river flows at a low gradient. The tidal influence ends at the bottom of Barsby Park several hundred meters up from the Island Highway (Terminal Ave.) overpass. Maffeo Sutton, Barsby and Bowen Park as well as Buttertubs Marsh Bird Sanctuary all border the river and are popular walking and recreational areas. Because of these parks in the lower portions of the river and the high ecological values that this river provides to Nanaimo, the river receives a great deal of public attention. In addition to recreation, these areas benefit our community, as well as our environment and they provide educational opportunities for the public and VIU students who use this system in several courses as an applied outdoor classroom (City of Nanaimo, 2008; McNeill et al. 2012).

1.3 Potential Environmental Concerns

Benson Creek and the Millstone River both flow through agricultural lands, therefore nutrient enrichment from fertilizers and animal waste are concerns. The Millstone River also crosses the Nanaimo Bypass (HWY 19), runs by Pryde Vista Golf Course, and currently flows directly by a city construction project that is in its final stages after approximately 2 years. It then flows through city neighbourhoods and Bowen Park containing several walking trails before emptying into Departure Bay. So the Millstone River is highly susceptible to storm water and general urban runoff, fertilizer enrichment, and fecal contamination from human and animal waste throughout the entire length of the Millstone River.

2.0 Project Objectives

Due to the growing awareness and efforts to protect the environment and natural resources as well as the high ecological values of this river system, this project will contribute to the ongoing monitoring efforts put forward by VIU and the RMOT 306 students since 2007. The 2012 RMOT 306 students will conduct water quality, microbiology and benthic invertebrate sampling, at various predetermined sites along the length of the Millstone River and one site in Benson Creek, a tributary that flows into Brannen Lake, to provide a continuing assessment of the river system and ecosystem health. This monitoring allows the students to look at conditions as they progress downstream and will be able to assess impacts from agricultural and storm water runoff, urban development, and general urban impacts. They will also analyze and compare the data to previous year's studies, and provide a results and discussions section in the paper that is to be submitted to Dr. John Morgan the instructor for the RMOT 306 course at VIU. The data from this project will provide valuable background information for organizations such as Fisheries and Oceans Canada (DFO), British Columbia Conservation Foundation (BCCF), the Regional District of Nanaimo (RDN), and the City of Nanaimo who might conduct future projects that will affect the Millstone watershed.

3.0 Methods Section

3.1 Site Locations

Site 1 was located on Benson Creek at the Biggs Road Bridge, approximately 500 meters upstream from Brannen Lake. Sampling was done on the downstream side of the bridge, with trail access adjacent to the bridge on the east side. The site is a small, low gradient riffle with a relatively shallow pool directly upstream. The substrate composition was approximately 45% gravel, 45% cobble, and 10% fines. Fines in the stream are in isolated pockets of the riffle and don't deteriorate invertebrate habitat. Benson Creek is located in an agricultural/residential area so nutrient enrichment and coliform presence was a concern. Minimal hazards were encountered at this site with the exception of high water levels during the second sampling event (Figure 1; Table 1; Appendix 1).

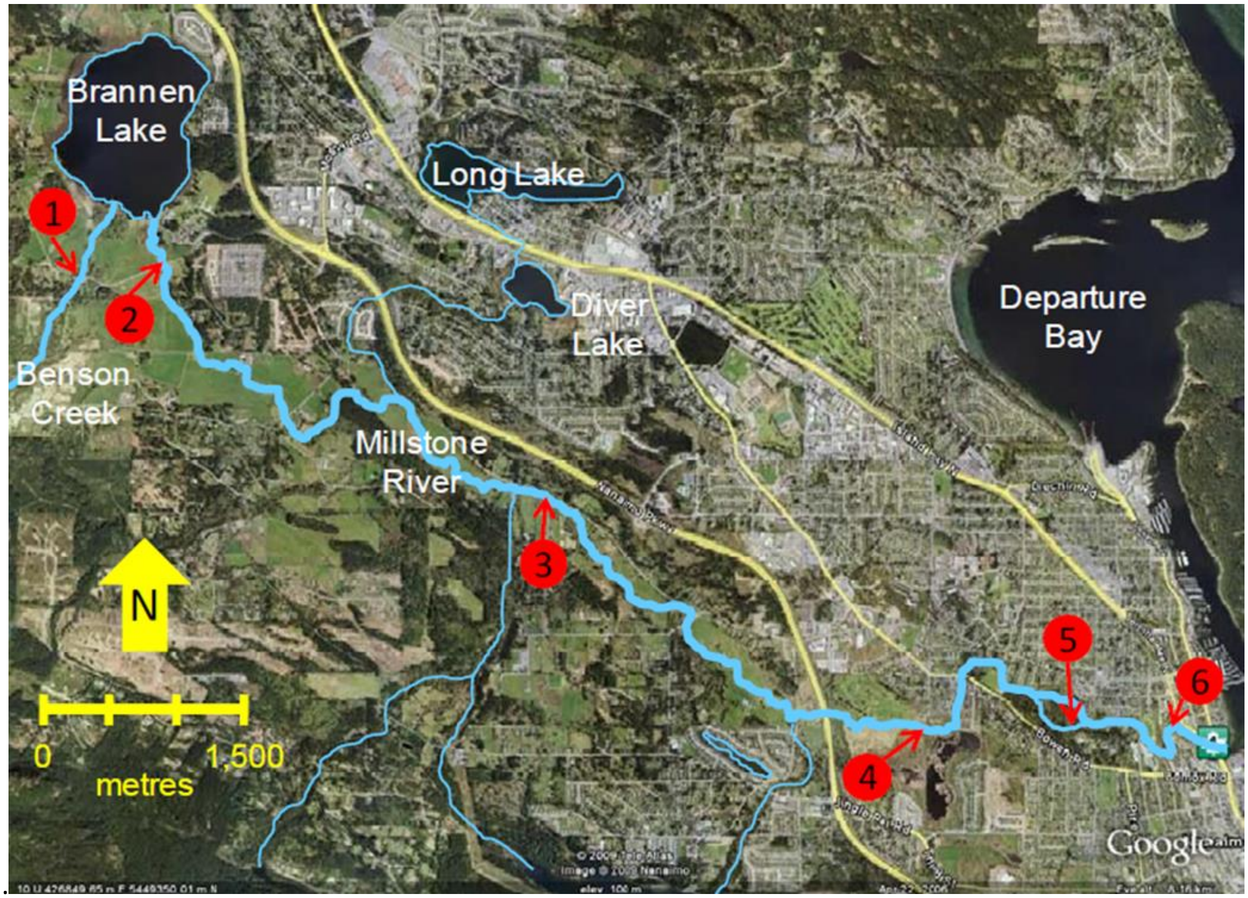

Figure 1: Benson Cr. and Millstone River site locations (Google, 2012; McNeill et al. 2012).

Table 1: Description of the sampling sites used for water quality and stream invertebrate assessments taken on the Millstone River watershed in October and November of 2012. All locations were initially sited on off Google Maps for rough UTM estimates. The UTM coordinates were proven based on zone 10U by using a Garmin etrex H GPS at each site.

Site	**Location**	**UTM Coordinates**	
		Easting	Northing
1	Benson Creek, Biggs road crossing	422752mE	5450702mN
2	Millstone River, Biggs road crossing	423314mE	5450798mN
3	Durnin Road crossing	426313mE	5448966mN
4	Millstone River, Pryde Vista Golf Course	429076mE	5447227mN
5	Millstone Bypass Channel	430223mE	5447304mN
6	Millstone, Barsby Park	430941mE	5447091mN

Site 2 was the most upstream site on the Millstone River and was located at the bridge crossing also on Biggs road, approximately 500 meters downstream from the outflow of Brannen Lake. Sampling was conducted on the upstream side of the bridge with relatively easy walking access through grasses and small shrubs. There was a barbed wire fence on either side of the bridge that may have been for cattle, although it did not hinder passage of the river and did not catch debris. The fenced off land was public land and the responsibility of the Ministry of Transportation, the area along with the road is patrolled by guards from the prison, who's land borders one bank of the river from the bridge out to the lake. The site is a small, long, and low gradient riffle, where the river substrate is made of 10% fines, 20% cobbles, and 70% gravel. Possible pollution sources where anticipated to be the same as Site 1 as they are located in relatively the same area. Parking was along the roadside next to an agricultural field. Streamside vegetation was fairly thick along the banks, and during the high flow sampling event navigation along the bank was difficult as water was at its absolute capacity at this point of the year. Getting into the site was easy but staging areas were mostly wet (Appendix 2).

Site 3 was located on the Millstone River where it crosses Durnin Rd., approximately 3 kilometers (km) downstream from site 2. Sampling was done on the downstream side of the bridge, with a simple trail access from the road. Again this site is a small, low gradient riffle, with a shallow glide directly upstream from the riffle. Substrate is made of both cobble and gravel being 45%, and 10% boulder. Although water depth and flow were acceptable and easily workable at the time of the first sampling event, it was well above safe levels, for working in the water, during the second high flow event. The area is made of residential acreages so agricultural pollution was a possible concern; however storm water effluent was also a likely to have impacts (Appendix 3).

Site 4 was located on the Millstone River near the Pryde Vista golf course parking area, approximately 3 km downstream from Site 3. It was easily accessed and is a smooth flowing glide.

Invertebrate sampling was not conducted at this site, as it was not completed for the fall 2011 report and water depths even at low flow would have made sampling difficult. Substrate is made of 50% gravel, and 40% cobble and 10% fines. Gravel had been added to the site in previous years in order to enhance Coho spawning habitat. Care was taken during sampling for possible redds, although no spawning salmon were observed. Flow rates were extremely high during the second event and no work was done far into the river. The site was adjacent to the Pryde Vista golf course, with residential housing nearby; HWY 19 is also nearby and directly upstream which all may have potential impacts to the river (Appendix 4).

Site 5 was located in Bowen Park directly below the Duck Pond in the Millstone side channel, approximately 3.5 km from Site 4. The side channel is 800 m in length and was built in 2007 to allow juvenile and adult Coho access to habitat above Deadman Falls. The site was a low gradient riffle, with substrate that shows 50% gravel, 40% cobble, 5% boulders, and 5% fines. This site was sampled for benthic invertebrates to be consistent with previous years sampling, and provide continuing data. The site is located within the municipal park with walking trails surrounding the area. Possible pollution sources could be fecal coliforms, as it is a popular dog walking area and other wildlife are frequently present in and around the pond. There were no hazards at this site because it is in a walking park and the flow of the side channel is controlled (Appendix 5).

Site 6 was in Barsby Park, which is approximately 170 m upstream from the mouth of the Millstone River which discharges in to Nanaimo harbor. The site is situated at the top end of the park above the staircase (a series of man-made pools in bedrock, allowing anadramous fish access upstream), it is just under the footbridge that crosses over the channel. This site again has easy foot access with a short walk from the Barsby Park parking lot. The area was a faster flowing riffle; at high flow no work was done in mid channel. Even taking flow measurements during the first sampling event was tricky and care was needed to keep steady footing. Substrate was a mixture of cobble, gravel, boulders, and fines however; cobble was the dominant substrate on site. Urban runoffs combined with a significant amount of garbage present on the banks at site 6 are potential pollution source (Appendix 6).

3.2 Hydrology

Basic velocity (m/sec) measurements were taken using the float method, and discharge was calculated using the velocity and cross sectional area of the channel. Velocity and discharge was calculated at all sites during the first sampling event (due to dangerous water levels, only sites 2 and 5 were measured for velocity and discharge during the second event). At each site a length of stream was measured (10 m where space permitted) and a Ping-Pong ball was dropped into the river above the top mark and the time it took to float to the bottom mark was timed using a stopwatch. This was completed during both sampling events in the same stretch of the stream, intervals of 25%, 50%, and 75% of the wetted width were used to attain and average of three times. From this the average velocity of the water could be calculated, (Velocity (m/sec) = distance/average time). To calculate discharge (m^3/sec), the average cross sectional area (m^2) for each site was calculated. This was done by taking the wetted width and multiplying it by the average depth; averages were taken from depths at 25%, 50%, and 75% intervals of the wetted width. Once the cross sectional area was calculated, and using a correction factor of .85 to account for the roughness of the channel bed, the flow or discharge was calculated (Discharge (m^3/sec) = velocity (m/sec) x cross section area (m^2) x .85). The results from these calculations are in in the results and discussion section (Morgan, 2012; Table 5).

3.3 Water Quality

3.3.1 Field Measurements

Samples for determining water quality were collected from each site on two separate occasions, the first sampling event was on October 29, 2012 during a low flow period, and the second was on

November 19, 2012 during a high flow period. An electronic water quality probe (YSI 556 MPS) was used in stream for field measurements to determine temperature (to the nearest 0.01 °C), pH (to the nearest 0.01 pH), conductivity (to the nearest 1 µS/cm), dissolved oxygen (DO) (to the nearest 0.01 mg/L) at each site (Table 2).

Table 2: Water quality and stream invertebrate sampling activities conducted at each site on the Millstone River during both sampling events. Symbol "O" indicates the first sampling event conducted on October 29, 2012 and symbol "N" indicates the second event conducted on November 19, 2012.

Water Quality					
Site	**Field Measurements**	**VIU Lab Analysis**	**ALS Lab Analysis**	**Microbiology**	**Stream Invertebrates**
1	O,N*	O,N	O,N	O	O
2	O,N	O,N	O,N	O	O
3	O,N*	O,N	*	*	*
4	O,N*	O,N	*	*	*
5	O,N	O,N	O,N	O	O
6	O,N*	O,N	*	*	*

Note: Basic Hydrology (velocity & discharge) measurements were not collected at sites 1, 3, 4, and 6 during the second sampling event during high flow. The symbol * denotes that no sample was taken during that event only.

3.3.2 Water Sampling

All standard preparations, as outlined in *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia*, including sterilization of equipment and calibration of instruments, were completed prior to sampling. A trip blank was used to measure any contamination that may have occurred during sampling and analyzing (MOELP[1], 1998).

Samples for determining water quality of the Millstone River were collected on both sampling events. At each event two sets of water samples were collected for analysis. The first sample set was taken from each of the six sites, and transported to the VIU biology lab. The second set consisted of three of the six sites, stored at VIU before being shipped to ALS laboratory services in Burnaby, B.C. for more in depth analysis of metals and other parameters (Appendix 9).

Water samples designated for the VIU laboratory were gathered in sterilized pre-labeled 500 ml plastic bottles that were rinsed three times mid-stream in location, and then used to collect each sample. All of the water samples were obtained following this same procedure. A team member would enter the stream approaching from downstream in order to move to the thalweg and face upstream to eliminate bottom sediment contamination. The sample container was immersed slightly below the water surface at approximately 10-20% of the stream depth. The samples were then logged, recorded and stored in a cooler with an icepack for transport to VIU laboratory facilities where they were stored in fridges at 4˚C. All water samples were taken and stored using these procedures (Table 3).

Table 3: Outline of sampling containers and preservatives used for all water quality samples taken from the Millstone River during the first and second sampling event. VIU laboratory provided all of the containers designated for analysis at the VIU laboratory whereas; ALS provided all containers and preservatives for the samples analyzed by ALS in Burnaby, BC.

Container		**Parameters**	**Preservative**	**Lab Analysis**
Size	**Type**			
500 ml	plastic	Total alkalinity, turbidity	None	VIU
1 L	plastic	Conductivity, pH, total hardness	None	ALS
250 ml	amber	Anion, Nutrients	Sulphuric acid	ALS
250 ml	plastic	Total Metals	Nitric Acid	ALS

Samples taken for analysis by the ALS laboratory were collected from sites 1, 2, and 5 during both sampling events. The samples were taken using the ALS provided containers which were pre-labeled, sterilized, and did not require in location stream rinsing. The samples were taken at the same time as VIU samples in the thalweg of the stream. Containers were opened immediately prior to immersion and were not filled over 80% of the total volume (for samples requiring preservatives), then inverted five times to ensure mixing of the preservative. Logging, recording, and storage was the same as noted above; except the samples were sent to ALS Laboratory by Dr. John Morgan the following Friday after sampling, November 2, 2012 and November 23, 2012 respectively.

3.3.3 VIU Laboratory Analysis

The water samples designated for the VIU laboratory were analyzed for total alkalinity, turbidity, hardness, nitrate, and phosphorus. Total alkalinity ($CaCO_2$) was measured to the nearest 0.1 mg/L using the HACH AL-DT digital titration method. Turbidity was measured in NTU (Nephelometric Turbidity Units) to the nearest 0.1 using the HACH DR2000 Spectrophotometer (Method 8006). Hardness was determined by using the following solutions: Buffer solution hardness 1, ManVar 2 hardness indicator hardness 2 and Titrant reagent hardness 3 (1 drop = 1 mg/L as $CaCo^3$). Nitrate was tested using a DR 2800 HACH Spectrophotometer (type LPG422.99)) using NitraVar 6 and 3 nitrate reagent powder. Phosphate was tested using a DR 2800 HACH Spectrophotometer (type LPG422.99) using PhosVar 3 phosphate reagent powder.

3.3.4 ALS Laboratory Analysis

The water samples designated for the ALS Laboratory were analyzed in Burnaby, BC in accordance to ALS standards. The ALS test parameters included conductivity, total hardness, pH, anions and nutrients, and 31 trace metals (Appendix 9).

3.3.5 Quality Assurance/ Quality Control

For quality assurance and control, both VIU and ALS laboratory facilities tested water quality for turbidity, alkalinity, hardness, nitrates, and phosphates. In addition, ALS conducted additional tests for content of anions and 31 trace metals. All samples taken were done so following the recommended procedures complying with the *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia* (MOELP[1], 1998).

Additional sanitary procedures were implemented during sample taking events to minimize the potential for contamination of the water samples. These procedures included using only approved sample containers that were sterilized and pre-rinsed. Sanitary gloves were worn by the sample taking team members and extra precautions were taken not to make contact with the inside of the outer lid or inner bottle with the glove hand. Pre-labeling of the containers was completed prior to the event, and a field log was maintained to log and record each sample taken and stored by a designated sample site code in order to minimize the chance of mixing samples. A chain of custody was completed for both sampling events.

3.3.6 Data Analysis - Comparison with Applicable Guidelines

All water quality results were compared with the applicable Government of BC water quality guidelines regarding aquatic life obtained from the BC Ministry of Environment, Land Use Task Force Resource Inventory Committee. *The Guidelines for Interpreting Water Data* outline the maximum allowable concentration for potential and acute effects, as well as the 30 day average concentration for potential chronic effects (MOELP[2], 1998).

3.4 Microbiology

3.4.1 Field Sampling

Water samples tested for total and fecal coliform (*Escherichia coli*) counts were collected from sites 1, 2, and 5 during the first sampling event in October 2012. At each sample location a team member would enter the watershed approaching from downstream in order to move to a central position facing upstream without creating disturbance. The sterile pre-labeled Whirl

Pak® was used to collect a 100 ml water sample by immersing the container pack slightly below the water surface at approximately 10-20% of the stream depth with careful care taken to only open the containers just prior to immersion, and not to fill the container over 80% of the total volume. Lastly, a tight seal was made by using the twist locks provided. Precautions were also taken not to disturb the bottom sediments or to allow floating debris to enter the container during sampling. All samples collected were transported in a cooler with icepacks, and stored at VIU in a fridge with temperature of 4°C prior to the lab analysis, which was conducted within 5 days of the sample collection date (Table 4).

Table 4: Coliform counts from first sampling event.

	Total Coliform (CFU/100 mL)	Fecal Coliform (CFU/100 mL)	% Fecal Coliform
Benson Cr Site 1	312	32	10.26%
Millstone Site 2	28	20	71.43%
Millstone Site 5	248	116	46.77%

3.4.2 Laboratory Analysis

Microbiology analysis was conducted at the VIU laboratory. Each sample was tested for total coliform and fecal coliform (E. coli) using the m-coliBlue24 membrane filtration method. For each of the 100 ml stream samples, a 25ml volume portion was extracted and filtered through a 27-µm membrane filter (marked with 3 mm gridlines) using a standard laboratory vacuum pump. Once the 25 ml sample had completely passed through the vacuum and filter, each filter was placed into a separate petri dish containing an absorbent pad saturated with m-ColiBlue24 broth. The petri dish containing the filter and absorbent pad were then placed into an air incubator at 37°C for a period of 24 hours. The cultures were then visually examined with a dissecting scope within the 24 hour period for the presence of bacterial colonies. The presence of a blue colony represents a “positive” *E.coli* result. A translucent, clear or cream/white colony represents a “negative” total coliform result. All colonies present on the membrane surface were counted and expressed as colony forming units (CFU) per 100 ml of sample water. For quality control during the vacuum and filtration process the apparatus was rinsed with approximately 5-10 ml of distilled water after each use. In summary, laboratory analysis confirmed that fecal coliform colonies were present in all samples tested, exceeding Water Quality guidelines (USEPA, 2002).

3.5 Stream Invertebrate Communities

3.5.1 Invertebrate Sampling Sites

Invertebrate sampling was conducted once during the first sampling session. All sampling was conducted according to the *Freshwater Biological Sampling Manual.* Sites 1, 2 and 5 were chosen as sampling sites due to consistency in substrate (primarily fines and gravel), water depth, site access and safety, as well as correspondence with locations selected in previous years (Cavanagh et al. 1997; Figure 1).

3.5.2 Invertebrate Sampling

Sites were sampled using a Hess sampler (0.09 square metres) and replicated three times per site starting at Site 5 and working upstream to obtain an accurate representation of the stream’s invertebrates inhabitants. The sampler was pressed into the substrate and all large substrate were removed and wiped clean of invertebrates before being out of the way. The substrate was stirred and agitated by hand for 60 seconds to ensure maximum collection efficiency of all invertebrate types present. The Hess sampler collection jar was emptied into a separate sealed jar after each of the three collection events. The Hess sampler was moved to a new location at the same site each time, representing a total of 0.27 square metres. The resulting nine samples were preserved with ethanol in order to be analyzed later.

3.5.3 VIU Invertebrate Laboratory Analyses

The invertebrates were analyzed at the VIU laboratory by BNRP students and identified to Family and Order as prescribed by Pacific Streamkeepers' procedures. Data sheets were completed recording abundance, diversity per square metre, dominant taxa and the three categories of pollution tolerance. Recorded data also included the EPT (*Ephemeroptera-Plecoptera-Trichoptera*) index, EPT to total ratio index and overall site assessment. During invertebrate analysis a minimum of two students were present during each sample count to increase validity of counts and taxa identification. To ensure accuracy, each group member validated all calculations. These quality control measures assured the integrity and veracity of sampling and analytical techniques (Taccogna and Munro, 1995).

4.0 Results Section

4.1 General Field Conditions

Water levels during the second sampling event on November 19, 2012 were much higher at bankfull than those from the first event on October 29, 2012. This indicated that Brannen Lake was at maximum capacity during the second sampling event and not the first event. Discharge was calculated at all 6 sites in October and due to hazards from the water levels discharge was only calculated for site 2 and 5. Site 5 discharge was consistent between both sampling events, this was predicted as its flow is regulated (Table 5).

During the 10 days previous to sampling in October the average air temperature was 7.33°c, and there had been 81 mm of rain. On the day of sampling the temperature was 10°c with rain. During the 10 days prior to the November sampling date the average temperature was 5.71°c, and there had been

73.9 mm of rain. On November 29th the temperature was 7.6°c and overcast (Environment Canada, 2012).

4.2 Water Quality

4.2.1 Field Measurements and VIU Laboratory Analysis

The averaged water temperature was 8.7 °C during both sampling events. Sample site 1 averaged 2.3°C colder than site 2 during the both sampling events. Site 2 is notably the beginning of the Millstone River which flows directly out of Brannen Lake. The DO levels were inconsistent between the two sampling events. During both sampling events almost all sampling sites were above the minimum guideline of 9.0 mg/L for early fish life stages. This trend was consistent in all sites except site 2, which was measured at 8.87 mg/L and is slightly below the minimum guideline. DO levels for all 6 sites were all only slightly higher from the first to the second sampling events. Conductivity ranged from 26-129 µs/cm during both sampling events and generally increased from upstream to downstream. The overall pH levels ranged from 7.26-8.48 during the first sampling event to 6.25-7.63 in the second event. Only one sampling site fell below the criteria for aquatic life which was site 3 during the second sampling event with a pH of 6.25. Generally, the noticeable trend from both sampling events was that pH levels increased from upstream to downstream (MOELP[2], 1998).

During the first sampling event water hardness and total alkalinity generally increased from upstream to downstream sample sites. The second sampling event displayed inconsistencies in this trend by a slight lowering of total alkalinity from the last two sites downstream. Sites 3 to 6 in the first sampling event and site 3 and 4 in the second sampling event all had levels of alkalinity above 20 mg/L indicating “low acid sensitivity” according to the *BC Water Quality Guidelines.* All other sites for both sampling events displayed levels in the “moderate sensitivity”. Total hardness was below 60mg/L for all sampling sites during both sampling events, indicating that the watershed has “soft water” conditions throughout, according to the *BC Water Quality Guidelines*. The turbidity (NTU) levels ranged from 0.17 to 4.48 NTU during the first sampling event and 0.18 to 3.94 NTU in the second. Generally, the noticeable trend from both sampling events was that turbidity levels increased from upstream to downstream (MOELP[2], 1998).

Table 5: Field measurements and VIU laboratory results for water quality samples taken from all 6 sites on the Millstone River during the October and November sampling events of 2012.

October Sampling Event										
Site	**Discharge**	**pH**	**Cond.**	**DO**	**Temp**	**Total Alk.**	**Turb.**	**Nitrate.**	**Phos.**	**Hard.**
#	**(m^3/s)**		**(µS/cm)**	**(mg/L)**	**(ºC)**	**(mg/L $CaCO^2$)**	**(NTU)**	**(mg/L)**	**(mg/L)**	**(mg/L $CaCO^3$)**
Blank	----	6.35	02	7.53	---	0.4	0.17	0.04	0.04	0
1	2.26	7.26	33	10.54	7.88	10.4	0.45	0.48	0.04	15
2	2.02	7.92	74	8.87	11.18	13.6	0.62	0.03	0.03	32
2 R	---	---	---	---	---	13.6	0.59	0.04	0.05	32
3	2.36	7.95	98	9.32	9.8	21.6	1.75	0.19	0.04	38
4	2.23	8.20	120	9.23	9.98	26.4	3.76	0.38	0.06	42
5	0.52	8.20	106	10.23	9.79	28.8	3.69	0.19	0.06	42
6	8.15	8.48	129	10	10.21	23.2	4.48	0.34	0.05	44
Avg.				9.39	9.81					
November Sampling Event										
Site	**Discharge**	**pH**	**Cond.**	**DO**	**Temp**	**Total Alk.**	**Turb.**	**Nitrate.**	**Phos.**	**Hard.**
#	**(m^3/s)**		**(µS/cm)**	**(mg/L)**	**(ºC)**	**(mg/L $CaCO^2$)**	**(NTU)**	**(mg/L)**	**(mg/L)**	**(mg/L $CaCO^3$)**
Blank	----				---	1.2	0.18	0.06	0.04	BDL
1	NA*	6.80	26	10.63	6.77	8.8	1.49	0.10	0.10	10
2	5.14	7.45	63	8.70	8.16	16.8	0.85	0.09	0.15	25
3	NA*	7.28	58	10.20	7.75	17.6	2.48	0.34	0.10	23
4	NA*	6.25	70	9.57	7.69	21.2	2.67	0.14	0.07	25
5	0.68	7.59	77	10.66	7.73	22.0	3.94	0.25	0.07	25
6	NA*	7.63	70	10.48	7.78	19.2	3.43	0.42	0.05	23
6 R	---	---	---	---	---	18.8	3.69	0.34	0.08	24
Avg.				8.61	7.65					

Note: Discharge measurements were not collected at sites 1, 3, 5, and 6 during the second sampling event.

4.2.2 ALS Laboratory Analysis

Water quality results obtained from the ALS Laboratories were compared to the *BC water quality guidelines*. The conductivity measurements from the ALS Laboratory samples were generally lower than the field measurements obtained with the YSI probe during both sampling events. During both sampling events, conductivity increased from upstream to downstream (MOELP[2], 1998).

The pH measurements from the ALS Laboratories were less variable (7.13-7.71) in comparison to the field measurements obtained with the YSI probe (6.25-8.48). Field measurements of pH were generally similar to the ALS laboratory results. Most of all Anions and Nutrients tested by ALS (Ammonia, Nitrate, Nitrite, Orthophosphate-Dissolved, and Phosphorus) were either below the detection limit and/or below the limits outlined by the *BC Water Quality Guidelines*. There was only a slight Increase in levels from upstream to downstream in both sampling events. Total metals tested by ALS showed they were generally below detection limit, except for aluminum, iron, silicon, strontium, and zinc demonstrated levels above detectable limits. Aluminum was the only metal that was above the *BC Water Quality Guidelines* (MOELP[2], 1998; Appendix 9).

4.3 Stream invertebrates

In comparison to samples taken in 2011, the samples collected on October 29, 2012 demonstrated a significant increase in the total abundance of invertebrates collected at all three sites. The total abundance count for the nine samples collected in 2012 was 1,411, while the total for 2011 was 698. The 2012 number represents 19 taxonomic groups of invertebrates. This indicates a significant increase in diversity relative to 2011 when only 9 taxa were represented. The same trend in density in 2011 appears again in 2012. In both sample years, density increased from upstream to downstream. In 2012, site 5 had the highest density among the three sites at 2,967 invertebrates per square metre. The most prominent taxa represented in 2012 were aquatic worms (oligochaete), caddisfly larvae and amphipods, although the numbers of each taxon varied among the three collection sites. These results are similar to the 2011 results, though site 5 experienced a change in dominant taxa collected, from mayflies in 2011 to amphipods one year later (McNeill et al. 2012; Taccogna and Munro, 1995; Figure 2; Table 6; Appendix 7).

According to the Pacific Streamkeepers' *Invertebrate Interpretation Sheet*, sites 1 and 2 had overall site assessment ratings of 3 which is within acceptable parameters. However, site 5 showed a decrease from acceptable in 2011 (3.25) to marginal in 2012 (2.5). The decrease in site 5 is due to a reduction in the EPT to Total Ratio Index. This indicates the possibility of the presence of (a) pollutant(s). There was an increase in the abundance of taxonomic groups; however, the decrease in the EPT to Total Ratio Index indicates the possibility of a negative trend becoming established, to the extent that there are more pollution-intolerant taxa than in 2011. This trend seems to be correlated with the increase in conductivity since 2011 (McNeill et al. 2012; Taccogna and Munro, 1995; Figure 3).

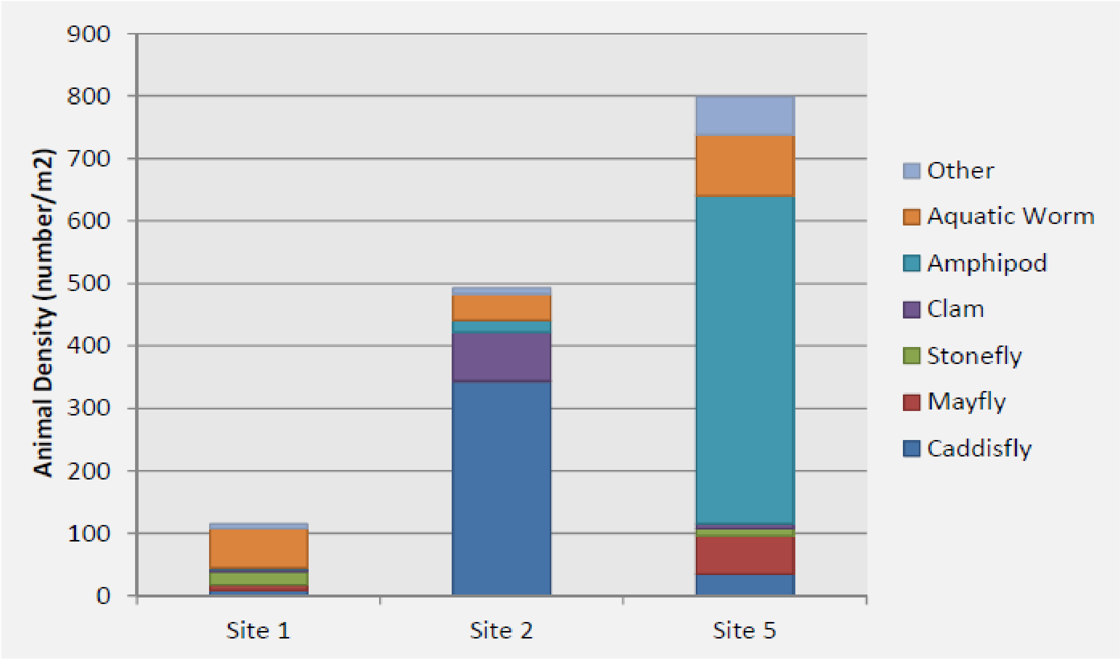

Figure 2: Invertebrate density obtained October 29, 2012 from Benson Cr and the Millstone River. The "other" category represents Damselfly, Water Penny, Dobsonfly, Gilled Snail, Alderfly Larva, Dragonfly Larva, Cranefly Larva, Blackfly Larva, Leeches, Midge Larva, Pouch and Pond Snails, True Bug Adult, and Water Mites. (Appendix 7)

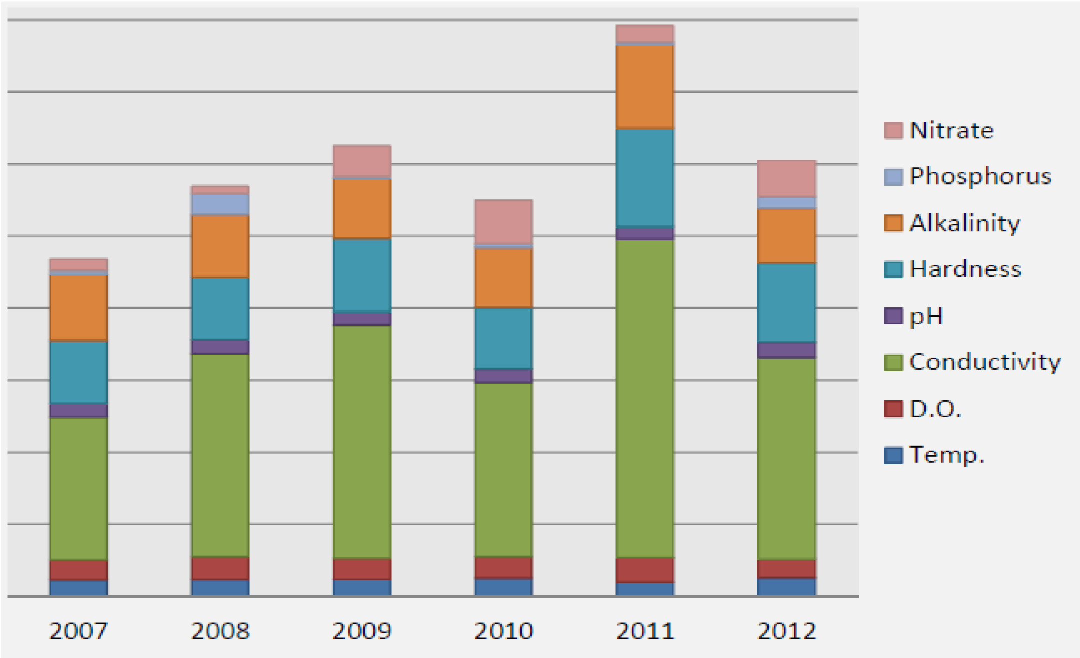

Figure 3: Millstone River water quality representation obtained by VIU 2007-2012 inclusive. (Brooks et al. 2009; Clark et al. 2011; Cox et al. 2008; Goeppel et al. 2010; McNeill et al. 2012)

Table 6: Abundance and density of invertebrates collected on October 29, 2012 from triplicate samples. Site assessment ratings are in accordance with Pacific Streamkeepers' and Shannon-Weiner Index calculations (Appendix 7; Appendix 8).

Pollution Tolerance	**Invertebrate Taxa**	**Site 1**	**Site 2**	**Site 5**
Category 1	Caddisfly Larva	9	343	37
Pollution	Mayfly Nymph	8	1	61
Intolerant	Stonefly Nymph	22		12
	Dobsonfly			8
	Gilled Snail			2
	Water Penny	1		
Category 2	Alderfly Larva			1
Somewhat	Clam, Mussel	4	78	7
Pollution	Cranefly Larva	2		
Intolerant	Damselfly Larva			1
	Dragonfly Larva	1	5	
	Amphipod	2	19	526
Category 3	Aquatic Worm	63	42	97
Pollution	Blackfly Larva			3
Tolerant	Leech		2	4
	Midge Larva		3	38
	Pouch And Pond Snails			
	True Bug Adult			4
	Water Mite	1		
		2		
Total Abundance		114	496	801
Density (number/m_2)		422	1,837	2,967
Site Assessment Rating		3	3	2.5
Shannon-Weiner Diversity Index		0.63	0.48	0.49

7.0 Conclusion and Recommendations

By sampling and testing several parameters, and the additional testing ALS conducted we have been able to achieve a thorough understanding of Benson Creek and the Millstone River. Comparison of 2012 results to 2011 showed: discharge drastically higher this year, water temperature was warmer during both sampling event which caused DO levels to be lower, conductivity and alkalinity had a decreasing trend, and pH showed an increasing trend. Aluminum was the only metal found to be above acceptable guidelines, and varying levels were found throughout different sites between sampling periods. This is consistent with previous year's data.

Microbiology results compared to 2011 showed that Site 1 had fecal coliforms became present in 2012. While Site 2 proportion of fecal coliforms increased, site 5 fecal coliform proportion decreased. Stream invertebrate showed an increase in density, abundance, and taxa. The site assessment rating for site 1 and 2 increased, site 5 decreased.

The Millstone River and Benson Creek overall are a healthy aquatic ecosystem, capable of supporting aquatic life. Recommendations for 2013 monitoring of the Millstone River and Benson Creek are to continue the monitoring program in order to provide long term data. Add sampling sites above the confluence of other tributaries of the Millstone River to gain a broader view of the Millstone Watershed water quality. Increase sampling times to include summer low flows. Send more samples to ALS, and have them utilize different tests that will detect metals to guideline amounts for Antimony, Arsenic, Cadmium, Chromium, Copper, Lead, Selenium, Silver, Thallium, and Vanadium.

8.0 References

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Appendix 1

Site 1: Benson Creek at Biggs Road

Photo 1 - Downstream view of Site 1 on Benson Creek near Biggs Rd on October 22, 2012.

Photo 2 - Upstream view of Site 1 on Benson Creek near Biggs Rd on October 22, 2012.

Appendix 2

Site 2: Millstone River at Biggs Rd. crossing

Photo 3 - Downstream view Site 2 on the Millstone River at the Biggs Rd. bridge on October 22, 2012.

Photo 4 - Upstream view of Site 2 on the Millstone River at Biggs Rd. bridge on October 22, 2012.

Appendix 3

Site 3: Millstone River at Durnin Rd. crossing

Photo 5 - Downstream view of Site 3 on the Millstone River at Durnin Rd on October 22, 2012.

Photo 6 - Upstream view of Site 3 on the Millstone River at Durnin Rd on October 22, 2012.

Appendix 4

Site 4. Millstone River at Pryde Vista Golf Course.

Photo 7 - The upstream channel Millstone River located at site 4 in Nanaimo British Columbia on October 20, 2012.

Photo 8 - The downstream channel Millstone River located at site 4 in Nanaimo British Columbia October 20, 2012.

Appendix 5

Site 5. Millstone River at Bowen Park Bypass channel.

Photo 9 - The downstream channel of the Millstone River located at site 5 in Nanaimo British Columbia on October 20, 2012.

Appendix 6

Site 6. Millstone River at Barsby Park.

Photo 10 - The downstream channel of the Millstone River located at site 6 in Nanaimo British Columbia on October 20, 2012.

Photo 11 - The upstream channel of the Millstone River located at site 6 in Nanaimo British Columbia on October 20, 2012.

Appendix 7

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: 29-Oct-12	
Station Name: Station #1		Flow status: Medium Flow	
Sampler Used:	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 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 9	EPT4 1
	Mayfly Nymph (EPT)	EPT2 8	EPT5 1
	Stonefly Nymph (EPT)	EPT3 22	EPT6 2
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny	1	1
Sub-Total		C1 40	D1 5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	4	1
	Cranefly Larva	2	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva	1	1
	Fishfly Larva		
	Amphipod (freshwater shrimp)	2	1
	Watersnipe Larva		
Sub-Total		C2 9	D2 4
Category 3	Aquatic Worm (oligochaete)	63	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult	1	1
	Water Mite	2	1
Sub-Total		C3 66	D3 4
TOTAL		CT 115	DT 13

Appendix 7 (cont.)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1: 114

DENSITY: Invertebrate density per total area sampled:

S1 114 ÷ 0.27m² = S2: 422 / m²

PREDOMINANT TAXON:

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

S3: Aquatic Worm

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 5 + 2 x 4 + 4 =

S4: 27

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 1 + 3 = 5

S5: 5

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

(9 + 8 + 22) / 114 =

S6: 0.34

SECTION 3 - DIVERSITY

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

S7: 12

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

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

Col. C for S3 / CT

63 / 114 =

S8: 0.55

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 4
EPT Index	R2 3
EPT To Total Ratio	R3 2
Predominant Taxon Ratio	R4 3

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

Appendix 7 (cont.)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: 29-Oct-12	
Station Name: Station #2		Flow status: Medium Flow	
Sampler Used: Hess Sampler	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 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 343	EPT4 4
	Mayfly Nymph (EPT)	EPT2 1	EPT5 1
	Stonefly Nymph (EPT)	EPT3 3	EPT6 6
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 344	D1 5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	78	1
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva	5	1
	Fishfly Larva		
	Amphipod (freshwater shrimp)	19	1
	Watersnipe Larva		
Sub-Total		C2 102	D2 3
Category 3	Aquatic Worm (oligochaete)	42	1
	Blackfly Larva		
	Leech	2	1
	Midge Larva (chironomid)	3	2
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 50	D3 5
TOTAL		CT 496	DT 13

Appendix 7 (cont.)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1: 496

DENSITY: Invertebrate density per total area sampled:

496 ÷ 0.27 m^2 =

S2: 1837.04 / m^2

PREDOMINANT TAXON:

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

S3: Caddisfly Larva

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 5 + 2 x 3 + 5 =

S4: 26

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

4 + 1 + 0 =

S5: 5

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

(343 + 1 + 0) / 496 =

S6: 0.69

SECTION 3 - DIVERSITY

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

S7: 13

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

343 / 496 =

S8: 0.69

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 4
EPT Index	R2 3
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 2

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

Appendix 7 (cont.)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Millstone River	Date:	29-Oct-12
Station Name:	Station #5	Flow status:	Medium Flow
Sampler Used: Hess Sampler	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates	0.27 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 37	EPT4 2
	Mayfly Nymph (EPT)	EPT2 61	EPT5 2
	Stonefly Nymph (EPT)	EPT3 12	EPT6 2
	Dobsonfly (hellgrammite)	8	1
Pollution Intolerant	Gilled Snail	2	1
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 120	D1 8
Category 2	Alderfly Larva	1	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	7	1
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva	1	1
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	526	2
	Watersnipe Larva		
Sub-Total		C2 535	D2 5
Category 3	Aquatic Worm (oligochaete)	97	5
	Blackfly Larva	3	1
	Leech	4	1
	Midge Larva (chironomid)	38	4
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails	4	1
	True Bug Adult		
	Water Mite		
Sub-Total		C3 146	D3 12
TOTAL		CT 801	DT 25

Appendix 7 (cont.)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell CT: S1 801

DENSITY: Invertebrate density per total area sampled:

S3 801 ÷ 0.27 m^2 = S2 2967 / m^2

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

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 8 + 2 x 5 + 12 = S4 46

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

(37 + 61 + 12) / 801= S6 0.14

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell DT: S7 25

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

526 / 801 = S8 0.66

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 4
EPT Index	R2 3
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

Average Rating
Average of R4, R5, R6, R8
2.5

Appendix 8

Millstone River Station 1

Calculation Table for Shannon-Weiner Diversity Index:

Common Name	Column C	p_i (C/T)	ln(p_i)	p_i x ln(p_i)
Caddisfly Larva	9	0.08	-2.53	-0.2024
Mayfly Nymph	8	0.07	-2.66	-0.1862
Stonefly Nymph	22	0.19	-1.66	-0.3154
Water Penny	1	0.01	-4.61	-0.0461
Clam, Mussel	4	0.03	-3.51	-0.1053
Cranefly Larva	2	0.02	-3.91	-0.0782
Dragonfly Larva	1	0.01	-4.61	-0.0461
Amphipod	2	0.02	-3.51	-0.0782
Aquatic Worm	63	0.54	-0.62	-0.3348
True Bug Adult	1	0.01	-4.61	-0.0461
Water Mite	2	0.02	-3.51	-0.0782
	115	1.00	-35.74	-1.5170

$H = -\Sigma\ (p_i \times \ln p_i)\ /\ \ln S = -(-1.5170)\ /\ \ln(11) = 1.5170\ /\ 2.3979 = 0.63$

Millstone River Station 2

Calculation Table for Shannon-Weiner Diversity Index:

Common Name	Column C	p_i (C/T)	ln(p_i)	p_i x ln(p_i)
Caddisfly Larva	343	0.693	-0.37	-0.2564
Mayfly Nymph	1	0.002	-6.21	-0.0124
Stonefly Nymph	3	0.006	-5.12	-0.0307
Clam, Mussel	78	0.158	-1.85	-0.2923
Dragonfly Larva	5	0.011	-4.51	-0.0496
Amphipod	19	0.038	-3.27	-0.1243
Aquatic Worm	42	0.086	-2.45	-0.2107
Midge Larva (chrionomid)	3	0.006	-5.12	-0.0307
	496	1.00	-28.90	-1.0071

$H = -\Sigma\ (p_i \times \ln p_i)\ /\ \ln S = -(-1.0071)\ /\ \ln(8) = 1.0071\ /\ 2.0794 = 0.48$

Appendix 8 (cont.)

Millstone River Station 5

Calculation Table for Shannon-Weiner Diversity Index:

Common Name	Column C	p_i (C/T)	ln(p_i)	p_i x ln(p_i)
Caddisfly Larva	37	.05	-3.00	-0.1500
Mayfly Nymph	61	.08	-2.53	-0.2024
Stonefly Nymph	12	.01	-4.61	-0.0461
Dobsonfly	8	.01	-4.61	-0.0461
Gilled Snail	2	.003	-5.81	-0.0174
Alderfly Larva	1	.001	-6.91	-0.0069
Clam/Mussel	7	.01	-4.61	-0.0461
Damselfly Larva	1	.001	-6.91	-0.0069
Amphipod	526	.65	-0.43	-0.2795
Aquatic Worm	97	.12	-2.12	-0.2544
Blackfly Larva	3	.005	-5.30	-0.0265
Leech	4	.005	-5.30	-0.0265
Midge Larva	38	.05	-3.00	-0.1500
Pond Snails	4	.005	-5.30	-0.0265
	801	1.00	-	-1.2922

$H = -\Sigma (p_i \times \ln p_i) / \ln S = -(-1.2922) / \ln(14) = 1.2922 / 2.6391 = 0.49$

Appendix 9

ALS Results, First Sampling Event October 29, 2012							
Project			ENVIRONMENTAL MONITORING COURSE				
Report To			John Morgan, VIU				
ALS File No.			L1233439				
Date Received			05-Nov-12 13:05				
Date			15-Nov-12				
RESULTS OF ANALYSIS							
Sample ID					MILLSTONE STN. #1	MILLSTONE STN. #2	MILLSTONE STN. #5
Date Sampled					29-OCT-12	29-OCT-12	29-OCT-12
Time Sampled					12:33	11:45	09:53
ALS Sample ID					L1233439-1	L1233439-2	L1233439-3
Matrix					Water	Water	Water
	BC Water Quality Guidelines BC Max mg/L	**BC Water Quality Guidelines BC 30-day Mean mg/L**	**UNITS**	**DETECTION LIMIT**			
Physical Tests							
Conductivity			**µS/cm**	02.0	32.2	71.2	118
Hardness (as CaCO3)			**mg/L**	0.50	13.1	29.7	41.4
pH	6.5 -90		**pH**	0.10	7.25	7.59	7.71
Anions and Nutrients							
Ammonia, Total (as N)	5.81(b)	1.12	**mg/L**	0.0050	<0.0050	<0.0050	0.0066
Nitrate (as N)	31.3	3	**mg/L**	0.0050	0.369	0.0094	0.220
Nitrite (as N)	0.06(c)	0.02	**mg/L**	0.0010	<0.0010	<0.0010	0.0015
Orthophosphate-Dissolved (as P)			**mg/L**	0.0010	<0.0010	<0.0010	0.0019
Phosphorus (P)-Total			**mg/L**	0.0020	0.0076	0.0143	0.0355
			mg/L				
Total Metals			**mg/L**				
Aluminum (Al)-Total	.01(d)	0.05	**mg/L**	0.20	<0.20	<0.20	0.45
Antimony (Sb)-Total	0.02		**mg/L**	0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.005		**mg/L**	0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	5	1	**mg/L**	0.010	<0.010	<0.010	0.020
Beryllium (Be)-Total	0.0053		**mg/L**	0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total			**mg/L**	0.20	<0.20	<0.20	<0.20
Boron (B)-Total	1.2		**mg/L**	0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.00001(e)		**mg/L**	0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total			**mg/L**	0.050	3.62	7.90	11.7
Chromium (Cr)-Total	0.001(f)		**mg/L**	0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.11	0.004	**mg/L**	0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.004(g)	0.002	**mg/L**	0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	1		**mg/L**	0.030	0.069	0.072	0.731
Lead (Pb)-Total	0.015(h)	0.004	**mg/L**	0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.87	0.096	**mg/L**	0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total			**mg/L**	0.10	0.99	2.43	2.95
Manganese (Mn)-Total	0.83(i)	0.72	**mg/L**	0.0050	<0.0050	0.0109	0.0640
Molybdenum (Mo)-Total	2	1	**mg/L**	0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.025(j)		**mg/L**	0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total			**mg/L**	0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	373		**mg/L**	2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total		0.002	**mg/L**	0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total			**mg/L**	0.050	3.07	2.95	3.59
Silver (Ag)-Total	0.0001(k)	0.00005	**mg/L**	0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total			**mg/L**	2.0	<2.0	3.7	9.0
Strontium (Sr)-Total			**mg/L**	0.0050	0.0145	0.0316	0.0886
Thallium (Tl)-Total	0.0003		**mg/L**	0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total			**mg/L**	0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	2		**mg/L**	0.010	<0.010	<0.010	0.025
Vanadium (V)-Total	0.006		**mg/L**	0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.033(l)	0.0075	**mg/L**	0.0050	<0.0050	<0.0050	0.0052

Appendix 9 (cont.)

ALS Results, Second Sampling Event November 19, 2012							
Project			ENVIRONMENTAAL MONITORING COURSE				
Report To			John Morgan, Vancouver Island University				
ALS File No.			L1241956				
Date Received			26-Nov-12 10:45				
Date			05-Dec-12				
RESULTS OF ANALYSIS							
Sample ID					MILLSTONE STN. #1	MILLSTONE STN. #2	MILLSTONE STN. #5
Date Sampled					19-NOV-12	19-NOV-12	19-NOV-12
Time Sampled					12:33	11:45	09:53
ALS Sample ID					L1241956-13	L1241956-14	L1241956-15
Matrix					Water	Water	Water
	BC Water Quality Guidelines BC Max mg/L	**BC Water Quality Guidelines BC 30-day Mean mg/L**	**UNITS**	**DETECTION LIMIT**			
Physical Tests							
Conductivity			**µS/cm**	02.0	25.5	62.2	74.7
Hardness (as CaCO3)			**mg/L**	0.50	11.0	24.8	26.0
pH	6.5 -90		**pH**	0.10	7.13	7.47	7.51
Anions and Nutrients							
Ammonia, Total (as N)	5.81(b)	1.12	**mg/L**	0.0050	<0.0050	0.0057	0.0078
Nitrate (as N)	31.3	3	**mg/L**	0.0050	0.148	0.0913	0.308
Nitrite (as N)	0.06(c)	0.02	**mg/L**	0.0010	<0.0010	<0.0010	<0.0010
Orthophosphate-Dissolved (as P)			**mg/L**	0.0010	<0.0010	0.0011	0.0036
Phosphorus (P)-Total			**mg/L**	0.0020	0.0119	0.0092	0.0294
			mg/L				
Total Metals			**mg/L**				
Aluminum (Al)-Total	.01(d)	0.05	**mg/L**	0.20	0.45	<0.20	0.60
Antimony (Sb)-Total	0.02		**mg/L**	0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.005		**mg/L**	0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	5	1	**mg/L**	0.010	<0.010	<0.010	0.014
Beryllium (Be)-Total	0.0053		**mg/L**	0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total			**mg/L**	0.20	<0.20	<0.20	<0.20
Boron (B)-Total	1.2		**mg/L**	0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.00001(e)		**mg/L**	0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total			**mg/L**	0.050	2.97	6.70	7.14
Chromium (Cr)-Total	0.001(f)		**mg/L**	0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.11	0.004	**mg/L**	0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.004(g)	0.002	**mg/L**	0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	1		**mg/L**	0.030	0.474	0.149	0.787
Lead (Pb)-Total	0.015(h)	0.004	**mg/L**	0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.87	0.096	**mg/L**	0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total			**mg/L**	0.10	0.87	1.95	1.99
Manganese (Mn)-Total	0.83(i)	0.72	**mg/L**	0.0050	0.0088	0.0189	0.0439
Molybdenum (Mo)-Total	2	1	**mg/L**	0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.025(j)		**mg/L**	0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total			**mg/L**	0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	373		**mg/L**	2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total		0.002	**mg/L**	0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total			**mg/L**	0.050	3.41	3.22	4.00
Silver (Ag)-Total	0.0001(k)	0.00005	**mg/L**	0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total			**mg/L**	2.0	<2.0	2.9	5.3
Strontium (Sr)-Total			**mg/L**	0.0050	0.0117	0.0263	0.0433
Thallium (Tl)-Total	0.0003		**mg/L**	0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total			**mg/L**	0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	2		**mg/L**	0.010	0.023	<0.010	0.031
Vanadium (V)-Total	0.006		**mg/L**	0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.033(l)	0.0075	**mg/L**	0.0050	<0.0050	<0.0050	<0.0050