DATA REPORT

Water Quality and Stream Invertebrate Assessment

for the Millstone River, Nanaimo, BC,

(Fall 2008)

Report prepared by:

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on the Millstone River, BC, during October-November 2008.

This study was undertaken by undergraduate students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU), offered as part of the Bachelor of Natural Resources Protection (Brandy Brooks, Matt Fuller, Leanne Isaac, Jill Patterson, Brandi Simmons and Lynsey Sobie). Students worked under the supervision of the course instructor, Dr. Eric Demers (Vancouver Island University). This report was compiled by Dr. Eric Demers based on student group reports.

VIU students contributed approximately 75 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 15 hours for project management and report compilation. Ms. Sarah Greenway provided 5 hours of laboratory support for this project.

Logistical support was provided by Fisheries and Oceans Canada (DFO). Funding for field expenses and analytical processing of water samples was provided by the BC Conservation Foundation, BC Living Rivers Trust Fund and Fisheries and Oceans Canada. ALS Laboratory (Vancouver, BC) provided reduced rates on their analytical services for this project.

2. Introduction

The Millstone River watershed encompasses an area of approximately 93 km^2 and is comprised of 26 km of streams, 16 tributaries and 8 lakes. The primary drainage network in the watershed consists of Benson Creek, Brannen Lake and the Millstone River. Benson Creek originates west of Mount Benson at Lucid Lake (elevation: 619 m), and flows in a northerly direction for approximately 12 km into Brannen Lake (elevation: 78 m). The Millstone River flows from Brannen Lake in a southeasterly direction for approximately 14 km to the Strait of Georgia at the Nanaimo Harbour.

During summer 2007, an 800-metre long bypass channel was constructed along the lower Millstone River in Bowen Park by the Nanaimo Fish and Game Protective Association, in partnership with Fisheries and Oceans Canada (DFO) and the City of Nanaimo. The bypass channel was built to provide anadromous salmonids with new spawning and juvenile rearing habitat, and access to the watershed above the Deadman Falls barrier in Bowen Park. Additional habitat restoration was conducted by DFO during 2008 to provide summer flow augmentation to the Millstone River and bypass channel.

A need was identified for continued monitoring of water and habitat quality of the Millstone River and bypass channel. Therefore, this report documents a water quality and stream invertebrate assessment conducted on the Millstone River during October-November 2008.

Specific objectives for this study of the Millstone River included:

- establish 10 water quality sampling stations;
- obtain field measurements of water quality at the 10 sampling stations during two sampling events (October, November 2008);
- obtain water samples from each sampling station during two sampling events (October, November 2008) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 6 sampling stations during one sampling event (October 2008) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted on Benson Creek and the Millstone River located in the City of Nanaimo, BC (Figure 1). Two groups of students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University (VIU) conducted all field sampling and laboratory analyses: one group (Matthew Fuller, Leanne Isaac and Brandi Simmons) was responsible for Benson Creek and the Millstone River upstream of the Nanaimo Parkway, while one group (Brandy Brooks, Jill Patterson and Lynsey Sobie) was responsible for the Millstone River downstream of the Nanaimo Parkway including the bypass channel.

3.1.1. Sampling Stations

Ten sampling stations were established on Benson Creek and the Millstone River, during October-November 2008 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of the Millstone River and to repeat sampling at stations previously used by VIU. Stations were numbered from upstream to downstream (Station 1 on Benson Creek; Stations 2-10 on the Millstone River). All stations were easily accessed via foot paths or road crossings. Station 1 was located on Benson Creek at a crossing on Biggs Road. Stations 2 and 3 were located on the Millstone River at crossings on Biggs Road and Jingle Pot Road, respectively. Station 4 was located 100 m downstream of Newfield Road crossing, at the McGarrigle Creek confluence. Station 5 and 6 were located at crossings on Westwood Road and Bowen Road, respectively. Stations 7-9 were located along the bypass channel (upstream entrance, midway and downstream outlet, respectively). Station 10 was located in Barsby Park, approximately 10 m upstream of the Millstone estuary. All stations consisted of shallow and gentle riffle sections.

3.1.2. Sampling Schedule

Field sampling was conducted on 27-28 October and 17-18 November 2008. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment. Table 2 lists the specific activities conducted at each station during each sampling event. Microbiology and stream invertebrate assessments were only completed during the October sampling event. Photographs showing site conditions during 27-28 October 2008 are included in Appendix 1.

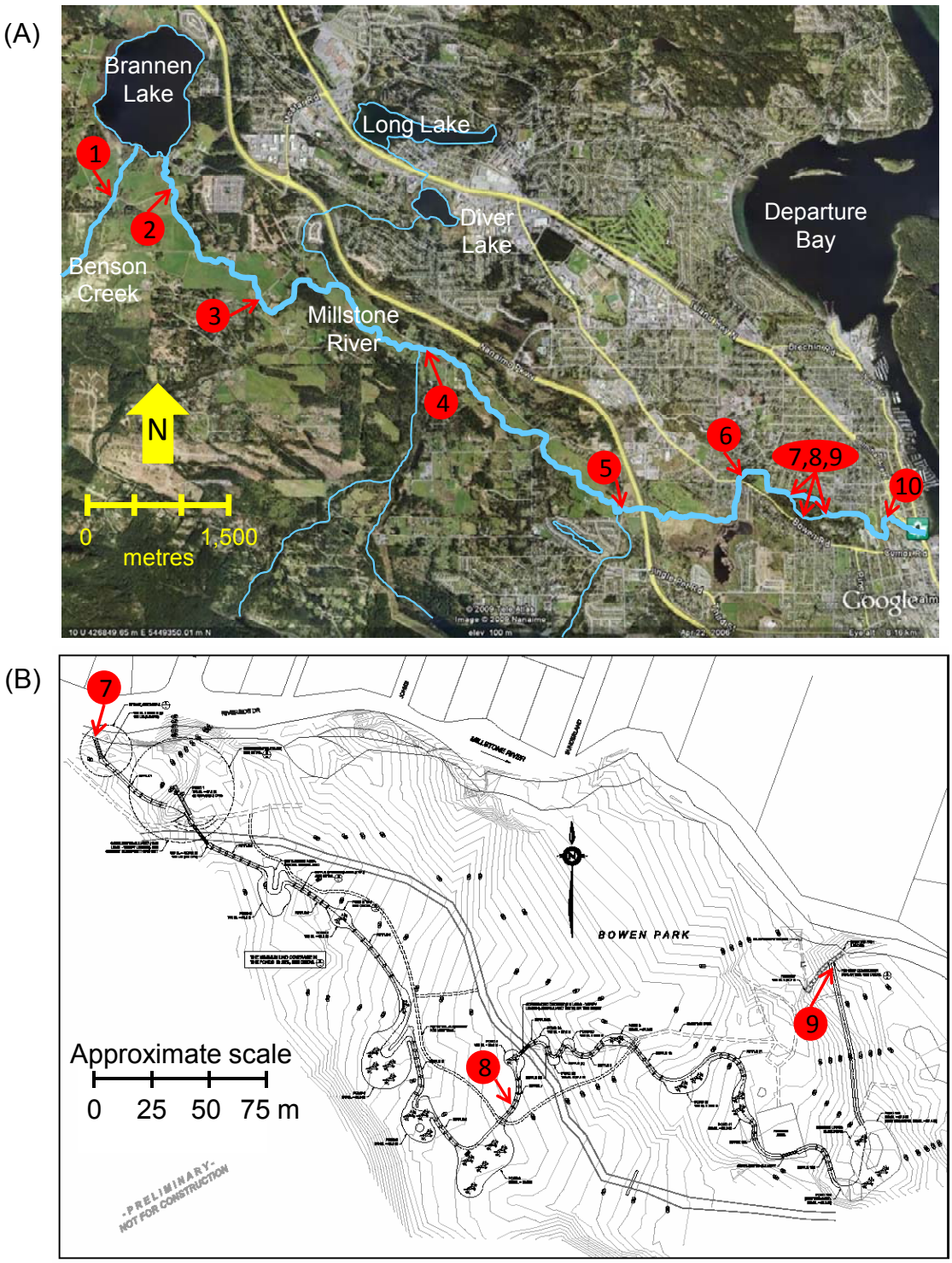

Figure 1. (A) Approximate location of the sampling stations used for water quality and stream invertebrate assessments on the Millstone River, during October-November 2008. Station 1 was located on Benson Creek. This map was obtained from Google Earth. (B) Approximate location of sampling stations 7-9 along the Millstone River Bypass Channel. This map was obtained from Fisheries and Oceans Canada. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. Map scales are approximated.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on the Millstone River, during October-November 2008. Station 1 was located on Benson Creek. All northing and easting coordinates are based on zone 10U and were approximated with Google Earth.

Station	UTM Coordinates		General Location
	Northing	Easting	
1	422736	5450704	Benson Creek, Biggs Road crossing
2	423348	5450814	Millstone River, Biggs Road crossing
3	424276	5449618	Jingle Pot Road crossing
4	426043	5449088	100 m downstream of Newfield Road crossing
5	428128	5447355	Westwood Road crossing
6	429365	5447653	Bowen Road crossing
7	429839	5447514	Bypass channel, upstream entrance
8	430047	5447279	Bypass channel, midway
9	430226	5447378	Bypass channel, downstream outlet
10	431035	5447202	Barsby Park, 10-m of estuary

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on the Millstone River, during October-November 2008. The symbols "O" or "N" indicate whether samples / measurements were taken during the October or November sampling events, respectively.

Station	Water Quality				Stream Invertebrates
	Field Measurements	VIU Analyses	ALS Lab Analyses	Microbiology	
1	O, N	O, N	O, N	O	O
2	O, N	O, N	O, N	O	O
3	O, N	O, N [1]	O, N	O	---
4	O, N	O, N	O, N	O	O
5	O, N	O, N	O [2], N	O	---
6	O, N	O, N	O, N	O	O
7	O, N	O, N	O, N	O	---
8	O, N	O, N	O, N	O	O
9	O, N	O, N	O, N	O	---
10	O, N	O, N	O, N [2]	O	O

Note: [1] A duplicate sample was collected at station 3 for analysis at the VIU Laboratory (November sampling event only).

[2] Duplicate samples were collected at station 5 (October sampling event) and station 10 (November sampling event) for analysis at the ALS Laboratory.

3.2. Water Quality

3.2.1. Field Measurements

Water quality sampling events were conducted on 27-28 October and 17-18 November 2008. At each sampling station, field measurements of water temperature (to the nearest 0.01 ^{o}C), dissolved oxygen (to the nearest 0.01 mg/L), conductivity (to the nearest 1 μSiemens/cm) and pH (to the nearest 0.01 pH unit) were obtained with a YSI 556 MPS electronic probe. The electronic probe was placed directly in the channel water.

3.2.2. Water Sampling

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

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

Table 3. Sampling containers and preservatives used for water quality samples taken from the Millstone River during October-November 2008. All containers and preservatives for analysis by ALS Laboratory were provided by ALS Laboratory, Vancouver, BC.

Analytical Parameters	Container	Preservative	Analysed by
Total hardness, total alkalinity, total suspended solids, reactive phosphorus, nitrate	500 ml plastic	None	VIU
Conductivity, pH, total hardness, total suspended solids	1 L plastic	None	ALS Laboratory
Anions, nutrients	250 ml amber glass	Sulphuric acid	ALS Laboratory
Total metals	250 ml plastic	Nitric acid	ALS Laboratory

Samples for analysis by ALS Laboratory were collected from all stations during both sampling events (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). Duplicate samples for analysis at the ALS Laboratory were collected at stations 5 and 10 during the October and November sampling events, respectively. All samples were obtained while standing on the stream bank or within the

stream channel by directly immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inversed five times for adequate mixing. All water samples were stored in a cooler on site, and shipped with ice packs within 72 hours for laboratory analyses at ALS Laboratory.

Quality control samples (trip blanks) were also included during both sampling events for analysis at the VIU Laboratory. Each trip blank was prepared at the VIU Laboratory and consisted of distilled water placed in a 500-ml plastic bottle. The trip blank bottle was transported to the sampling stations, but remained unopened.

3.2.3. VIU Laboratory Analyses

Water samples transported to Vancouver Island University were analysed for total hardness, total alkalinity, total suspended solids, reactive phosphorus and nitrate. Total hardness (as $CaCO_3$) was measured to the nearest 1 mg/L using a HACH HA-71A test kit. Total alkalinity (as $CaCO_3$) was measured to the nearest 0.1 mg/L using the HACH AL-DT digital titration method. Total suspended solids (TSS) were measured to the nearest 1 mg/L using a HACH DR2800 Spectrophotometer (Method 8006). Reactive phosphorus (orthophosphate) was measured to the nearest 0.01 mg/L using a HACH DR2800 Spectrophotometer (Method 8048). Nitrate was measured to the nearest 0.01 mg/L using a HACH DR2800 Spectrophotometer (Method 8192).

3.2.4. ALS Laboratory Analyses

Water samples submitted for external analyses were processed as per ALS Laboratory standard analytical procedures. The analytes were: conductivity, total hardness, pH, total suspended solids (TSS), six anions and nutrients, and total metals (31 metals).

3.2.5. Quality Assurance / Quality Control

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers. Duplicate sampling provided an estimate of the overall precision associated with the field technique and laboratory analysis. The inclusion of trip blanks provided means of detecting any widespread contamination resulting from the container (including caps).

3.2.6. Data Analyses – Comparison with Applicable Guidelines

Water quality results were compared with the applicable provincial and federal water quality guidelines for the protection of freshwater life. The BC Water Quality Guidelines are the maximum allowable concentration (for potential acute effects) and the 30-day average concentration (for potential chronic effects) (BCMWLAP 1998a, 1998b). The guidelines from the Canadian Council of Ministers of the Environment were also used for water quality comparisons (CCME 2003). Both sets of guidelines were applicable to all sampling stations.

It is important to note that for some metal parameters, analytical detection limits were above applicable guidelines. These include aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, thallium and vanadium. For these metals, measured values reported to be below method detection limits cannot be assumed to be below the applicable guidelines.

3.3. Microbiology

3.3.1. Field Sampling

Water samples for total and fecal coliform enumeration were collected from each sampling station on 27-28 October 2008 (Table 2). At each station, a sterile pre-labelled 120-ml Whirl-Pak® bag was used to collect a 100-ml water sample by directly immersing the bag by hand just below the water surface while facing upstream. All samples were stored in a cooler with ice packs and transported within 48 hours to Vancouver Island University for laboratory analysis.

3.3.2. Laboratory Analyses

In the laboratory, water samples were tested for total coliform and fecal coliform (*Escherichia coli* or *E. coli*) using the m-coliBlue24 membrane filtration method (Millipore Corporation). A 10-ml volume of sample water was extracted from each sample bag with a sterile pipette and filtered through a 47-µm membrane filter (marked with 3-mm gridlines) using a vacuum pump. The filtration apparatus was then rinsed with approximately 5 ml of sterile water. A filtration blank was also completed with 10 ml of sterile water using the same filtration procedures. Each membrane filter (including the blank) was then transferred to a Petri plate containing an absorbent pad saturated with m-ColiBlue24 broth. All membrane filters were incubated at 37°C for 20 hours (until bacterial colonies were clearly visible).

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

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

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

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

3.4. Stream Invertebrates

3.4.1. Sampling Stations

Stream invertebrate samples were collected from stations 1, 2, 4, 6, 8 and 10 on 27-28 October 2008 (Table 1; Figure 1). The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples, safety and site access. At the time of sampling, all stations consisted of shallow riffles (water depth ~10-25 cm), with water velocity of ~0.5-1.0 m/s, and primarily sand and gravel substrate.

3.4.2. Invertebrate Sampling

At each station, three replicate samples (triplicates) were obtained using a Hess sampler (stations 1, 2 and 4) or Surber sampler (stations 6, 8 and 10) as per the Pacific Streamkeepers procedures (Taccogna and Munro 1995). Each site was approached by walking from downstream. The invertebrate sampler was hand-pressed into the substrate to isolate a 0.09-m^2 sampling area. All stones and debris 5 cm or larger within the sampling area were held under water in front of the collecting net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the collecting net was then transferred into a 125-ml plastic sample jar. The net was carefully inspected to ensure all contents were transferred into the sample jar. Samples were stored in a cooler and transported to Vancouver Island University, where laboratory analyses were completed within 48 hours of sampling.

3.4.3. VIU Laboratory Analyses

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

4. Results

Although no discharge measurements were collected during this study, field observations suggested that water levels in Benson Creek and the Millstone River were not at bankfull at the time of sampling.

During this sampling program, weather conditions were sunny with clouds, no precipitation and air temperature of 7-9°C. Average air temperature during the 10-day period prior to each sampling event was 8.0°C for the October event and 9.2°C for the November event (data for Victoria Airport retrieved from http://www.theweathernetwork.com). Total rainfall during the 10-day period prior to each sampling event was 2.0 mm for the October event and 20 mm for the November event.

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 8.8°C during both sampling events (Table 5). Water temperature was generally 1-2°C lower in Benson Creek than in the Millstone River owing to differences in elevations drained and differential heating/cooling. During both sampling events, all dissolved oxygen levels were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998), except for station 5 during November where dissolved oxygen was 8.44 mg/L. Dissolved oxygen concentrations were higher at all stations during the October sampling event. Overall, dissolved oxygen concentrations were at 72-108% saturation.

Conductivity ranged from 38 to 109 µS/cm and increased as expected from upstream to downstream (i.e., from station 1 to 10) (Table 5). Conductivity differed by <4% within station between the October and November sampling events, except for station 1 where conductivity was much lower during November. Water pH ranged from 6.76 to 7.96 during this study. There was a general increasing trend in pH from upstream to downstream during both sampling events, except at middle stations (stations 5-6 in October, stations 4-5 in November) where higher pH values were recorded.

During both sampling events, total hardness and total alkalinity generally increased from upstream to downstream stations (Table 6). Overall, total alkalinity was above 20 mg/L during both sampling events (except for station 1 during November), indicating "low acid sensitivity" as defined by RISC (1998). Total hardness was below 60 mg/L during both sampling events, indicating "soft water" as defined by RISC (1998).

Levels of total suspended solids (TSS) were relatively low during both sampling events (range: 1-8 mg/L), averaging 2.2 and 4.0 mg/L during the October and November sampling events, respectively (Table 6).

Reactive phosphorus results were highly variable, with unusually high values for stations 1-5 during the November sampling event (Table 6). This anomaly, combined with the elevated results obtained for the field blank which was analysed simultaneously, suggests inadequate laboratory processing and/or contamination for these samples. The remaining reactive phosphorus measurements ranged from 0.04 to 0.21 mg/L, and there was no apparent spatial or temporal trends.

Table 5. Field measurements taken from ten stations on the Millstone River during October and November 2008.

Station	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH
		27-28 October 2008		
1	6.15	13.09	65	7.15
2	10.61	11.01	73	7.14
3	9.55	11.05	75	6.99
4	9.03	11.05	87	7.03
5	7.89	11.05	99	7.96
6	8.93	10.63	104	7.56
7	8.99	11.52	106	7.31
8	8.92	12.03	107	7.19
9	8.86	12.53	107	7.25
10	9.01	12.36	109	7.39
		17-18 November 2008		
1	7.27	11.13	38	6.76
2	9.04	9.46	71	6.79
3	8.83	9.71	74	6.81
4	8.76	9.24	89	7.21
5	8.66	8.44	97	7.43
6	9.00	9.40	101	7.09
7	9.02	10.81	103	7.19
8	9.03	10.92	104	7.33
9	9.09	11.04	105	7.40
10	9.12	11.23	105	7.58

Nitrate concentrations were higher during the November sampling event at all stations, except stations 1 and 6 (Table 6). During the October sampling event, nitrate levels ranged from 0.02 to 0.07 mg/L in the Millstone River (stations 2-10), but were higher at station 1 in Benson Creek (0.61 mg/L). The elevated nitrate levels in Benson Creek were also observed with the ALS Laboratory results (see below). In addition, similar high nitrate levels have been observed repeatedly at this location during other water quality monitoring projects (E. Demers, unpublished data; 2004-2007). During the November sampling event, nitrate levels ranged from 0.05 to 0.24 mg/L.

Table 6. Laboratory results for water samples taken from ten stations on the Millstone River during October and November 2008. Duplicate samples (samples A and B) were obtained from Station 3 during the November sampling event. Trip blank samples were not analysed for total hardness, total alkalinity and total suspended solids (shown as "N/A").

Station	Total Hardness (mg/L $CaCO_3$)	Total Alkalinity (mg/L $CaCO_3$)	Total Suspended Solids (mg/L)	Reactive Phosphorus (mg/L)	Nitrate (mg/L)
		27-28 October 2008			
1	20	22.0	1	0.15	0.61
2	25	23.4	3	0.06	0.04
3	27	24.3	2	0.06	0.04
4	34	28.9	1	0.04	0.02
5	36	34.2	1	0.07	0.02
6	30	33.2	2	0.04	0.07
7	35	38.0	3	0.12	0.05
8	33	33.2	3	0.11	0.04
9	35	38.8	5	0.11	0.06
10	34	35.6	1	0.21	0.03
Field Blank	N/A	N/A	N/A	0.13	0.06
		17-18 November 2008			
1	25	15.6	3	5.82	0.13
2	26	23.7	4	2.44	0.13
3 (Sample A)	29	21.8	4	5.58	0.11
3 (Sample B)	30	22.0	4	2.76	0.13
4	36	27.1	5	5.82	0.18
5	37	28.4	5	2.80	0.24
6	30	34.0	8	0.19	0.05
7	32	34.4	2	0.13	0.14
8	31	33.6	2	0.07	0.11
9	28	34.4	5	0.07	0.14
10	30	35.2	2	0.08	0.12
Field Blank	N/A	N/A	N/A	4.07	0.20

A comparison of the water quality results from the duplicate samples taken during the November sampling event indicates that most values were within ±17% of each other (Table 6). The only exception was the reactive phosphorus concentration, which differed by 68%. Results for trip

blank samples were within the range of measurements observed for reactive phosphorus and nitrate (instead of near detection limits), suggesting that either these analytes were present in the distilled water used or some contamination occurred during laboratory processing (especially for reactive phosphorus).

4.1.2. ALS Laboratory Analyses

Water quality results from ALS Laboratories were compared to the BC Provincial water quality guidelines and the federal CCME guidelines for the protection of aquatic life (Table 7).

The conductivity measurements from ALS Laboratories were consistent with the field measurements obtained with the electronic probe during both sampling events and differed by <9%. During both sampling events, conductivity increased from upstream to downstream stations.

Similarly, trends in total hardness measurements from ALS Laboratories were generally consistent with the VIU laboratory results, although ALS Laboratories results were generally less variable among stations.

All total suspended solids (TSS) results were below detection limits (<3.0 mg/L) during both sampling events, except for stations 5 and 9 during the October sampling event and stations 9 and 10 during the November sampling event.

The pH measurements from ALS Laboratories were less variable (7.26-7.86) than field measurements obtained with the electronic probe. Field measurements of pH were generally lower than the ALS Laboratories results. This discrepancy possibly reflects improper probe calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis. Measurements for the November sampling event were on average 0.3 pH units higher than for the October sampling event.

All anion levels were well below applicable guidelines. Nitrate levels from ALS Laboratories were slightly lower than the VIU laboratory results, although in both cases overall levels and trends were consistent.

During the October sampling event, total metal concentrations were below the applicable water quality guidelines except at stations 5 and 9. At stations 5 and 9, aluminim and iron concentrations exceeded the applicable water quality guidelines, and zinc also exceeded the applicable water quality guidelines at station 9. During the November sampling event, total metal concentrations were below the applicable water quality guidelines except at stations 7 and 9. The zinc concentration exceeded the applicable water quality guidelines at station 7, and aluminum and iron concentrations exceeded the applicable water quality guidelines at station 9. Station 9 was the only station at which exceedances were observed during both sampling events.

Table 7. Laboratory results (ALS Laboratory) for water samples taken from 10 stations on the Millstone River during 27-28 October and 17-18 November 2008. Duplicate samples are identified with letters (A,B). All values are expressed in mg/L unless specified otherwise. The values enclosed in boxes exceeded at least one of the applicable water quality guidelines. See additional notes on the next page.

	BC Water Quality Guidelines [a]			27-28 October 2008										
	BC Max	BC 30-day Mean	CCME [b]											
Variable	mg/L	mg/L	mg/L	1	2	3	4	5A	5B	6	7	8	9	10
General/Physical														
Conductivity (µS/cm)				65.4	72.6	73.8	87.1	96.5	97.1	109	112	114	116	115
Hardness, Total				25.0	27.6	27.9	32.1	33.1	32.8	36.7	37.8	37.5	37.4	37.7
pH (pH units)	6.5 - 9.0		6.5 - 9.0	7.49	7.26	7.56	7.33	7.32	7.33	7.36	7.45	7.46	7.48	7.54
Total Suspended Solids				<3.0	<3.0	<3.0	<3.0	10.20	4.90	<3.0	<3.0	<3.0	6.20	<3.0
Nutrients														
Bromide (Br)				<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	600	150		2.63	5.05	5.12	6	7.3	7.3	8.97	9.29	9.67	10.1	10.1
Fluoride (F)	0.2 [c]			<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.021	0.02	0.021	0.022	0.021
Nitrate (as N)	200	40	13	0.26	<0.0050	<0.0050	0.01	<0.0050	<0.0050	0.01	0.01	0.01	0.01	0.01
Nitrite (as N)	0.06 [d]	0.02 [d]	0.06	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0014
Sulfate (SO_4)	100			6.23	4.53	4.63	5.2	5.5	5.5	5.7	5.8	5.8	5.8	5.9
Total Metals														
Aluminum (Al) [n]	0.10 [e]	0.05 [e]	0.10 [e]	<0.20	<0.20	<0.20	<0.20	0.5	<0.20	<0.20	<0.20	<0.20	0.22	<0.20
Antimony (Sb) [n]	0.02			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [n]	0.005			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1		<0.010	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	<0.010	0.011	0.016	<0.010
Berylium (Be)	0.0053			<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)				<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [n]	0.00001 [f]		0.00001 [f]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)				7.0	7.4	7.5	8.7	8.9	9.0	10.2	10.4	10.4	10.3	10.5
Chromium (Cr) [n]	0.001 [g]		0.001 [g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [n]	0.11	0.004		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [n]	0.003 [h]	0.002 [h]	0.002 [h]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	0.3		0.3	<0.030	0.094	0.119	0.152	0.914	0.438	0.238	0.188	0.253	0.383	0.188
Lead (Pb) [n]	0.007 [i]	0.004 [i]	0.001 [i]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)				1.9	2.2	2.3	2.5	2.6	2.5	2.8	2.8	2.8	2.8	2.8
Manganese (Mn)	0.71 [j]	0.67 [j]		<0.0050	0.017	0.009	0.010	0.102	0.043	0.018	0.015	0.027	0.033	0.012
Molybdenum (Mo)	2	1	0.073	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [n]	0.025 [k]		0.025 [k]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)				<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [n]		0.002	0.001	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)				3.63	2.72	2.77	2.93	3.33	2.97	2.92	3.00	2.95	3.04	2.87
Silver (Ag) [n]	0.0001 [l]	0.00005 [l]	0.0001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)				2.8	3.6	3.7	4.7	6.0	6.0	7.4	7.5	7.8	7.8	7.9
Strontium (Sr)				0.025	0.027	0.027	0.052	0.058	0.057	0.064	0.065	0.066	0.067	0.066
Thallium (Tl)	0.0003	0.0008		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)				<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2			<0.010	<0.010	<0.010	<0.010	0.027	0.011	<0.010	<0.010	<0.010	0.013	<0.010
Vanadium (V) [n]	0.006	0.02		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [m]	0.0075 [m]		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.010	<0.0050

Table 7. Laboratory results (ALS Laboratory) for water samples taken from 10 stations on the Millstone River during 27-28 October and 17-18 November 2008. Duplicate samples are identified with letters (A,B). All values are expressed in mg/L unless specified otherwise. The values enclosed in boxes exceeded at least one of the applicable water quality guidelines. See additional notes on the next page.

	BC Water Quality Guidelines [a]			17-18 November 2008										
	BC Max	BC 30-day Mean	CCME [b]											
Variable	mg/L	mg/L	mg/L	1	2	3	4	5	6	7	8	9	10A	10B
General/Physical														
Conductivity (µS/cm)				38.4	71.4	74.4	90.2	98.4	102	103	105	106	106	106
Hardness, Total				15.0	27.0	27.7	32.9	33.3	34.7	35.6	35.5	35.9	35.7	35.9
pH (pH units)	6.5 - 9.0		6.5 - 9.0	7.37	7.62	7.64	7.74	7.76	7.75	7.77	7.80	7.82	7.85	7.86
Total Suspended Solids				<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	4.60	4.60	3.30
Nutrients														
Bromide (Br)				<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	600	150		1.52	4.49	4.74	6.06	7.18	7.73	7.96	8.18	8.36	8.31	8.32
Fluoride (F)	0.2 [c]			<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Nitrate (as N)	200	40	13	0.15	0.05	0.06	0.11	0.13	0.13	0.14	0.14	0.14	0.15	0.15
Nitrite (as N)	0.06 [d]	0.02 [d]	0.06	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Sulfate (SO_4)	100			2.68	4.28	4.51	5.2	5.2	5.5	5.6	5.6	5.6	5.6	5.6
Total Metals														
Aluminum (Al) [n]	0.10 [e]	0.05 [e]	0.10 [e]	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.24	<0.20	<0.20
Antimony (Sb) [n]	0.02			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As) [n]	0.005			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)	5	1		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	0.016	<0.010	<0.010
Berylium (Be)	0.0053			<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)				<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [n]	0.00001 [f]		0.00001 [f]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)				4.2	7.2	7.4	9.0	9.1	9.7	9.9	9.9	10.0	10.0	10.0
Chromium (Cr) [n]	0.001 [g]		0.001 [g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co) [n]	0.11	0.004		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu) [n]	0.003 [h]	0.002 [h]	0.002 [h]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)	0.3		0.3	<0.030	0.104	0.195	0.180	0.225	0.214	0.268	0.259	0.392	0.266	0.282
Lead (Pb) [n]	0.007 [i]	0.004 [i]	0.001 [i]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)				1.1	2.2	2.3	2.5	2.6	2.5	2.6	2.6	2.7	2.6	2.6
Manganese (Mn)	0.71 [j]	0.67 [j]		<0.0050	0.017	0.020	0.017	0.018	0.019	0.025	0.027	0.036	0.024	0.024
Molybdenum (Mo)	2	1	0.073	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni) [n]	0.025 [k]		0.025 [k]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)				<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [n]		0.002	0.001	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)				3.44	3.04	3.17	3.33	3.36	3.43	3.56	3.49	3.66	3.49	3.53
Silver (Ag) [n]	0.0001 [l]	0.00005 [l]	0.0001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)				<2.0	3.6	3.7	5.2	6.4	6.8	7.0	6.9	7.1	7.0	7.1
Strontium (Sr)				0.017	0.029	0.030	0.071	0.069	0.069	0.070	0.069	0.069	0.069	0.070
Thallium (Tl)	0.0003	0.0008		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)				<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010
Vanadium (V) [n]	0.006	0.02		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)	0.033 [m]	0.0075 [m]		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.009	<0.0050	0.007	<0.0050	<0.0050

Table 7. (Continued)

NOTES:

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

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

[b] Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines (WQGs) compiled from CCME (2003).

[c] Fluoride guideline is 0.2 mg/L for hardness < 50 mg/L.

[d] Nitrite guideline is dependent on chloride concentration. Guideline range shown is based on chloride concentration < 2 mg/L.

[e] Aluminum guidelines for pH ≥ 6.5.

[f] The BC maximum cadmium guideline is $0.001 * 10^{\{0.86\ [\log(\text{hardness})] - 3.2\}}$ mg/L. Guideline shown is based on hardness of 15-38 mg/L.

[g] Chromium guideline is for the more toxic Chromium VI. The guideline for Chromium VI is 0.0089 mg/L.

[h] The BC maximum copper guideline is 0.001 * [0.094(hardness) + 2] mg/L. The BC 30-day mean copper guideline is 0.002 µg/L for hardness < 50 mg/L. The CCME guideline for copper is 0.002 mg/L at hardness of 1-120 mg/L. Guidelines shown are based on hardness of 15-38 mg/L.

[i] The BC maximum lead guideline is $0.001 * e^{\{1.273\ [\ln(\text{hardness})] - 1.46\}}$ mg/L. The BC 30-day mean lead guideline is $0.001 * [3.31 + e^{\{1.273\ [\ln(\text{hardness})] - 4.704\}}]$ mg/L. The CCME guideline for lead is 0.001 mg/L for hardness of 0-60 mg/L. Guidelines shown are based on hardness of 15-38 mg/L.

[j] The BC maximum manganese guideline is 0.01102 * (hardness) + 0.54 mg/L. The BC 30-day mean manganese guideline is 0.0044 * (hardness) + 0.605 mg/L. Guidelines shown are based on hardness of 15-38 mg/L.

[k] Nickel guideline is 0.025 mg/L for hardness of 0-60 mg/L.

[l] The BC maximum silver guideline is 0.0001 mg/L for hardness ≤100 mg/L. The BC 30-day mean silver guidelines is 0.00005 mg/L for hardness ≤100 mg/L.

[m] The BC maximum zinc guideline is 0.033 mg/L for hardness ≤90 mg/L. The BC 30-day mean zinc guidelines is 0.0075 mg/L for hardness ≤90 mg/L.

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

It should be noted that the above metal exceedances occurred for samples with total suspended solids concentrations that were above minimum detection limits. Total metal analyses measure the combined amount of metals dissolved in water and bound to particles. In general, dissolved metals are more bio-available (hence toxicologically available) than metals that are bound to particles. It is unclear whether the observed elevated metals represented dissolved metals or metals bound to suspended particles.

A comparison of the water quality results from the duplicate samples taken during the October sampling event indicates that values were 0-84% of each other. Duplicate measurements for total suspended solids, iron, manganese and titanium differed by 70-84%, while values for other analytes differed by ≤11%. The variability in precision may be due to contamination during collection / analysis or variable environmental conditions. During the November sampling event, water quality results from the duplicate samples were within 6% of each other, except for total suspended solids, which differed by 33%.

4.2. Microbiology

All samples collected from the Millstone River contained some coliform bacteria (Table 8). Total coliform levels generally increased from upstream to downstream, with the highest levels observed at station 9 (4,800 CFU / 100 ml). The proportion of total coliform made up of *E. coli* bacteria was low at stations 1-5 (4-22%), but exceeded 50% at stations 6-10 (67-87%).

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

Table 8. Total coliform and *E. coli* counts from water samples taken at ten stations on the Millstone River during 27-28 October 2008. All values are expressed as CFU (colony forming units) per 100 ml. No microbiology samples were collected during 17-18 November 2008.

Station	Total Coliform	*E. coli*	% *E. coli*
1	240	10	4.2
2	230	50	21.7
3	1210	110	9.1
4	1950	250	12.8
5	2040	110	5.4
6	440	320	72.7
7	1280	1110	86.7
8	2820	1900	67.4
9	4800	3300	68.8
10	2490	1700	68.3
Filtration blank	0	0	---

4.3. Stream Invertebrates

A total of 1,023 stream invertebrates representing 13 broad taxonomic groups were counted at six stations on the Millstone River during 27-28 October 2008 (Table 9; Figure 2; Appendix 2). Animal density was generally consistent among stations, except at station 2 where density was at least 3 times higher than at the other stations. Aquatic worms (oligochaetes) were the most common taxonomic group at all stations, except station 8 where midge larvae were the dominant taxon.

Site assessment ratings ranged from 1.75 to 3.00 suggesting "acceptable" (stations 1, 2, 4, 6) to "marginal" (stations 8, 10) invertebrate community abundance and diversity. In general, site assessment ratings decreased from upstream to downstream. Similarly, the representation of pollution-sensitive mayfly nymphs, stonefly nymphs and caddisfly larvae (EPT taxa) decreased from upstream to downstream. Station 8, located in the bypass channel, had similar animal density compared to most other stations, suggesting adequate invertebrate colonization since channel construction in 2007.

Table 9. Abundance and density of stream invertebrates obtained from triplicate samples taken at six stations on the Millstone River during 27-28 October 2008. Overall site assessment ratings are also provided for each station (out of a maximum rating of 4.00). Invertebrate Survey Field Data Sheets are included in Appendix 2. No stream invertebrate samples were collected on 17-18 November 2008.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 2	Station 4	Station 6	Station 8	Station 10
Category 1 Pollution Intolerant	Caddisfly larva	12	174	8	0	0	0
	Mayfly nymph	8	1	30	3	2	1
	Stonefly nymph	10	2	2	26	12	3
Category 2 Somewhat Pollution Intolerant	Clam, Mussel	2	17	2	2	0	1
	Cranefly Larva	2	1	4	0	0	0
	Crayfish	0	0	1	0	0	0
	Damselfly Larva	0	0	1	0	0	1
	Dragonfly Larva	0	0	0	2	0	0
	Scud (amphipod)	2	2	23	5	27	13
Category 3 Pollution Tolerant	Aquatic Worm (Oligochaete)	53	227	81	82	27	95
	Leech	0	2	0	0	0	0
	Midge larva (Chironomid)	1	0	2	0	46	1
	Water mite	2	0	0	1	0	1
	Total Abundance	92	426	154	121	114	116
	Density (number / m^2)	341	1,578	570	448	422	430
	Site Assessment Rating	2.50	2.75	3.00	2.50	2.25	1.75

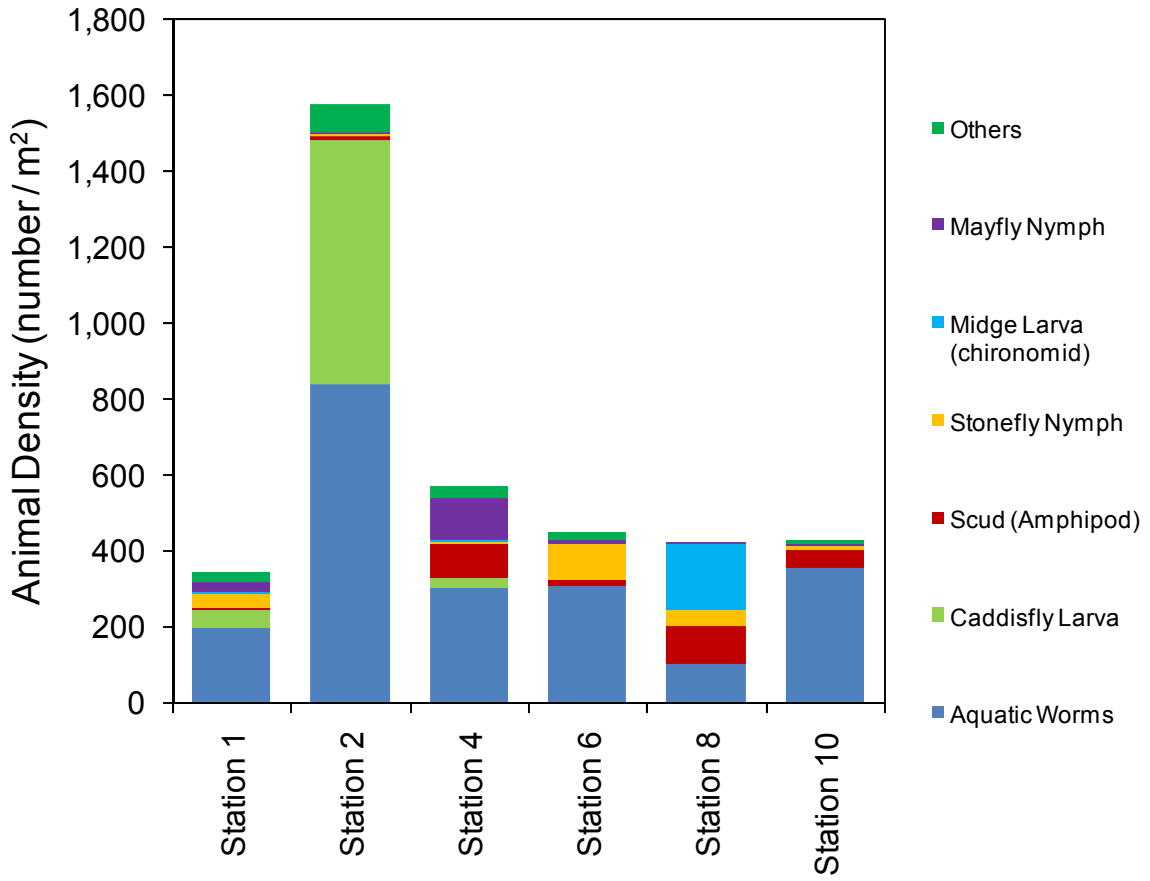

Figure 2. Density of stream invertebrates obtained from triplicate samples taken at six stations on the Millstone River during 27-28 October 2008. The "Other" category includes clam / mussel, cranefly larva, water mite, damselfly nymph, dragonfly nymph, leech and crayfish (in decreasing order of overall density). Data are summarized in Table 9 and Invertebrate Survey Field Data Sheets are included in Appendix 2.

5. Acknowledgements

The authors would like to acknowledge Margaret Wright and Mel Sheng (Fisheries and Oceans Canada) and James Craig (BC Conservation Foundation) for their continued support in facilitating this and other monitoring projects. Additional support was provided by students attending the Environmental Monitoring (RMOT 306) course at Vancouver Island University – Laura Brown, Luke Clarke, Melissa Colwell, Mya Cormie, Terry McDonald and Matt Rochetta. The Resource Management Officer Technology (RMOT) and Biology Departments at Vancouver Island University provided some laboratory supplies, equipment, vehicle and covered fuel expenses. The BC Living Rivers Trust Fund (administered by the BC Conservation Foundation) and Fisheries and Oceans Canada provided funding for analytical processing of water samples. ALS Laboratory provided reduced rates on some of their analytical services for this project and other projects conducted as part of the Environmental Monitoring course.

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7. Appendices

APPENDIX 1. Photographs showing site conditions at each sampling station on the Millstone River during 27-28 October 2008.

Photo 1. Benson Creek at the Biggs Road crossing (station 1).

Photo 2. Millstone River at the Biggs Road crossing (station 2).

APPENDIX 1. (Continued)

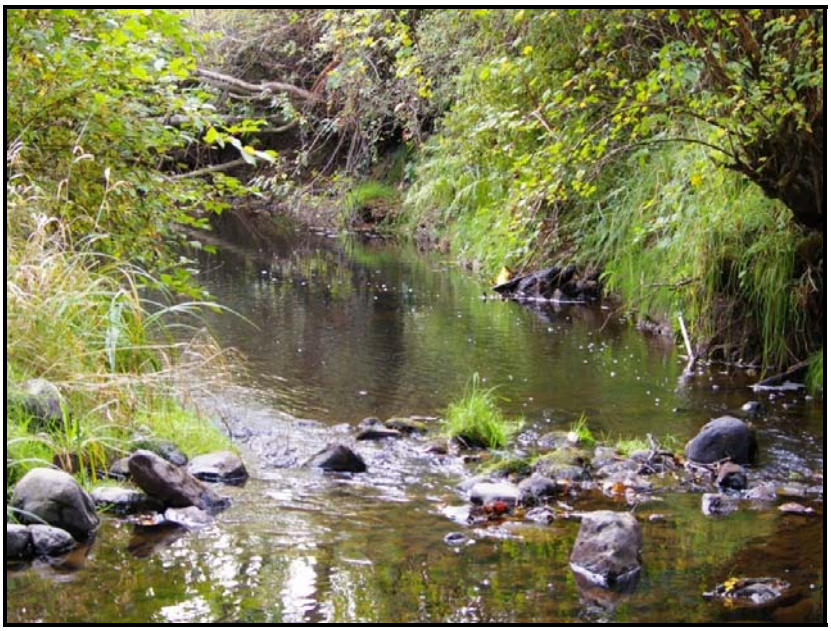

Photo 3. Millstone River at the Jingle Pot Road crossing (station 3).

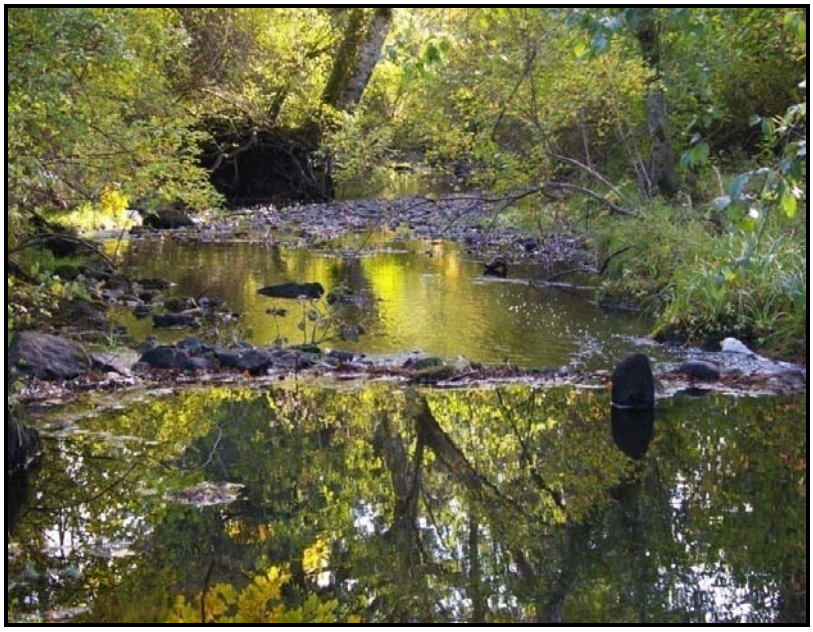

Photo 4. Millstone River approximately 100 m downstream of the Newfield Road crossing (station 4).

APPENDIX 1. (Continued)

Photo 5. Millstone River at the Westwood Road crossing (station 5).

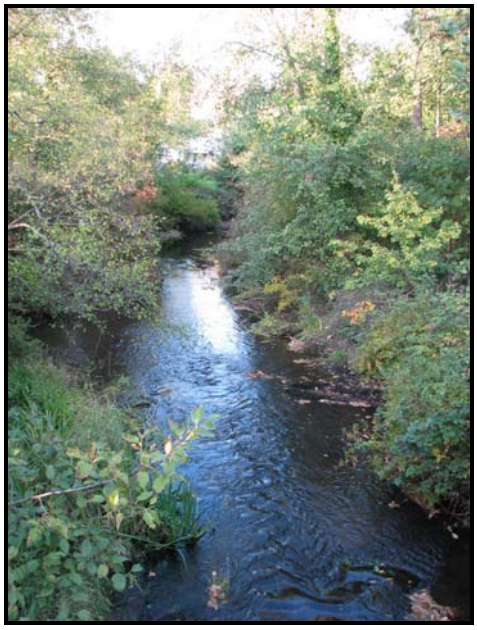

Photo 6. Millstone River at the Bowen Road crossing (station 6).

APPENDIX 1. (Continued)

Photo 7. Millstone River at the upstream entrance to the bypass channel (station 7).

Photo 8. Millstone Bypass Channel, approximately midway along the bypass channel (station 8).

APPENDIX 1. (Continued)

Photo 9. Downstream outlet of the Millstone Bypass Channel into the Millstone River (station 9).

Photo 10. Millstone River in Barsby Park, approximately 10 m upstream of the estuary (station 10).

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for triplicate stream invertebrate samples collected at Stations 1, 2, 4, 6, 8 and 10 on the Millstone River during 27-28 October 2008.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Benson Creek		Date: 28 October 2008
Station Name:	**Station 1**		Flow status: Low
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 0.27 m^2	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)	12	2
	Mayfly Nymph (EPT)	8	1
	Stonefly Nymph (EPT)	10	1
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		30	4
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	2	1
	Cranefly Larva	2	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	2	1
	Watersnipe Larva		
Sub-Total		6	3
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	53	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	1	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	1
Sub-Total		56	4
TOTAL		92	11

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 92

DENSITY: Invertebrate density per square metre:

92 ÷ 0.27 = 341

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 4 + 2 x 3 + 4 = 22

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

2 + 1 + 1 = 4

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(12 + 8 + 10) / 92 = 0.33

SECTION 3 - DIVERSITY

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

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

53 / 92 = 0.58

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	3
EPT Index	2
EPT To Total Ratio	2
Predominant Taxon Ratio	3

Average Rating
2.50

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Millstone River		Date:	28 October 2008
Station Name:	**Station 2**		Flow status:	Low
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Hess	3	0.09 x 3 =	0.27	m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)	174	2
	Mayfly Nymph (EPT)	1	1
	Stonefly Nymph (EPT)	2	1
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		177	4
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	17	2
	Cranefly Larva	1	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	2	1
	Watersnipe Larva		
Sub-Total		20	4
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	227	2
	Blackfly Larva		
	Leech	2	2
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		229	4
TOTAL		426	12

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 426

DENSITY: Invertebrate density per square metre:

426 ÷ 0.27 = 1578

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 4 + 2 x 4 + 4 = 24

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

2 + 1 + 1 = 4

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(174 + 1 + 2) / 426 = 0.42

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 12

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

227 / 426 = 0.53

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	2
EPT To Total Ratio	2
Predominant Taxon Ratio	3

Average Rating
2.75

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Millstone River		Date:	28 October 2008
Station Name:	**Station 4**		Flow status:	Low
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Hess	3	0.09 x 3 = 0.27 m^2		

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)	8	2
	Mayfly Nymph (EPT)	30	3
	Stonefly Nymph (EPT)	2	1
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		40	6
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	2	1
	Cranefly Larva	4	2
	Crayfish	1	1
	Damselfly Larva	1	1
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	23	2
	Watersnipe Larva		
Sub-Total		31	7
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	81	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	2	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		83	3
TOTAL		154	16

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 154

DENSITY: Invertebrate density per square metre:

154 ÷ 0.27 = 570

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 6 + 2 x 7 + 3 = 35

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

2 + 3 + 1 = 6

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(8 + 30 + 2) / 154 = 0.26

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 16

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

81 / 154 = 0.53

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	3
EPT To Total Ratio	2
Predominant Taxon Ratio	3

Average Rating
3.00

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Millstone River		Date:	27 October 2008
Station Name:	**Station 6**		Flow status:	Low
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates		
Surber	3	0.09 x 3 =	0.27	m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 **Pollution Intolerant**	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	3	2
	Stonefly Nymph (EPT)	26	4
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		29	6
Category 2 **Somewhat Pollution Tolerant**	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	2	1
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva	2	1
	Fishfly Larva		
	Scud (amphipod)	5	1
	Watersnipe Larva		
Sub-Total		9	3
Category 3 **Pollution Tolerant**	Aquatic Worm (oligochaete)	82	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	1	1
Sub-Total		83	4
TOTAL		121	13

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 121

DENSITY: Invertebrate density per square metre:

121 ÷ 0.27 = 448

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 6 + 2 x 3 + 4 = 28

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 2 + 4 = 6

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 3 + 26) / 121 = 0.24

SECTION 3 - DIVERSITY

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

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

82 / 121 = 0.68

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	4
EPT Index	3
EPT To Total Ratio	1
Predominant Taxon Ratio	2

Average Rating
2.50

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: 27 October 2008
Station Name: **Station 8**		Flow status: Low
Sampler Used: Surber	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 Pollution Intolerant	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	2	1
	Stonefly Nymph (EPT)	12	3
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		14	4
Category 2 Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	27	1
	Watersnipe Larva		
Sub-Total		27	1
Category 3 Pollution Tolerant	Aquatic Worm (oligochaete)	27	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	46	3
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		73	6
TOTAL		114	11

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 114

DENSITY: Invertebrate density per square metre:

114 ÷ 0.27 = 422

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C): Midge Larva (chironomid)

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 4 + 2 x 1 + 6 = 20

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 3 = 4

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 2 + 12) / 114 = 0.12

SECTION 3 - DIVERSITY

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

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

46 / 114 = 0.40

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	3
EPT Index	2
EPT To Total Ratio	1
Predominant Taxon Ratio	3

Average Rating
2.25

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: 27 October 2008
Station Name: **Station 10**		Flow status: Low
Sampler Used: Surber	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1 / Pollution Intolerant	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	1	1
	Stonefly Nymph (EPT)	3	2
	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		4	3
Category 2 / Somewhat Pollution Tolerant	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	1	1
	Cranefly Larva		
	Crayfish		
	Damselfly Larva	1	1
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	13	2
	Watersnipe Larva		
Sub-Total		15	4
Category 3 / Pollution Tolerant	Aquatic Worm (oligochaete)	95	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	1	1
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	1	1
Sub-Total		97	5
TOTAL		116	12

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 116

DENSITY: Invertebrate density per square metre:

116 ÷ 0.27 = 430

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 3 + 2 x 4 + 5 = 22

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 2 = 3

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

Good	Accpetable	Marginal	Poor
0.75-1.0	0.50-0.75	0.25-0.50	0-0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 1 + 3) / 116 = 0.03

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 12

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

Good	Accpetable	Marginal	Poor
0-0.40	0.40-0.60	0.60-0.80	0.80-1.0

Col. C for S3 / CT

95 / 116 = 0.82

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Accpetable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	3
EPT Index	2
EPT To Total Ratio	1
Predominant Taxon Ratio	1

Average Rating
1.75