DATA REPORT

Water Quality and Stream Invertebrate Assessment

for the C.W. Young Channel, Englishman River, BC,

(Fall 2009)

Report prepared by:

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23 July 2010

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1. Background

This report documents a water quality and stream invertebrate assessment conducted on the C.W. Young Channel, Englishman River, BC, during November 2009.

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

VIU students contributed approximately 35 student-hours to this project, including site visits, project proposal, field sampling, laboratory analyses, and oral and written presentations. Dr. Eric Demers contributed approximately 10 hours for project management and report compilation. Ms. Sarah Greenway provided 5 hours of laboratory support for this project.

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

2. Introduction

The C.W. Young Channel is located on the northern bank of the Englishman River on Vancouver Island, BC, within the Englishmen River Regional Park. It is approximately 7 km upstream from the Englishman River Estuary in Parksville Bay and begins just below the Morison Creek confluence (Hawkes et al., 2008). The channel is approximately 4,100 metres long and provides off-channel habitat and pond habitat for spawning and rearing Pacific salmon and trout. The entire channel is dependent on surface flow from the Englishmen River.

This report documents a water quality and stream invertebrate assessment conducted on the C.W. Young Channel, Englishman River, BC, during November 2009.

Specific objectives for this study of the C.W. Young Channel included:

- establish 5 water quality sampling stations;
- obtain field measurements of water quality at the 5 sampling stations during two sampling events (early and late November 2009);
- obtain water samples from each sampling station during two sampling events (early and late November 2009) for detailed laboratory analyses; and,
- collect stream invertebrate samples at 3 sampling stations during one sampling event (early November 2009) for analysis at Vancouver Island University.

3. Methods

3.1. Study Site

This project was conducted at the C.W. Young Channel located along the Englishman River (Figure 1). The original C.W. Young Channel was constructed in 1992 by Fisheries and Oceans Canada (DFO). In 2007, the C.W. Young Channel was lengthened by another 2 km, with the outlet of the channel a few hundred metres upstream of the Top Bridge Crossing. This brought the total length of constructed side channel habitat in the Englishman River to 4,100 m (Hawkes et al., 2008). The channel was built to provide resident and anadromous salmonids with new spawning and juvenile rearing habitat.

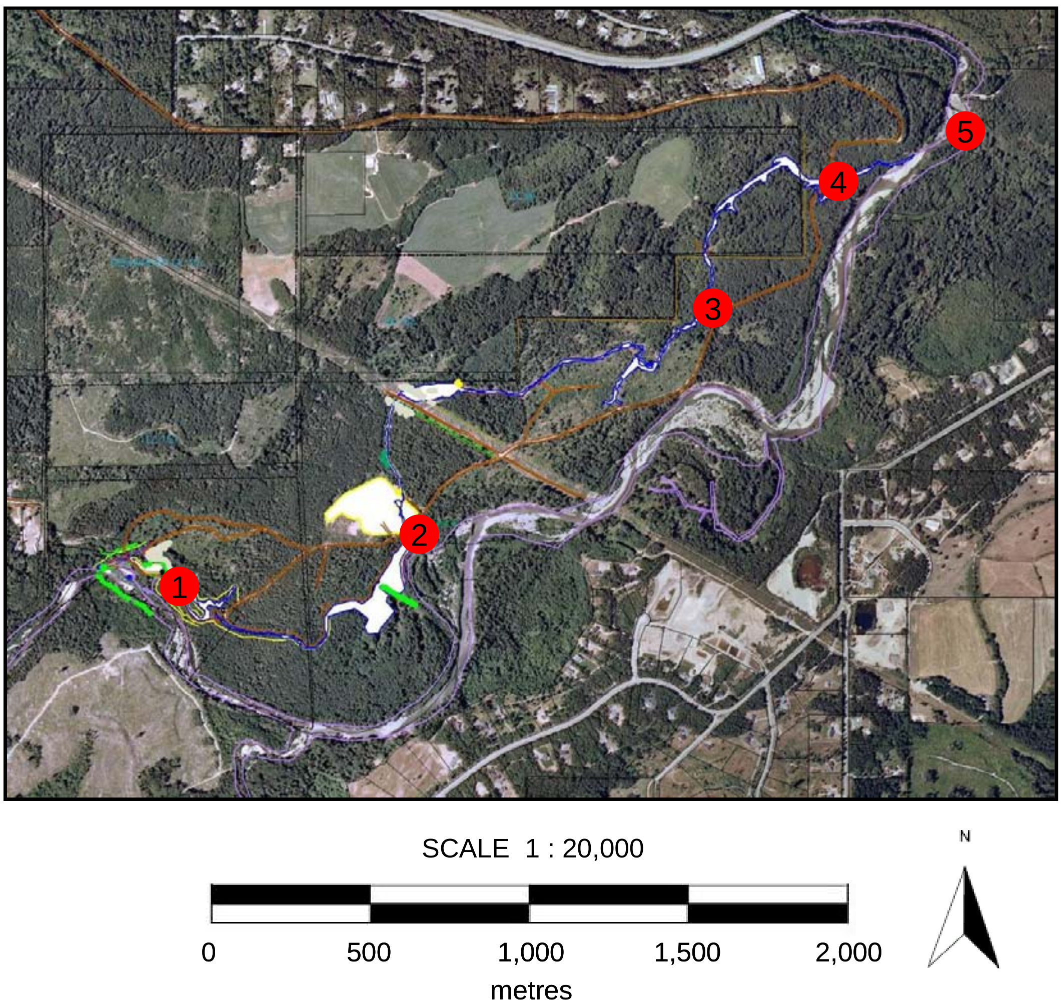

Figure 1. Approximate location of the sampling stations used for water quality and stream invertebrate assessments on the C.W. Young Channel, during November 2009. The C.W. Young Channel and Englishman River are outlined in blue and purple, respectively. Access roads are outlined in brown. Table 1 provides details of the specific location of each station. Table 2 details the sampling activities conducted at each station. This map was obtained from Hawkes et al. (2008). Map scale is approximated.

3.1.1. Sampling Stations

Five stations were established on the C.W. Young Channel and Englishman River, during November 2009 (Tables 1 and 2; Figure 1). The location of each station was chosen to provide adequate coverage for the length of the C.W. Young Channel. In addition, the station locations were based on channel inspection locations provided by DFO (see Table 1 for corresponding DFO inspection point numbering). Stations were numbered from the upstream end to the downstream end of the channel. All stations were easily accessed via foot paths or access road crossings. Station 1 was located one metre downstream of the steel valve at the upstream entrance into the channel and served as a reference station for initial conditions at channel entry. stations 2-4 were located at intervals along the channel. Station 5 was located on the main stem Englishman River, approximately 250 m downstream of the channel outlet. This station served as a reference to compare spatial changes that occur within the channel and in the main river channel.

Table 1. Description of the sampling stations used for water quality and stream invertebrate assessments on the C.W. Young Channel and Englishman River, during November 2009. Inspection point numbers refer to corresponding locations as identified by Fisheries and Oceans Canada (DFO).

Station	DFO Inspection Point No.	Distance from Upstream End (m)	General Location
1	2	0	Upstream channel entrance, 1 m downstream of steel pipe valve
2	5	1,250	Road crossing, start of 2007 channel extension
3	7	2,900	Channel section near access road
4	9	3,800	1 m upstream of steel sill structure
5	N/A	N/A	Main stem Englishman River, 250 m downstream of channel outlet

3.1.2. Sampling Schedule

Field sampling was conducted on 4 and 25 November 2009. For this study, samples were collected for water quality analyses, microbiology and stream invertebrate assessment. Table 2 lists the specific activities conducted at each station during each sampling event. Microbiology and stream invertebrate assessments were only completed during the early November event. Photographs showing site conditions and sampling activities are included in Appendix 1.

3.2. Water Quality

3.2.1. Field Measurements

Water quality sampling events were conducted on 4 and 25 November 2009. At each sampling station, field measurements of water temperature (to the nearest 0.01 ^{o}C), dissolved oxygen (to the nearest 0.01 mg/L), conductivity (to the nearest 1 μSiemens/cm) and pH (to the nearest 0.01 pH unit) were obtained with a YSI 556 MPS electronic probe. The electronic probe was placed directly in the channel water.

Table 2. Water quality and stream invertebrate sampling activities conducted at each station on the C.W. Young Channel and Englishman River, during November 2009. The symbols "A" or "B" indicate whether samples / measurements were taken during the early or late November sampling events, respectively.

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

Note: [1] A duplicate sample was collected at station 9 for analysis at the VIU Laboratory.

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 both sampling events for analysis at the VIU Laboratory. 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 24 hours of sampling.

Samples for analysis by ALS Laboratory were collected from stations 1-4 during both sampling events (Table 2). At each station, water samples were collected in three clean laboratory-supplied and pre-labelled sample containers (Table 3). All samples were obtained while standing on the stream bank or within the stream channel by directly immersing the containers just below the water surface while facing upstream. Care was taken not to disturb the bottom sediments. Samples for analysis of nutrients and total metals were preserved with laboratory-supplied sulphuric acid and nitric acid, respectively. Bottles with preservatives were inversed five times for adequate mixing. All water samples were stored in a cooler on site, and shipped with ice packs within 48 hours for laboratory analyses at ALS Laboratory.

Quality control samples (one trip blank and one field blank) were also included during both sampling events for analysis at the VIU Laboratory. The 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. The field blank was prepared by transferring 500 ml of distilled water into a plastic bottle while in the field.

Table 3. Sampling containers and preservatives used for water quality samples taken at the C.W. Young Channel and Englishman River during November 2009. 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

3.2.3. VIU Laboratory Analyses

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

3.2.4. ALS Laboratory Analyses

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

3.2.5. Quality Assurance / Quality Control

Throughout this study, measures were taken to ensure that potential contamination of water samples was minimized. This included using only clean and rinsed containers, preserving samples as prescribed by the analytical laboratory, and storing collected samples in well-labelled containers. Duplicate sampling provided an estimate of the overall precision associated with the field technique and laboratory analysis.

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. <u>Microbiology</u>

3.3.1. Field Sampling

Water samples for total and fecal coliform enumeration were collected from each sampling station on 4 November 2009 (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 24 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 100-ml volume of sample water was filtered through a 47-μm membrane filter (marked with 3-mm gridlines) using a vacuum pump. The filtration apparatus was then rinsed with approximately 5 ml of sterile water. A filtration blank was also completed with 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, 3 and 4 on 4 November 2009 (Table 1; Figure 1). The sampling stations were selected based on hydrological characteristics, apparent substrate uniformity, space available for replicate samples, safety and site access. At the time of sampling, all stations consisted of shallow riffles (water depth ~10-25 cm), with water velocity of ~0.25-1.0 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 and procedures as per the Pacific Streamkeepers procedures (Taccogna and Munro 1995). Each site was approached by walking from downstream. The cylindrical, 34-cm diameter Hess sampler was hand-pressed into the substrate to isolate a circular 0.09-m^2 sampling area. All stones and debris 5 cm or larger within the sampling area were held under water in front of the collecting net and rubbed gently by hand to dislodge invertebrates. Cleaned stones and debris were then placed downstream of the sampling area. The streambed was then gently agitated to a depth of 5 cm to loosen any remaining invertebrates. The content of the collecting net was then transferred in a 125-ml plastic sample jar. The net was carefully inspected to ensure all content was transferred into the sample jar. Samples were stored in a cooler and transported to Vancouver Island University, where laboratory analyses were completed within 24 hours of sampling.

3.4.3. VIU Laboratory Analyses

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

Index, EPT (Ephemeroptera-Plecoptera-Trichoptera) Index, EPT to Total Ratio Index, Predominant Taxon Ratio Index, and overall Site Assessment Rating.

4. Results

Although no discharge measurements were collected during this study, field observations suggested that water levels in the C.W. Young Channel were not at bankfull during the early November sampling event. However, heavy rainfall between sampling events caused the C.W. Young Channel be at bankfull during the late November sampling event.

Average air temperature during the 10-day period prior to each sampling event was 6-8^{o}C (data for Comox Airport retrieved from http://www.theweathernetwork.com). Total rainfall during the 10-day period prior to each sampling event was 46 mm for the early November sampling event and 240 mm for the late November sampling event.

4.1. Water Quality

4.1.1. Field Measurements and VIU Laboratory Analyses

Water temperature averaged 7.6^{o}C and 6.8^{o}C during the early and late November sampling events, respectively (Table 5). The decrease in water temperature between events reflected a similar decrease in air temperature between sampling events. All dissolved oxygen levels (range: 10.65-11.96 mg/L) were above the minimum guideline of 9.0 mg/L for early fish life stages (RISC 1998). Overall, dissolved oxygen concentrations were at 88-99% saturation.

Mean conductivity decreased from 70 to 52 μS/cm between the early and late November sampling events, likely as a result of dilution due to increased discharge. During both sampling events, there was a general increase from upstream to downstream stations. Water pH was near neutral throughout this study, and averaged 6.92 and 6.94 during the early and late November sampling events, respectively.

Total alkalinity ranged averaged 20.6 and 21.2 mg/L during the early and late November sampling events, respectively (Table 5). Overall, total alkalinity was above 20 mg/L during both sampling events, indicating “low acid sensitivity” as defined by RISC (1998).

Levels of turbidity increased between the early (average: 0.2 FAU) and late November sampling events (average: 5.0 FAU), likely as a result of the higher water velocity / discharge and erosion potential (Table 5).

A comparison of the water quality results from the duplicate samples taken at station 9 indicates that most values were within ±5% of each other.

Table 5. Field measurements and laboratory results (VIU Laboratory) for water samples taken from five stations on the C.W. Young Channel and Englishman River on 4 and 25 November 2009. Results for total alkalinity and turbidity at station 3 during both sampling events represent the average of duplicate samples.

	Field Measurements				VIU Laboratory	
Station	**Temperature (^{o}C)**	**Dissolved Oxygen (mg/L)**	**Conductivity (µS/cm)**	**pH**	**Total Alkalinity (mg/L $CaCO_3$)**	**Turbidity (FAU)**
4 November 2009						
1	7.08	11.96	63	6.82	18.4	0
2	7.31	11.34	65	7.02	18.5	0
3	7.90	11.09	72	6.94	22.5	0
4	7.87	11.14	72	6.99	20.9	1
5	7.68	11.16	76	6.82	22.7	0
25 November 2009						
1	6.24	11.96	40	8.13	21.9	5
2	6.34	11.33	41	6.44	20.0	4
3	7.15	10.65	59	6.36	23.2	5
4	7.18	11.07	59	6.29	24.0	6
5	7.15	11.09	59	7.50	16.8	5

4.1.2. ALS Laboratory Analyses

Water quality results were compared to the BC Provincial water quality guidelines and the federal CCME guidelines for the protection of aquatic life (Table 6).

The conductivity measurements from ALS Laboratories were consistent with the field measurements obtained with the electronic probe and differed by ≤5%.

Total hardness followed similar trends as conductivity, namely a general increase from upstream to downstream stations and a decrease between sampling events. Total hardness was below 60 mg/L during both sampling events, indicating “soft water” as defined by RISC (1998).

Table 6. Laboratory results (ALS Laboratory) for water samples taken from 4 stations at the C.W. Young Channel during 4 and 25 November 2009. 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]										
	BC Max	BC 30-day Mean	CCME [b]	4 November 2009				25 November 2009			
Variable	mg/L	mg/L	mg/L	1	2	3	4	1	2	3	4
General/Physical											
Conductivity (µS/cm)				63.2	61.8	70.4	70.6	38.7	39.8	56.7	57.1
Hardness, Total				23.7	22.5	27.6	26.9	15.4	15.9	23.7	23.3
pH (pH units)	6.5 - 9.0		6.5 - 9.0	7.50	7.44	7.42	7.44	8.00	7.81	7.53	7.45
Nutrients											
Ammonia-N	8.18 [c]	1.57 [c]	0.715 [c]	<0.020	<0.020	<0.020	<0.020	0.054	0.074	0.044	0.085
Nitrate (as N)	200	40	13	0.0464	0.0360	0.0392	0.0388	0.0715	0.0647	0.287	0.284
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
Ortho Phosphate (as P)				<0.0010	<0.0010	0.0012	<0.0010	<0.0010	0.0045	0.0055	0.0057
Total Phosphorus				0.0023	0.0034	0.0060	0.0093	0.0147	0.0137	0.0172	0.0179
Total Metals											
Aluminum (Al) [n]	0.10 [e]	0.05 [e]	0.10 [e]	<0.20	<0.20	<0.20	$\boxed{0.27}$	$\boxed{0.32}$	$\boxed{0.29}$	$\boxed{0.3}$	$\boxed{0.28}$
Antimony (Sb) [n]	0.02			<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
Barium (Ba)	5	1		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Berylium (Be)	0.0053			<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)				<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	1.2			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd) [n]	0.00001 [f]		0.00001 [f]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)				8.1	7.6	8.4	8.1	4.7	4.9	6.4	6.3
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
Cobalt (Co) [n]	0.11	0.004		<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
Iron (Fe)	0.3		0.3	0.048	0.146	0.135	$\boxed{0.377}$	0.294	$\boxed{0.325}$	$\boxed{0.353}$	$\boxed{0.341}$
Lead (Pb) [n]	0.006 [i]	0.004 [i]	0.001 [i]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)	0.87	0.096		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)				0.8	0.9	1.6	1.7	0.9	0.9	1.9	1.9
Manganese (Mn)	0.68 [j]	0.66 [j]		<0.0050	0.011	0.005	0.008	0.011	0.011	0.008	0.008
Molybdenum (Mo)	2	1	0.073	<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
Phosphorus (P)				<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	373			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se) [n]		0.002	0.001	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)				2.44	2.39	3.01	3.19	3.43	3.48	4.55	4.46
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
Sodium (Na)				3.0	3.2	3.3	3.4	2.2	2.3	2.9	2.8
Strontium (Sr)				0.032	0.031	0.031	0.031	0.020	0.021	0.025	0.025
Thallium (Tl)	0.0003	0.0008		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)				<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)	2			<0.010	<0.010	<0.010	0.015	0.013	0.012	0.015	0.014
Vanadium (V) [n]	0.02	0.006		<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

Table 6. (Continued)

NOTES:

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

[a] BC Water Quality Guidelines (WQG) compiled from
http://www.env.gov.bc.ca/wat/wq/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] Total ammonia guideline is dependent on water temperature and pH. Guideline shown is based water temperature of 7-8^{o}C and pH of 7.4-8.0 for the tested water.

[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 15-28 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 15-28 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 15-28 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 15-28 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.

Field measurements of pH (range: 6.29-8.13) were generally lower and more variable than the ALS Laboratories results (range: 7.42-8.00). This discrepancy possibly reflects improper calibration, differences in air space content among sampling containers and/or time elapsed between sampling and laboratory analysis.

All nutrient levels were below applicable guidelines and/or below detection limits. Total ammonia was below detection limit (i.e., <0.02 mg/L) during the early November sampling event, but increased during the late November sampling event when levels reached 0.044-0.085 mg/L. Nitrate concentrations increased between the early (average: 0.040 mg/L) and late November sampling events (average: 0.177 mg/L). The highest nitrate levels were observed at station 3 and 4 during the late November sampling event (0.287 and 0.284 mg/L, respectively).

Orthophosphate was mainly below or near detection limit (i.e., ≤0.0012 mg/L) during the early November sampling event, but increased during the late November sampling event when levels reached 0.0045-0.0057 mg/L (expect station 1, where orthophosphate level was below detection limit). Total phosphorus increased between the early (average: 0.0053 mg/L) and late November sampling events (average: 0.0159 mg/L), and there was a general increase from upstream to downstream stations during both sampling events. Overall, total phosphorus levels were mainly within the low to moderate range typical of "oligotrophic" (<0.010 mg/L) to "mesotrophic" (0.010-0.025 mg/L) waters as defined by RISC (1998).

With the exception of aluminium and iron, all metals with applicable guidelines were below minimum detection limits. Total aluminium and iron concentrations exceeded the applicable guidelines at station 4 during the early November sampling event and at all stations during the late November sampling event (except at station 1 where iron did not exceed the guideline).

It should be noted that the above total metal exceedances occurred for samples with turbidity levels 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.

4.2. Microbiology

All samples collected from the C.W. Young Channel and Englishman River contained some coliform bacteria (Table 7). In the C.W. Young Channel, total coliform counts generally increased from upstream to downstream, with the highest levels observed at station 3 (total coliform: 644 CFU / 100 ml; *E. coli*: 18 CFU / 100 ml).. Overall, the observed total coliform levels were higher than in a similar study conducted at the C.W. Young Channel during Fall 2008, when total coliform was <300 CFU / 100 ml and no *E. coli* bacteria were observed (VIU, 2009).

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

Table 7. Total coliform and *E. coli* counts from water samples taken at five stations on the C.W. Young Channel and Englishman River on 4 November 2009. All values are expressed as number of bacteria per 100 ml. No samples were collected on 25 November 2009.

Station	Total Coliform	*E. coli*	% *E. coli*
1	384	41	10.7%
2	357	24	6.7%
3	656	20	3.0%
4	644	18	2.8%
5	571	16	2.8%
Filtration blank	0	0	–

4.3. Stream Invertebrates

A total of 234 stream invertebrates representing 9 broad taxonomic groups were counted at three stations on the C.W. Young Channel on 4 November 2009 (Table 8; Figure 2; Appendix 2). Animal density was high at station 1 (711 animals/m^2), and relatively low at stations 3-4 (70-85 animals/m^2. Overall, mayfly nymph was the most common taxonomic group, although none were found at station 3.

Site assessment ratings ranged from 1.00-3.25 suggesting “acceptable” to “poor” invertebrate community abundance and diversity. These results differ from those of a similar study conducted at the C.W. Young Channel during Fall 2008, when site assessment ratings ranged from 3.0-3.5 (VIU, 2009). The reason for the highly variable results in this study remain unknown, but may involve differences in stream habitat, flow conditions and/or substrate type among stations.

Table 8. Abundance and density of stream invertebrates obtained from triplicate samples taken on 4 November 2009 at three stations on the C.W. Young Channel. Overall site assessment ratings are also provided for each station (out of a maximum rating of 4.00). Invertebrate Survey Field Data Sheets are included in Appendix 2. No samples were collected on 25 November 2009.

Pollution Tolerance	Invertebrate Taxa	Station 1	Station 3	Station 4
Category 1 Pollution Intolerant	Caddisfly larva	3		
	Mayfly nymph	133		15
	Stonefly nymph	20		1
Category 2 Somewhat Pollution Intolerant	Cranefly larva			2
	Damselfly nymph	1		
	Scud (Amphipod)	20		
Category 3 Pollution Tolerant	Aquatic Worm (Oligochaete)	14	18	5
	Leech		1	
	Midge larva (Chironomid)	1		
	Total Abundance	192	19	23
	Density (number / m^2)	711	70	85
	Site Assessment Rating	3.25	1.00	2.25

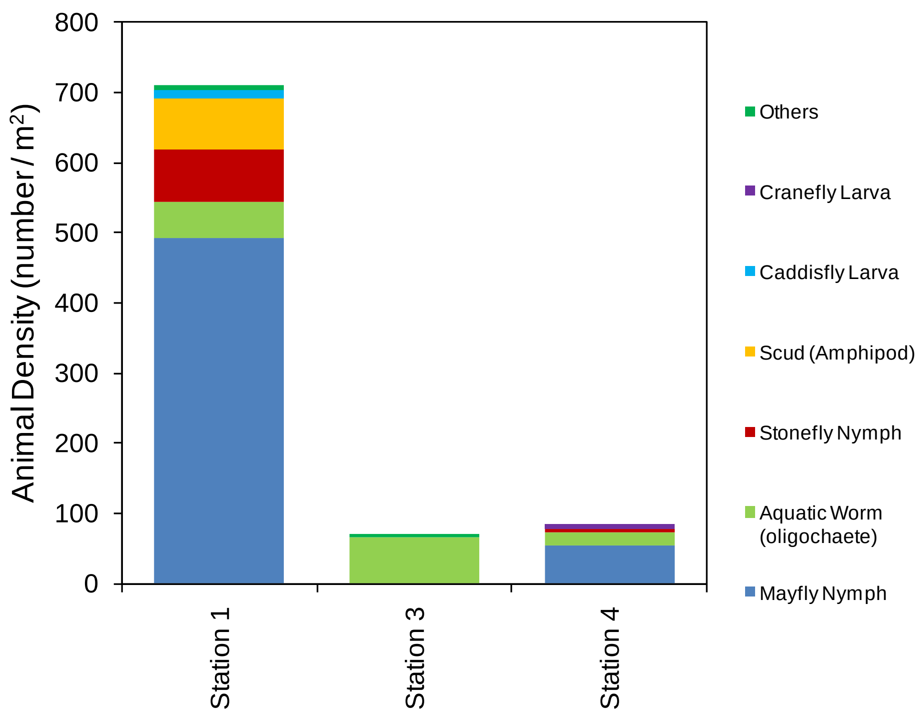

Figure 2. Density of stream invertebrates obtained from triplicate samples taken on 4 November 2009 at three stations on the C.W. Young Channel. The “Other” category includes damselfly larva, leech, and midge larva (chironomid). Data are summarized in Table 8 and Invertebrate Survey Field Data Sheets are included in Appendix 2.

5. Acknowledgements

The authors would like to thank Joan Michel (Parks and Trails Coordinator, Recreation and Parks Department, Regional District of Nanaimo) for facilitating site access and providing a map of the site. We 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 – Macgregor Anderson, Matthew Corbett, Richard de Vos, Alex Goeppel, Nick Hamilton, Jonathan Hupman, Brett Isbister, Anthony Kennedy, Ricki Merriman, Florence Raffaelli, Krystal Reaume, Jo-Leen Sellars and Stephanie Vickers. The Resource Management Officer Technology (RMOT) and Biology Departments at Vancouver Island University provided some laboratory supplies, equipment, vehicle and covered fuel expenses. The Regional District of Nanaimo, BC Conservation Foundation's "Living Rivers - Georgia Basin / Vancouver Island" program, 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.

6. References

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7. Appendices

APPENDIX 1. Photographs showing site conditions and sampling activities conducted on the C.W. Young Channel during 25 November 2009.

Photo 1. Downstream view of the C.W. Young Channel near station 1 during 25 November 2009.

APPENDIX 1. (Continued)

Photo 2. Downstream view of the C.W. Young Channel near station 2 during 25 November 2009.

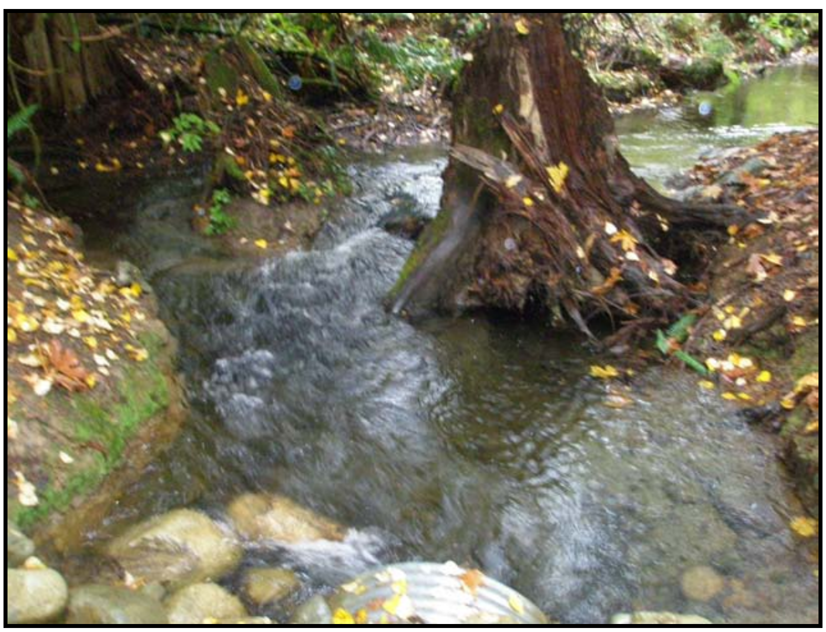

Photo 3. Upstream view of the C.W. Young Channel near station 3 during 25 November 2009.

APPENDIX 1. (Continued)

Photo 4. View of the water gauge at the pedestrian bridge over the C.W. Young Channel downstream of station 4 during 25 November 2009.

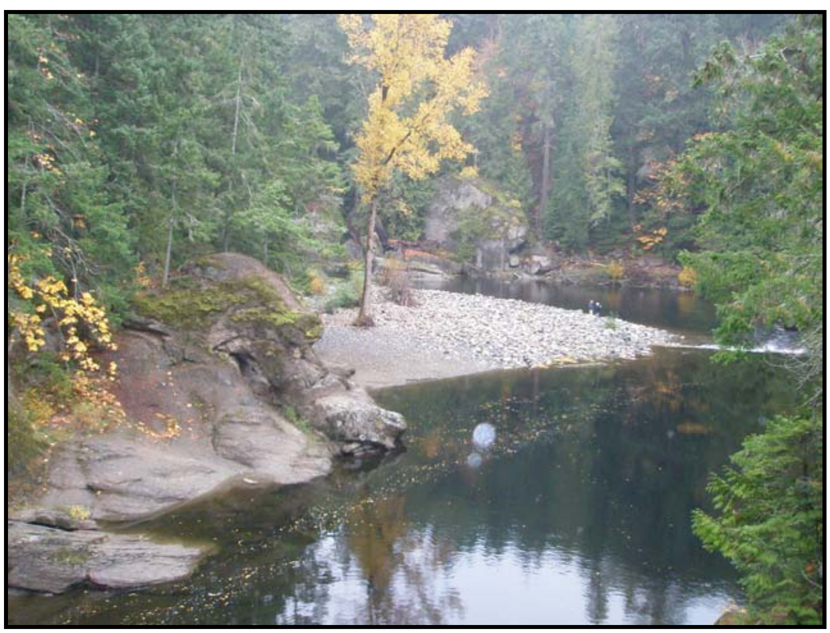

Photo 5. View of the confluence of the C.W. Young outlet with the Englishman River (station 5) during 25 November 2009.

APPENDIX 2. Invertebrate Survey Field Data Sheet completed for triplicate stream invertebrate samples collected at stations 1, 3 and 4 on the C.W. Young Channel during 4 November 2009.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	CW Young Channel	Date:	4 November 2009
Station Name:	**Station 1**	Flow status:	Moderate
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates	0.09 x 3 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	3	1
	Mayfly Nymph (EPT)	133	3
	Stonefly Nymph (EPT)	20	1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		156	5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva	1	1
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	20	2
	Watersnipe Larva		
Sub-Total		21	3
Category 3	Aquatic Worm (oligochaete)	14	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	1	1
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		15	2
TOTAL		192	10

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 192

DENSITY: Invertebrate density per square metre:

192 ÷ 0.27 = 711

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 5 + 2 x 3 + 2 = 23

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 3 + 1 = 5

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

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

(EPT1 + EPT2 + EPT3) / CT

(3 + 133 + 20) / 192 = 0.81

SECTION 3 - DIVERSITY

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

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

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

Col. C for S3 / CT

133 / 192 = 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
Accpetable	3
Marginal	2
Poor	1

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

Average Rating
3.25

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: CW Young Channel		Date: 4 November 2009
Station Name: **Station 3**		Flow status: Moderate
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)		
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		0	0
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		0	0
Category 3	Aquatic Worm (oligochaete)	18	1
	Blackfly Larva		
	Leech	1	1
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		19	2
TOTAL		19	2

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 19

DENSITY: Invertebrate density per square metre:

19 ÷ 0.27 = 70

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 0 + 2 x 0 + 2 = 2

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 0 + 0 = 0

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 0 + 0) / 19 = 0.00

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 2

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

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

Col. C for S3 / CT

18 / 19 = 0.95

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

Average Rating
1.00

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: CW Young Channel		Date: 4 November 2009	
Station Name: **Station 4**		Flow status: Moderate	
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 x 3 = 0.27 m^2	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	15	2
	Stonefly Nymph (EPT)	1	1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		16	3
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	2	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		2	1
Category 3	Aquatic Worm (oligochaete)	5	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		5	1
TOTAL		23	5

APPENDIX 2. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 23

DENSITY: Invertebrate density per square metre:

23 ÷ 0.27 = 85

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

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 9 + 2 x 1 + 1 = 12

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 2 + 1 = 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	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 15 + 1) / 23 = 0.70

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 5

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

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

Col. C for S3 / CT

15 / 23 = 0.65

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

Average Rating
2.25