Cottle Creek

Environmental Monitoring Program Final Report

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EXECUTIVE SUMMARY

A proposal was put forward to sample four different locations within Cottle Creek, located in Nanaimo, British Columbia. The creek serves as a drainage port for over 59 hectares of land which before 1999 was the largest green space in North Nanaimo. Recent development has altered the stream and has raised many concerns regarding sedimentation, water quality and over all stream condition. The purpose of this assessment was to test the general condition of the stream through water sampling, invertebrate monitoring and flow structure. Samples were taken from four different locations in two separate sampling events during pre rainfall and post rainfall conditions.

Temperature readings dropped between the two sampling events which was consistent with air temperature declines during the months of October and November. Discharge increased slightly between the two sampling events. These results were also consistent with rainfall measurements supplied by Environment Canada for the months sampling was conducted. The dissolved oxygen remained above the provincial guidelines of 9mg/l for fish embryos (RISC 1998). Nitrates showed normal levels for typical surface water however rose significantly during the second sampling event yet remained within the provincial guidelines throughout the study period. Phosphate levels during the first sampling event were high which was most likely due to the creek headwater consisting of a large wetland and a large amount of urbanization surrounding the creek. The general trend for water hardness was a steady decrease from upstream to downstream for both sampling events. Water hardness was neither soft nor hard as defined by the B.C water interpretation guidelines.

Turbidity levels in the creek stayed within the guidelines for aquatic life and only increased in faster flowing sampling locations such as station two or four. The pH level showed an increasing trend with distance traveled downstream. This trend was not as notable in the second sampling event however; the second event did show a noticeable trend. Alkalinity was found to be at the highest level in the upper sections of the river, decreasing in the lower sections and overall decreasing from the first to second sampling event due to dilution from heightened stream flow. Conductivity showed two different trends. During the first sampling event, conductivity was highest in the upper reaches and stayed relatively stable in the lower reaches. However during the second sampling event, conductivity increased downstream. Overall, both sampling events showed a high conductivity rating for a coastal BC stream. Total coliforms in the upper reaches of the creek were quite high in relation to the lower reaches of the creek. Total colony forming units were much higher the farther downstream samples were taken. Invertebrate samples showed a total of 527 individuals belonging to all three categories of pollution tolerance. The greatest portion of these individuals (309) belonged to the pollution tolerant category.

1.0 Introduction

1.1 Project Overview

A proposal was put forward to conduct an environmental monitoring project on Cottle Creek, located in Nanaimo, British Columbia. This proposal was accepted and resulted in two separate sampling events being conducted by four Bachelor of Natural Resource Protection students from Vancouver Island University. Sampling was conducted on two separate dates; October 30th, 2013 and November 30th, 2013. This work was completed as part of RMOT 306 Environmental Monitoring studies, under the instruction of Dr. Eric Demers. Data collected during this project was compiled and compared to data collected from Cottle Creek in 2012 by former RMOT 306 students. Data collected from this project will assist in identifying potential environmental impacts through water quality, microbiology and invertebrate sampling.

1.2 Historical review and potential environmental concerns

Cottle Creek originates above Cottle lake and consists of three separate tributaries; Upper Cottle Creek from the headwater off of Rutherford road to Cottle Lake; north Cottle Creek from Lost Lake to Cottle Lake; and Lower Cottle Creek from Cottle Lake to Departure Bay. Cottle Creek covers an area of approximately 4.5 km^2 collecting surface and sub-surface drainage throughout the Linley Valley.

The lake itself was inducted into Nanaimo's city park system in 2003. The park reserve surrounding the lake covers roughly 59 hectares and includes trails, natural habitats, and wildlife sanctuaries. As of 1999, Cottle Creek was considered one of the largest undeveloped green zones in North Nanaimo (City of Nanaimo 1999). The forested areas surrounding Cottle

Creek and Cottle Lake are mainly comprised of second growth Douglas fir, Red Cedar and scattered Arbutus. The Low lying vegetation includes Salal, various fern species and a variety of fruit bearing shrubs such as Huckleberry, Salmonberry and Himalayan blackberry. Over the last 14 years large scale development has been under progress in the area, specifically urban development. Much of the natural area has been changed into residential estates, housing, or roadways in order to support Nanaimo's growing population. These developments add to existing and potential impacts to Cottle Creek's biodiversity and overall stream health. Impacts may include sedimentation, stream bank erosion, loss to fish habitat, and pollution resulting from urban runoff and fertilizer use. Clear cutting and construction without proper erosion control measures have been the number one impact to date (City of Nanaimo 1999). City by law protects a 15 meter riparian buffer on both sides of Cottle Creek; which helps reduce erosion impacts from ongoing development in the area. The Cottle creek system supports a natural Cutthroat trout population and is prime spawning habitat for multiple native amphibian species.

2.0 Project objectives

The objectives for the assessment of Cottle Creek were to examine the environmental conditions of the creek for comparison to data collected in 2012. Four site locations were selected to assess overall stream health by conducting the following tests: water quality, microbiology, invertebrate sampling and hydrology. Results were compiled and analyzed to determine specific pollutant hazards within the creek, reflecting the invertebrate populations and overall stream health. Fisheries and Oceans Canada, British Columbia Conservation

Foundation, City of Nanaimo, and the Nanaimo and Area Land Trust have a special interest in the data collected as it will be used for long-term monitoring purposes.

3.0 Methods

3.1 Sampling locations & habitat Characteristics

Four monitoring sites were chosen to sample water quality, invertebrate communities, and microbiology. These sites were selected based on previous sampling events in 2012 by the Regional District of Nanaimo Community Watershed Monitoring project. The purpose of the RDN project is to establish a long-term sampling project which will help with watershed management. The sites selected by the RDN Community Watershed Monitoring Group were based on general characteristics of each site; bottom substrate, stream flow and velocity, safety, access, and a good general representation of the stream. All these considerations were taken into account when choosing the sites. As a result of low rainfall during the sampling period, a new site was chosen to replace a dry sampling location previously selected by the RDN Community Watershed Monitoring Group. The new sampling site was selected in a location where Cottle Creek exits Cottle Lake. This site was chosen as it is unlikely to become dry at any period throughout the year and will ensure repeat sampling events will be possible. This new site was selected to replace the previously chosen station number two.

3.1.1 Cottle Creek Station 1

Station 1 on Cottle Creek is located just upstream of the crossing of Landalt Road (10U 0427941mE, 5452180mN) (Figure 1). Sampling was conducted upstream of the road crossing, on the West side of the road. This site was in a stage of extremely low flow levels at the time of the initial site visit, and water depth at no point exceeded more than knee height. The site consisted of multiple riffles with a few scattered pools. Bottom substrate mainly consisted of small gravel with some small cobble mixed in as well. The site was located in very close proximity to Landalt Road, and was down a steep embankment in a forested area of the stream above a culvert.

Figure 1. Station 1 on Cottle Creek, site map. UTM coordinates 10U 0427941mE, 5452180mN. Main Access off of Landalt Road and Arrowsmith Road junction (Google Earth).

3.1.2 North Cottle Creek Site Station 2

The newly selected site two is located where North Cottle Creek enters Cottle Lake (10U 428724mE, 5452292mN) (Figure 2). This site will have water flow throughout all water levels, and is suitable for sampling due to bottom substrate which consisted of gravel and cobble; this site has relatively easy access via the trail off of Burma Road. This site is located in a forested area and is heavily used as a walking and jogging trail. Site vegetation includes mainly second growth Douglas fir and scattered Arbutus. Riparian foliage includes Salal, Huckleberry and Salmonberry.

Figure 2. Station 2 on Cottle Creek, site map. UTM coordinates 10U 0428587mE, 5452624mN. Main Access is from the end of Burma Road, access to the actual site is by trail at the end of Burma Road (Google Earth).

3.1.3 Cottle Creek Station 3

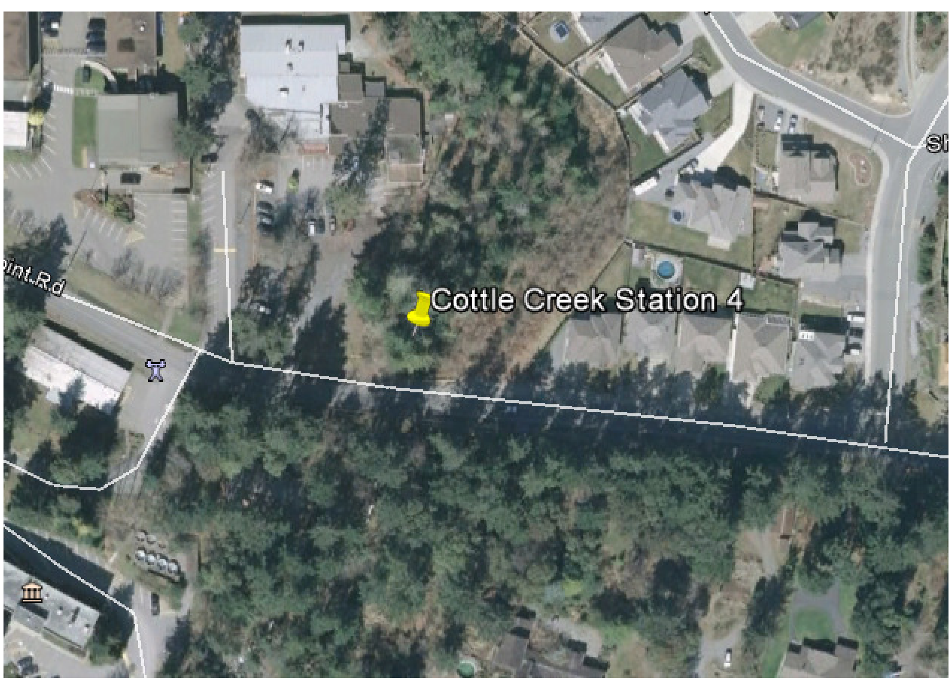
Station 3 on Cottle Creek is located at the crossing of Nottingham Drive (10U 0430192mE, 5452022mN) (Figure 3). Sampling for this station took place upstream of the bridge, on the north side of Nottingham Drive. Although the stream was in a low flow stage at the time of the site visit, the water height at this portion of the stream was quite deep. Right under the small bridge upstream from the road bridge was at least one meter in depth. The whole site consisted of one deep pool, which riffled out into a shallow riffle beneath the bridge. Bottom substrate consisted of fines such as mud, and small gravel. This site is located in an area currently under heavy urban development. The majority of vegetation at this site had recently been cleared and only a small riparian area remained intact and consisted of mainly Red aspen and various grasses.

Figure 3. Cottle Creek Station 3, site map. UTM coordinates 10U 0430192mE, 5452022mN. Main access for this station is directly off of Nottingham Drive (Google Earth.

3.1.4 Cottle Creek Station 4

Station 4 on Cottle creek is located in the lower portion of the river, at the crossing of Stephenson Point Road (10U 430579mE, 5451398mN) (Figure 4). Sampling at this site took place upstream, on the north side of Stephenson Point Road above the culvert. Water flow was moderate in the lower section of the creek, and the stream bed mainly consisted of riffles and a small pool. Bottom substrate in this section of the river was larger than the other sites, mainly consisting of fairly large cobble. The area surrounding this site is predominantly composed of buildings and homes with a large portion of the surrounding land comprised of paved parking areas. The riparian area surrounding the creek remains relatively intact and extends roughly ten meters on either site of the creek thalweg. Riparian vegetation mainly consisted of second growth Douglas fir, Red Alder and scattered Arbutus. Riparian foliage was comprised of Huckleberry, Salmonberry and a large quantity of Himalayan Blackberry.

Figure 4. Cottle Creek station 4, site map. UTM coordinates 10U 430579mE, 5451398mN. Main access to this site is directly off of Stephenson Point Road (Google Earth).



3.2 Sampling frequency

Sampling of water quality, microbiology, and stream macro invertebrates took place on October 30, 2013 and November 30, 2013. The sampling in October targeted low flow conditions, while the November samples targeted high flow conditions. All samples, once collected, were immediately analyzed at the Vancouver Island University Lab. Water quality samples from both sampling events were sent to ALS environmental in Vancouver. An overall breakdown of sampling conducted at each site is provided in (Table 1).

3.2.1 Water Quality Sampling Frequency

Water Quality was sampled at each of the four Cottle Creek stations, on both sampling events. Samples taken for water quality were tested on the day of sampling and were stored in a cooler at 4˚C during transport to the laboratory. Samples for the ALS analysis were taken at stations 1, 2 and 4 and three sample containers were filled at each site.

3.2.2 Hydrology Sampling Frequency

Hydrology tests were conducted at each site during both sampling events. All measurements were taken on site using a basic float method.

3.2.3 Microbiology Sampling Frequency

Microbiology was measured at all four sites and was only measured during the first sampling event conducted on October 30, 2013. Samples were collected and analyzed immediately upon return to Vancouver Island University lab. Samples were placed in an incubator and removed after a 24 hour period at which point colonies were counted and recorded.

3.2.4 Macroinvertebrate Sampling Frequency

Macro invertebrate samples were taken only during the first sampling event on October 30, 2013. Samples were collected at Cottle Creek stations 1, 2, and 4. Triplicate samples were taken at each station, and samples were kept alive for analysis.

3.3 Water Quality

Water quality sampling took place during both sampling events at each Cottle Creek station. All water quality samples were analyzed immediately following sampling. Every water quality sample taken followed protocols from “Access from the stream bank” from the “Ambient freshwater and effluent sampling manual”(Cavanagh et al. 1997). All samples taken for water quality followed standard procedures and protocols given in the manual to ensure quality control. Trip blanks also accompanied each sampling event, and replicate samples were taken at a 10% frequency to further ensure quality control during sampling.

Parameters that were tested during water quality analysis included pH, temperature (°C), dissolved oxygen (DO mg/L), turbidity (NTU), conductivity (µs/cm), alkalinity (mg/L as $CaCO_3$), hardness (mg/L as $CaCO_3$), orthophosphates (mg/L PO_4^{3-}), and nitrates (mg/L NO_{3-}). Dissolved oxygen and temperature were taken in the field using an electronic probe. All other parameters tested were carried out in the Vancouver Island University Lab. All data collected was compared to the “Guidelines for Interpreting Water Quality Data” prepared by the Ministry of Environment, Lands and Parks (RISC 1998).

3.3.1 ALS Analysis

Further water quality samples were obtained and sent to the ALS Environmental Lab located at 8081 Lougheed Highway, Burnaby, BC. These samples were only taken at stations 1, 2 and 4 on Cottle creek. Samples for ALS analysis were collected in 3 separate containers at each location specified. Each sample was tested for a different set of parameters. The 1 L white plastic bottles were tested for general parameters, the 250 mL white plastic bottles were tested for total metals, and the amber glass 250 mL bottles were tested for nutrients. Each bottle had a specific preservation method which was specified by the lab with directions being followed exactly as directed. Water samples taken for the ALS analysis also followed the “Access from stream bank” procedures given in the “Ambient freshwater and effluent sampling manual” (Cavanagh et al. 1997).

3.4 Microbiology Sampling

Microbiology samples were taken at all four Cottle creek stations, and only took place during the first sampling event during low water flows. Sampling was conducted following procedures from the “Ambient freshwater and effluent sampling manual” (Cavanagh et al. 1997). Samples were taken using sterile 100 mL Whirlpack bags, and 10% of samples taken included filtration blanks. Testing of these microbiology samples was conducted in accordance with the USEPA “Total Coliforms and *E. coli* Membrane Filtration Method” (USEPA 2003). Using this method, it was possible to determine total and fecal coliform present in the water samples, by culturing the water samples on a differential membrane filtration medium called m-ColiBlue24 Broth.

In this case, the 100 mL of water contained in the sterile packs was filtered. The filter paper was then placed in the m-ColiBlue24 Broth, and placed in an incubator overnight. The next morning, the petri dishes were observed for colony growth, the blue colonies that developed indicated, fecal coliform presence within the sample and red colony presence indicated non fecal coliform growth (USEPA 2003).

3.5 Macroinvertebrate Sampling

Sampling of macroinvertebrates was done during the first sampling event, and only at stations 1, 2 and 4. For the purpose of this stream monitoring, invertebrates were collected in order to distinguish the health of the stream. There were triplicate samples collected at each station, meaning that 9 samples were collected in total. Each sample was stored in its own jar and labeled correctly.

Samples were collected at each station using a Hess sampler. Consistency was critical, so all samples were taken in relatively similar stream flow and bottom substrate conditions. All samples were collected following the “Ambient and Freshwater Sampling Manual” under the “Benthic fauna biological sample” guidelines (Cavanagh et al. 1997). Once the samples were collected, they were stored in labeled jars, and were taken back to the lab for immediate analysis.

Samples were observed under a dissecting microscope, and all organisms were separated into order. For the purpose of this stream monitoring, we followed the Pacific Stream Keepers procedures (Taccogna and Munro 1995). Once all invertebrates were separated, counts were made of each group and were recorded on data analysis sheets. Each triplicate sample from each station was combined and recorded on one data sheet. Once the data sheets were completed, a Shannon-Weiner diversity index was calculated, as well as an overall site assessment rating which helped in determining overall stream health.

Table 1. Breakdown of sample types collected at each Cottle Creek sampling location; including which event period they were collected during.

	First sampling event	**Second Sampling event**
Site 1	Water quality ALS Hydrology Microbiology Macro Invertebrates	Water Quality ALS Hydrology
Site 2	Water quality ALS Hydrology Microbiology Macro Invertebrates	Water Quality ALS Hydrology
Site 3	Water Quality Hydrology Microbiology	Water Quality Hydrology
Site 4	Water quality ALS Hydrology Microbiology Macro Invertebrates	Water Quality ALS Hydrology

4.0 Results and Discussion

4.1 Field Conditions

During the 2013 sampling period on Cottle Creek, creek levels remained at either extremely low (during the first sampling event), or at most, a moderate height in the second sampling event. This was reflected by extremely low discharge, especially in the lower portion of the creek (Table 1).

Low water levels were attributed to an extremely dry fall, in which October had only 17.30mm of rain recorded in the entire month, with 0 mm of rain recorded in the 10 days prior to sampling (http://nanaimo.weatherstats.ca/metrics/precipitation.html). The insufficient amount of rainfall resulted in one of the stations (station two) being so low that it was not able to be sampled during the first sampling event; therefore an alternate site at the outflow of the lake had to be utilized. November rains resulting in 23.4 mm of rain in the 10 days prior to sampling increased discharge slightly during the second sampling event in all sections of the creek as seen in table 1 (http://nanaimo.weatherstats.ca/metrics/precipitation.html). Although increases in water discharge and height did occur, they are still believed to be well below historic average as the creek never reached bankfull width during the entire sampling period (therefore the creek was categorized as being in low flow conditions throughout the study).

Average air temperatures for October and November accurately reflected the water temperatures recorded during the sampling events. During October, the average high was 9.1°C, while the high was 18.9°C, and the low was -1.4°C; this reflected in stream temperatures close to 7°C (http://nanaimo.weatherstats.ca/metrics/temperature.html). In November, air temperature averaged 5.6°C, with a high of 15.1°C, and a low of -4.4°C; this reflected in stream temperatures dropping to nearly 3°C (http://nanaimo.weatherstats.ca/metrics/temperature.html).

4.2 Water Quality

4.2.1 Field Measurements

Parameters measured in the field included stream width, average stream depth, average velocity, dissolved oxygen and temperature. Using these measurements taken in the field, the average discharge could be calculated as well to determine water flow variation between sampling periods. Discharge is important to note when looking at other water quality parameters and trends in data.

Discharge increased slightly between the two sampling events, which was expected due to rainfall that occurred near the end of October and into November. It should be noted that the discharge during the first sampling event was recorded to be the least at station 4 (the lower creek near the ocean) (Table 2). This is most likely caused from the bottom substrate at this site allowing for water to flow below the ground (cracked bedrock). This lowered the average water depth, which then caused a lowered recordable discharge above the ground. It is also possible that measurements were not taken correctly at this particular site. This outlier was corrected when stream levels increased in the second sampling event.

Temperature in the creek also followed expected trends, decreasing from an average of 6.9°C during the first sampling event down to an average of 4.2°C during the second sampling event (Table 2). This coincided with cooler air temperatures observed between October and

November. Within our sampling reach, Cottle Creek flows through Cottle Lake between stations one and two. The temperature outlier of 6.1°C during the second sampling event at station 2 is most likely due to the lake effect, as warm surface water is flowing out of the lake, directly into the creek (Table 2). As water flows and mixes downstream, it is exposed to the cooler air resulting in a temperature drop to 3.5°C, which is similar to the temperature recorded in the section above the lake. Temperatures from this year were much different than those recorded in 2012 (but showed similar trends), with an October average temperature approaching 10°C, and an average November temperature near 6°C (MOE 2013).

Dissolved Oxygen throughout the creek during both sampling events remained above water quality guidelines of 9mg/L for fish embryos (RISC 1998). During the first sampling event, the dissolved oxygen (DO) remained fairly constant, with the only small drop occurring at station 3 where water was either stagnant or moving very slowly (Table 2). The second sampling event showed an increase in DO in the entire stream, most likely due to lower temperatures and high mixing due to increase in discharge (Table 2). In the second sampling event, DO was lowest at station two directly below the lake where temperature was higher and less mixing had occurred (Table 2). DO measurements remained similar, and demonstrated similar trends to those observed in 2012 (MOE 2013).

Table 2. Field measurements taken from four stations on Cottle Creek, Nanaimo, B.C., during a sampling period of October 30 to November 20, 2013. The table shows parameters collected during both the first sampling event and the second sampling event. Dissolved oxygen and temperature were recorded using an YSI probe, all other measurements were obtained using normal protocols and calculations.

Sampling Event and Site	Stream Width (m)	Average Stream Depth (m)	Area (m^2)	Average Velocity (m/s)	Average Discharge (m^3/s)	Dissolved Oxygen (mg/L)	Temperature (°C)
Oct 30, 2013 - Site 1	2.69	0.0743	0.199867	0.22	0.044	11.38	6.8
Oct 30, 2013 - Site 2	3.42	0.0417	0.1425	0.32	0.046	11.07	6.8
Oct 30, 2013 - Site 3	2.65	0.2647	0.7015	N/A	N/A	10.96	7.0
Oct 30, 2013 - Site 4	2.26	0.0297	0.0670	0.30	0.020	11.74	7.1
Nov 20, 2013 - Site 1	3.7	0.0293	0.10853	0.46	0.050	13.26	3.2
Nov 20, 2013 - Site 2	1.51	0.0490	0.07399	0.91	0.067	11.95	6.1
Nov 20, 2013 - Site 3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nov 20, 2013 - Site 4	2.03	0.0723	0.146769	0.60	0.088	13.36	3.5

4.2.2 VIU Lab Analysis

Nitrates in the stream during the first sampling period remained within normal levels for typical flowing surface water (RISC 1998). In the second sampling event however, levels of Nitrates rose significantly to levels not seen unless anthropogenic influence is a factor (Table 3). Measurements of nitrates stayed within guidelines for aquatic life throughout the study period (RISC). This large increase in nitrates is probably attributed to the first fall rains of the year flushing terrestrial nutrients into the creek. The close proximity to houses and farmland, especially in the lower, probably attributes to levels reaching 1.36 mg/L in the lower reaches (Table 2).

Phosphate levels during the first sampling event were discovered as high, and the system could be seen as eutrophic using the Redfield ratio, as phosphorus levels were at times higher, or almost exactly that of the nitrate concentrations in the creek (Table 3). This is most likely due to the creek headwater consisting of a large wetland, and the large amount of urbanization surrounding the creek (lawns in many cases go right to the water's edge). Phosphate levels also increased during the second sampling event, as expected with the first fall runs flushing terrestrial nutrients into the creek (Table 3).

Water hardness in the first sampling event was found to be moderate throughout the stream, meaning the water was neither soft nor hard water as defined by the BC Water Interpretation Guidelines (1998). The general trend for water hardness was decreasing from upstream to downstream in both sampling events (Table 3). The higher water hardness in the upper reaches of the creek above the lake is most likely attributed to the large wetland at the head of the creek contributing a large nutrient load. Water hardness also decreased overall during the second sampling event, reaching as much as 25 mg/L lower at station two (Table 3). As a result of this, water in the lower creek was defined as being soft water (levels below 60 mg/L detected) during the second sampling event (RISC 1998).

Turbidity was low throughout the creek with no specific trend observable, besides a slight increase in turbidity in fast flowing sections such as station two and four (Table 3). Turbidity stayed within the guidelines for aquatic life during both sampling events where neither changed by more than 5 NTU's (RISC 1998). Turbidity increased in the second sampling event, which is to be expected with higher flows.

Water pH showed an increasing trend with distance traveled downstream during the first sampling event, going from 7.88 to 8.06 (Table 3). This trend was not as evident in the second sampling event, as pH readings in the upper creek surpassed lower creek readings, however the same low to high trend can be seen in the lower creek. During the second sampling event, pH levels decreased in all areas of the creek by an average of 0.6 pH units.

Alkalinity readings were highest in the upper reaches of the creek during both sampling events, and decreased in the lower reaches of the creek (Table 3). The lower reaches of the creek did not show a trend in itself. Between sampling events, there was an average decrease in alkalinity throughout the system of 21 mg/L. This decrease was expected with higher creek discharge causing a dilution effect.

Conductivity showed two different trends. During the first sampling event, conductivity was highest in the upper reaches of the creek, and stayed relatively stable in the lower reaches between 145 and 155 µs/cm (Table 3). During the second sampling event, conductivity increased with distance downstream. Between the two sampling events, it appeared that there was an overall increase in conductivity in the lower reaches of the stream, and a stable reading in the upper reaches of the stream. Overall, conductivity readings in the entire creek for both sampling events were high for a typical B.C. Coastal stream (RISC 1998). The high readings are probably attributed to organic input from the large wetland that head waters the stream.

Table 3. Measurements of general water quality parameters in water samples taken from four stations Cottle Creek, Nanaimo, B.C., on October 30, 2013, and November 20, 2013. Samples were analyzed the day of collection at the VIU laboratory. Guidelines for aquatic life for each parameter are including at the bottom of the table.

Water Samples	Nitrate (mg/L)	Phosphate (mg/L)	Hardness (mg/L)	Turbidity (NTU's)	pH	Alkalinity (mg/L)	Conductivity- 20k range (µS/cm)
October 30, 2013							
Site 1	0.01	0.04	85	0.48	7.88	78.8	187
Site 1 Replicate	0.03	0.07	86	0.62	7.85	72.4	188
Site 2	0.08	0.05	63	0.86	7.91	60.8	154
Site 3	0.10	0.04	61	0.64	8.01	53.2	146
Site 4	0.05	0.04	65	0.93	8.06	61.2	155
Blank	0.03	0.02	N/A	N/A	N/A	N/A	<MDL
November 20, 2013							
Site 1	0.38	0.15	66	1.32	7.24	57.2	110
Site 1 Replicate	0.43	0.08	69	1.31	7.54	57.6	190
Site 2	1.36	0.09	38	3.8	7.11	32.8	140
Site 3	0.72	0.06	47	1.19	7.3	44	160
Site 4	0.26	0.09	48	2.57	7.56	45.6	170
Blank	0.05	0.02	<MDL	0.1	6.71	5.2	<MDL
Guidelines	200	N/A	N/A	N/A	6.5 - 9.0	N/A	N/A

4.2.3 Microbiology Analysis at VIU Laboratory

Microbiology analysis found that total coliform in the upper reaches of the creek was quite high in relation to the lower reaches of the creek (Table 4). It is possible that the large wetland at the headwaters is contributing to the higher coliform counts in the upper reaches. Although total coliform counts were lower in the lower reaches of the creek, the *E.coli* units were much higher in the lower end of the creek the farther downstream samples were taken (Table 4). This could be due to the lower section of the creek near the lake being in a large undeveloped green space. It is possible animals living in this section may be utilizing the source of water and defecating in it. There is also a popular trail for walking dogs running alongside the creek near the lake which could contribute to defecation into the creek. Levels were highest at site 4, which is very close to a main road, and near to the ocean (Table 4).

Table 4. Coliform forming unit results including total coliform forming units and *E. coli* forming units obtained from all 4 stations on Cottle Creek, Nanaimo, B.C., during the first sampling event of October 30, 2013. Replicate and blank samples were included for quality assurance measures.

Sample	Total Coliform (CFU/100 mL)	E. coli colonies (CFU/100 mL)
Site 1	1072	0
Site 1 replicate	1512	8
Site 2	516	4
Site 3	792	8
Site 4	432	80
Trip Blank	0	0

4.2.4 Quality Assurance and Quality Control

Multiple quality assurance measures were taken when sampling in the field. For each sampling event, a trip blank was put in the cooler and accompanied all samples throughout the period in the field, and in the lab. Trip blanks were then analyzed in the lab along with the other samples. All trip blank samples remained within levels that were expected, in both monitoring general parameters (Table 3) and microbiology (Table 4).

Replicate samples were also obtained in the field to ensure quality of samples. During both sampling events, station one was used as our replicate site. These replicates accompanied all samples while in the field and the lab. All replicate samples were analyzed, recorded, and compared to the original station one samples. In most cases, replicate samples very closely mimicked the original samples obtained at station one, although some discrepancies did occur.

The most prevalent discrepancy that occurred was with conductivity during the November 20, 2013 sampling event. Conductivity readings in our replicate sample were found to be 80 µs/cm higher than that of the original station one sample (Table 3). Another discrepancy occurred with the coliform data. Our replicate sample had nearly 500 more colonies formed, and had 8 *E.coli* colonies when compared to the 0 *E.coli* colonies observed in the original station one sample (Table 3).

4.2.5 ALS Lab Analysis

Nitrate analysis carried out by the ALS laboratory had similar results to those found by the VIU laboratory. There was no specific trend observed in nitrate concentration throughout the stream, but nitrate levels were observed to peak during the second sampling event (Table 5).

Phosphate analysis did not show any trend. This is due to all samples obtained, except for the station one sample obtained on the second sampling event, being below the minimum detection limit (Table 5). These results are much different than those obtained by the VIU lab, in which levels of phosphate were found to be high. This is probably due to more precise sampling equipment used at the ALS laboratory. Total phosphorus in the ALS analysis shows a slightly different trend than that of the VIU analysis. Total phosphorus was high in the upper reaches of the stream and directly below the lake, but decreased further downstream (Appendix A). The total phosphorus concentration also decreased the second sampling event in the upper reaches of the creek, and increased in the lower reaches. Total phosphorus levels were still indicative of an impacted system verging on, or in the mesotrophic range (RISC 1998).

Water hardness displayed the same trends when comparing the ALS analysis to the VIU analysis. During the first sampling event, hardness decreased with downstream location (Table 5). All stations in the first sampling event still remained in the moderate hardness level as defined by B.C. Water Quality Guidelines for aquatic life (1998). Water hardness also decreased in the second sampling event, and water in the lower reaches of the stream once again became soft water.

Water pH remained constant throughout almost the entire sampling period, never changing by more than 0.1 pH units (Table 5). This was much different than what was observed through the VIU analysis, and can most likely be attributed to more precise equipment. There was a small observable decrease in pH during the second sampling event; however, it was not nearly as drastic as results obtained from VIU.

Conductivity for the first sampling event remained fairly constant with results previously found. There was high conductivity observed in the upper reaches of the creek, and a lower, but stable conductivity reading in the lower creek (Table 5). Readings by ALS in the first sampling event were on average 20 points higher than those obtained by VIU lab analysis. During the second sampling event, there was a large decrease in conductivity in relation to an increase in discharge. ALS analysis showed a trend during the second sampling event different from that of VIU, in which conductivity decreased going downstream rather than increased.

Table 5. Measurements of general water quality parameters from water samples taken at three stations on Cottle Creek, Nanaimo, B.C. on October 30, 2013, and from water samples taken at two stations on Cottle Creek, Nanaimo, B.C. on November 20, 2013. Samples were sent on the day of collection to the ALS laboratory in Vancouver, B.C. Guidelines for aquatic life for each parameter are included at the bottom of the table.

Water Samples	**Nitrate (mg/L)**	**Phosphate (mg/L)**	**Hardness (mg/L)**	**pH**	**Conductivity- 20k range (µS/cm)**
October 30, 2013					
ALS Site 1	0.063	<0.0010	86.1	7.95	208
ALS Site 2	0.036	<0.0010	66.5	7.89	172
ALS Site 4	0.074	<0.0010	67.4	7.95	175
November 20, 2013					
ALS Site 1	0.267	0.0018	63.7	7.85	166
ALS Site 4	0.486	<0.0010	50	7.85	137
Guidelines	200	N/A	N/A	6.5 - 9.0	N/A

Water samples were also tested for a wide spectrum of metals. Metals tested by ALS remained under the B.C. Water Quality Guidelines for Aquatic Life for the entire sampling period (RISC 1998). All metals that were tested and had recordable levels (that is levels above minimum detection limit) showed a decreasing trend between sampling periods. This is due to increased discharge and the dilution factor. The only exception to this was in the case of Iron, where it increased during the second sampling period (Table 6). This could be due to natural rock formations being eroded away or possibly by anthropogenic influence such as metal debris being discarded into the creek.

Table 6. Metal measurements obtained from water samples at stations one, two and four on Cottle Creek, Nanaimo, B.C. on October 30, 2013, and from water samples obtained at stations one and four on November 20, 2013. All water samples were sent for analysis to the ALS laboratory on the day of collection. B.C. guidelines for aquatic life are included on the far right of the table.

	October 30, 2013			November 20, 2013		
Metals present	**Station 1**	**Station 2**	**Station 4**	**Station 1**	**Station 4**	**Guidelines**
Aluminum (Al)	<0.20	<0.20	<0.20	<0.20	<0.20	0.1
Antimony (Sb)	<0.20	<0.20	<0.20	<0.20	<0.20	0.02
Arsenic (As)	<0.20	<0.20	<0.20	<0.20	<0.20	0.005
Barium (Ba)	<0.010	<0.010	<0.010	<0.010	<0.010	5
Beryllium (Be)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0053
Bismuth (Bi)	<0.20	<0.20	<0.20	<0.20	<0.20	N/A
Boron (B)	<0.10	<0.10	<0.10	<0.10	<0.10	1.2
Cadmium (Cd)	<0.010	<0.010	<0.010	<0.010	<0.010	0.000021
Calcium (Ca)	23.0	18.0	18.0	16.9	13.5	>8
Chromium (Cr)	<0.010	<0.010	<0.010	<0.010	<0.010	0.001
Cobalt (Co)	<0.010	<0.010	<0.010	<0.010	<0.010	0.11
Copper (Cu)	<0.010	<0.010	<0.010	<0.010	<0.010	0.0078
Iron (Fe)	0.130	0.292	0.276	0.312	0.353	1
Lead (Pb)	<0.050	<0.050	<0.050	<0.050	<0.050	0.027
Lithium (Li)	<0.010	<0.010	<0.010	<0.010	<0.010	0.87
Magnesium (Mg)	6.98	5.24	5.47	5.19	3.97	N/A
Manganese (Mn)	0.0239	0.0295	0.0670	0.0289	0.0224	1.21
Molybdenum (Mo)	<0.030	<0.030	<0.030	<0.030	<0.030	2
Nickel (Ni)	<0.050	<0.050	<0.050	<0.050	<0.050	0.065
Phosphorus (P)	<0.30	<0.30	<0.30	<0.30	<0.30	N/A
Potassium (K)	<2.0	<2.0	<2.0	<2.0	<2.0	N/A
Selenium (Se)	<0.20	<0.20	<0.20	<0.20	<0.20	0.002
Silicon (Si)	7.91	4.66	6.35	6.14	5.47	N/A
Silver (Ag)	<0.010	<0.010	<0.010	<0.010	<0.010	0.0001
Sodium (Na)	11.2	9.8	10.8	08.7	8.1	N/A
Strontium (Sr)	0.0853	0.0676	0.0617	0.0640	0.0486	N/A
Thallium (Tl)	<0.20	<0.20	<0.20	<0.20	<0.20	N/A
Tin (Sn)	<0.030	<0.030	<0.030	<0.030	<0.030	N/A
Titanium (Ti)	<0.010	<0.010	0.013	<0.010	<0.010	N/A
Vanadium (V)	<0.030	<0.030	<0.030	<0.030	<0.030	N/A
Zinc (Zn)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.033

4.3 Stream Invertebrate Communities

4.3.1 Total Densities and Pollution Categories

Triplicate samples at three stations along Cottle Creek were utilized to obtain invertebrate samples totaling 527 individuals (Figure 5). These individuals belonged to three different categories including pollution tolerant, semi-tolerant and pollution intolerant. In total we obtained 131 pollution intolerant individuals, 87 semi-tolerant individuals, and 309 Pollution tolerant individuals. At each station, the majority of the population consisted of pollution tolerant species. Trends in invertebrate communities point to the top end of the stream being the most impacted, with the largest number of pollution tolerant individuals (Figure 5). It was also observed that the top end of the creek had the highest number of invertebrates, with a decreasing number of individuals at each downstream location.

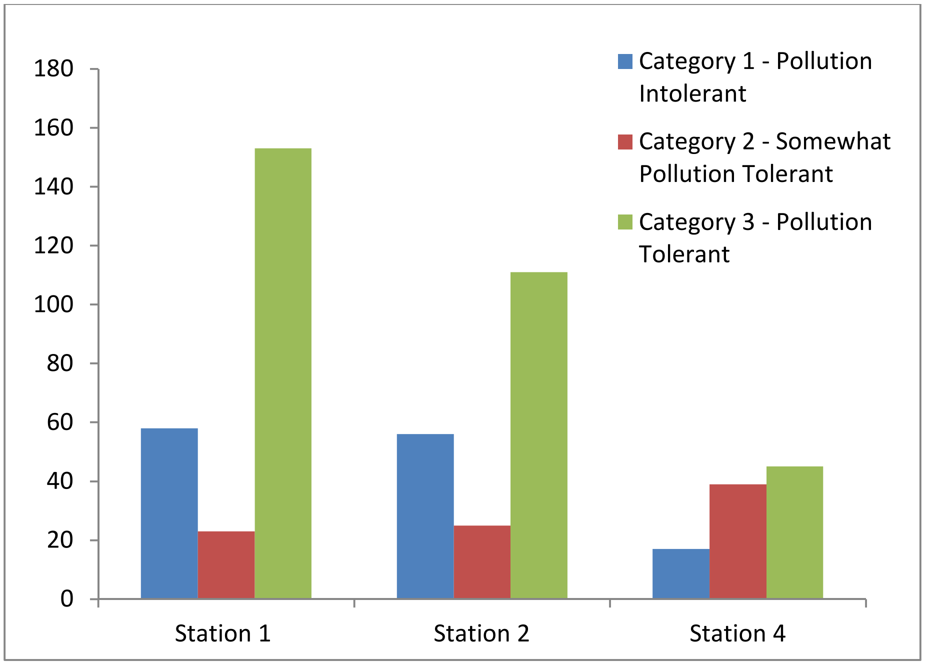


Figure 5. Triplicate invertebrate samples at three stations were obtained on Cottle Creek, Nanaimo, B.C. on October 30, 2013. Invertebrates were taken to the VIU lab on the day of collection, counted, and split into individual categories. Above are the category breakdowns for invertebrates found at each station (combined triplicate samples).

4.3.2 Taxon Richness and Diversity, Overall Stream Rating

Four different categories are used to determine the overall stream health when sampling invertebrates. The pollution tolerance index is calculated using the number of taxa found in each category (pollution tolerant, semi-tolerant, and intolerant). In this case each station had a good index with a wide range of taxa in each category (Figure 6).

EPT taxa are the number of pollution intolerant taxa present in each station sample. In this case each station had acceptable EPT ratings (Figure 6). The total number of EPT organisms in the samples collected at each station was quite poor overall, as the number of pollution tolerant insects outnumbered all other categories at each station.

The predominant rating for each station on the creek was also acceptable. There were a large number of pollution tolerant individuals at each station, but each station also had a good number of individuals in the other categories which resulted in either acceptable or good ratings (Figure 6).

Overall, the creek was determined to be in a healthy state. Site ratings ranged from 2.75 at station one up to 3.25 at station two (Figure 6). Station three had a rating of exactly 3, which is considered an acceptable rating. The creek average station rating was exactly 3.00, meaning the creek is at an acceptable level of health and that the invertebrate communities are doing well, with a good balance of individuals in each taxa.

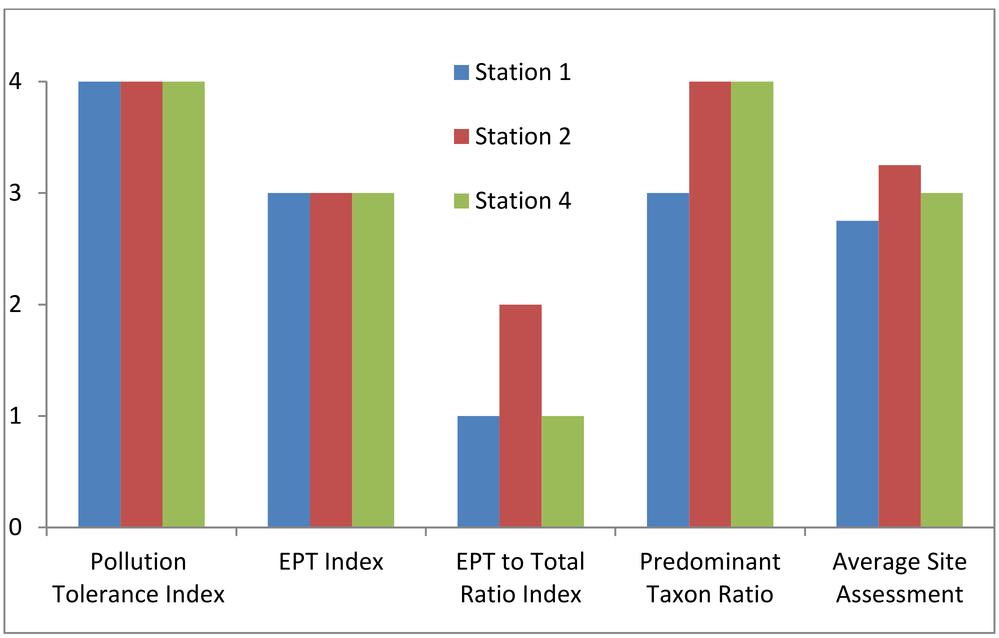


Figure 6. Invertebrate diversity assessments using triplicate invertebrate samples obtained from three stations on Cottle Creek, Nanaimo, B.C. on October 30, 2013. Above are the ratings each site received based on the number of invertebrates counted in each pollution category and the number of taxa present. The Pollution tolerance index, EPT index, EPT to total ratio index, and predominant taxon ratio are all used together to determine overall station and stream health.

4.3.3 Quality Control and Quality Assurance

At each station, triplicate samples were obtained. Samples were obtained working from downstream to upstream in similar substrate. Samples were analyzed and counted the day of collection, with organisms still alive so that they were readily visible (due to movement). Samples were counted by each individual and then exchanged, and counts of each species and taxa were compared to make sure accurate counts were achieved.

5.0 CONCLUSION & RECOMENDATIONS

5.1 Conclusion

After sampling over two events, results indicated that the overall Cottle Creek watershed was a healthy system. All water quality measurements were within guidelines and invertebrate communities maintained an acceptable richness and abundance of pollution intolerant species. Although most results proved normal and fluctuated with typical seasonal variation some anthropogenic influences on the creek were observed. Phosphate levels in particular were at times higher which could be perceived as eutrophic using the Redfield ratio. The heightened phosphate levels are likely due to the creek headwater consisting of a large wetland and extensive urbanization surrounding the creek. During the microbiology analysis it was observed that the E.coli units were much higher in the lower reaches of the creek. This could be due to the lower reaches being largely located in an undeveloped green space. Wildlife utilizing the stream as a drinking source could result in possible defecation nearby allowing surface runoff to pick up contaminants.

5.2 Recommendations

It would be recommended to continue monitoring the Cottle Creek area on an annual basis. Due to the ongoing development surrounding the creek issues concerning stream health could vary from year to year. Annual sampling would be necessary for comparison of years following new urban developments and to establish a baseline. In addition trends could be noted and compared to stream flows in correspondence with Environment Canada's water quality guidelines.

6.0 Acknowledgements

We would like to acknowledge the hard work and dedication of Eric Demers, RMOT faculty at Vancouver Island University for overseeing this project. Thank you to the sponsoring committees for providing the funding required for this project to be successful.

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Appendix A. ALS Water quality sample original data for Cottle Creek for the two sampling events on October 30, 2013 and November 20, 2013.

Sample ID	COTTLE CREEK- STATION 1	COTTLE CREEK- STATION 2	COTTLE CREEK- STATION 4	COTTLE CREEK - STATION 1	COTTLE CREEK - STATION 4
Date Sampled	30-OCT-13	30-OCT-13	30-OCT-13	20-NOV-13	20-NOV-13
Time Sampled	10:00	10:00	10:00	10:00	10:00
ALS Sample ID	L1386524-4	L1386524-5	L1386524-6	L1395801-4	L1395801-5
Matrix	Water	Water	Water	Water	Water
Physical Tests					
Conductivity	208	172	175	166	137
Hardness (as CaCO3)	86.1	66.5	67.4	63.7	50.0
pH	7.95	7.89	7.95	7.85	7.85
Anions and Nutrients					
Ammonia, Total (as N)	<0.0050	0.0162	0.0066	0.0150	0.0076
Nitrate (as N)	0.0630	0.0368	0.0745	0.267	0.486
Nitrite (as N)	<0.0010	<0.0010	<0.0010	0.0011	0.0018
Total Nitrogen	0.357	0.403	0.306	0.552	0.672
Orthophosphate-Dissolved (as P)	<0.0010	<0.0010	<0.0010	0.0018	<0.0010
Phosphorus (P)-Total	0.0107	0.0097	0.0061	0.0096	0.0072
Total Metals					
Aluminum (Al)-Total	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony (Sb)-Total	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total	23.0	18.0	18.0	16.9	13.5
Chromium (Cr)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	0.130	0.292	0.276	0.312	0.353
Lead (Pb)-Total	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	6.98	5.24	5.47	5.19	3.97
Manganese (Mn)-Total	0.0239	0.0295	0.0670	0.0289	0.0224
Molybdenum (Mo)-Total	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total	7.91	4.66	6.35	6.14	5.47
Silver (Ag)-Total	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total	11.2	9.8	10.8	8.7	8.1
Strontium (Sr)-Total	0.0853	0.0676	0.0617	0.0640	0.0486
Thallium (Tl)-Total	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	<0.010	<0.010	0.013	<0.010	<0.010
Vanadium (V)-Total	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Appendix B. Field data sheets for triplicate invertebrate samples obtained at stations one, two and four on Cottle Creek, Nanaimo, B.C., on October 30, 2013.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Cottle Creek	Date:	30-Oct-13
Station Name:	Site 1 - Upper Cottle	Flow status:	Low
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates	0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 22	EPT4 4
	Mayfly Nymph (EPT)	EPT2 11	EPT5 2
	Stonefly Nymph (EPT)	EPT3 25	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 58	D1 8
Category 2	Alderfly Larva	10	2
	Aquatic Beetle		
	Aquatic Sowbug		
Somewhat Pollution Tolerant	Clam, Mussel		
	Cranefly Larva	4	2
	Crayfish		
	Damselfly Larva	5	2
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	4	1
	Watersnipe Larva		
Sub-Total		C2 23	D2 7
Category 3	Aquatic Worm (oligochaete)	22	2
	Blackfly Larva	98	2
	Leech		
Pollution Tolerant	Midge Larva (chironomid)	15	2
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	18	2
Sub-Total		C3 153	D3 8
TOTAL		CT 234	23

Appendix B. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1	234

DENSITY: Invertebrate density per total area sampled:

234 ÷ .27 m^2 =

S2	866 / m^2

PREDOMINANT TAXON:

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

S3	Blackfly Larva

SECTION 2 - WATER QUALITY ASSESSMENTS

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

Good	Acceptable	Marginal	Poor	3 x D1 + 2 x D2 + D3	S4
>22	17-22	11-16	<11	3 x __8___ + 2 x __7___ + __8___ =	46

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor	EPT4 + EPT5 + EPT6	S5
>8	5-8	2-4	0-1	___4__ + __2___ + __2___ =	8

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

Good	Acceptable	Marginal	Poor	(EPT1 + EPT2 + EPT3) / CT	S6
0.75-1.0	0.50-0.74	0.25-0.49	<0.25	(_22_ + _11_ + _25_) / _234_=	0.248

SECTION 3 - DIVERSITY

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

S7	23

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

Good	Acceptable	Marginal	Poor	Col. C for S3 / CT	S8
<0.40	0.40-0.59	0.60-0.79	0.80-1.0	__98__ / __234___ =	0.42

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

Average Rating
Average of R4, R5, R6, R8
2.75

Appendix B. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Cottle Creek	Date:	30-Oct-13
Station Name:	Site 2 - Lake Outflow	Flow status:	Low
Sampler Used:	Number of replicates	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates	
Hess	3	0.27	m^2

Column A	Column B	Column C	Column D
Pollution Tolerance	**Common Name**	**Number Counted**	**Number of Taxa**
Category 1	Caddisfly Larva (EPT)	EPT1 42	EPT4 3
	Mayfly Nymph (EPT)	EPT2 1	EPT5 1
	Stonefly Nymph (EPT)	EPT3 11	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail	2	1
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 56	D1 7
Category 2	Alderfly Larva	1	1
	Aquatic Beetle		
	Aquatic Sowbug		
Somewhat Pollution Tolerant	Clam, Mussel	2	1
	Cranefly Larva	4	1
	Crayfish		
	Damselfly Larva		
	Dragonfly Larva	8	1
	Fishfly Larva		
	Amphipod (freshwater shrimp)	10	2
	Watersnipe Larva		
Sub-Total		C2 25	D2 6
Category 3	Aquatic Worm (oligochaete)	53	2
	Blackfly Larva	2	1
	Leech		
Pollution Tolerant	Midge Larva (chironomid)	54	2
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	1
Sub-Total		C3 111	D3 6
TOTAL		CT 192	DT 19

Appendix B. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 192

DENSITY: Invertebrate density per total area sampled:

S1 192 ÷ .27 m^2 = S2 711 / m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C) S3 Midge Larva

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x __7___ + 2 x __6___ + __6___ = S4 39

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

__3___ + ___1__ + ___2__ = S5 6

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

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

(EPT1 + EPT2 + EPT3) / CT

(_42_ + _1_ + _11_) / _192_= S6 0.28

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 19

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

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

Col. C for S3 / CT

___54__ / __192__ = S8 0.28

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

Average Rating
Average of R4, R5, R6, R8
3.25

Appendix B. (Continued)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)			
Stream Name:	Cottle Creek	Date:	30-Oct-13
Station Name:	Site 4 - Lower Cottle	Flow status:	Low
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2	

Column A	**Column B**	**Column C**	**Column D**
Pollution Tolerance	**Common Name**	**Number Counted**	**Number of Taxa**
Category 1	Caddisfly Larva (EPT)	EPT1 5	EPT4 3
	Mayfly Nymph (EPT)	EPT2 5	EPT5 1
	Stonefly Nymph (EPT)	EPT3 6	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)	1	1
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 17	D1 7
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
Somewhat Pollution Tolerant	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
	Damselfly Larva	11	1
	Dragonfly Larva	2	2
	Fishfly Larva		
	Amphipod (freshwater shrimp)	26	3
	Watersnipe Larva		
Sub-Total		C2 39	D2 6
Category 3	Aquatic Worm (oligochaete)	29	2
	Blackfly Larva	5	1
	Leech		
Pollution Tolerant	Midge Larva (chironomid)	8	2
	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	3	1
Sub-Total		C3 45	D3 6
TOTAL		CT 101	DT 19

Appendix B. (Continued)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 101

DENSITY: Invertebrate density per total area sampled:

S1 101 ÷ .27 m^2 = S2 374 / m^2

PREDOMINANT TAXON:

Invertebrate group with the highest number counted (Col. C) S3 Aquatic Worm

SECTION 2 - WATER QUALITY ASSESSMENTS

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

Good	Acceptable	Marginal	Poor	3 x D1 + 2 x D2 + D3	S4
>22	17-22	11-16	<11	3 x __7___ + 2 x __6___ + __6___ =	39

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor	EPT4 + EPT5 + EPT6	S5
>8	5-8	2-4	0-1	___3__ + __1___ + __2___ =	6

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

Good	Acceptable	Marginal	Poor	(EPT1 + EPT2 + EPT3) / CT	S6
0.75-1.0	0.50-0.74	0.25-0.49	<0.25	(__5___ + ___5__ + __6___) / _101_=	0.16

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 19

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

Good	Acceptable	Marginal	Poor	Col. C for S3 / CT	S8
<0.40	0.40-0.59	0.60-0.79	0.80-1.0	___29__ / __101___ =	0.29

SECTION 4 - OVERALL SITE ASSESSMENT RATING

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

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

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