Environmental Monitoring
Field Project of Cottle Creek

RMOT 306

Submitted to: Eric Demers, Ph. D.

Submitted by: Cory Dennill, Lane Vienneau, Jeremy Pauls and Max Goldman

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Vancouver Island University

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Executive Summary

A complete stream ecosystem analysis of Cottle Creek was conducted by four undergraduate students from Vancouver Island University in Fall 2015. From analysis water quality, hydrology, microbiology, and stream invertebrate communities, data from this report can be compiled and compared to data from 2013 to present in order to understand the long-term health conditions of this urban creek. All samples were taken on November 4 and 25, 2015, at four Sites spanning from the upper reaches of the watershed to just above its outflow into the Strait of Georgia. Two sets of samples were taken; one set to be analyzed by the undergraduate students in a lab at Vancouver Island University, and the other to be analyzed at a professional facility, ALS Laboratories in Burnaby, BC. Analysis revealed expected results based upon the creek's proximity to the city; a population of fecal and non-fecal coliforms in the watershed and the highest population of aquatic invertebrates are "somewhat pollution tolerant". Unexpectedly, and of great interest was the alkalinity of the water, which was high, meaning that Cottle Creek is not sensitive to the introduction of acid into the water, which is positive. The most important recommendation is to continue the annual monitoring of Cottle Creek in order to observe any long-term creek health trends occurring.

Section 1 and 2: Introduction and Background

Four undergraduate students from the Bachelor of Natural Resource Protection program at Vancouver Island University would like to propose an environmental management project at Cottle Creek in Nanaimo, BC. The creek flows through mostly Linley Valley Park, an undeveloped area in North Nanaimo. The four sites chosen for sampling are located on the three tributaries of the creek and are easily accessible since they are within close proximity of roads and trails. The Cottle Creek project will begin in October of 2015, and will conclude in December of 2015 with a final written report. As well as providing insight into short-term assessments of the stream, the data from this study will be compiled with data from previous years to provide long-term information about the conditions of Cottle Creek. The riparian area consists of large mature stands of trees which provide habitat for Columbian black-tailed deer (*Odocoileus hemionus columbianus*), raccoons (*Procyon lotor*), beaver (*Castor canadensis*), mink (*Neovision vison*), reptiles, amphibians and several species of birds (City of Nanaimo 2005). A long-steep gradient near the discharge into Hammond Bay, prevents most anadromous fish from inhabiting Cottle Creek, however it does support steelhead (*Oncorhynchus mykiss*) populations (City of Nanaimo 1999).

The area to be sampled, Linley Valley, has been occupied since the 1880's, originally by the Cottle family who originated from North England. Cottle Creek is named after John Cottle, a man who worked in the local coal mine and homesteaded along the watershed. Other families began homesteading in the area around 1900 and the lake was constantly used by the children for fishing and swimming. A local shareholder bought the area in 1970 and owned it

until the Nanaimo and Area Land Trust society (NALT) fundraised to acquire the park in 2003, when it was added to the Nanaimo Park System (City of Nanaimo 2005).

The headwaters of Cottle Creek begin north of Linley Valley Park off Rutherford Road and flow into Cottle Lake. The creek also flows from the west under Landalt Road into Cottle Lake. From the lake, Cottle Creek flows East in the direction of Nottingham Drive and finally discharges into Hammond Bay. The total Cottle Creek watershed covers roughly 4.5 km^2 or 1113 acres, and passes through many developed areas (City of Nanaimo 2005). Figure 1 shows a map of Nanaimo with the four sites chosen for sampling along the watershed. Areas of development have documented increasing levels of silt resulting from the clearing of steep slopes around the creek. Natural ponds have been built up the by this silt and prevents the sediment from dispersing throughout the creek; however, this creates large areas of contaminated wetlands. Other past impacts that have been recorded include a fish barrier and source of bank erosion in the form of a culvert under Landalt Road, and pollution due to cattle grazing (City of Nanaimo 1999).

Section 3: Project Objectives

Natural Resource Protection students have monitored Cottle Creek since 2013. More specifically, the students have monitored water quality, microbiology, and invertebrate biology in the creek. Data collected from this year's sampling will contribute to past years' data and be used comparatively to analyze the stream health trends from 2013 to the present. Using four stations located along the length of Cottle Creek, students will gather and analyze water quality, microbiology (coliforms), and invertebrate biology which will be valuable to determine

long-term environmental health. This data will be useful to the City of Nanaimo, as well as the Department of Fisheries and Oceans Canada (DFO) in determining environmental management strategies for Cottle Creek. Although there are no anadromous Pacific salmon in Cottle Creek, this data will be particularly helpful to DFO's management strategies, as Cottle Creek is a known breeding and rearing ground for Pacific run steelhead (*Oncorhynchus mykiss*) and contains a resident population of coastal cutthroat trout (*Oncorhynchus clarkii clarkii)* (City of Nanaimo, 1999).

Section 4 Environmental Sampling and Analytical Procedures

Section 4.1 Sampling Stations

For this study four different sample stations along sections of Cottle Creek were used. At each sample station water quality, microbiology, and stream invertebrate activity were sampled. These four sites are a continuation of the annual monitoring that has taken place at Cottle Creek by the Bachelor of Natural Resource Protection students at Vancouver Island University since 2013. Previous to VIU's affiliation with the Cottle Creek project, the Regional District of Nanaimo Community Watershed Monitoring Project started to monitor Cottle Creek in 2012. This group originally decided on four sampling stations along Cottle creek based on accessibility, safety, water flow, stream substrate, and providing a good representation of the overall stream conditions. Since 2013, the VIU students continuing this project have tried to keep the same four locations that were originally chosen for sampling to keep consistency from year to year and provide long term results and trends. Site 2, originally stationed on North Cottle Creek was dry during our original site assessment, and so a different location just

downstream of Cottle Lake was selected to replace site 2. All sites were visited on October 22nd, 2015 during a preliminary site visit, October 25th, 2015, and on the sampling days of November 4th, 2015, and November 25th, 2015.

Site 1 was located at Landalt road where Cottle creek crosses under the road (49° 13' 5.398"N, 123° 59' 22.280"W) (Figure 1). Sampling took place on the upstream (west) side of the road as the downstream side is fenced off, which was not problematic. This site had approximately 75% canopy cover with lots of leaf litter on the ground and in the stream. The creek bed was a mix of cobbles and fines. See Table 1 for a full list of the hydrology measurements taken on October 25th, 2015 from all sites. Some hazards in this area include slippery surfaces, wildlife, vehicles and a steep gradient hike down to the creek from the road. Table 2 provides a full list of the site safety assessment taken on October 22nd, 2015.

Site 2 was moved from north Cottle Creek to downstream of Cottle Lake (49° 13' 7.8"N, 123° 58' 35.3"W) (Figure 1). Site 2 is located along a walking trail which provided easy access. The stream bed was made up of primarily cobble and has a gradient of 5°. Some potential hazards in this area include tree roots which are a tripping hazard, and people in the area because of the nearby walking trail. Overall, this site provides relatively good footing around the creek. Furthermore, due to being at the mouth of Cottle Lake, canopy cover was approximately 30%.

Site 3 was located where Cottle Creek crosses Nottingham Drive. Sampling took place on the upstream (North) side of the road (49° 13' 1.221"N, 123° 57' 30.919"W) (Figure 1). The biggest hazard at site 3 was the steep climb down from the road to the creek, and the potholes

hidden in the soil surrounding the creek. In-creek footing was solid and consists of mostly gravel. A series of different features were noted in this area including a pool, a riffle, and a glide. As with the other sites, Site 3 was covered in leaf litter with lots of vegetation on the bank of the creek, producing approximately 80% canopy cover. The substrate consisted of gravel and fines.

Site 4 was located where Cottle Creek meets Stephenson Point Road. The sample location was again upstream (north) of the road (49° 12’ 41.207”N 123° 57’ 11.402”W) (Figure 1). Site 4 showed a diversity of riffles and glides. The substrate consisted of cobbles, boulders and gravel, and canopy cover was estimated to be 70%. Some potential hazards at Site 4 were the inherited risks of vehicles and people in a residential area, as well as wildlife, such as Columbian black tailed deer (*Odocoileus hemionus columbianus*).

Figure 1: Map of Nanaimo with the four sites chosen for sampling (Map from City of Nanaimo Website).

Figure 2: Overview of Site 1 facing west/downstream. Photo taken October 22, 2015 by Lane Vienneau.

Figure 3: Overview of Site 2 facing south/downstream. Photo taken October 25, 2015 by Lane Vienneau.

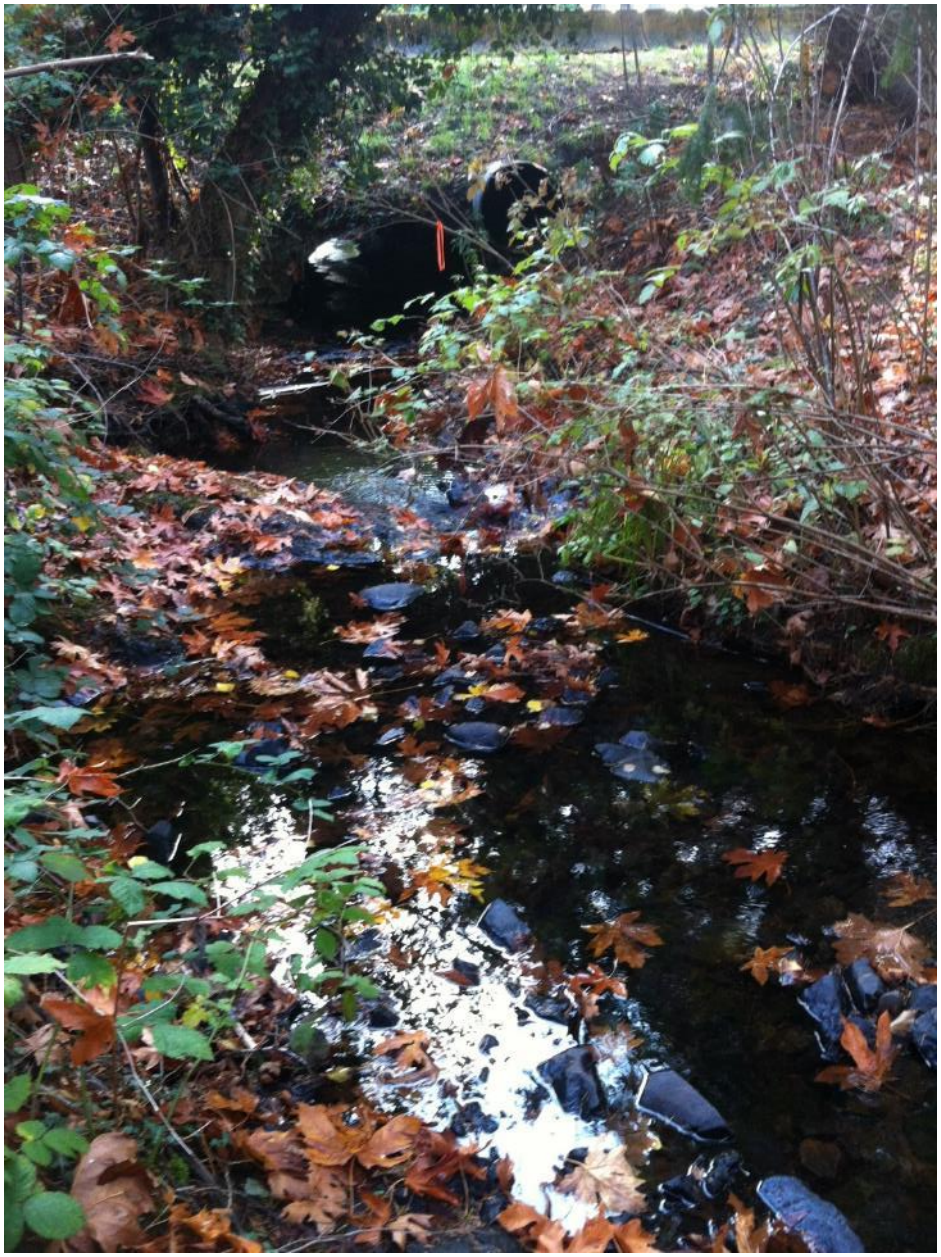

Figure 4: Overview of Site 3 facing south/downstream. Photo taken October 22, 2015 by Jeremy Pauls.

Figure 5: Overview of Site 4 facing southeast/downstream. Photo taken October 22, 2015 by Lane Vienneau.

Table 1*:* Hydrological measurements for Cottle Creek taken on October 25, 2015

Site Location	Site #1	Site #2	Site #3	Site #4
Bank full depth (m)	0.43m	0.50m	0.28m	0.46m
Wetted Width (m)	2.28m	1.34m	2.44m	2.39m
Water Depth (m)	0.24m	0.13m	0.10m	0.23m
Gradient (°)	3	5	1	2
Average Discharge (m^3/s)	$0.016m^3/s$	$0.010m^3/s$	$0.0007m^3/s$	$0.033m^3/s$
Average Velocity (m/sec)	0.03m/s	0.06m/s	0.003m/s	0.06m/s

Table 2: Site Safety Assessment conducted October 22, 2015.

Site Location	Site 1	Site 2	Site 3	Site 4
Access	Easy from road	Easy walking trail	Steep climb under bridge	Easy access from road
Hazards	Slippery, steep slope wildlife, vehicles (close to road), trees/ widowmakers	Close to trail, people, dogs, some tripping hazard, tree failure potential.	Steep climb down boulders to get to site, vehicles close to road, wildlife, potholes	Vehicles close to road, potential for tree failure, wildlife, people (residential area).
Embankment	Medium gradient, muddy, lots of leaf litter and tripping hazards (deadfall)	Very small gradient, easy walking.	Very steep gradient down to creek, very easy flat walking once down to creek.	Small gradient down to creek.
In stream Footing	Easy footing, mix of cobble and gravel.	Easy footing, mostly cobble.	Easy, mostly gravel	Easy in most parts, some poking cobble/ boulders.

Section 4.2 Sampling Frequency

Sampling for the Cottle Creek project took place at two different events in an attempt to record high flow and low flow conditions. The first event took place on November 4th, 2015, which was a sunny, temperate day. Flow was higher than that of October 22nd, 2015. The second sample took place on November 25th, 2015, which was a clear and cold day. Flow was

higher than that of November 4th, 2015. Samples were then taken back to the VIU lab and analyzed the same day as sample collection. The students also took water samples from stations #1, #2, and #4 during both sample events and sent them to the ALS Environmental Laboratory in Burnaby for professional water quality results. Microbiology was tested at all four stations during the first sampling event only, which were analyzed in the VIU lab on the day of sample collection, November 4th, 2015. Stream Invertebrates were also collected during the first sampling event at stations #1, #2, and #4, with three replicates taken at each station. These invertebrate samples were be brought back to the VIU Lab and analyzed on November 4th, 2015.

Section 4.3 Hydrology

Initial hydrology measurements were taken on October 25th, 2015. The measurements were repeated on November 4th and 25th, 2015 as well. These measurements included bank full depth, water depth, wetted width, velocity, discharge and gradient. The full results of the hydrology tests have been summarized in Table 2**.** Bank full depth was measured by running a measuring tape across the high water mark along the stream bank on both sides and using a meter stick to measure the depth at 25%, 50%, and 75% across the stream. The numbers were then averaged. Water depth was measured in the same fashion, however the meter stick only measured the actual depth of the stream at the same locations. Wetted width was measured by placing a measuring tape across the wet portion of the streambed. Velocity was calculated by sectioning off 1 meter of stream and then placing a ping pong ball in the water to measure the time it took to travel 1 meter. This experiment was conducted 3 times and the results averaged to produce a m/s value. In order to measure discharge, the area of the wetted width

and wetted depth was first calculated, then the product of that number was multiplied to find discharge in m^3/sec. Gradient was calculated by looking through a Leupold RX-800i TBR rangefinder upstream at a target of the same height from the ground.

Section 4.4 Water Quality

Water quality was tested on November 4th, 2015 and November 25th, 2015, during both low flow and high flow conditions in order to compare how the water quality is affected by water flow. Water quality samples were taken from all sample stations and assessed at the VIU campus lab in Nanaimo. The water samples were analyzed for general water quality parameters and nutrient content. Before analysis, the water samples taken were stored in an iced cooler for approximately 3 hours. Separate water samples were sent to the ALS Environmental Laboratory in Burnaby. Samples from stations #1, #2, and #4 were sent to this private lab on November 4th, and November 25th, 2015. The results from this private lab included general water quality parameters, nutrient analysis, and a scan of the total metals in the water. The samples for ALS Laboratories were also collected on November 4th, 2015 and November 25th, 2015 and were stored in an iced cooler for approximately 4 hours before being placed in another iced cooler for the shipping to Burnaby, taking approximately 3 hours to complete the trip.

<u>Section 4.4.1 Quality Control/Quality Assurance</u>

Quality control was ensured by multiple means when sampling for water quality. Before samples were taken, unsanitized (VIU) bottles were rinsed three times with field water before the actual sample was taken. Doing this ensured that the sample contained only sample water, with no chance of any contamination from prior sampling. Bottles destined for ALS were

presanitized and therefore no precautionary measures were necessary. Chain of custody was also guaranteed for all samples. While in the field, samples were either with the students, or locked in a vehicle. Furthermore, all samples were labelled “Cottle Creek Site #” so that there was no chance the samples could be mixed up during analysis in the lab.

Quality assurance was also guaranteed by multiple means. A trip blank accompanied the students in the cooler for the entire duration of the project in order to ensure no contamination from outside sources. Furthermore, a site replicate was taken during each sampling event and then sampled in the VIU lab. The results of the analysis of the trip replicate were then compared with the sample from the same site in order to judge analysis accuracy and to ensure the results were replicable. Finally, all water sample were drawn from mid-depth at midstream in order to ensure an accurate representation of the site.

Section 4.5 Microbiology

A microbiology test was taken at all four sample sites during the first sampling event on November 4th, 2015 only. The sample for this was supposed to be taken in sterile 100 mL Whirpak bags, however due to error on the students’ part, the water used came from unsterilized VIU water bottles, consisting of the same water used for water quality tests. While the bottles were rinsed with sample water 3 times before being collected, the bottles were not sterile. The microbiology tests did follow the other methods used by the U.S. Environmental Protection Agency. The purpose of the microbiology test was to determine the levels of bacteria by testing for coliforms and *E. coli* in the water sample. The USEPA method involved running 100 mL of sample water through a filter, then allowing the filter to sit in a chemical that

promotes growth of bacteria for 24 hours. Upon completion of the waiting period, individual bacteria did grow to be noticed by the eye, and were then counted. Only 25 mL of sample water was used, so in order to follow the USEPA's protocols, the counted results were multiplied by 4. The chemical used in this process, ColiBlue24 Broth underwent quality control measures prior to being put on the market and came with a certificate of analysis when purchased. Filtration blanks were used during testing at rate of 10% for the number of tests that were conducted.

Section 4.6 Stream Invertebrates

Stream invertebrates were sampled on November 4th, 2015. The sampling took place at Sites #1, #2 and #4 by using a Hess sampler. At each site, three samples were taken to ensure a good representation of the stream environment. The invertebrates in the water samples were then brought directly back to the lab at the VIU campus and counted and identified. There was no need to add a preservative to the sample because the invertebrates were taken to the lab the same day.

The invertebrates in the sample were taxonomically identified to Order or Family (DFO 2000). Invertebrate survey field data sheets were used to categorize and count taxa based on their sensitivity to pollution. These invertebrates are a good indicator of potential pollutants in the water affecting invertebrates. Also calculated was the abundance of invertebrates, the density of invertebrates, diversity, and the predominant taxon of invertebrates in the stream. An overall assessment about site quality was made based on the invertebrates that were sampled.

Section 4.6.2 Quality Control/Quality Assurance

Quality control measures were used to make sure the correct number of specimens are counted. The invertebrates in each sample were individually counted by two different students and the results were compared to ensure the same results are achieved. The invertebrates were also identified by two different students to make sure the correct species are identified. As well, each site had triplicate samples taken. Furthermore, the Shannon-Weiner Diversity Index of each site was calculated, in order to confirm stream invertebrate health. Each sample was labeled at the time of sampling to make sure the correct samples were counted and recorded for the correct areas.

Section 5: Health and Safety

Student health and safety was the number one concern when conducting, sampling, and analyzing during this project. Safety was ensured by carrying cell phones, and contacting professor Eric Demers when going to the field to sample. Students never sampled alone; only sampled during daytime hours; wore weather-appropriate, high-visibility clothing; were aware of all potential hazards; and also conducted regular check-ins with each other and professor Demers. Prominent risks throughout each site included potential tree failure as Maple trees are present at each site and can be failure prone, as well as potential wildlife conflict as many Columbia black tailed deer frequented the Cottle Creek watershed which had the potential to attract cougars (*Puma concolor*). Each site has been assessed for potential risks, which are available in Table 2.

Section 6: Results and Discussion

Section 6.1 Hydrology

Hydrology was tested for in both main sampling events. This testing consisted of wetted width, wetted depth, average velocity, discharge, and gradient (See table 3). All 4 sample sites saw an increase in discharge from the first event on November 4th 2015, to the second event on November 24th 2015. An increase in discharge and flow was predicted due to the rain that was received in the days leading up to the second sampling event. Site 2 had a dramatic change in discharge between events. Site 2 is located just at the outflow of Cottle Lake and has a gradient of 5˚. During the first event, this site had the least discharge out of all tested sites. During the second sampling event, Site 2 had changed; created was a new side channel due to the mass discharge of water exiting the lake. Due to the dramatic change of flow, sampling was moved 10 m downstream and hydrology was tested where both the main channel and the new side channel had connected. Produced was a much more accurate measurement of discharge. The greatest discharge found was 0.1m^3/s at Site 4 during the second sampling event. The discharge results at Site 4 were predictable because the site is the farthest downstream and would have the most input of water to the stream. Overall, Cottle creek is not huge in size or volume and will fluctuate greatly based on the amount of precipitation in the area (See Appendix).

In addition, the changes in water temperature reflected the changes in ambient air temperature between the two sampling day. The second sampling day, November 4th, 2015 was a very cold day, and the temperatures recorded in the water reflected that. Due to the cold water, dissolved oxygen also (mostly) increased in response to the temperature, and oxygen

levels fell within acceptable dissolved oxygen parameters for aquatic life (BC 2015) (See Appendix).

Table 3: Field analysis taken at Cottle Creek on November 4, 2015 and November 25, 2015.

Date and Site	Wetted Width (m)	Wetted Depth (m)	Average Velocity (m/s)	Average Discharge (m^3/s)	Gradient (˚)	Temperature (Celsius)	Dissolved Oxygen (mg/L)
Nov 4/15; Site 1	0.90	0.10	0.062	0.006	3	7.7	11.4
Nov 4/15; Site 2	0.53	0.05	0.222	0.001	5	7.9	11.5
Nov 4/15; Site 3	0.96	0.04	0.198	0.008	1	8.2	8.7
Nov 4/15; Site 4	0.94	0.09	0.250	0.021	2	8.2	7.8
Nov 25/15; Site 1	2.13	0.12	0.092	0.024	3	3.4	12.2
Nov 25/15; Site 2	2.05	0.13	0.313	0.083	5	2.7	10.5
Nov 25/15; Site 3	2.86	0.13	0.179	0.067	1	3.0	12.5
Nov 25/15; Site 4	3.10	0.15	0.216	0.100	2	3.4	12.9

Section 6.2 Water Quality

The water quality parameters tested in the VIU lab for Cottle Creek included; pH levels, alkalinity, hardness, conductivity, phosphates, nitrates and total dissolved solids. ALS also tested for these but included 31 metals as well. By correlating the results from the VIU lab and from ALS an accurate means of estimating the overall water quality of the stream was possible.

Section 6.2.1 pH Levels

The pH scale is representative of how acidic or basic a liquid is. The scale ranges from 0 to 14 with the values lower than 7 indicating an acidic solution and values higher than 7

indicating a basic solution. The pH levels recorded in the VIU lab were quite similar to the results we obtained from ALS. VIU lab analysis results showed an average level of 7.725 for the first event and 7.525 for the second event from all four sites (See table 4). ALS recorded an average of 7.66 for the first event and 7.73 for the second event for Sites 1, 2 and 4. In both cases, Site 2 was the most acidic and Site 1 had the most basic readings. Despite the slight variation in results, all pH readings fell well within the BC Water Quality Guidelines of between 6.5 and 9 indicating that the pH levels in Cottle Creek are not harmful to aquatic life (BC 2015) (See Appendix).

Section 6.2.2 Alkalinity

Alkalinity tests measure the amount of base present in a liquid. Since basic solutions naturally neutralize acidic solutions, these are a good indicator of how sensitive a water system is to acids. The BC Water Quality Guidelines state that readings over 20 milligrams per liter indicates a low sensitivity to acids (BC 2015).The VIU results were an average of 48.78 milligrams per liter for the first event and 46.03 milligrams per liter for the second event (See table 4). The results indicate that the stream has a low sensitivity to acids (See Appendix).

Section 6.2.3 Hardness

The relative hardness of a stream is indicative of the amount of divalent ions present in the water system which mainly come from calcium and magnesium. The concentration of these elements has a direct correlation with the toxicity of other metals and therefore changes the toxicity level threshold in the BC Water Quality Guidelines for certain metals. The VIU results varied slightly with the ALS results for the first event but not for the second event. VIU lab analysis demonstrated an average of 94.05 milligrams per liter and ALS recorded 73.2

milligrams per liter for the first event. Despite this variation, these results both fall in the normal range of between 60 and 120. Anything lower than 60 is considered softwater and anything over 120 is considered hardwater. The results for the second event were slightly above the threshold of being considered softwater since the VIU results were 62 milligrams per liter and the ALS results were 60.7 milligrams per liter (See table 4). Both the results from the first event and the second indicate that the covalent ions in Cottle Creek are having a moderate effect on the toxicity of metals in the stream (BC 2015) (See Appendix).

Section 6.2.4 Conductivity

The conductivity of a liquid is directly related to hardness, owing to the fact that they both pertain to the concentration of metals in a solution. High concentrations make it is easier for electricity to move through liquids due to the conductive nature of metals. However if levels become too high, they can have negative physiological effects on plants and animals. Conductivity is reported in terms of micro Siemens per centimeter and natural waters can vary from 50 to 1500 with coastal waters generally sitting around 100 and interior streams upwards of 500. The results between labs varied in this category with ALS recorded levels almost twice as much as the VIU results. VIU lab analysis revealed an average of 106.5 and 74.175 µS/cm for events 1 and 2 respectively and ALS recorded an average of 191.67 and 169.33 µS/cm for events 1 and 2 respectively (See table 4). The results from both labs fall well within the naturally occurring range and are similar to what we would expect in a coastal environment (BC 2015) (See Appendix).

Section 6.2.5 Phosphates

The phosphate testing carried out in the VIU lab depicted questionable results which were indicative of an extremely eutrophic environment (See table 4). During the second sampling event, taken into account and observed was the surrounding environment only to realize that the stream was not nearly eutrophic. Some of the recorded levels were 7 times the threshold of being considered eutrophic which seemed suspiciously high. Furthermore, four other groups using the same testing machine for different streams made the same observations. For this reason it is concluded that the machine was producing inaccurate results which is considered irrelevant to the analysis. The ALS results varied slightly between the three sites they analyzed and from the first and second events. Except for two exceptions, which were off by 0.0002 and 0.0006 milligrams per liter, all readings fell within the mesotrophic category which indicates this stream has an intermediate level of productivity (BC 2015) (See Appendix).

Section 6.2.6 Nitrates

Nitrates are a highly available form of nitrogen that plants can utilize as a nutrient to provide good health. Levels that exceed the water quality guidelines can cause eutrophication and can ultimately diminish water quality by increasing the biological oxygen demand to levels the environment cannot keep up with and therefore increasing the difficulty of sustaining aquatic life. Phosphorus is usually the limiting factor that prevents this from occurring too quickly. Excessive levels can be indicative of human influence from agriculture, sewage drainages, fertilizers, and mining among other things. The results obtained in the VIU lab were variable. Water quality guidelines state that anything under 0.3 milligrams per liter is

considered normal and for the first event, Site 2 had no detectable levels and Sites 1, 3 and 4 were all above the normal limit. For the second event, Sites 3 and 4 were roughly 5 times the normal limit and Sites 1 and 2 were 3 and 2 times the normal limit respectively (See table 4). The results from ALS were consistently lower. For the first event, Site 2 showed undetectable levels, Site 1 was quite low and levels in Site 3 were normal. For the second event, all levels were normal and consistent throughout. These results indicate that there are an adequate amount of nutrients in Cottle Creek in the form of nitrates (BC 2015) (See Appendix).

Section 6.2.7 Total Dissolved Solids

During the VIU lab analyses, an error was made on part of the undergraduate students. Instead of testing for total suspended solids, also known as turbidity, tested for was total dissolved solids, also known as filterable residue. The total suspended solids parameter measures the amount organic and inorganic material over 2 microns in size. Total dissolved solids measures anything smaller than 2 microns in size. Since there is no data pertaining to total suspended solids, focus will be on total dissolved solids for this section. High levels of total dissolved solids are not necessarily indicative of poor water quality. Dissolved solids can include many things such as the salt present in oceanic waters so it is best if results are correlated with other aspects or parameters. Naturally occurring levels range from 0 to 1000 milligrams per liter with higher levels recorded in the interior and lower levels in coastal locations (BC 2015). VIU lab analysis results were consistent, with an average of 92.36 milligrams per liter, which is what we would expect given the location of Cottle Creek and its proximity to the Pacific Ocean (See table 4) (See Appendix).

Section 6.2.8 ALS Laboratory Analyses

In the VIU labs, the undergraduate students utilized all the resources available, which were limited to the parameters listed above. ALS took this one step further and tested for 31 different metals and provided the concentrations for those that were above the minimum detection limit. The metals that were not above the detection limit are not necessarily absent from the water column but they may be at a level that the testing equipment cannot pick up. This being said, calcium, iron, magnesium, manganese, silicon and strontium were the only metals that were above the minimum detection limit and out of these six metals, none were above the BC Water Quality Guidelines for aquatic life (BC 2015).

Section 6.2.9 Quality Control/Quality Assurance

Quality control was ensured by multiple means when sampling for water quality. Before samples were taken, unsanitized (VIU) bottles were rinsed three times with field water before the actual sample was taken. Doing this ensured that the sample contained only sample water, with no chance of any contamination from prior sampling. Bottles destined for ALS were presanitized and therefore no precautionary measures were necessary. Chain of custody was also guaranteed for all samples. While in the field, samples were either with the students, or locked in a vehicle. Furthermore, all samples were labelled “Cottle Creek Site #” so that there was no chance the samples could be mixed up during analysis in the lab.

Quality assurance was also guaranteed by multiple means. A trip blank accompanied the students in the cooler for the entire duration of the project in order to ensure no contamination from outside sources. Furthermore, a site replicate was taken during each sampling event and then sampled in the VIU lab. The results of the analysis of the trip replicate

were then compared with the sample from the same site in order to judge analysis accuracy and to ensure the results were replicable. Finally, all water sample were drawn from mid-depth at midstream in order to ensure an accurate representation of the site.

Table 4: VIU Lab Analysis Results of Cottle Creek from Samples Taken on November 4 2014 and November 25 2015.

Date and Site	pH	Alkalinity (mg/L CaCO3)	Hardness (mg/L CaCO3)	Phosphate (mg/L PO43-)	Nitrate (mg/L NO3-)	Conductivity (µS/cm)	Total Dissolved Solids (mg/L)
Nov 4/15; Site 1	8.0	44	85.5	0.06	0.62	105.6	100.4
Nov 4/15; Site 2	7.5	66.4	102.6	0.05	<0.01	90.5	87.2
Nov 4/15; Site Rep.	7.4	83.2	85.5	0.05	<0.01	N/A	N/A
Nov 4/15; Site 3	7.5	39	102.6	0.06	0.32	112.2	107.9
Nov 4/15; Site 4	7.9	46	85.5	0.05	0.88	117.7	112.5
Nov 4/15; Trip Blank	N/A	N/A	N/A	0.03	0.05	N/A	N/A
Nov 25/15; Site 1	7.8	52.6	76	0.21	0.97	92.9	102.8
Nov 25/15; Site 2	7.3	44.7	57	0.07	0.72	45.6	51.5
Nov 25/15; Site 3	7.4	42.0	57	0.08	1.47	73.8	82.7
Nov 25/15; Site Rep.	7.4	41.0	58	0.18	0.92	N/A	N/A
Nov 25/15; Site 4	7.6	44.8	58	0.22	1.57	84.8	93.9
Nov 25/15; Trip Blank	N/A	N/A	N/A	0.21	0.08	N/A	N/A

Section 6.3 Microbiology

Coliforms were analyzed from all four sites from the samples taken on November 4th, 2015. All tests produced positive results for the presence of fecal and non-fecal coliforms (See

table 5). Site 1 contained 900 non-fecal colony forming units (CFU), and 40 fecal CFU per 100 mL. Site 2 had the highest CFU, with 1372 non-fecal units, and 8 fecal units per 100 mL. Furthermore, Site 3 had 840 non-fecal CFU and 12 fecal CFU per 100 mL. Moreover, Site 4 contained 784 non-fecal CFU and 32 fecal CFU per 100 mL. All of the results from Cottle Creek exceed the maximum amounts of CFU outlined in the British Columbia Water Quality Guidelines for untreated drinking water, which have a zero tolerance for fecal or non-fecal coliform forming units (BC 2015) (See Appendix).

Cottle Creek did produce unexpected microbiology results. Site 3 and 4 are both located in residential areas, which given the likelihood of pets in the water and sewage runoff, one would expect those sites to have the highest coliform content. Conversely, Site 2, located in Linley Valley Park, away from residential influences, had the highest coliform content while Sites 3 and 4 had the lowest. The water at Site 2 did have a noticeably higher turbidity (personal observation) which could account for the higher coliform content. Site 1 was also expected to have lower coliform content based on its remoteness; however this was also not the case.

Table 5: Microbiology analysis results from Cottle Creek, taken on November 4 2015.

Coliform	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Non-Fecal (CFU/100 mL)	900	1372	840	784
Fecal (CFU/100 mL)	40	8	12	32
Total (CFU/100 mL)	940	1380	852	816

Section 6.4 Stream Invertebrates Communities

Section 6.4.1 Total Density

Freshwater benthic macroinvertebrate species density was calculated by dividing the total number of macroinvertebrates captured at each site (Sites 1,2, and 4 respectively) by the total area sampled at each site. One-time application of a Hess sampler was completed to gather these invertebrates at each station with a total area of 2.7m^2 sampled from each site. Hess samplers at Sites 1,2, and 4 contained 49, 76, and 104 invertebrates respectively, thus, total density for Site 1 was calculated as 49/2.7m^2= 18.15 invertebrates/m^2, while Site 2 was calculated as 76/2.7m^2=28.15 invertebrates/m^2, and Site 4 was calculated as 104/2.7m^2= 38.52 invertebrates/m^2. Additionally, average total density of all sites was calculated by taking the summation of invertebrates from all sites and dividing that number by the summation of total area sampled, as 229/8.1m^2= 28.272 invertebrates/m^2. Once total density of all sites had been calculated, the mean number of invertebrates found per m^2 per site was calculated by taking the summation of each Site's density of invertebrates/m^2 and dividing that number by the total number of Sites as (18.15+28.15+38.52)/3= 28.273 invertebrates/m^2, which is notably close to the total density calculation of 28.272 invertebrates/m^2. Total density of macroinvertebrates and taxon examined per site can be found in Tables 6, 7, and 8 (DFO 2000).

Table 6: Total number of macroinvertebrates and taxon captured at Site 1 on November 4 2015.

Column B Common Name	Column C Number Counted	Column D Number of Taxa
Mayfly Nymph	1	1
Stonefly Nymph	2	1
Gilled Snail	2	1
Cranefly Larva	1	1
Amphipod	21	1
Aquatic Worm	22	2

Table 7: Total number of macroinvertebrates and taxon captured at Site 2 on November 4 2015.

Column B Common Name	Column C Number Counted	Column D Number of Taxa
Mayfly Nymph	3	1
Stonefly Nymph	2	1
Aquatic Sowbug	5	1
Cranefly Larva	5	2
Dragonfly Larva	1	1
Amphipod	43	1
Aquatic Worm	12	1
Midge Larva	5	1

Table 8: Total number of macroinvertebrates and taxon captured at Site 4 on November 4 2015.

Column B Common Name	Column C Number Counted	Column D Number of Taxa
Caddisfly Larva	1	1
Mayfly Nymph	10	1
Stonefly Nymph	4	1
Gilled Snail	1	1
Amphipod	62	1
Aquatic Worm	19	1
Midge Larva	7	2

EPT indexes for each site were calculated based upon the summation of the total number of EPT taxa found at each site. Sites 1,2, and 4 all scored in the "Marginal" category as they scored 2, 2, and 3, respectively (see Appendix). EPT to total ratio indexes were also calculated by taking the total number of EPT organisms and dividing that number by the total number of organisms captured in each Site. Sites 1, 2, and 4 all scored as "poor" in this category as they scored 0.06, 0.07, and 0.144 respectively (see Appendix). Finally, predominant taxon ratio was calculated by taking the number of invertebrates found in the predominant taxon and dividing that number by the total number of invertebrates captured. Site 1 contained 22 oligochaetes as the predominant taxon, which was then divided by the total number of invertebrates which was 49 to get a score of 0.45, Site 2 contained 43 amphipods as the predominant taxon which was divided by 76 total invertebrates to get a score of 0.57, and Site 3 contained 62 amphipods as the predominant taxon which was divided by 104 total invertebrates to get a score of 0.596. All Sites scored as "acceptable" (see Appendix). EPT species are important as they are found in the "pollution intolerant" category and are indicators of good stream health when found in high numbers (DFO 2000).

Shannon-Weiner Diversity Index (*H*) results were also calculated to indicate species diversity per site. Tables 9, 10, and 11 were created based on necessary calculations for the Shannon-Weiner Diversity Index formula to aid in species diversity calculations. Species diversity in Site 1 based on the Shannon-Weiner Diversity Index was calculated as *H*= -(-1.142)/ln (7) = 0.587, while Site 2 was calculated as *H*= -(-1.44)/ln (9) =0.655, and Site 4 was calculated as *H*= -(-1.241)/ln (7) =0.638. Values that are closer to 1 reflect poor species diversity and as one can see, all values were over the halfway point of .500 being on the lower

end of the diversity spectrum. Lower diversity of the stream does not necessarily reflect the streams health, as a higher number of "pollution tolerant" invertebrates may be present in the sample (DFO 2000).

Table 9: Necessary calculations for Site 1 of the Shannon-Weiner Diversity Index formula where Pi is the proportion of taxon i, and ln is the natural logarithm.

Common Name	Column C	*P*i(C/T)	ln(*P*i)	*P*i*ln(*P*i)
Mayfly Nymph	1	0.020408	-3.89	-0.079
Stonefly Nymph	2	0.040816	-3.2	-0.131
Gilled Snail	2	0.040816	-3.2	-0.131
Cranefly Larva	1	0.020408	-3.89	-0.079
Amphipod	21	0.428571	-0.85	-0.363
Aquatic Worm	22	0.44898	-0.8	-0.36
Total	49	1		-1.142

Table 10: Necessary calculations for Site 2 of the Shannon-Weiner Diversity Index formula where Pi is the proportion of taxon i, and ln is the natural logarithm.

Common Name	Column C	*P*i(C/T)	ln(*P*i)	*P*i*ln(*P*i)
Mayfly Nymph	3	0.039474	-3.23	-0.13
Stonefly Nymph	2	0.026316	-3.64	-0.1
Aquatic Sowbug	5	0.065789	-2.72	-0.18
Cranefly Larva	5	0.065789	-2.72	-0.18
Dragonfly Larva	1	0.013158	-4.33	-0.06
Amphipod	43	0.565789	-0.57	-0.32
Aquatic Worm	12	0.157895	-1.85	-0.29
Midge Larva	5	0.065789	-2.72	-0.18
Total	76	1		-1.44

Table 11: Necessary calculations for Site 4 of the Shannon-Weiner Diversity Index Formula where Pi is the proportion of taxon i, and ln is the natural logarithm.

Common Name	Column C	*P*i(C/T)	ln(*P*i)	*P*i*ln(*P*i)
Caddisfly Larva	1	0.009615	-4.64	-0.045
Mayfly Nymph	10	0.096154	-2.34	-0.225
Stonefly Nymph	4	0.038462	-3.26	-0.125
Gilled Snail	1	0.009615	-4.64	-0.045
Amphipod	62	0.596154	-0.52	-0.308
Aquatic Worm	19	0.182692	-1.7	-0.311
Midge Larva	7	0.067308	-2.7	-0.182
Total	104	1		-1.241

Compared to 2014 results which yielded 22 total invertebrates for Site 1, 94 total invertebrates for Site 3, and 30 total invertebrates for Site 4, invertebrate totals for 2015 were higher in Sites 1 and 4 as Site 1 contained 49 invertebrates, Site 2 contained 76 invertebrates, and Site 4 contained 104 total invertebrates. Since Site 3 was used for sampling in 2014 whereas Site 2 was used for sampling in 2015, this is where the discrepancy lies, as one cannot accurately compare the totals for these sites based on the difference in continuity and in habitat sampled (Kee et. al, 2014).

Section 6.5.1 Taxon Richness and Diversity

Taxon diversity was calculated by taking the number of taxon found in each Site and dividing that by the total number of invertebrates captured in the Site. Numbers closer to 0 are representative of low taxon diversity as that would indicate no taxa found per site. For example, Site 1 displayed a taxon diversity of 7(taxa)/49(invertebrates)= 0.14, while Site 2 displayed a taxa diversity of 9/76= 0.12, and Site 3 displayed a taxa diversity of 7/104= 0.07, with a mean taxa diversity of 0.11 for all three Sites, and a total taxa diversity for all three Sites

(all different taxa found/ total number of invertebrates captured) of 12/229= 0.05. Again, high diversity is not a good indicator of stream health as there may be more "pollution tolerant" taxa present within a sample. Instead, species which have been found are ranked in categories based on their pollution tolerance, which is a much better indicator of stream health. Category 1 species are "Pollution Intolerant" which include the EPT taxa amongst other taxa, category 2 species are "Somewhat Pollution Tolerant", and category 3 species are "Pollution Tolerant" (DFO 2000).

Site 1 contained five "pollution intolerant" invertebrates amongst three taxa, twenty-two "somewhat pollution intolerant" invertebrates amongst two taxa, and twenty-two "pollution tolerant" invertebrates amongst two taxa. Oligochaetes (22 captured) were the predominant taxon in Site 1, and are found in the "pollution tolerant" category. Based on these numbers and an overall site rating of 2/4 (see Appendix), one may conclude that "pollution tolerant" species and "somewhat pollution tolerant" species thrive in this section of Cottle creek while "pollution intolerant" species do not, indicating marginal stream health (DFO 2000).

Site 2 contained five "pollution intolerant" invertebrates amongst two taxa, fifty-four "somewhat pollution tolerant" invertebrates amongst five taxa, and seventeen "pollution tolerant" invertebrates amongst two taxa. Amphipods (43 captured) were the predominant taxon in Site 2, which are again found in the "somewhat pollution tolerant" category. Overall site assessment of Site 2 was calculated to be 2.25/4 (see Appendix). Once again, based on these numbers one may conclude that "somewhat pollution tolerant" and "pollution tolerant" species thrive in this area which is once again indicative of marginal stream health (DFO 2000).

Sixteen “pollution intolerant” invertebrates were found amongst three taxa, sixty-two “somewhat pollution tolerant” invertebrates found amongst one taxa, and twenty-six “pollution tolerant” species were captured amongst three taxa in Site 4. Amphipods (62 captured) were also the predominant taxa found in Site 4. Overall site assessment of Site 4 was calculated to be 2/4 (see Appendix), which when paired with the number of “somewhat pollution tolerant” and “pollution tolerant” invertebrates found indicates marginal stream health (DFO 2000).

Overall, twenty-six “pollution intolerant” invertebrates amongst four taxa were captured, while one hundred and thirty-eight “somewhat pollution tolerant” invertebrates amongst five taxa were captured, and sixty-five “pollution tolerant” invertebrates amongst three taxa were captured (Figure 1). Average site assessment rating for all three sample sites is 2.08. Again, as one can see from these numbers, stream health is marginal at best. Since Cottle Creek flows through Linley Valley where there is runoff from cattle farming, and through a residential area in Hammond Bay which is frequented by many people and animals, one may hypothesize that this is the reasoning behind “somewhat pollution tolerant” and “pollution tolerant” invertebrates thriving here and stream health being rated as marginal (DFO 2000).

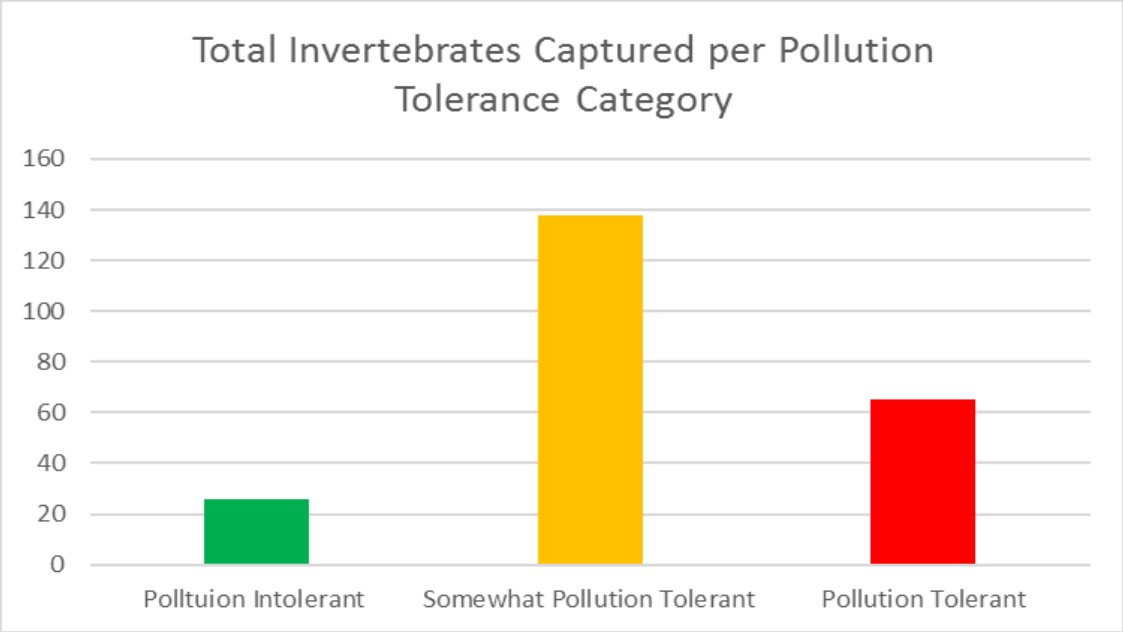

Figure 6: Total number of invertebrates captured per pollution tolerance category on November 4 2015.

Section 6.6.1 Quality Control/Quality Assurance

When sampling, invertebrates were captured and immediately placed into small plastic cups with lids and tape around the lids with the collector's initials on the tape for continuity. Invertebrates were collected on the same day in which they were analyzed in the lab and were kept in a cooler with the collector between time of capture and time of analysis to ensure no discontinuity within the samples.

Conclusions and Recommendations

Considering Cottle Creek's proximity to Nanaimo, especially main transit routes, the stream is relatively health. Furthermore, due to the stream's relative small size, it seems that the stream blends into its surroundings, which was apparent while sampling due to a lack of human trash and unnatural braided trails in the riparian area. The water quality results, rather healthy, revealed predictable biological and microbiological results.

In addition, we recommend keeping Cottle Lake Park/Linley Valley untouched bt development because the lake is an important contributor to the overall health of the creek and preventing pollutants from entering the waterway. Moreover, we recommend a bylaw that prevents the use of fertilizers in wet seasons, to prevent the flow of those substances into the creek, given its relationship to residential areas.

Finally, we recommend continuing annual monitoring of this delicate, important waterway in the heart of Nanaimo, British Columbia.

Acknowledgements

First, we would like to thank the support investment of all interested parties to this project. As well, we would like to thank Dr. Eric Demers for his guidance, wisdom, and knowledge throughout the collection, analysis, and discussion of Cottle Creek. Finally, we thank Vancouver Island University for providing us with all analysis equipment necessary to carry out this project.

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Appendices

Column B	Column C	Column D
Common Name	Number Counted	Number of Taxa
Mayfly Nymph	1	1
Stonefly Nymph	2	1
Gilled Snail	2	1
Cranefly Larva	1	1
Amphipod	21	1
Aquatic Worm	22	2

Common Name	Column C	*P*i(C/T)	ln(*P*i)	*P*i*ln(*P*i)
Mayfly Nymph	1	0.020408	-3.89	-0.079
Stonefly Nymph	2	0.040816	-3.2	-0.131
Gilled Snail	2	0.040816	-3.2	-0.131
Cranefly Larva	1	0.020408	-3.89	-0.079
Amphipod	21	0.428571	-0.85	-0.363
Aquatic Worm	22	0.44898	-0.8	-0.36
Total	49	1		-1.142

Shannon-Weiner Index:

H= -(-1.142)/ln(7)= 0.587

SITE 1

Column B	Column C	Column D
Common Name	Number Counted	Number of Taxa
Mayfly Nymph	3	1
Stonefly Nymph	2	1
Aquatic Sowbug	5	1
Cranefly Larva	5	2
Dragonfly Larva	1	1
Amphipod	43	1
Aquatic Worm	12	1
Midge Larva	5	1

Common Name	Column C	*P*i(C/T)	ln(*P*i)	*P*i*ln(*P*i)
Mayfly Nymph	3	0.039474	-3.23	-0.13
Stonefly Nymph	2	0.026316	-3.64	-0.1
Aquatic Sowbug	5	0.065789	-2.72	-0.18
Cranefly Larva	5	0.065789	-2.72	-0.18
Dragonfly Larva	1	0.013158	-4.33	-0.06
Amphipod	43	0.565789	-0.57	-0.32
Aquatic Worm	12	0.157895	-1.85	-0.29
Midge Larva	5	0.065789	-2.72	-0.18
Total	76	1		-1.44

Shannon-Weiner Index:

H= -(-1.44)/ln(9)= 0.655

SITE 2

Column B	Column C	Column D
Common Name	Number Counted	Number of Taxa
Caddisfly Larva	1	1
Mayfly Nymph	10	1
Stonefly Nymph	4	1
Gilled Snail	1	1
Amphipod	62	1
Aquatic Worm	19	1
Midge Larva	7	2

Common Name	Column C	*P*i(C/T)	ln(*P*i)	*P*i*ln(*P*i)
Caddisfly Larva	1	0.009615	-4.64	-0.045
Mayfly Nymph	10	0.096154	-2.34	-0.225
Stonefly Nymph	4	0.038462	-3.26	-0.125
Gilled Snail	1	0.009615	-4.64	-0.045
Amphipod	62	0.596154	-0.52	-0.308
Aquatic Worm	19	0.182692	-1.7	-0.311
Midge Larva	7	0.067308	-2.7	-0.182
Total	104	1		-1.241

Shannon Weiner Index:

H= -(-1.241)/ln(7)= 0.638

SITE 4

Site #1 Cottle

- Dissolved O_2 = 11.4 mg/L
- " " = [redacted] 97%
- Conductivity = [redacted] µS/cm 105.6
- Total Dissolved Solids = [redacted] mg/L 100.4
- Temperature = 7.7

Wetted depth = 9.75cm
Wetted width = 2.2m
Velocity = 16.26 seconds per meter

Site #2

- D. O_2 = 11.5 mg/L
- D. O_2 = 97%
- Conductivity = 90.5 µS/cm
- TDS = 87.2 mg/L
- Temp = 7.9°C

- Wetted depth = 13.5 cm
- Wetted width = 170 cm
- Velocity = 4.5 s/m

Site #3

O_2 = 8.7 mg/L
DO% 74
Conductivity 1122 µS/cm
TDS - 107.9
~~8%~~ 8.2 °C

Wd = 2.9m
Wd = 10cm
Velocity = 5.04 s per 1m

S.t. 4

2.7m LW
11.5cm Wd
Velocity 4.75s + 3.25s *1m

DO(mg/L) = 7.8
DO(%) = 66
Cond.(uS/cm) = 117.7
TDS (mg/L) = 112.5

Nov 25/15

Site 1:
DO: 12.2 mg/L
Cond: 92.9 µS/cm
TDS: 102.8
Temp: 3.9°C

Site 2
DO: 10.5 mg/L
Cond: 45.6 µS/cm
TDS: 51.5
Temp: 2.7°C

Site 3
DO = 12.5 mg/L
Cond: 73.8 µS/cm
TDS: 82.8
Temp: 3.0°C

Site 4
DO = 12.9 mg/L
Cond = 84.8 µS/cm
TDS: 93.9
Temp. 3.4°C

Fecal Coliforms: (CFU/100mL)

Site 4.

Red	Blue	
196	8	= 204.

Site 3

Red	Blue	
210	3	= 213

Site 2 REP

Red	Blue	
	3	Site 2 REP: 507

Subset:

Sq No	Red	Blue	Oocs
1	5		
2	3		
3	3		2
4	4		
5	6		
6	4		
7	4		
8	3		1
9	8		
10	7		
Tot.	47.	0	3
Avg	4.7	0	0.3

Red Count = $4.7 \times \frac{908}{9} = 474$

Oocs Count = $0.3 \times \frac{908}{9} = 30$

Blue = 3

Hilroy

Coliformes	Red	Blue
Site 1	225	10 = 235
Site 2	343	2 : 345

Hardness:
Site 1: 76 mg/L
Site 2: 57 mg/L
Site 3: 57 mg/L
Site 4: 58 mg/L
Site Rep: 58 mg/L

ALKALINITY:
Site 1: 526/10 = 52.6 mg/L $CaCO_3$
Site 2: 447/10 = 44.7 mg/L $CaCO_3$
Site 3: 420/10 = 42.0 mg/L $CaCO_3$
Site 4: 448/10 = 44.8 mg/L $CaCO_3$
Site 3 Rep: 410/10 = 41.0 mg/L $CaCO_3$

Phosphate:
S.Te1: 0.21 mg/L
S.Te2: 0.07
S.Te3: 0.08 mg/L
S.Te4: 0.22 mg/L
S.Te3REP: 0.18 mg/L
Trip Blank: 0.2 mg/L

Nitrate:
S.Te1: 0.97 mg/L NO_3^-
S.Te2: 0.72 mg/L NO_3^-
S.Te3: 1.47 mg/L
S.Te4: 1.57 mg/L
S.TeREP(3): 0.92 mg/L
Trip Blank: 0.08 mg/L

Day 2 Sampling
BD
WW
WD

Nov 25 Sampling Event
Lab Analysis

pH:
S.Te1: 7.8 pH
S.Te2 7.3
S.Te3 7.4
S.Te4 7.6
S.Te3REP 7.4

Turbidity:
S.Te1: 0.68 NTU
S.Te2: 5.39 NTU
S.Te3: 2.83 NTU
S.Te4: 3.73 NTU
S.Te3REP 2.73

S.Te1
V: 9.62, 10.45, 12.63 = 10.9
Bd: 30, 52, 41, 20 =

S.Te2
V: 2.83, 4.13, 2.76 =
Bd: 40, 42, 43, 30 =

S.Te3
Avg Dep: 15, 15, 12.9
V: 5.13, 5.35, 6.28
Bd: 36, 32, 39, 36.5

S.Te4
AD: 19, 29, 11.4
V: 7.05, 7.66, 9.15
Bd: 42, 53, 60, 43

Hilroy

Phosphate:

Site 1: 0.06 mg/L PO_4^{3-}
Site 2: 0.05 mg/L PO_4^{3-}
Site 3: 0.06 mg/L
Site 4: 0.05 mg/L
Site 2 REP: 0.05 mg/L PO_4^{3-}
Trip Blank: 0.03 mg/L

Nitrate:

Site 1: 0.62 NO_3^- Mg/L
Site 2: 0.00 → less than 0.01 NO_3^- mg/L
Site 3 0.32 NO_3^- Mg/L
Site 4 0.88 NO_3^- Mg/L
Site 2 REP: less than 0.01 NO_3^- mg/L
Trip Blank: 0.05 NO_3^- Mg/L

→ Where included in results section?

If turbidity was not taken in first event, use TDS both.

RMOT 306 Lab - Cattle Creek Quality
Nov 4/15

Monitors: Oxyguard #1 ; YSI

Invert Sampling: Cory + Lane
Water Quality: Max + Jer.

Site 2 = Sample + Replicate. Need Conductivity + T

Fecal Coliform: ✓ Lab Analysis

pH:
Site 1: 8.0
Site 2: 7.5
Site 3: 7.5
Site 4: 7.9
Site 2 REP: 7.4

Alkalinity:
Site 1: 44 mg/L $CaCO_3$
Site 2: 66.4 mg/L $CaCO_3$
Site 3: 39 mg/L $CaCO_3$
Site 4: 46 mg/L $CaCO_3$
Site 2 REP: 83.2 mg/L $CaCO_3$

Hardness:
Site 1: ~~136.8 CaCO3~~ mg/L 85.5 mg/L $CaCO_3$
Site 2: 102.6 mg/L $CaCO_3$
Site 3: 102.6 mg/L $CaCO_3$
Site 4: 85.5 mg/L $CaCO_3$
Site 2 REP: 85.5 mg/L $CaCO_3$

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: Nov. 4, 2015
Station Name: Site #4		Flow status:
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 2.7 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 1	EPT4 1
	Mayfly Nymph (EPT)	EPT2 10	EPT5 1
	Stonefly Nymph (EPT)	EPT3 4	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail	1	1
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 16	D1 3
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	62	1
	Watersnipe Larva		
Sub-Total		C2 62	D2 1
Category 3	Aquatic Worm (oligochaete)	19	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	7	2
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 26	D3 3
TOTAL		CT 104	DT 7

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1: 104

DENSITY: Invertebrate density per total area sampled:

S1: 104 ÷ 2.7 m^2 = S2: 38.518 / m^2

PREDOMINANT TAXON:

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

S3: Amphipod (62)

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

$(3 \times \frac{3}{9}) + (2 \times \frac{1}{2}) + \frac{3}{3} =$

S4: 14

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 1 + 1 =

S5: 3

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

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

(EPT1 + EPT2 + EPT3) / CT

(1 + 10 + 4) / 104 =

S6: 0.144

SECTION 3 - DIVERSITY

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

S7: 7

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

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

Col. C for S3 / CT

62 / 104 =

S8: 0.596

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	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 3

Average Rating
Average of R4, R5, R6, R8
2

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: Nov. 4, 2015
Station Name: Site #2		Flow status:
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 2.7 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 1	EPT4
	Mayfly Nymph (EPT)	EPT2 3	EPT5 1
	Stonefly Nymph (EPT)	EPT3 2	EPT6 1
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 5	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug	5	1
	Clam, Mussel		
	Cranefly Larva	5	2
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva	1	1
	Fishfly Larva		
	Scud (amphipod)	43	1
	Watersnipe Larva		
Sub-Total		C2 54	D2 5
Category 3	Aquatic Worm (oligochaete)	12	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	5	1
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 17	D3 2
TOTAL		CT 76	DT 9

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

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

S1: 76

DENSITY: Invertebrate density per total area sampled:

S1: 76 ÷ 2.7 m^2 = S2: 28.15 / m^2

PREDOMINANT TAXON:

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

S3: Amphipod

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 2 + 2 x 5 + 2 = S4: 18

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 1 = S5: 2

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 3 + 2) / 76 = S6: 0.07

SECTION 3 - DIVERSITY

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

S7: 9

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

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

Col. C for S3 / CT

43 / 76 = S8: 0.57

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	R1: 3
EPT Index	R2: 2
EPT To Total Ratio	R3: 1
Predominant Taxon Ratio	R4: 3

Average Rating
Average of R4, R5, R6, R8
2.25

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: Nov. 4, 2015
Station Name: Site #1		Flow status:
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 2.7 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	EPT4
	Mayfly Nymph (EPT)	EPT2 1	EPT5 1
	Stonefly Nymph (EPT)	EPT3 2	EPT6 1
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail	2	1
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 5	D1 3
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	1	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	21	1
	Watersnipe Larva		
Sub-Total		C2 22	D2 2
Category 3	Aquatic Worm (oligochaete)	22	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 22	D3 2
TOTAL		CT 49	DT 7

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 = 49

DENSITY: Invertebrate density per total area sampled:

S1 49 ÷ 2.7 m^2 = S2 18.15 / m^2

PREDOMINANT TAXON:

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

S3 Oligochaete

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 3 + 2 x 2 + 2 = S4 15

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 1 = S5 2

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 1 + 2) / 49 = S6 0.06

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 7

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

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

Col. C for S3 / CT

22 / 49 = S8 0.45

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	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 3

Average Rating
Average of R4, R5, R6, R8
2

Nov 25 Sampling:

Site 1
W width: 213cm
Avg depth: 11.5
Velocity : 9.62 s/m ; 10.45 ; 12.63
Bw: 5.45 m
Bd: 30, 52, 41, 20

Site 2
W width: 2.05m
Avg depth: 13.3
Velocity : 2.83, 4.13, 2.76
Bw 2.7
Bd 40, 42, 43, 30

Site 3
W width: 2.86m
Avg depth 15 15 12 9
Velocity 5.13, 5.35, 6.28
Bw: 3.78
Bd 36 37 39 36.5

Site 4
W width 3.1
Bw 3.55
Bd 42, 53, 60, 43
Avg depth 14, 29, 11, 4
Velocity 7.05, 2.66, 4.15