Water Quality and Stream Invertebrate Assessment for the C.W. Young Channel, Englishman River, BC

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Report submitted to:

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1.0 Introduction/Background

The Englishman River is a river of special concern that partially runs through Parksville and Errington, BC. It originates on the slopes of Mount Arrowsmith and travels about 40 km before reaching the Strait of Georgia. It travels along a diverse landscape including waterfalls, deep pools and floodplains. It travels through old growth, agricultural land and city landscapes. The latter two have great potential for impacting the river's integrity, which is already of concern. The river has an active history of recovery plans and projects that show an immense importance for continual monitoring of water quality. Our team is comprised of 4 third year students in the Bachelors of Natural Resource Protection program at Vancouver Island University, under the guidance of Dr. Eric Demers. Information from this monitoring could be added to years of monitoring for our greater understanding of health of the river.

The ecological and cultural importance of this river has been recognized as being so important that both a regional park and a provincial park have been formed along the river. In 1940, the provincial park was formed about halfway up the river, or 13 km southwest of Parksville, in order to protect some of the increasingly rare old growth Douglas fir forest (British Columbia Parks 2015). In 2005, the Regional District of Nanaimo (RDN) partnered with the province of BC, Nature Conservancy of Canada, The Nature Trust of BC and Ducks Unlimited to form the Englishman River Regional Park, a 207-hectare park and conservation area further downstream of the provincial park (Regional District of Nanaimo, 2012). The regional park is a great example of the ecological importance of this river as it contains a community fish hatchery and salmon spawning side channel (Regional District of Nanaimo, 2012). Roosevelt elk, a blue listed species in BC (Species at Risk, 2012), frequent the park along with a great number of animals from various species (Regional District of Nanaimo, 2012).

The name of the river itself shows some of the social and cultural importance of the river. The name is said to come from an old First Nations legend where the First Nations people found the skeleton of a white man near one of the river's waterfalls and thus gave the river its name (British Columbia Parks, 2015). The river provides many recreational activities to both locals and tourists. The provincial park contains two cascading waterfalls, many trails, and a swimming hole for people to enjoy (British Columbia Parks, 2015). Further downstream the regional park provides more trails, fishing opportunities, equestrian use and mountain biking. The regional park is also home to BC Rivers Day celebrations every year to celebrate the return of the salmon (Regional District of Nanaimo 2012). The celebration of salmon return really highlights the importance of these fish and this river to BC.

The Englishman River is considered to be one of the most important salmon-bearing streams on the central east coast of Vancouver Island. The river and its watershed support 4 salmon species including pink (*Oncorynchus gorbuscha*), chum (*Oncorynchus keta*), chinhook (*Oncorynchus tshawytscha*), and coho (*Oncorynchus kisutch*). Other species including rainbow trout (*Oncorynchus mykiss*) and cutthroat trout (*Oncorynchus clarkii*) are found in the river system (Government of British Columbia, 2015). In 2000, the river was designated as a sensitive stream under the Fish Protection Act as well as part of the United Nations Mount Arrowsmith Biosphere Reserve (Government of British Columbia, 2015). Recently the Outdoor Recreation Council of BC recognized the river as one the most threatened watersheds in BC (Government of British Columbia, 2015). The integrity of water quality in the Englishman River is extremely important not only for the overall recreational and ecological integrity of the river but also because the river is a main water supply source for the city of Parksville (Government of British Columbia, 2015). The river is now of special interest to many groups interested in the conservation of the long-term integrity of the river including Regional District of Nanaimo (RDN), Fisheries and Oceans Canada (DFO) and BC Conservation Foundation (BCCF).

The Englishman River Regional Park was the perfect staging ground for our monitoring activities as it was consistent with the sampling locations from prior data collections. These sites, 5 in total, were more specifically located along the C.W. Young Channel. The selected sites were intended to be diagnostic of the overall channel, which is almost entirely contained within the park. This channel is of the utmost importance to spawning salmon as the mainstem channel in the area has not been stable since the late 1970's (Regional District of Nanaimo, 2012).

2.0 Project Objectives

The project objectives for the Englishman side channel included collecting water samples to assess water quality as well as invertebrate sampling to assess the overall biodiversity and health of the channel community. These results were compared to previous years (2013 and 2014) to help assess the overall health of the side channel and look for any trends.

The project used the 5 site locations for sampling that were selected in 2008 and used consistently over the study years (Appendix 1). Four of the sample sites were located directly in the channel and one site was located at the outlet of the channel where it meets up with Englishman River. The project was helpful for estimating the overall health of the channel for salmon rearing. The invertebrate sampling further helped estimate the overall health of the channel including testing the overall diversity of the channel.

The sampling provides valuable information to help assess the overall water quality of the side channel that was created in the 1990's by the Department of Fisheries and Oceans Canada, Regional District of Nanaimo, BC Ministry of Environment, and forestry companies. These stakeholders have invested time and money into creating and maintaining this important spawning channel for Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), Chum salmon (*Oncorhynchus keta*) and Pink salmon (*Oncorhynchus gorbuscha*). (Regional District of Nanaimo, 2014).

3.0 Methods

3.1 Location and Characteristics

The five pre-determined site locations were visited on October 21, 2015 as part of a pre-assessment evaluation of site locations and determine site access and overall terrain. The environmental assessment was conducted over several weeks to determine water quality, hydrology, and biodiversity throughout the C. W. Young side channel with site five located at the discharge point into the Englishman River. The five sites along the side channel are spread throughout the side channel to obtain a relatively even distribution for assessment parameters while considering safe access points.

Site 1 is located upstream of the side channel near the metal inlet pipe, which allows water to be discharged from the Englishman River into the side channel (Appendix 2). The metal pipe is >50 metres long and can be adjusted to increase or decrease flow. There is a second metal pipe located upstream from the main valve pipe, with a metal screen located <5 metres downstream from the pipe. A steep bank >10 metres runs southerly along site 1, followed by a gravel path/road and >20 metres of vegetation, which divides the Englishman River and side channel. Water quality parameters were taken 1 metre downstream from the metal inlet pipe during both sampling periods.

Site 2 is located north of the main road/path that runs through the park and along most of the side channel (Appendix 2). The north side of the road was chosen sampling due to the culvert that runs under the road and discharges to the north. The metal culvert is >1 metre in diameter and >5 metres in length (Appendix 2). Water quality and velocity parameters were taken 3 metres downstream of the metal culvert; with velocity calculations calculated over 5 metres. Site 2 has a high concentration of large boulders with large woody debris (LWD). Dense vegetation is located along the west and east banks of site two with steep banks >2 metres on both sides. Three wooden salmon ponding boxes installed by the fish hatchery and used for pink salmon (*Onchorhynchus gorbuscha*) are situated downstream from site 2 (Appendix 2).

Site 3 is located >20 metres south of the main road/path and has a large abundance of LWD with presence of small gravel substrate (Appendix 2). The side channel runs south while taking a westerly turn at site 3. The southern portion of the site has dense vegetation, while the northern side contains grassy vegetation surrounded by dense vegetation. There is a path that runs from the main gravel road to site 3, which becomes more apparent with site visitation. Water quality, velocity, and invertebrate sampling were taken 2 metres downstream from the LWD pictured in appendix 2.

Site 4 is located near the lower section of the side channel just above a metal bridge/ grate and is surrounded by dense vegetation between the Englishmen River located >20 metres south-east (Appendix 2). The metal bridge is >2 metres long and narrows below a wide pool section of the side channel. The site is surrounded by various sizes of substrate, including large boulders, fines and LWD. The bridge located <3 metres below site 3 connects a walking path to the main road/path, which is a high traffic area connecting the main gravel road to several walking paths. There is a steep bank <2 metres along either side of the site, which produces light vegetation including low brush and ferns. Water quality, and invertebrates sampling were taken 1 metre above the metal bridge/ grate as pictured in appendix 2.

Site 5 is located at the discharge point of the side channel into the Englishman River (Appendix 2). The area has a high abundance of small to medium size substrate, with presence of LWD scattered throughout the area adjacent to the site. Site 5 is located on the northern shore of the Englishman River, which acts as a drainage point for the side channel, which were <2 metres at the initial site visit. The Englishman River was >5 metres wide, with moderate to low flow and <0.5 metres deep at the side channel. There is a large abundance of LWD located along the side channel between sites 4 and 5 along with rough terrain and a long section of undercut along steep sections of rock where chum salmon were observed (Appendix 2). There was dense vegetation on the northern side of the Englishman River at side channel drainage point. This site is important to test as this is the only drainage point from the side channel into the Englishman River. Water quality parameters were taken 3 metres beyond the discharge point of the side channel.

3.2 Sampling Frequency

Samples were collected on two different sampling events. These samples were collected on the 4th of November 2015 and the 25th of November 2015. For each of the five sampling stations, general water quality and microbiology samples were taken. At three of the sites water samples were collected to be sent for laboratory analyses to Australian Laboratory Services (ALS), located in Burnaby, BC for both sampling events. Three samples of stream invertebrates were collected using the HESS sampler on the first sampling event, due to the potential for high flow at the time of the second sampling event invertebrates and microbiology were not re-sampled. Water velocity was taken on both sampling events at two predetermined sites.

3.3 Hydrology and Environment

At two of the sampling sites velocity, water depth, wetted width and bankfull width was collected. Using this data, discharge was calculated to help with the assessment of water quality parameters such as dissolved oxygen and potential turbidity. Throughout the five sampling sites the substrate, stream composition such as large woody debris (LWD), and riparian area makeup was noted to help assess with the overall health and biodiversity of the stream.

3.4 Water Quality

3.4.1 Field Measurements

An electronic probe was used to measure the site water temperature within ± 0.01ºC and dissolved oxygen within ±0.01 mg/L. To obtain a precise measurement the electronic probe was submerged in a representative, average flow area and held in the water for one minute at each site of the five sites. This ensured that the most accurate recording was taken.

3.4.2 Water Sample Collection

Two sampling dates were used, one on the 4th of November 2015 and the second event taken on the 25th of November 2015. These dates were used to capture low and high flow times within the side channel, however high flow was in the earlier sampling event on the 4th of November 2015. Each sampling event had samples taken from all five sites for the team’s analyses at Vancouver Island University (VIU) laboratory and three samples taken for ALS analyses from three predetermined sites.

All the samples were taken starting downstream and working towards the headwater intake valve of the side channel, this helps eliminate any potential contamination. Each sample taken for the team’s VIU analyses was taken in a medium flow portion of the channel, the bottles was rinsed three times, and completely submerged opening first then held facing up channel in the mid column. The ALS sample bottles were pre sterilized (no need for rinsing), and samples taken same as VIU bottles.

The sample containers were transported to the sample sites in a cooler with the labels pre-filled out and attached to appropriate bottles. Once samples were collected they were placed back in the cooler with ice pack to ensure preservation, both sampling events took place the morning of VIU analyses and the ALS were sent for analyses that same day.

3.4.3 VIU Laboratory Analysis

Invertebrate analyses and water quality analyses was conducted at the Nanaimo campus of VIU on the same day as the samples were collected from all five sites. Using a designated electronic meter pH and conductivity (µS/cm) were determined. Nitrate (mg/L NO_3^-) was tested using a HACH DR2800 spectrophotometer, and using the HACK AL-DT titration method total alkalinity (mg/L as $CACO_3$) was tested. Turbidity (NTU), and reactive phosphorus (mg/L PO_4^{3-}) were tested.

3.4.4 ALS Laboratory Analysis

Samples from sites one, two and four were shipped to the ALS laboratories within 24 hours of the samples being taken. Each site consisted of an amber 250 ml glass bottle in which sulphuric acid was added as preservative, and a 250 ml plastic in which nitric acid was added as a preservative. These acids were added to ensure the integrity of the samples were maintained until analyses was conducted. The samples were analyzed for total metals, conductivity, nutrients, pH, and hardness. Each sample was taken from the center of the water column, and inverted once acids added to ensure proper mixture.

3.4.5 Quality Assurance/Quality Control

For each sampling event a trip blank was created at VIU using distilled water and a replicate was taken from site 4 on both sampling events. Both the trip blank and replicates from each sampling event were analyzed at VIU each event to ensure that contamination could be ruled out.

Each of the sites have been selected from the same sites as the previous years (2008-2014) to ensure that reliability could be followed over the years. Each of the samples were taken from the same location at each site to ensure accurate reading for both sampling events.

3.4.6 Data Analysis

The Approved Water Quality Guidelines from the Province of British Columbia was referenced for freshwater aquatic organisms from both laboratory compiled results. These guidelines were used to see if the laboratory results met or exceeded the provincial standard parameters.

3.5 Stream Invertebrates

3.5.1 Invertebrate Sample Collection

Invertebrate sampling was conducted at sites 1, 3, and 4 with triplicates taken at each site. A Hess sampler was used during invertebrate sampling, which covers 0.9 metres^2 of substrate. Each one of the triplicate sample sites were chosen based on sufficient water velocity, level substrate characteristics and taken at least 1 metre from each other. Each sampling process conducted was consistent throughout, which involved scraping the substrate for approximately 2 minutes for each sample. The samples were carefully lifted out of the water, followed by rinsing out any matter left in the mesh screen into the plastic canister. The samples were transferred from the canister into plastic cups, which were labeled and taped for quality control.

3.5.2 Invertebrate Data Analysis

Invertebrate data analysis was conducted at the Vancouver Island University laboratory located in building 270. The invertebrate samples were conducted using dissecting trays, tweezers, pipettes, petri dishes, and dissecting microscopes. Each of the 3 triplicate samples from each site were transferred into dissecting trays and spread evenly throughout the tray. Portions of the tray were transferred onto the petri dishes, along with larger invertebrates transferred with pipettes and tweezers. As the invertebrates were identified they were tallied onto a sheet of paper. Once the 3 samples from each site were completed; the total number of each species and their respective taxa were transferred onto the invertebrate survey field data sheet. The species are tallied followed by the taxa, which is calculated with the sample area to determine predominant taxon, diversity, water quality assessment, diversity, predominant taxon ratio index, and overall site assessment rating. The Shannon -Wiener Index was also calculated based on the species diversity and overall number of species.

4.0 Results and Discussion

4.1 Water Quality

Temperature and dissolved oxygen were the only two mentionable parameters measured in the field. Temperature was consistent throughout the sites on both sampling events; however, a large decrease in temperature was noted during the second sampling event. The first event had an average temperature of 7.24^{o}C with a range of 7.2 to 7.3^{o}C. The second event had an average temperature of 3.06^{o}C with a range of 2.7 to 3.5^{o}C. These findings are similar to those reported from 2011 and 2014. It should be noted that these sampling years had dates that closest matched our sampling dates and that 2013 did not report there temperatures. Years prior to 2001 sampled earlier. Ambient temperature was not recorded; although, the team noticed a decrease during the second event similar to the findings for water temperatures. Dissolved Oxygen was found to increase for the second sampling event. The average for the first event was 10.94 mg/L (range of 11.6 to 10.4) where the average from the second event was 12.38 mg/L (range of 12.9 to 11.9). The findings for dissolved oxygen are fairly consistent with reports from prior years. The dissolved oxygen and temperature consistently has been found to be within BC Water Quality Guidelines for aquatic life (RISC, 1998). The results for each sampling station can be found in table 1.

In the lab, the team assessed conductivity, turbidity, alkalinity, hardness, pH, nitrate levels and total phosphate. The results for alkalinity suggest the water to be on the edge of being moderate to low sensitivity (RISC, 1998). Conductivity was found to be fairly consistent between the two sampling events but with a slightly higher average as the first event yielded an average of 46.2 where the second was 50.4 μS/cm. Conductivity was found to increase as the samples were taken farther downstream as expected. This was expected because of increased input sources and areas as the water travels downstream. These results are similar to those found in 2011, 2012 and 2014. In other years conductivity decreased for the second sampling event. This may be explained simply through the variation of different rain events and their timing for each years as conductivity is greatly influenced by these. The first rain large rain event of a year most often results in high conductivity results and decrease as ions are flushed out with the preceding rains. These results can be seen in table 1.

Similarly, turbidity as well as alkalinity, hardness and pH all appear to be rather consistent between sampling events. The averages for turbidity were 1.922 and 1.852 NTU respectively which may be explained by the fairly consistent rain events between sampling dates. Alkalinity had averages of 20.66 and 22.2 mg/L and hardness had 25.2 ad 27.6 mg/L respectively. The slightly higher averages for the second event is expected as conductivity was found to increase as well. These results are also found in years with a similar conductivity increase. PH had averages of 7.12 and 7.56 respectively. Results available via table 1 below.

Nutrients were also measured in lab by the team; however, total phosphate showed a great deal of variance even between the same sample tested twice and between the team's lab results and those from ALS (figures1 and 2). What can be said for total phosphate is that in both the team's lab results and the ALS results, the average is slightly higher in the second event, this could potentially be due to the increased number of dead salmon seen to be present in the second event. Total nitrate was much more consistent within sampling events and when compared to ALS results. For comparison sake, figure 3 shows this for the first sampling event. Similar to phosphate, nitrogen levels were found to increase during the second event. The reasoning for this increase could also be from the increased presence of dead salmon or from another nutrient source providing more nutrients (phosphorus and nitrogen) during the second event. The team's lab result had averages for phosphate of 0.08 and 0.296 mg/L while nitrate came in at 0.176 and 0.252 mg/L respectively.

Table 1: Field and team lab results for water quality samples taken from the 5 stationson the C.W. Young Channel and Englishman River.

Englishman River - Water Quality

Date: November 4, 2015	Unit	Site 1	Site 2	Site 3	Site 4	Site 5	Replicate (4)	Trip Blank
conductivity	µS/cm	45	45	43	54	44	51	-
turbidity	NTU	0.68	1.39	5.26	1.48	0.8	1.71	-
alkalinity	mg/L	19.4	21.6	20.5	24.2	17.6	25.8	-
hardness	mg/L	23	22	25	29	27	30	-
ph	-	7.2	7	7.1	7.1	7.2	7.2	-
phosphate	mg/L	0.03	0.09	0.08	0.11	0.09	0.05	0.02
nitrate	mg/L	0.18	0.13	0.17	0.23	0.17	0.26	0.05
Temperature	°C	7.2	7.2	7.3	7.2	7.3	-	-
Dissolved Oxygen	mg/L	11.6	10.7	10.6	10.4	11.4	-	-
% Saturation	%	96	88	87	86	94	-	-

* Temperature, Dissolved Oxygen and % Saturation measured in field

Englishman River - Water Quality

Date: November 25, 2015	Unit	Site 1	Site 2	Site 3	Site 4	Site 5	Replicate (4)	Trip Blank
conductivity	µS/cm	47	47	46	57	55	57	-
turbidity	NTU	1.81	2.44	2.12	1.91	0.98	1.52	-
alkalinity	mg/L	18.8	19.4	19.1	24	18	22.2	-
hardness	mg/L	27	27	26	33	25	33	-
ph	-	7.4	7.6	7.7	7.6	7.5	7.4	-
phosphate	mg/L	0.53	0.28	0.26	0.2	0.21	0.80/0.56	0.40/0.66
nitrate	mg/L	0.31	0.21	0.23	0.27	0.24	0.57	0.08
Temperature	°C	3.1	3.1	2.7	2.9	3.5	-	-
Dissolved Oxygen	mg/L	12.8	12.1	12.2	11.9	12.9	-	-
% Saturation	%	94	90	89	87	92	-	-

* Temperature, Dissolved Oxygen and % Saturation measured in field

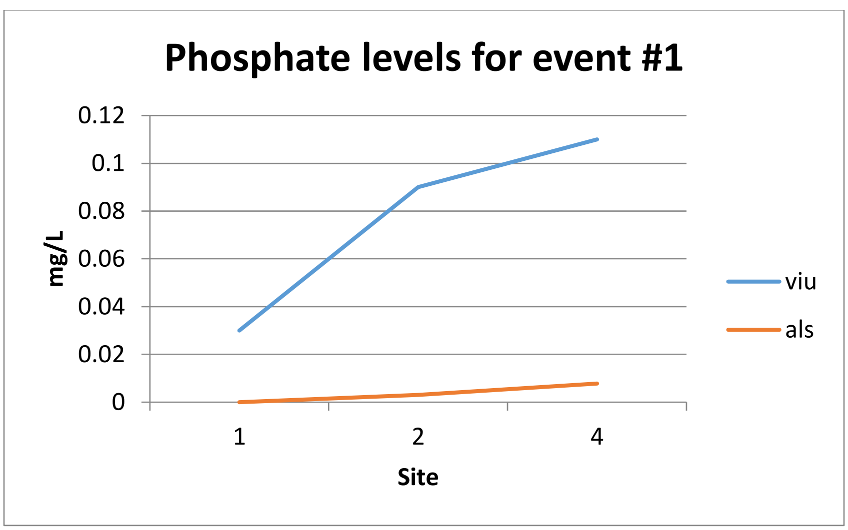

Figure 1: Comparing phosphate levels from ALS and VIU lab analyses for the first sampling event.

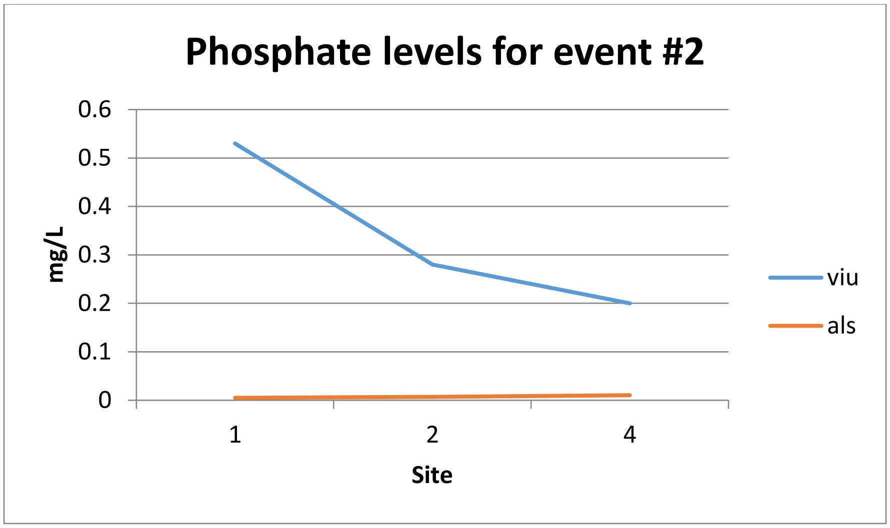

Figure 2: Comparing phosphate levels from ALS and VIU lab analyses for the second sampling event.

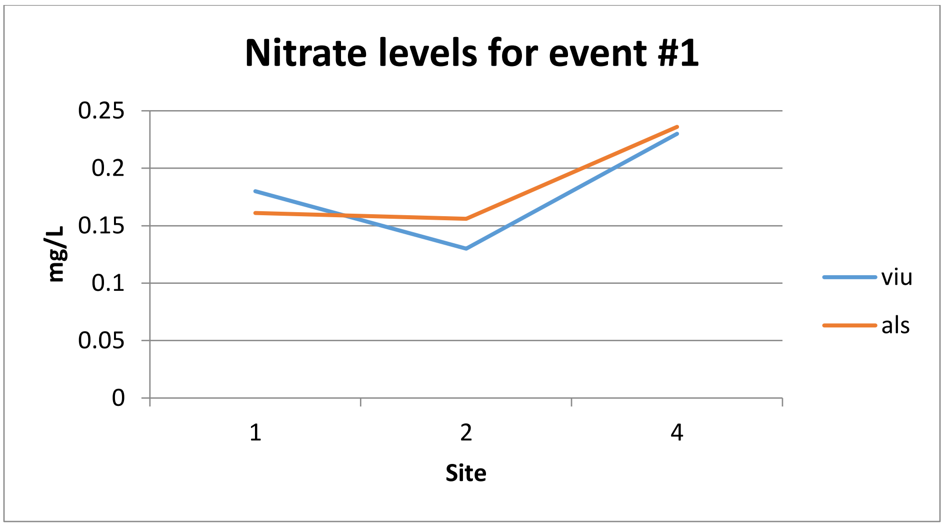

Figure 3: Comparing nitrate levels from ALS and VIU lab analyses for the first sampling event.

4.2 ALS lab results

To aid in quality assurance, samples from 3 sites were submitted to ALS for analyses. ALS provided results for conductivity, hardness, pH, total nitrogen, total phosphate as well as metal presence levels (Appendix 3). Table 2 shows the comparative results for both the team's lab results and ALS lab results for parameters tested by both groups. What is evident, as precluded to earlier, is that different parameters had different degrees of variation between VIU lab results and ALS. Hardness, pH and nitrogen seem fairly consistent between labs, but conductivity and especially phosphate levels show a rather large degree of variation (figure 1 and 2). While some parameters may show a larger degree of variance, it should be noted that both labs show similar trends. For instance, while phosphate may have the largest degree of difference, both have a trend of increasing further downstream. Similarly conductivity increases further downstream. It should also be noted that the results for conductivity are minimal when looked at with a broader spectrum (still considered to have low conductivity). With the exception of phosphate, all levels measured categorize the stream as the same regardless of lab differences such as both labs determining the water to be soft.

Phosphate levels were the only parameter to have a more substantial and notable difference. The team suggests that the VIU lab results be ignored when determining phosphate levels due to a lack of confidence in the hach phosphate test. This idea is not original to this team as past sampling teams have found similar results and suggested similar actions. The lack of confidence was intensified while testing samples for the second sampling event. In this instance the hach test yielded a measure of 0.66 mg/L of phosphate for the trip blank. The test was ran again for the trip blank using "fresh" water which got a measure of 0.40 mg/L. This difference is very large especially given it was water taken from the same trip blank container. Trip blank should not have a high reading like this. The first sampling event yielded a measure for the trip blank of 0.02 mg/L. All measures recorded during the second analyses appear to have been substantially higher with the lowest measure being 0.20 mg/L where ALS found it to be 0.0104 mg/L for the same site (Table 2). Another facture was that the replicate measured had a difference of greater than 25% when a precision test was done for the phosphate tests.

Looking over ALS data from past years, the only notable trend is decreasing average phosphate levels as can be seen in figure 4. Other than that trend, parameters are relatively consistent year to year or had variability that followed no trend.

Table 2: ALS and VIU lab result comparison.

Date: Nov. 4, 2015	VIU 1	ALS 1	VIU 2	ALS 2	VIU 4	ALS 4
Conductivity	45	62.9	45	62.2	54	73.4
Hardness (as CaCO3)	23	22.9	22	23.3	29	28.6
pH	7.2	7.50	7.0	7.34	7.1	7.36
Nitrogen	0.18	0.161	0.13	0.156	0.23	0.236
Phosphate	0.03	<0.0020	0.09	0.0030	0.11	0.0078
Date: Nov. 25, 2015	**VIU 1**	**ALS 1**	**VIU 2**	**ALS 2**	**VIU 4**	**ALS 4**
Conductivity	47	67.0	47	66.3	57	78.7
Hardness (as CaCO3)	27	23.8	27	23.7	33	29.1
pH	7.4	7.46	7.6	7.42	7.6	7.60
Nitrogen	0.31	0.259	0.21	0.315	0.27	0.302
Phosphate	0.53	0.0051	0.28	0.0070	0.20	0.0104

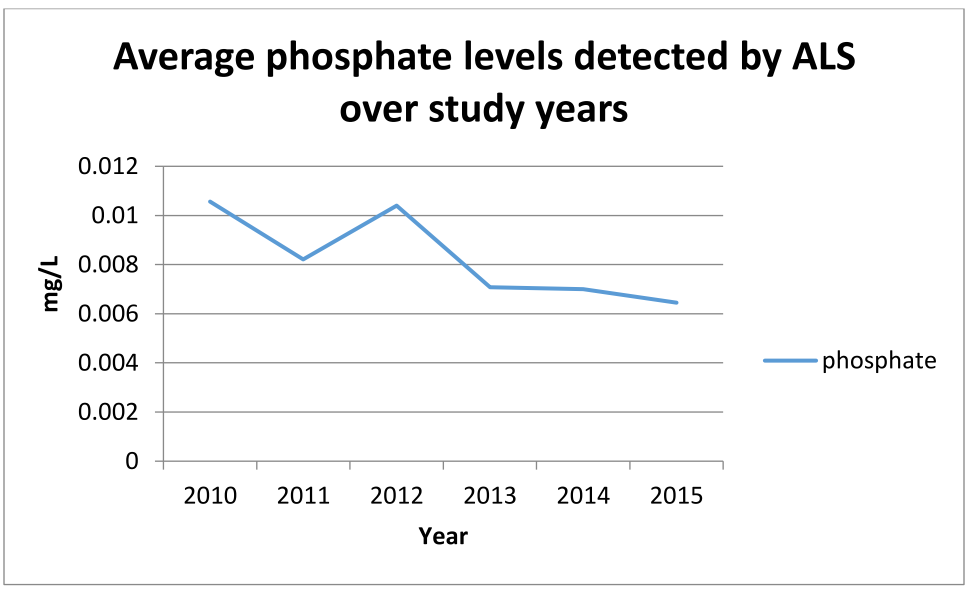

Figure 4: Average phosphate levels detected by ALS over the study years.

When looking at the metal levels detected by ALS, only one metal is of concern: aluminum. Aluminum is the only metal to have exceeded BC Water Quality Guidelines (RISC,

1998) and was only detected above the minimum detection limit once (site 4 from November 4th). It is expected that it was above the guidelines in more than the one instance but that it simply could not be detected due to a detection limit of 0.20 mg/L where the guideline for aquatic life is 0.1 mg/L (RISC, 1998). Aluminum has been found to exceed the guideline in years prior as well. There is also a chance that other metals exceeded the guidelines but where undetected due to detection limits including cadmium, copper, lead and silver. No trends were noted for metals between the two sampling events.

4.3 Invertebrates

Invertebrate sampling determined the channel to be healthy overall from site assessment ratings and the Shannon-Wiener Indexes from sampling sites 1, 3 and 4.

Site 1 produced a total of 60 invertebrate species with mayfly nymph being the predominant species at 16. The overall site assessment from the invertebrate survey interpretation sheet was calculated at 3.5, which is between acceptable and good (Appendix 4). The Shannon-Wiener Index for site 1 was calculated at 0.86, which determined the species richness and diversity scored high for equally abundance. (Appendix 5).

Site 3 produced a total of 20 invertebrate species with mayfly nymph being the predominant species with a total of 6. The overall site assessment rating was 3.25, which is above 3 for acceptable (Appendix 4). The Shannon-Wiener Index was calculated at 0.92 from 6 different species, which was found to be the highest Shannon-Wiener Index calculation from the 3 sites (Appendix 5). Although site 3 had the highest Shannon-Wiener Index it produced the lowest amount of invertebrate species between the 3 sites.

Site 4 produced a total of 166 invertebrate species with mayfly nymph being the predominant species at 63. The site assessment average rating was 3.5, which is between acceptable and good (Appendix 4). The Shannon-Wiener Index was calculated at 0.72, which shows a relatively even distribution of species at site 4 (Appendix 5).

The average site rating for sites 1, 3, and 4 was calculated at 3.42, which is on the higher end of the assessment rating of above acceptable to good. The Shannon-Wiener Index was averaged at 0.833 from the sites sampled, and portrays a positive diversity index. Site 4 was determined to have the largest proportion of invertebrate species due to the large pool located directly in front of site 4, which narrows into a small portion of the side channel. The pool consists of large amounts of LWD and gravel substrate, which is consistent with productive mayfly habitat.

Our findings were consistent with previous years data taken since 2008 and show mayfly nymphs as being the predominant species from past studies indicating low pollution in the side channel as mayfly nymphs are a pollution intolerant species.

4.4 Microbiology

Whirl packs were used to collect water samples to conduct the coliform testing back in the VIU laboratory. Overall in the Englishman Side Channel there was an average of 306 CFU per 100 ml with a fecal percentage of 26% as shown below in table 3. This could be due to the wide range of park usage by dog walkers, equestrian riders, wildlife and other potential sources. This is fairly consistent with previous years, and while has no impact on water quality for aquatic life, it does mean that the water needs treatment to meet drinking water standards (RISC 1998).

Table 3: Coliform totals and percentage for water taken from the Englishman Side Channel 04 November 2015. Expressed as number of Colony Forming Units (CFU) per 100 ml.

Total Coliforms for all 6 sites	1836
Fecal Coliforms	474
Non Fecal Coliforms	1362
Non Coliform	272
Percent fecal	26%
Percent non fecal	74%

4.5 Hydrology

At sampling sites 2 and 3 water velocity and discharge was measured and calculated. Because channel flow is regulated, by a valve, the velocity, discharge and wetted depth was relativity similar in the two sampling events. On November 4th the side channel had an average water velocity of 0.44m/s and a discharge of 0.54m$^{3/}$sec. The results on November 25th were very similar showing an average water velocity of 0.50m/s and a discharge of 0.53m$^{3/}$sec. The results showed that although the Englishman River was at different water levels the side channel is regulated at the intake keeping the velocity and discharge the same (Table 4).

Table 4: Average water velocity and discharge of the C.W Young Channel

4-Nov-15	Water Velocity M/Sec	Discharge M^3/Sec
Site #2	0.51	0.70
Site #3	0.36	0.39
Average	**0.44**	**0.54**

25-Nov-15	Water Velocity M/Sec	Discharge M^3/sec
Site #2	0.60	0.60
Site #3	0.40	0.46
Average	**0.50**	**0.53**

4.6 Quality Control/Assurance

Each sampling event a trip blank was taken to the field in the cooler, it was carried in the field with all samples to ensure quality assurance. On both occasions the trip blank was analyzed alongside the remaining six samples taken in the field. The 25th of November sampling event there was a surprising result showing a high amount of phosphorus. This was surprising given that it was distilled water. Conductivity and phosphate results on the 25th of November showed similar trends but also a fair amount of separation between VIU and ALS results. For quality control, a replicate was taken at sampling site 4 on both sampling events.

5.0 Conclusion and Recommendations

Overall, the Englishman River C.W Young side channel results showed us that it is a healthy channel with an abundant amount of invertebrates, vegetation, and spawning salmon. The only water quality parameter that did not fit into the B.C. Water Quality Guidelines was aluminum and that was only detected in one instance. The invertebrates throughout the channel had an overall healthy assessment. There was diverse vegetation surrounding the channel showing a healthy stream. Throughout the survey of the channel a healthy amount of Chum salmon (*Oncorhynchus keta*) was spotted in the channel. Some of the salmon had already spawned and many were currently searching for spawning grounds. Over the past ten years data has been collected by students at Vancouver Island University in the Natural Resource Protection Program. The data since 2013 are rather consistent in average although 2013 and 2014 had lower overall nutrients. Over the years, since the study started in 2008, there has been a steady increase in conductivity, hardness, and phosphate. Overall the Englishman River C.W. Young side channel is healthy with a very bio diverse aquatic ecosystem.

Some recommendations are using the exact location year after year, this could be accomplished using GPS waypoints and having better descriptions of each site location. Another useful tool could be using information from the hatchery that is located on the channel. A general recommendation for the channel is to continue monitoring and to especially watch for high aluminum levels. Some metals were identified to have detection limits below the guidelines, so it is also recommended that those tests be altered to have lower detection limits.

6.0 Acknowledgements

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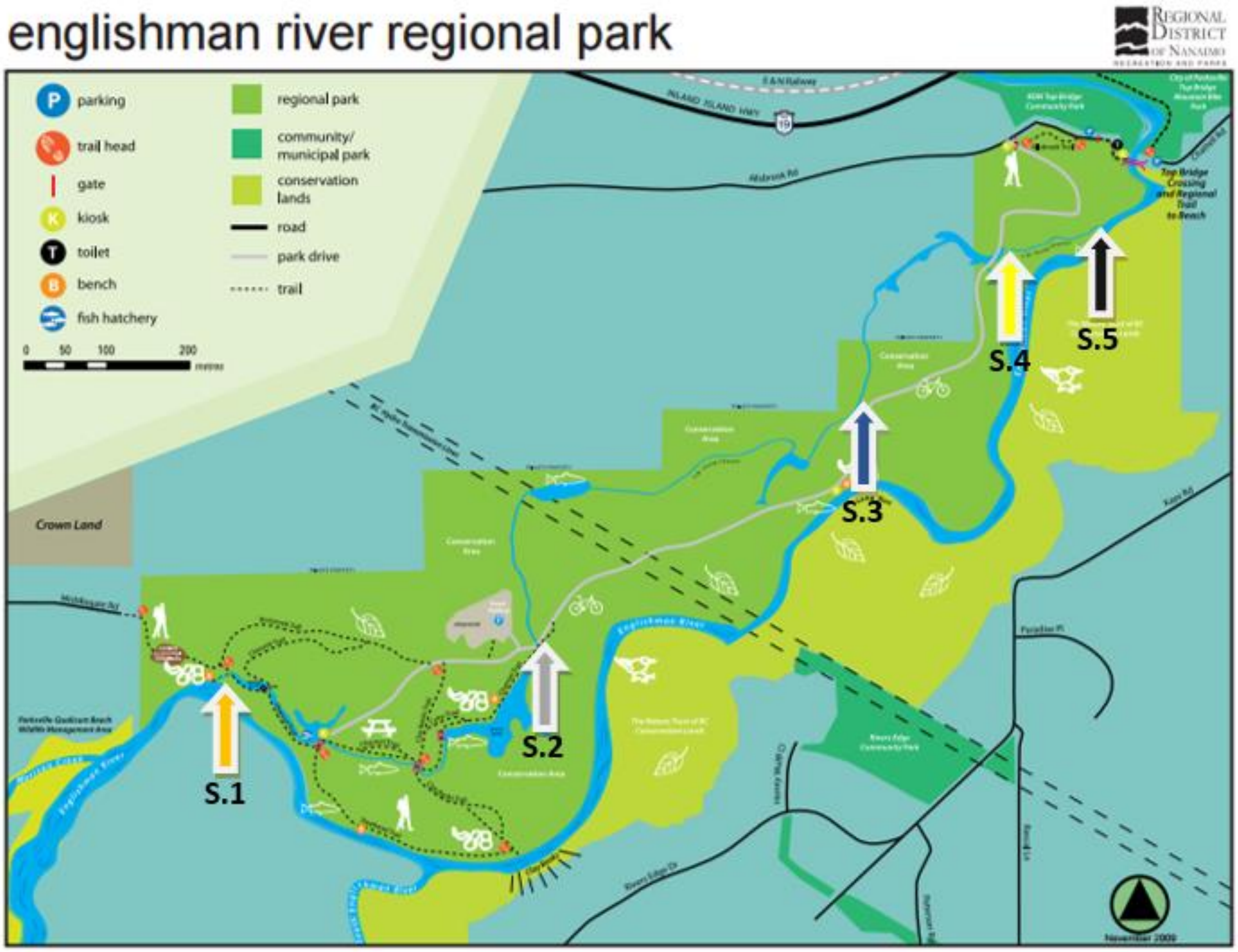
Appendix 1: Site Map with arrows showing sites.



Appendix 2: Pictures of Sites

Site 1- Picture of pipe and control valve for flow located at the top end of the side channel. Picture taken on November 18, 2015.

Site 2 - Picture of South side of site 2 showing culvert running under main gravel road. Picture taken on November 18, 2015.

Site 2- Picture of North side of culvert running under main gravel road where site 2 is located. Picture taken on November 18, 2015.

Site 3- Picture of site 3 located 30 metres north of the main gravel road. Site 3 is located just beyond the LWD crossing the side channel. Picture taken November 18, 2015.

Site 4- Picture of Site 4 located south of the main gravel road. Picture showing metal bridge used to access multiple leisure trails. Picture taken November 18, 2015

Site 5- Picture of discharge of Side Channel meeting Englishman River.
Picture taken November 18, 2015

Picture of *Oncorhynchus keta* in between site 4 and site 5. Picture taken November 18, 2015

Picture of egg rearing structures downstream of site 2. Picture taken November 18, 2015

Appendix 3: Raw Data (Page 1 of 2)

Water Quality (VIU Lab)

4-Nov-15	1	2	3	4	5	Replicate (4)	Trip Blank
conductivity (µS/cm)	45	45	43	54	44	51	-
turbidity (NTU)	0.68	1.39	5.26	1.48	0.8	1.71	-
alkalinity (mg/L)	19.4	21.6	20.5	24.2	17.6	25.8	-
hardness (mg/L)	23	22	25	29	27	30	-
ph	7.2	7	7.1	7.1	7.2	7.2	-
phosphate (mg/L)	0.03	0.09	0.08	0.11	0.09	0.05	0.02
nitrate (mg/L)	0.18	0.13	0.17	0.23	0.17	0.26	0.05
Temperature (◦C)	7.2	7.2	7.3	7.2	7.3	-	-
Dissolved Oxygen (mg/L)	11.6	10.7	10.6	10.4	11.4	-	-
Saturation (%)	96	88	87	86	94	-	-
25-Nov-15	1	2	3	4	5	Replicate (4)	Trip Blank
conductivity (µS/cm)	47	47	46	57	55	57	-
turbidity (NTU)	1.81	2.44	2.12	1.91	0.98	1.52	-
alkalinity (mg/L)	18.8	19.4	19.1	24	18	22.2	-
hardness (mg/L)	27	27	26	33	25	33	-
ph	7.4	7.6	7.7	7.6	7.5	7.4	-
phosphate (mg/L)	0.53	0.28	0.26	0.2	0.21	0.80/0.56	0.40/0.66
nitrate (mg/L)	0.31	0.21	0.23	0.27	0.24	0.57	0.08
Temperature (◦C)	3.1	3.1	2.7	2.9	3.5	-	-
Dissolved Oxygen (mg/L)	12.8	12.1	12.2	11.9	12.4	-	-
Saturation (%)	94	90	89	87	92	-	-

Appendix 3: Raw Data (Page 2 of 2)

Water Quality (VIU Lab)\

Client Sample ID			ENGLISHMAN RIVER - STATION 1	ENGLISHMAN RIVER - STATION 2	ENGLISHMAN RIVER - STATION 4	ENGLISHMAN RIVER - STATION 1	ENGLISHMAN RIVER - STATION 2	ENGLISHMAN RIVER - STATION 4
Date Sampled			4-Nov-2015	4-Nov-2015	4-Nov-2015	25-Nov-2015	25-Nov-2015	25-Nov-2015
Time Sampled			8:05	8:05	8:05	9:15	9:30	10:00
ALS Sample ID			L1698773-10	L1698773-11	L1698773-12	L1707349-10	L1707349-11	L1707349-12
Parameter	Lowest Detection Limit	Units	Water	Water	Water	Water	Water	Water
Physical Tests (Water)								
Conductivity	2.0	uS/cm	62.9	62.2	73.4	67.0	66.3	78.7
Hardness (as CaCO3)	0.50	mg/L	22.9	23.3	28.6	23.8	23.7	29.1
pH	0.10	pH	7.50	7.34	7.36	7.46	7.42	7.60
Anions and Nutrients (Water)								
Ammonia, Total (as N)	0.0050	mg/L	<0.0050	<0.0050	0.0256	<0.0050	0.0113	0.0255
Nitrate (as N)	0.0050	mg/L	0.0939	0.0812	0.0932	0.143	0.146	0.157
Nitrite (as N)	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Nitrogen	0.030	mg/L	0.161	0.156	0.236	0.259	0.315	0.302
Orthophosphate-Dissolved (	0.0010	mg/L	<0.0010	<0.0010	0.0034	0.0021	0.0036	0.0059
Phosphorus (P)-Total	0.0020	mg/L	<0.0020	0.0030	0.0078	0.0051	0.0070	0.0104
TN:TP				52.0	30.3	50.8	45.0	29.0
Total Metals (Water)								
Aluminum (Al)-Total	0.20	mg/L	<0.20	<0.20	0.31	<0.20	<0.20	<0.20
Antimony (Sb)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	0.10	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total	0.050	mg/L	7.85	7.98	8.88	7.80	7.75	8.72
Chromium (Cr)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	0.030	mg/L	0.042	0.106	0.426	0.117	0.219	0.238
Lead (Pb)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	0.10	mg/L	0.79	0.83	1.55	1.04	1.06	1.77
Manganese (Mn)-Total	0.0050	mg/L	<0.0050	0.0055	0.0115	<0.0050	0.0068	0.0067
Molybdenum (Mo)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	0.30	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	2.0	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total	0.050	mg/L	2.50	2.61	3.38	3.41	3.43	3.84
Silver (Ag)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total	2.0	mg/L	2.9	2.9	3.2	3.9	3.8	3.9
Strontium (Sr)-Total	0.0050	mg/L	0.0300	0.0307	0.0335	0.0339	0.0335	0.0347
Thallium (Tl)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	0.010	mg/L	<0.010	<0.010	0.016	<0.010	0.011	0.010
Vanadium (V)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Appendix 4: Invertebrate survey field data sheets sites 1, 3, and 4.(Page 1 of 4)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Englishmen River SC site #1		Date: November 4
Station Name: Side channel site #4		Flow status:
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = $0.09 m^2$) x no. replicates $0.09 m^2$ x 3 = 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 3	EPT4 1
	Mayfly Nymph (EPT)	EPT2 16	EPT5 2
	Stonefly Nymph (EPT)	EPT3 15	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 34	D1 5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel	2	1
	Cranefly Larva	1	1
Somewhat Pollution Tolerant	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)	4	2
	Watersnipe Larva		
Sub-Total		C2 7	D2 4
Category 3	Aquatic Worm (oligochaete)		
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	13	2
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	6	1
Sub-Total		C3 19	D3 3
TOTAL		CT 60	DT 12

Appendix 4: Invertebrate survey field data sheets sites 1, 3, and 4. (Page 2 of 4)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 60

DENSITY: Invertebrate density per total area sampled:

S1 60 ÷ 0.27 m^2 = S2 222.22 / m^2

PREDOMINANT TAXON: Invertebrate group with the highest number counted (Col. C) S3 Mayfly Nymph 16

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 5 + 2 x 4 + 3 = S4 26

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 2 + 2 = S5 5

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

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

(EPT1 + EPT2 + EPT3) / CT

(3 + 16 + 15) / 60 = S6 0.57

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: S7 12

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

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

Col. C for S3 / CT

16 / 60 = S8 0.27

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 4
EPT Index	R2 3
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 4

Average Rating
Average of R4, R5, R6, R8
3.5

Appendix 4: Invertebrate survey field data sheets sites 1, 3, and 4. (Page 3 of 4)

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Englishmen RiverSC site #3		Date: November 4
Station Name: Side channel site #3		Flow status:
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m²) x no. replicates 0.09m² x 3 = 0.27 m²

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 6	EPT5 2
	Stonefly Nymph (EPT)	EPT3 5	EPT6 2
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 12	D1 5
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
Somewhat Pollution Tolerant	Crayfish		
	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Scud (amphipod)		
	Watersnipe Larva		
Sub-Total		C2 0	D2 0
Category 3	Aquatic Worm (oligochaete)		
	Blackfly Larva		
	Leech	2	1
	Midge Larva (chironomid)	4	2
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite	2	1
Sub-Total		C3 8	D3 4
TOTAL		CT 20	DT 9

Appendix 4: Invertebrate survey field data sheets sites 1, 3, and 4. (Page 4 of 4)

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: S1 20

DENSITY: Invertebrate density per total area sampled:

S1 20 ÷ 0.27 m^2 = S2 74.07 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (Col. C) S3 Mayfly Nymph 6

SECTION 2 - WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 5 + 2 x 0 + 4 = S4 19

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 2 + 2 = S5 5

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

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

(EPT1 + EPT2 + EPT3) / CT

(1 + 6 + 5) / 20 = S6 0.6

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

6 / 20 = S8 0.3

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 3
EPT To Total Ratio	R3 3
Predominant Taxon Ratio	R4 4

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

Appendix 5: Shannon-Wiener Index Results

Site 1 Shannon-Wiener Index table

Common name	Column C	P_i (C I T)	ln (p_i)	P_i * ln(p_i)
Midge Larva	4	0.20	-1.60	-0.322
Stonefly Nymph	5	0.25	-1.39	-0.347
Caddisfly Larva	1	0.05	-3.00	-0.150
Mayfly Nymph	6	0.30	-1.20	-0.361
Leech	2	0.10	-2.30	-0.230
Water Mite	2	0.10	-2.30	-0.230
TOTAL	20	1.00	---	-1.640

Common name	Column C	P_i (C I T)	ln (p_i)	P_i * ln(p_i)
Midge Larva	13	0.21	-1.56	-0.328
Stonefly Nymph	15	0.25	-1.39	-0.347
Water Mite	6	0.10	-2.30	-0.230
Mayfly Nymph	16	0.27	-1.31	-0.354
Cranefly Larva	1	0.02	-3.91	-0.078
Caddisfly Larva	3	0.05	-3.00	-0.150
Clam, Mussel	2	0.03	-3.51	-0.105
Scud	4	0.07	-2.66	-0.186
TOTAL	60	1.00	---	-1.778

$$\frac{-(-1.778)}{\ln(8)} = 0.86$$

Site 3 Shannon-Wiener Diversity Index

$$\frac{-(-1.640)}{\ln(6)} = 0.92$$

Site 4 Shannon-Wiener Diversity Index

Common name	Column C	P_i (C I T)	ln (p_i)	P_i * ln(p_i)
Midge Larva	18	0.11	-2.21	-0.243
Stonefly Nymph	41	0.25	-1.39	-0.347
Water Mite	11	0.06	-2.81	-0.169
Mayfly Nymph	63	0.40	-0.92	-0.367
Cranefly Larva	6	0.03	-3.51	-0.105
Caddisfly Larva	1	0.01	-4.61	-0.046
Clam, Mussel	6	0.03	-3.51	-0.105
Scud	11	0.06	-2.81	-0.169
Planaria	1	0.01	-4.61	-0.046
Aquatic Worm	6	0.03	-3.51	-0.105
Damselfy Larva	2	0.01	-4.61	-0.046
TOTAL	166	1.00	---	-1.748

$$\frac{-(-1.748)}{\ln(11)} = 0.72$$