# WATER QUALITY, MICROBIOLOGY, AND INVERTEBRATE SAMPLING IN RICHARDS CREEK, CROFTON, BC

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## EXECUTIVE SUMMARY

This environmental monitoring project was executed at Richards Creek, BC in 2019 to align with long term study by students of Vancouver Island University (VIU). Richards Creek is approximately 9.2km long and is part of the Somenos water basin located in North Cowichan. The creek flows from Crofton lake winding through residential and agricultural land until it reaches Somenos Lake. Samples were collected at multiple pre-determined locations along Richards Creek on low-flow and high-flow dates to align with previous studies. Samples collected during this study were subject to various quality assurance and quality control measures through collection, preservation, storage, transportation, shipment, and analysis. Different methodologies were applied to obtain information regarding water quality, hydrology, nutrient levels, microbiology, and stream invertebrate communities present in Richards Creek. Water quality results were compared to the BC Fresh Water Guidelines where some of the levels tested did not meet the guidelines. One of the sampling stations consistently showed dissolved oxygen concentrations less than 2mg/L which creates hypoxic conditions and is ultimately detrimental to fish health. Samples shipped for professional analysis at Australian Laboratory Services (ALS) in Burnaby, BC detected the presence of multiple metals. Aluminum, Calcium, and Iron were identified to be present above recommended levels and the source of these contaminants remains unknown. Excessive amounts of Phosphorus were detected in both VIU and ALS labs indicating eutrophication in some parts of this system. Without remediation efforts the conditions at Richards Creek will likely deteriorate further.

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# 1.0 INTRODUCTION AND BACKGROUND

## 1.1 Project Overview

This environmental monitoring project of Richards Creek, located in North Cowichan, BC, ran from October 28 to November 18, 2019. Three third-year Bachelor of Natural Resource Management and Protection students from Vancouver Island University conducted this project under the direction of Dr. Eric Demers.

Richards Creek is part of the Somenos water basin located in North Cowichan. This creek originates at the Crofton Reservoir and flows south for 10km, ending at the northeast end of Somenos Lake in Duncan, BC. It varies in width from 2-8m and gradient ranges between 0.1 – 5.0%. Headwaters for this creek originate from Mount Richards and Maple Mountain, which both drain into the Crofton Reservoir. This reservoir is the primary flow source for the creek and is also a source of potable water for the Crofton area, managed by the District of North Cowichan (Lanarc Consultants Limited 1999). Flow from this reservoir into Richards Creek is regulated by a 5cm valve/pipe located 60m below the lake outlet (Guimond and Sheng 2005). As well as regulating the water flow to Richards Creek, the valve/pipe also acts as an impassable barrier for fish species swimming up and down the creek. From the reservoir, Richards Creek then flows southeast through forested areas that turn into lowlands occupied by agriculture before taking a turn at Richards Trail and heading southwest to Somenos Lake (Lanarc Consultants Limited 1999).

## 1.2 Historical Overview

Agriculture has greatly modified the lowland portion of Richards Creek, as farmers have straightened the creek to flow along field edges and removed important riparian vegetation on the creek banks. Flooding of vegetable and hay fields in some areas extends up to 600m wide,

which is then drained back into the creek. The creek has also had many ditches dug as part of previous agriculture drainage improvements (Lanarc Consultants Limited 1999). Farmers have withdrawn large quantities of water from the creek for the purpose of crop watering, which greatly reduced the already low flow. Richards Creek was once a productive spawning area for a number of anadromous fish including Coho Salmon, Chum Salmon, and Steelhead. However, the productivity of these fish populations has been limited due to the lack of appropriate spawning and rearing habitat in the creek (Madrone Environmental Services Limited 2015). Restoration efforts were made by DFO in 2008 to try to improve the creek and prevent flooding during the rainy season. Fences were also installed to prevent instream cattle watering and allow riparian vegetation to grow.

### 1.3 Potential Environmental Concerns

The high use and modification of the creek for agricultural land use, the stress of urban areas, particularly bridges and culverts, as well as the large amounts of water licenses surrounding Richards Creek are all environmental concerns. The ditching of the creek for use in farming has resulted in high nutrient runoff. Cattle and other livestock have eaten away the riparian vegetation along the bank of the creek. This, combined with the low flow of water caused by the valve/pipe and the withdrawal of water by farmers, has resulted in lower water levels and rising water temperatures, making it unhealthy for fish and many species of invertebrates that usually inhabit the creek (Madrone Environmental Services Limited 2015). During the summer months, water has been recorded at temperatures of 20°C when leaving the reservoir. This high temperature is lowered slightly as the creek flows south by groundwater springs that flow into the creek (Guimond and Sheng 2005). Summer conditions (with increasing temperatures and extended periods without precipitation) prevent the groundwater springs from

keeping the creek sufficiently cool. Warming temperatures along with low flow volume present undeniable environmental concern. The creek is also exposed to garbage and other waste products as a result of running through urban areas where humans may have contaminated the area. This was especially apparent in the lower part of the stream, near Somenos Lake.

### 1.4 Project Objectives

The primary objective of this project is to gather and examine data on the water quality, hydrology, nutrient levels, microbiology, and macroinvertebrates present in Richards Creek, Crofton, BC. A total of four stations were sampled and laboratory analyses performed. Samples were analyzed at Vancouver Island University (VIU) in Nanaimo, BC as well as Australian Laboratory Services (ALS) in Burnaby, BC. Data that was collected during this study of Richards Creek, Crofton, BC was analyzed in comparison to the BC Fresh Water Guidelines, and other previous studies completed by Vancouver Island University students at this location. When compared to the previous years of data collected in this long-term study, conclusions may be drawn about the overall environmental health of the creek.

## 2.0 METHODS

### 2.1 Sampling Stations

#### *2.1.1 Locations*

Richards Creek in Crofton, BC is approximately 9.2km long and flows from Crofton lake winding through residential and agricultural land until it reaches Somenos Lake. The locations for sampling have been pre-determined to align with long-term study by students of Vancouver Island University. Written descriptions of the locations (including UTM coordinates) of Stations 1-4 were provided by Eric Demers, (VIU) as well as the map seen on the next page in Figure 1.

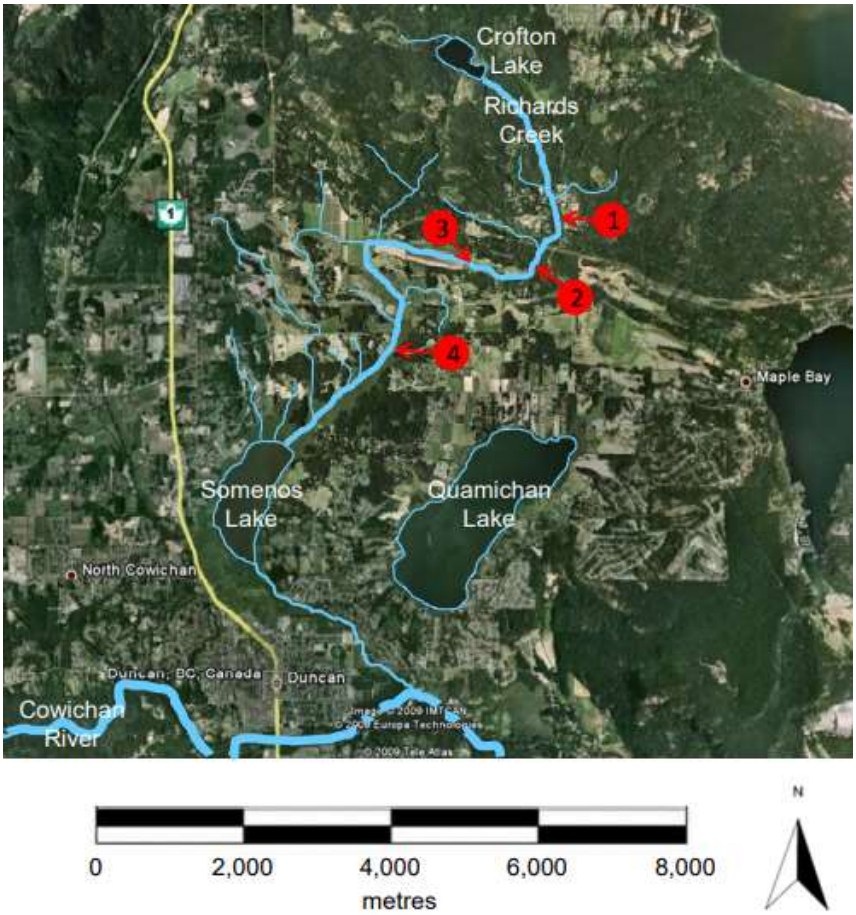



Figure 1. Approximate Locations of Stations 1-4 at Richards Creek in Crofton, BC.

Each location was verified by a site visit conducted on October 19, 2019 to evaluate access, egress, parking, safety concerns, and other information relevant to each specific location. Locations are not precise and allow for an approximate 25m buffer for safe access and suitable sampling habitat. Field sketches and google map reference documents for Stations 1-4 can be found in the Appendix of this report.

Station 1 is located near the intersection of Osbourne Bay Road and Escarpment Way in Crofton, BC. There is a gravel pull-out area for safe parking of multiple vehicles near the sample site. This site borders a farm and has level grassy terrain to walk through the riparian area which

provides ~25-50% canopy cover. Approximately 10-15m from the parking area the sample site displayed flowing riffle habitat for water sample collection and gravel substrate for invertebrate sample collection.

Station 2 is located near the end of Rice Rd, Crofton, BC. This site is on private property as indicated by a gate and no-trespassing sign. On October 19, 2019 access permission was granted by contacting the phone number on the gate. The description provided of the location of Station 2 was a water-level-gauge that had been recently uninstalled. Pink flagging tape ~15m on the left side of the driveway marks the access point to the ~15m walk over uneven terrain to a secondary piece of flagging tape at the creek. This sampling location had identifiable markers and displayed riffle glide habitats with gravel substrates suitable for sampling.

Station 3 is located at a culvert crossing on Richards Trail, Crofton, BC. There are multiple large farm fields that surround this section of Richards Creek and provide good visibility for any residential traffic travelling downhill. Access to the site was through a sloped slippery grassy ditch, and the sampling area was identified ~10m downstream away from the flat slip hazard rocks visualized near the cement flow-through culvert.

Station 4 is located near a bridge on Herd Road, Crofton, BC. During the initial site visit heavy traffic >50km/hr was observed travelling over the non-pedestrian bridge and safe parking was achieved on the shoulder/ditch area. Safe access to the intended sampling site was identified ~10m upstream of the bridge, as there was a steep bank to unknown depth directly under the bridge. A small riffle was identified as a possible sampling location.

### *2.1.2 Habitat Characteristics*

To accurately recall and describe the habitat characteristics of Stations 1-4, field notes (Appendix Tab A) and multiple high-resolution photographs (Appendix C) were taken during

each site visit on October 19, October 28, and November 18, 2019. The habitat characteristics of Stations 1-4 are briefly summarized in the following table:

Table 1: Summarization of Habitat Characteristics of Stations 1-4 Richards Creek, Crofton, BC

| | **Station 1** | **Station 2** | **Station 3** | **Station 4** |
|---|---|---|---|---|
| **Water Type** | Riffles<br>Glides | Riffles<br>Glides | Riffles<br>Glides | Pools<br>Glides |
| **% Canopy Cover** | 25 - 50% | 75 - 100% | 0 - 25% | 0% |
| **Instream Cover** | Terrestial<br>Vegetation | LWD | Boulders | Aquatic<br>Vegetation |
| **Substrate** | Fines<br>Pebbles<br>Gravel | Pebbles<br>Gravel<br>Boulders | Gravel<br>Boulders<br>Pebbles | Unidentifiable<br>through algae<br>green water |
| **Flaura/Fauna** | Birds,<br>Insects, | Red-legged frog* | Songbirds,<br>Insects, | Waterfoul,<br>Amphibians,<br>Insects, |

* Red-legged frog (*Rana aurora aurora*) photograph in Appendix

### *2.1.3 Sampling Frequency*

Water samples, nutrient samples, microbiology samples, and invertebrate samples were collected to align with availability of laboratory resources for analysis of suspected low-flow and high-flow conditions. Samples were analyzed in laboratories at Vancouver Island University (VIU) and Australian Laboratory Services (ALS) on October 30, 2019 (sampling event 1) and November 20, 2019 (sampling event 2). The sampling frequency information for this project is summarized on the Table 2 on the following page.

Table 2: Sampling Frequency Information of Richards Creek, Crofton, BC

| Station | **Sampling Event 1**<br>**October 28, 2019 (Field Collection)**<br>**October 30, 2019 (Lab Analysis)** | **Sampling Event 2**<br>**November 18, 2019 (Field Collection)**<br>**November 20, 2019 (Lab Analysis)** |
|---|---|---|
| **1** | VIU Water Sample + Replicate,<br>ALS Water Sample<br>ALS Nutrient Samples,<br>Microbiology Sample,<br>3 Invertebrate Samples | VIU Water Sample + Replicate,<br>ALS Water Sample,<br>ALS Nutrient Samples |
| **2** | VIU Water Sample,<br>ALS Water Sample,<br>ALS Nutrient Samples,<br>Microbiology Sample,<br>3 Invertebrate Samples | VIU Water Sample, |
| **3** | VIU Water Sample,<br>ALS Water Sample,<br>ALS Nutrient Samples,<br>Microbiology Sample,<br>3 Invertebrate Samples | VIU Water Sample,<br>ALS Water Sample,<br>ALS Nutrient Samples |
| **4** | VIU Water Sample,<br>Microbiology Sample, | VIU Water Sample,<br>ALS Water Sample,<br>ALS Nutrient Samples |

## 2.2 Basic Hydrology

Information regarding the basic hydrology was collected at Station 1 during both sampling events. This information was obtained using a floating object (a small container partially filled with water), a stop watch, and a measuring tape. These items allow for basic calculations of flow and discharge which can be important parameters for interpreting water quality data.

## 2.3 Water Quality

### *2.3.1 Field Measurements*

Field measurements were taken at Stations 1-4 during sampling events 1 and 2. Water temperature and dissolved oxygen were measured to the nearest 0.1° C and 0.1mg/L respectively. These field measurements were conducted with electronic probes signed out from and returned to Vancouver Island University.

### *2.3.2 Water Sample Collection*

Water samples were collected into labelled plastic containers before being transported to various laboratories for analysis. Proper procedure for water sample collection was followed: Appropriate personal protective equipment (PPE), approach from downstream, rinse bottle and lid 3x each, submerge open container toward flow of water careful not to disturb sediment, secure lid and check appropriate label, and transport sealed in a cooler to a refrigerator (4°C) for analysis within 72 hours.

Water samples collected from Stations 1-4 were analyzed at the VIU laboratory during sampling events 1 and 2. At the ALS laboratory, water samples collected from Stations 1-3 were analyzed on sampling event 1, and water samples from Stations 1, 3, and 4 were analyzed on sampling event 2.

### *2.3.3 VIU Laboratory Analysis*

Multiple parameters regarding water quality were analyzed during sampling events 1 and 2 by students (Kelsey Danielson, Matt Van Osch, and Noah Wickham) of Vancouver Island University. The water quality parameters measured and equipment used in the VIU laboratory are shown on Table 3 on the following page.

Table 3: Summary of Water Quality Parameters Measured and Equipment Used at VIU

| Parameter | Unit | Equipment |
|---|---|---|
| Conductivity | µS/cm | Pinpoint Conductivity Meter |
| pH | N/A | Oakton pHTestr 10 pH |
| Turbidity | NTU | HACH 2100 Potable Turbidimeter |
| Alkalinity (as $CaCO_3$) | mg/L | HACH AL-DT digital titration method |
| Hardness (as $CaCO_3$) | mg/L | HACH HA-4P test kit |
| Nitrate | mg/L | HACH DR2800 Spectrophotometer Method 8192 |
| Phosphate | mg/L | HACH DR2800 Spectrophotometer Method 8048 |
| Coliform (Oct 30) | CFU/100mL | m-coliBlue24 membrane filtration method |

The methods and procedures to obtain each of the water quality parameter measurements in Table 3 were provided on laminate step-by-step instructional guides available next to the appropriate lab station and equipment. Each of the methods utilized had been previously practiced by VIU students, and therefore thought to produce quality results.

### *2.3.4 ALS Laboratory Analysis*

Multiple parameters regarding water quality were analyzed during sampling event 1 and 2 by professionals at Australian Laboratory Services (ALS) in Burnaby, BC. In addition to the water quality parameters measured in the VIU laboratory (excluding Coliform), ALS Laboratories detected the amounts of different nutrients and various metals. Stations 1, 2, and 3 were sampled during sampling event 1, and Stations 1, 3, and 4 were sampled during sampling event 2.

### *2.3.5 Quality Assurance / Quality Control*

Multiple checks for quality assurance and quality control are incorporated into the design of this study. These primarily include the proper execution of methods and procedures: Wearing personal protective equipment (PPE) including gloves, cleaning and rinsing equipment before use, proper storage and preservation of samples, producing a replicate sample to evaluate precision, and a trip blank to evaluate contamination. The trip blank will help to monitor for potential contamination of storage or transportation or samples.

## 2.4 Microbiology

### *2.4.1 Water Sample Collection*

Water samples were collected at Stations 1-4 during sampling event 1 to determine the presence of coliforms and *E. Coli* in Richards Creek, Crofton, BC. A replicate sample was taken at Station 4. Each sample was collected by the use of a Whirl-pak 100mL plastic bag.

### *2.4.2 VIU Laboratory Analyses*

Each microbiology sample was vacuum pumped through a 47µm membrane filter. These filters were placed in a 50µm petri dish. To facilitate the growth of coliforms and *E. Coli* colonies, m-ColiBlue24 Broth was added to each petri dish. Once all samples were filtered and placed in petri dishes, they were incubated for 24 hours at 35 ± 0.5°C (USEPA 2003).

Photographs were taken once incubation was completed. Photographs of the samples were analyzed using one of two methods (depending on the number of colonies in each sample). If there were only a few colonies in a petri dish, a whole plate count was completed. If there were large amounts of colonies, a sub-plate count method was used to extrapolate the overall count for the whole plate. Both methods were used to determine the Colony Forming Units (CFU)/100mL for the stream.

### *2.4.3 Quality Assurance / Quality Control*

Each sample was collected with a sterile Whirl-Pak bag that was prelabeled with location, station number, and date. Each sample was sealed and transported back to the VIU lab for analysis. To ensure the quality of the results, samples were analyzed 48-72hrs after collection. In the lab, sterilized tools were used to prevent contamination as well as repetitive triplicate cleaning with distilled water after each use to prevent any cross contamination.

## 2.5 Stream Invertebrate Communities

### *2.5.1 Invertebrate Sample Collection*

Invertebrate samples were collected at Stations 1-3 during the first sampling event. Each consecutive sample was taken upstream of the previous sample. All samples were collected using a Hess sampler in similar substrate at all locations. Specimens captured were kept alive for analysis. Triplicate samples were taken at Stations 1-3. In total, nine invertebrate samples were collected at three stations of Richards Creek.

### *2.5.2 VIU Laboratory Analyses*

Lab analysis of the invertebrates at VIU was completed on October 30, 2019. Each sample was emptied into a tray along with water. Each sample was searched thoroughly until all organisms (including non-invertebrates) were separated for identification. Analysis was completed under a microscope to determine Family and Order and recorded on data sheets.

### *2.5.3 Quality Assurance / Quality Control*

For quality assurance, all invertebrate samples were collected into clean pre-labeled plastic containers, with date collected, location, station number, and sample number on each bottle. For quality control, triplicate samples were collected and analyzed. Invertebrate samples taken at Richards Creek were analyzed in the VIU laboratory approximately 48hrs after

collection. This enabled the organisms to be kept alive which may aid in accurate identification and analysis.

#### *2.5.4 Data Analysis*

Once all invertebrates had been identified, all specimens from an individual station were entered onto an invertebrate survey field data sheet. These sheets allow the pollution tolerance index of the stream to be determined as well as the stream diversity, predominant taxon ratio, predominant taxon, EPT index and overall site assessment rating. Additionally, a Shannon-Weiner Diversity Index was completed for each station, as well as the diversity index.

# 3.0 RESULTS AND DISCUSSION

## 3.1 General Field Conditions

### *3.1.1 Hydrology*

Discharge measurements were taken at Station 1 during both sampling events. During sampling event 1, the water levels were noted to be very low (12.5cm deep). During sampling event 2, the water levels were noted to be significantly higher (52cm deep). This increased the amount of discharge by from 0.078$m^3/s$ to 0.551$m^3/s$, or 706%. This drastic rise in water level and discharge is likely due to heavy rain fall, or potentially adjustments to the dam valve to Richards Creek at Somenos Lake.

## 3.2 Water Quality

### *3.2.1 Field Measurements*

Field measurements were taken at Stations 1-4 during sampling events 1 and 2. These results of the field measurements are summarized on Table 4 on the following page.

Table 4: Results for Temperature, Dissolved Oxygen and Discharge at Richard's Creek, Duncan.

| Station | Water Temperature (°C) | Dissolved Oxygen (mg/L) | Discharge Rate ($m^3/s$) |
|---|---|---|---|
| Sampling Event 1 - October 28, 2019 | | | |
| **1** | 7.5 | 11.7 | 0.078 |
| **2** | 7.5 | 11.7 | |
| **3** | 7.2 | 11.6 | |
| **4** | 7 | 1.7 | |
| Sampling Event 2 - November 18, 2019 | | | |
| **1** | 9.4 | 10.6 | 0.551 |
| **2** | 9.9 | 10.8 | |
| **3** | 9.9 | 10.3 | |
| **4** | 13.3 | 1.3 | |

### *3.2.1i Water Temperature*

The water temperature was measured and recorded at Stations 1-4 during sampling events 1 and 2. During sampling event 1 the temperatures were observed to decrease from Station 1 to Station 4, yet during sampling event 2 the temperatures were observed to increase from Station 1 to Station 4. It is unclear what may have produced these seemingly opposite trends.

Overall, the water temperature increased 1.9-6.3°C at each station from sampling event 1 to sampling event 2. The greatest difference in water temperature between sampling events was seen at Station 4 which increased from 7°C to 13.3°C. There are a variety of factors that may have potentially influenced the increasing water temperature results, but the source remains unknown.

#### *3.2.1ii Dissolved Oxygen*

Dissolved Oxygen (DO) was measured and recorded at Stations 1-4 on sampling events 1 and 2. During both sampling events the DO was consistent at Stations 1-3 only fluctuating by 0.1mg/L between stations. These DO results are at a high enough level to support spawning and active growth of fish species according to the BC Fresh Water Guidelines.

Station 4 DO results were much lower (at least 10mg/L less) compared to Stations 1-3. The DO was measured and recorded to be 1.7mg/L and 1.3mg/L respectively. Multiple tests with the probe were taken during sampling event 1 and 2 to confirm that the probe was not malfunctioning. Furthermore, tests were taken at different depths to confirm that the probe was not reading the oxygen level on the bottom. Performing these precautionary steps enabled confidence in our results of less than ~2mg/L even though it was a drastic difference from other stations.

As per the BC Fresh Water Guidelines, the DO level at Station 4 could potentially cause hypoxia in fish, and ultimately is not high enough to support fish populations.

### 3.3 VIU Laboratory Analyses

During sampling events 1 and 2, analyses were performed at VIU and ALS laboratories to determine several water quality variables in the samples collected from Richards Creek, BC. The complete sets of data for these results are found in the Appendix of this report. Table 5 on the following page summarizes the results from the VIU lab for conductivity, pH, turbidity, alkalinity, and hardness.

Table 5: VIU Results for Conductivity, pH, Turbidity, Alkalinity, and Hardness at Richard's Creek, Duncan.

| Station | Conductivity (µS/cm) | pH | Turbidity (NTU) | Alkalinity (mg/L) | Hardness (mg/L) |
|---|---|---|---|---|---|
| Sampling Event 1 - October 30, 2019 | | | | | |
| **1** | 90 | 8.3 | 1.84 | 23.6 | 42 |
| **2** | 133 | 8.4 | 1.96 | 32 | 60 |
| **3** | 141 | 8.1 | 1.95 | 40.8 | 68 |
| **4** | 205 | 7.6 | 1.9 | 38 | 92 |
| Sampling Event 2 - November 20, 2019 | | | | | |
| **1** | 128 | 8.3 | 1.91 | 32 | 60 |
| **2** | 148 | 8.4 | 1.77 | 34 | 64 |
| **3** | 171 | 8 | 4.49 | 46.8 | 72 |
| **4** | 204 | 7.3 | 4.51 | 50 | 88 |

### *3.3.1 Conductivity*

Conductivity was recorded for Stations 1-4 on sampling events 1 and 2. Ultimately, comparing the VIU laboratory results to the ALS laboratory results showed the values were very similar. VIU laboratory results from sampling event 1 determined conductivity ranged from 90 to 205 µS/cm, increasing in value with progression downstream. The VIU laboratory results for sampling event 2 ranged from 128 to 204 µS/cm, again increasing in value with progression downstream. The ALS results from sampling event 1 showed conductivity ranging from 97.9 to 146 µS/cm for Stations 1-3, and subsequently determined conductivity ranging from 143 to 221 µS/cm for sampling event 2. There is a notable increase in conductivity at Station 4 compared to Stations 1-3 which is also demonstrated in data collected in previous years.

### 3.3.2 pH

The pH was recorded for Stations 1-4 on sampling events 1 and 2. In the VIU laboratory, the measured pH decreased in the downstream direction on both sampling events. During sampling event 1, the pH dropped by 0.7 across all 4 stations (with the exception of a slight increase at station 2). The pH measured in sampling event 2 also displayed a trend of decreasing in the downstream direction as it dropped 1.0 across all 4 stations (again with a slight increase at station 2). At Station 2, the pH during both events was 8.4 which was 0.1 higher than Station 1.

ALS results did not align with the VIU results. The trend from ALS for sampling event 1 indicated an increase in pH from Station 1 to Station 3 ranging from 7.46 to 7.60. For sampling event 2, Stations 1, 3, and 4 showed a decreased in pH from 7.46 to 7.18 (which was more consistent with the VIU trends observed). As per BC Water Quality Guidelines, the pH in Richards Creek is within the guidelines specified for freshwater.

### 3.3.3 Turbidity

Turbidity was recorded for Stations 1-4 on sampling events 1 and 2. During sampling event 1 the turbidity ranged between 1.84 and 1.96 Nephelometric Turbidity Units (NTU), however, sampling event 2 determined the turbidity to be between 1.77 and 4.51NTU. Although there was a notable increase in turbidity for Stations 3-4 between sampling events 1 and 2, the determined values fall within acceptable parameters established by the BC Fresh Water Guidelines.

### 3.3.4 Alkalinity

Alkalinity was recorded for Stations 1-4 on sampling events 1 and 2. During both sampling events, all results produced a value higher than 20mg/L of $CaCO_3$. The lowest alkalinity value determined was 23.6mg/L of $CaCO_3$ at Station 1 during sampling event 1, and

the highest alkalinity value determined to be 50mg/L of $CaCO_3$ at Station 4 during sampling event 2. As per the BC Work Water Quality Guidelines, alkalinity with a value >20mg/L of $CaCO_3$ has a low acid sensitivity therefore all water samples collected had low acid sensitivity.

### 3.3.5 Hardness

Hardness (as $CaCO_3$) results from Richards Creek, BC displayed a trend of increasing values in the downstream direction. During sampling event 1, hardness ranged from 42mg/L at Station 1 up to 92mg/L at Station 4. This trend was consistent during sampling event 2, where Station 1 hardness was measured to be 60 mg/L of $CaCO_3$ and increased to a value of 88mg/L of $CaCO_3$ at Station 4.

As per the Guidelines for Interpreting Water Quality Data, the values for soft water are <60mg/L of $CaCO_3$, and hard water is above >120mg/L of $CaCO_3$. Station 1 during sampling event 1 was the only sample identified to be considered soft water.

The ALS results produced a similar trend to the VIU lab analysis, with the values increasing the further downstream they were collected. Overall the results from ALS were lower than the ones produced at VIU. During sampling event 1, the hardness values ranged from 37 to 54.7mg/L of $CaCO_3$, and during sampling event 2 the values ranged from 49.5 to 82.1mg/L of $CaCO_3$. The ALS results determined all samples to be soft water with the exception of Stations 3 and 4 on sampling event 2.

### 3.3.6 Nitrate

VIU laboratory analysis determined the total amount of nitrate and phosphate present in samples and used this information to calculate a Red Field Ratio. These results are summarized on Table 6 on the following page.

Table 6: VIU Results for Nitrate, Phosphate, and Redfield Ratio for Richards Creek, BC.

| Station | Nitrate | Phosphate | Redfield Ratio 16N:1P |
|---|---|---|---|
| Sampling Event 1 - October 28, 2019 | | | |
| **1** | 0.27 | 0.03 | 0.563 |
| **2** | 0.38 | 0.03 | 0.792 |
| **3** | 0.5 | 0.04 | 0.781 |
| **4** | 1.01 | 0.59 | 0.107 |
| Sampling Event 2 - November 18, 2019 | | | |
| **1** | 0.52 | 0.09 | 0.361 |
| **2** | 0.64 | 0.02 | 2 |
| **3** | 0.59 | 0.16 | 0.230 |
| **4** | 0.35* | 0.66 | 0.033 |

* Result influenced by human error in the VIU laboratory

At Stations 1-4, the values determined for nitrate were much lower than the BC Fresh Water Guidelines, with only one station exceeding the guideline of <1mg/L of nitrate. The ALS results were similar to the VIU results where values were <1mg/L of nitrate. This indicates that the stream was not eutrophic from an excess of nitrate.

### *3.3.7 Phosphate*

All of the VIU results determined for phosphate exceeded the parameter set by the BC Fresh Water Guidelines. During sampling event 1, phosphate levels ranged from 0.03mg/L at Station 1 up to 0.59 mg/L at Station 4. During sampling event 2, total phosphate levels ranged from 0.02mg/L at Station 1 up to 0.66mg/L at Station 4.

Overall, ALS phosphate results were lower than the VIU results. During sampling event 1, the ALS results ranged from 0.0071mg/L at Station 1 up to 0.0124 mg/L at Station 3. During sampling event 2, Station 3 measured 0.0591mg/L and Station 4 measured 0.211 mg/L.

Results at Richard's Creek indicated that the phosphate levels are creating a eutrophic environment. According to the BC Water Quality Guidelines, phosphate levels are considered eutrophic if they meet or exceed 0.025mg/L. Both the VIU and ALS results confirm that Stations 3 and 4 are definitely eutrophic.

#### *3.3.8 Redfield Ratio*

By comparing collected results from the nitrate and phosphate values and entering them into a Redfield Ratio, the results from Richards Creek indicated that it is nitrate limited. According to the Redfield Ratio, the ratio of nitrate to phosphate is optimal at 16N:1P. In almost all cases, the Redfield ratio came out with a result below 1, which indicates that the stream has an abundance of phosphate in the stream. The only outlier was during sampling event 2, where results indicated Station 3 was phosphate limited.

### 3.4 ALS Laboratory Analyses

#### *3.4.1 Total Metals Analysis*

Various metals were detected and measured at ALS Laboratories in Burnaby, BC. Most of the metals tested at the ALS lab were below the detection limit of the devices used. Some metals were determined to exceed guideline levels such as aluminum, calcium and iron. These metals are summarized in Table 7 and discussed on the following page. The sources of the excess levels of Aluminum, Calcium, and Iron detected in Richards Creek remain unknown.

Table 7: Results for Aluminum, Calcium, Iron from the ALS results of Richard's Creek, Duncan BC.

| Station | Aluminum (mg/L) | Calcium (mg/L) | Iron (mg/L) |
|---|---|---|---|
| Sampling Event 1 - October 28, 2019 | | | |
| **1** | 0.53 | 11.4 | 1.07 |
| **2** | 0.53 | 16.0 | 0.918 |
| **3** | <0.20 | 16.3 | 0.143 |
| Sampling Event 2 - November 18, 2019 | | | |
| **1** | <0.20 | 15.5 | 0.246 |
| **3** | 0.45 | 19.4 | 0.462 |
| **4** | 1.41 | 24.1 | 1.76 |

The water quality guidelines concentration for Aluminum is listed as 0.1mg/L. For both sampling events 1 and 2, the concentration of Aluminum exceeded the water quality guideline at least 2 stations. The sensitivity of the ALS equipment was not able to detect the presence of aluminum below 0.2 mg/L, meaning it may have still been above the guideline level of 0.1mg/L but remains undetermined.

During sampling event 1, Calcium results ranged from 11.4mg/L at Station 1 up to 16.3mg/L at Station 3, and during sampling event 2 these results ranged from 15.5mg/L up to 16.3mg/L. For Calcium, all stations exceeded the water quality guidelines of 8mg/L during both sampling events.

For Iron, at least one of the stations exceeded the guideline of 1mg/L during both sampling events. During sampling event 1, Station 1 exceeded the guideline by 0.07mg/L. During sampling event 2, Station 4 exceeded the guideline by 0.76mg/L.

### 3.5 Microbiology

Microbiology water samples were taken at Station 1-4 during sampling event 1 and analyzed at the VIU laboratory. Total coliforms present in the water, expressed as Coliform Forming Units (CFU/100mL) and percentage of fecal coliforms were determined for each sample. These results are summarized in Table 8 below.

Table 8: VIU Results for Microbiology Samples from Stations 1-4 of Richards Creek, BC

| Station | Total coliforms (CFU/100ml) | Fecal coliforms | % Fecal coliforms |
|---|---|---|---|
| **1** | 444 | 12 | 2.70% |
| **2** | 792 | 0 | 0% |
| **3** | 1,624 | 12 | 0.74% |
| **4** | 1,512 | 16 | 1.06% |
| **Replicate (St 4)** | 1,412 | 12 | 0.85% |

Station 1 had the lowest number of coliforms at only 444 CFU/100mL. However, it did have the highest percentage of fecal coliforms at 2.70%. Station 2 had the second lowest number of coliforms at 792 CFU/100mL. Zero fecal coliforms at station 2, giving it a fecal coliform percentage of 0. Station 3 had the highest amount of microbiology with 1,624 CFU/100mL and a fecal percentage of only 0.74%. Two samples were taken from Station 4 (one as a replicate). The Station 4 sample contained 1,512 CFU/100mL, of which 1.06% were fecal coliforms and the replicate sample produced 1,412 CFU/100mL with a fecal coliform percentage of 0.85%. These results were unexpected, as we had predicted that due to the lower part of the creek flowing through agricultural land, there would be a higher number of fecal coliforms. Ultimately, the results show that Richards Creek has a very low percentage of fecal coliforms.

## 3.6 Stream Invertebrate Communities

### *3.6.1 Site Rating and Diversity*

A total of 344 invertebrates were collected from Stations 1-3 during sampling event 1. A site assessment average rating was assigned to each sampling station based on the Pacific Streamkeepers Handbook, a with a maximum rating of 4.00 and a minimum of 1.00. This assigned rating number is based on the stream's water quality and invertebrate diversity. Invertebrate Survey Field Data Sheets can be found in Appendix Tab D.

Station 1 had an assessment rating of 3.25, reflecting an acceptable to good site. The dominant species present was Mayfly nymph, indicating a healthy, pollutant-free stream. Although station 1 did not have the highest average rating, it did have the highest density of invertebrates measuring at 685/m². Station 2 received the highest average rating at 3.50, which is between acceptable and good and the invertebrate density was 325/m². The dominant species present at this location was also Mayfly nymph. Station 3 received the lowest average rating at 3.00, reflecting an acceptable site. This site also had the lowest invertebrate density at 262/m² and the dominant species present was aquatic worms, which are tolerate to pollution.

### *3.6.2 Taxon Richness and Diversity*

Shannon-Weiner Diversity Index was calculated to determine the species diversity at each sampling station. The higher the diversity, or the higher the Shannon-Weiner Diversity Index number, the wider range of species there is present in that section of the stream.

Station 1 had the highest diversity index rating at 0.655 and 20 different taxa present, indicating that this site had the highest species richness. Station 2 had the next highest at 0.550 and 15 different taxa present. Station 3 had the lowest diversity index with only 0.464 with 17 different taxa present.

Water quality, substrate composition, and riparian cover may be potential factors that influenced the difference in results between stations. Station 1 had significant riparian vegetation and a solid rock/muddy substrate. Station 2 had excellent riparian vegetation and small pebble substrate. Station 3 had very little riparian vegetation and larger cobble-sized substrate. Overall, we concluded that the high number of category 1 invertebrates indicates that Richards Creek is relatively clean and free of pollutants.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

A majority of the analysis of water quality variables, nutrient levels, microbiology, and macroinvertebrates employed during this study of Richards Creek ecosystem determined that the overall environmental quality is fairly healthy. Not all of the results indicate a healthy ecosystem. Several of the analyses performed at both the VIU and ALS laboratories determined values greatly exceeding the BC Fresh Water Guidelines. Some of the identified environmental concerns for Richards Creek included: rising water temperatures, hypoxic conditions detrimental to fish health, excessive nutrient loading of phosphorus, and metal contamination from unknown sources. Without remediation efforts focused near Station 4, it is likely that hypoxic conditions detrimental to fish health will continue. It is unknown if farmers continue to use fertilizers in the agricultural fields surrounding Richards Creek, or if any efforts have been made to educate them on the effects of nutrient overloading on water quality and fish health. We recommend further student outreach associated with this project in the future to approach and attempt to converse with landowners about sources of Phosphorus near Richards Creek. We suggest this may be potentially mutually beneficial as they may have insight to the source of metals leaching into the water.

## 5.0 ACKNOWLEDGEMENTS

We would like to Acknowledge Eric Demers for facilitating this study and taking the extra time to provide us with organized field sample collection kits with all the necessary equipment. Additionally, we would like to acknowledge Mike from Vancouver Island University who patiently helped us execute the microbiology procedure safely.

## 6.0 REFERENCES

Guimond and Sheng. 2005. A Summary of Water Quality Monitoring in the Somenos Basin 2003-2005. Pacific Salmon Commission. Vancouver, BC. 27p.

Lanarc Consultants Limited. 1999. The Somenos-Quamichan Basin. Department of Fisheries and Oceans. Lake Cowichan, BC. 36p.

Madrone Environmental Services Limited. 2015. Somenos Basin Coho Salmon Summer Habitat Assessment. Somenos Wildlife Society. Duncan, BC. 14p.

US Environmental Protection Agency (UEPA). 2003. Total Coliforms and *E.coli* Membrane Filtration Method, Revision 3. 9p.

## 7.0 APPENDIX INDEX

# A)
# Field Notes and Sketches

FIELD NOTES & SKETCHES
"SITE VISITS"
DUNCAN, BC, CANADA

10:30 meet group @ Drinkwater Rd TimHortons to discuss RFP assignment
Decide to locate sites in order: 4, 3, 2, 1 for RICHARDS CREEK

1135 Arrive at Site 4 - Herd Rd/Bridge
Observations: heavy traffic (50+km/hr) non-pedestrian bridge
Uneven grassy terrain decends to steeper (0 sidewalk space)
bank area. Evidence of human activity under bridge, garbage etc.
Marshy green still water (unknown depth) with pools and some
side channels. 20+ Mallard Ducks / 1 frog witnessed. Team
verbalized ideal sampling location ~5-10m upstream of bridge.
Noticed (potential) virtually ~~zero~~ canopy cover

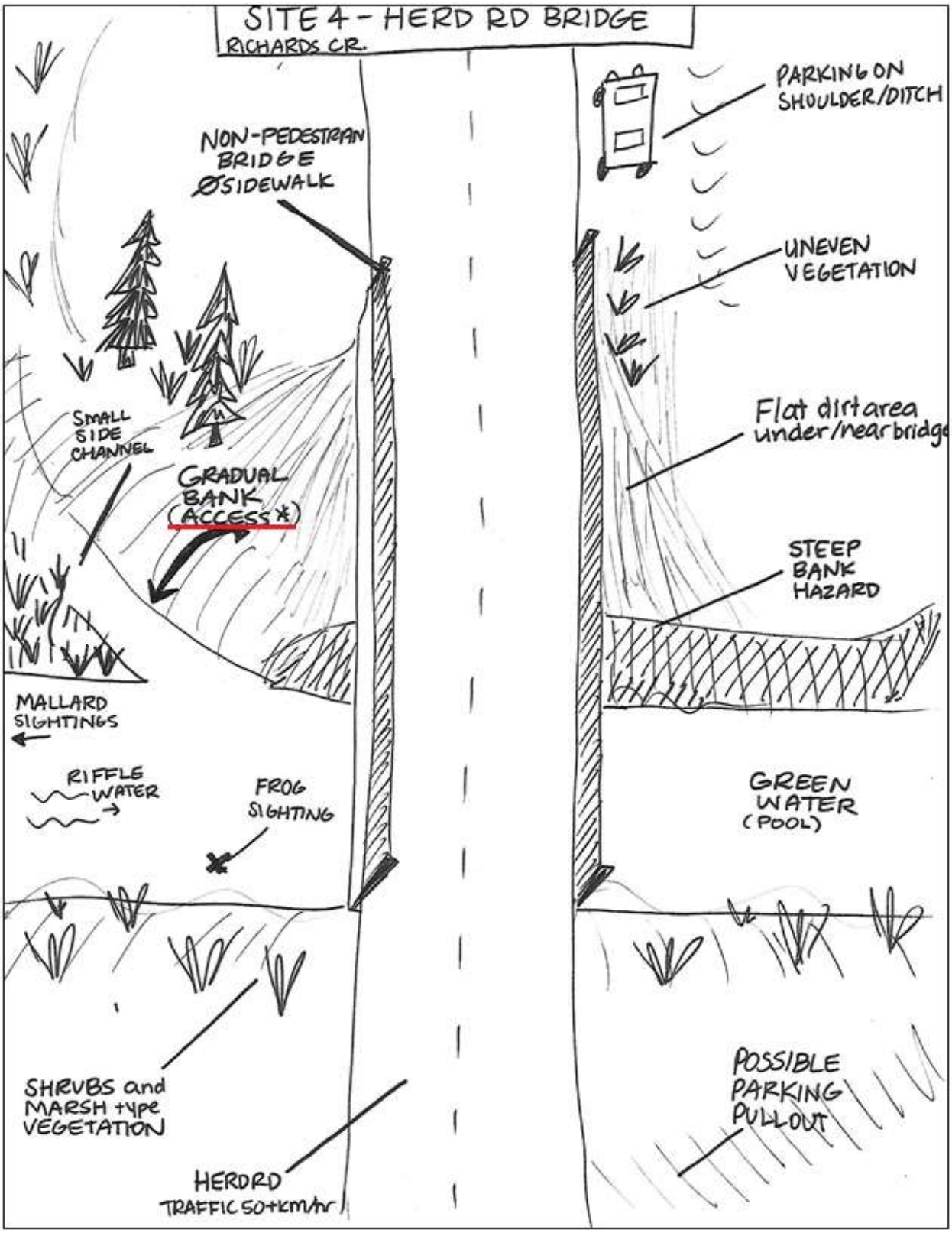
1205 Arrive at Site 3 - Richards Trail / Culvert Crossing
observations: moderate to heavy traffic (<50km/hr) location
noted to be at bottom of narrow paved road at base of hill from
both directions. Farm fields border the road allow visibility for 50+m.
Steep ditch (likely floods to 2nd culvert + rain) slippery flat rocks when
approaching culvert. Team verbalized sampling location ~10m culvert.
Appears to be slow moving glide/riffle areas. ~~[redacted]~~ 25-50% canopy cover.

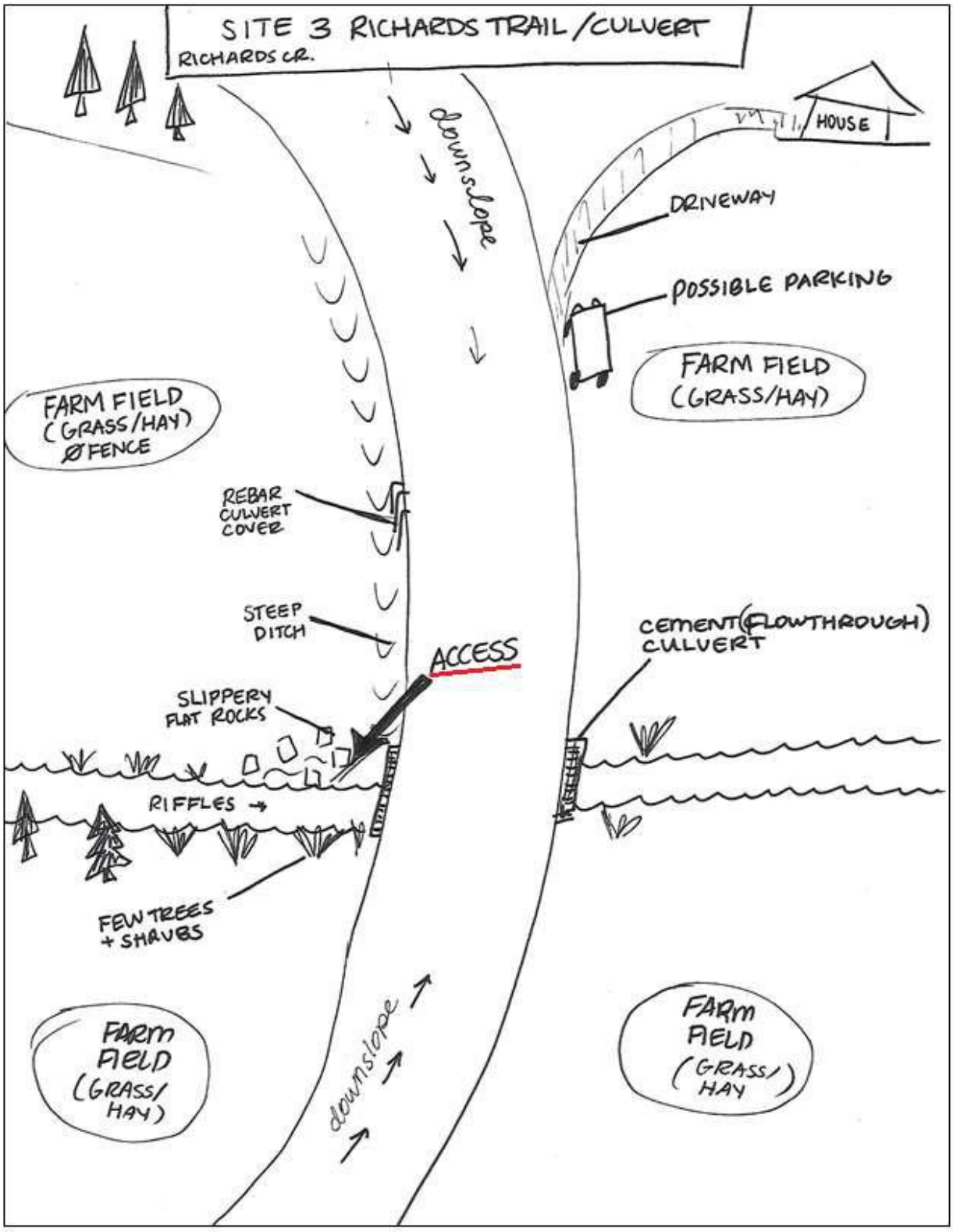
1220 Arrive at Site 2 - Rice Road/Private Property

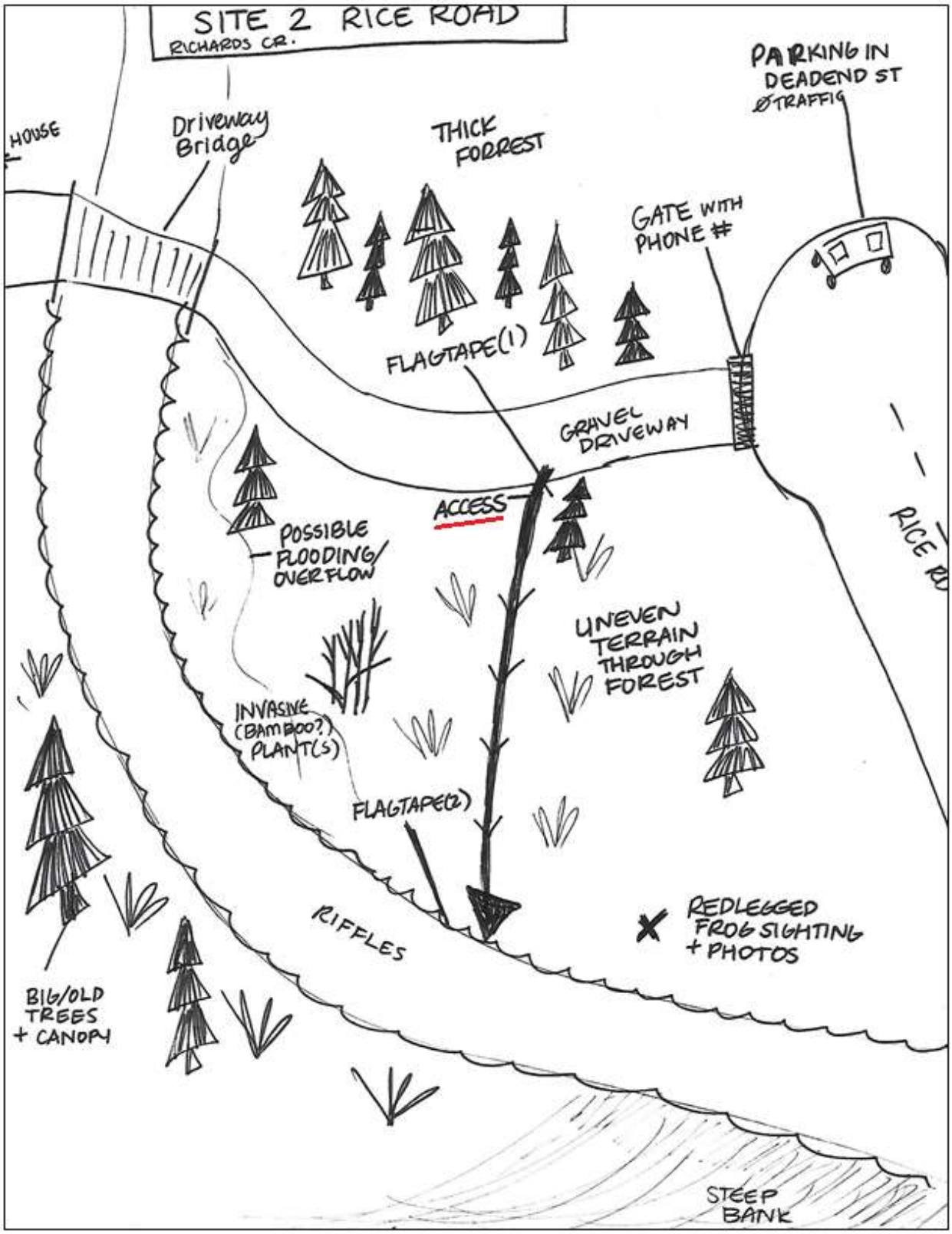
1224 Phonecall from M. VanOsch to (250) 746 7143 spoke to "Holly" who
granted consent to access property. (Phone # found on gate ☒ private prop signage
Holly advises Fisheries removed weir/watergauge from unknown spot

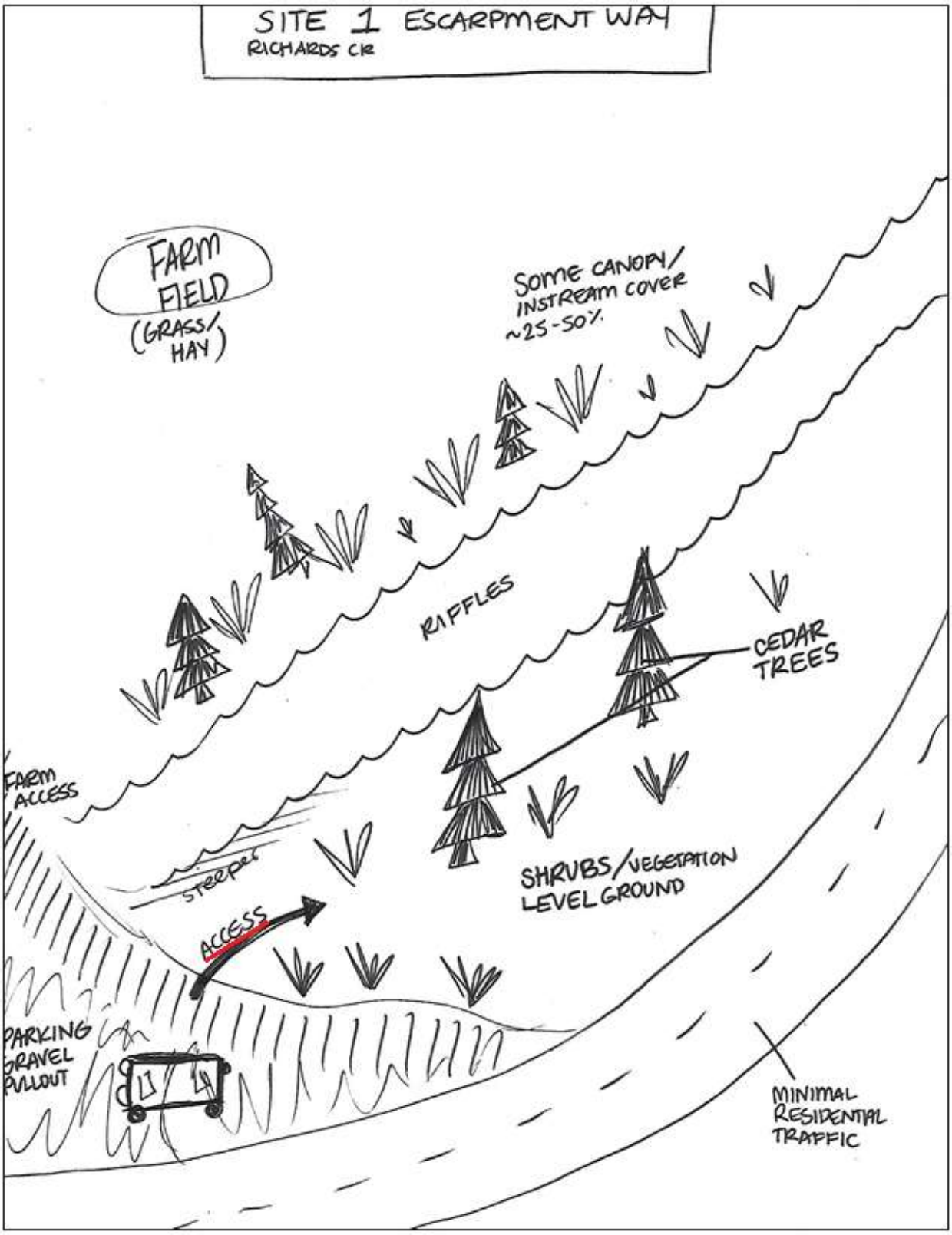
1235 Team follows pink/red flagging tape found ~10-20m from driveway gate
another 10-20m to creekside verbalized sample locations.
Observations: Quiet cul-de-sac virtually zero traffic at end of narrow,
steep, winding road. Site access via gravel driveway on uneven forrest
floor relatively low slope / gradual descent through some vegetation
to clearing/creek area marked with pink tape (same as entrance). Habitat
Riffles and glides with steep bank on opposite side. Potential bamboo
type invasive plant noted. Red ~~leg frogged~~ legged Frog found and photograp
Almost 100% canopy cover noted.

1255 Arrive at Site 1 - Escarpment Way / Gravel farm driveway
Observations: safe parking on farm access/gravel area totally off
the roadway. Level terrain some grass, shrubs, few trees. Area
seems relatively undisturbed ∅ garbage ∅ infastructure noted. Team
verbalized sample locations (near 2 large cedar trees ~10ft apart)
Riffles and glide type areas with ~50% canopy cover. Possible observation
of "Bush Tit" bird species


SITE 4 - HERD RD BRIDGE
RICHARDS CR.
PARKING ON SHOULDER/DITCH
NON-PEDESTRAIN BRIDGE Ø SIDEWALK
UNEVEN VEGETATION
Flat dirt area under/near bridge
SMALL SIDE CHANNEL
GRADUAL BANK (ACCESS*)
STEEP BANK HAZARD
MALLARD SIGHTINGS
RIFFLE WATER
FROG SIGHTING
GREEN WATER (POOL)
SHRUBS and MARSH type VEGETATION
POSSIBLE PARKING PULLOUT
HERD RD
TRAFFIC 50+km/hr


SITE 3 RICHARDS TRAIL / CULVERT
RICHARDS CR.
downslope
HOUSE
DRIVEWAY
POSSIBLE PARKING
FARM FIELD (GRASS/HAY)
FARM FIELD (GRASS/HAY) Ø FENCE
REBAR CULVERT COVER
STEEP DITCH
ACCESS
CEMENT (FLOWTHROUGH) CULVERT
SLIPPERY FLAT ROCKS
RIFFLES →
FEW TREES + SHRUBS
FARM FIELD (GRASS/ HAY)
downslope
FARM FIELD (GRASS/ HAY)


SITE 2 RICE ROAD
RICHARDS CR.
PARKING IN DEADEND ST Ø TRAFFIC
HOUSE
Driveway Bridge
THICK FORREST
GATE WITH PHONE #
FLAGTAPE(1)
GRAVEL DRIVEWAY
ACCESS
POSSIBLE FLOODING/ OVERFLOW
RICE RD
UNEVEN TERRAIN THROUGH FOREST
INVASIVE (BAMBOO?) PLANT(S)
FLAGTAPE(2)
RIFFLES
REDLEGGED FROG SIGHTING + PHOTOS
BIG/OLD TREES + CANOPY
STEEP BANK


SITE 1 ESCARPMENT WAY
RICHARDS CR
FARM FIELD (GRASS/HAY)
SOME CANOPY/ INSTREAM COVER ~25-50%
RIFFLES
CEDAR TREES
FARM ACCESS
STEEP
ACCESS
SHRUBS/VEGETATION LEVEL GROUND
PARKING GRAVEL PULLOUT
MINIMAL RESIDENTIAL TRAFFIC

## B)
## Map References

## STATION 4


(Modified map from Google)


(Location stamped photo)

## STATION 3


(Modified map from Google)


(Location stamped photo)

## STATION 2


(Modified map from Google)


(Location stamped photo)

## STATION 1


(Modified map from Google)


(Location stamped photo)

## C)
## Photographs

Photo # 1

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | Richards Creek via Herd Rd Bridge shows uneven terrain and vegetation for access and egress |

Photo # 2

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | Green slow-moving/pooling water with insteam vegetation |

Photo # 3

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | Steep embankment gravel area under Herd Rd bridge |

Photo # 4

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | View from under Herd Rd bridge looking upstream – evidence of waterfoul visible in algae markings |

Photo # 5

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | Uneven terrain covered with vegetation on far-side of creek versus gradual access on near-side of creek |

Photo # 6

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | View of Richard Creek from Herd Rd bridge showing green water surrounded by marsh type vegetation with virtually zero canopy cover |

Photo # 7

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 4 | Oct 16th 2019 | The one tree located near Site 4 Richard Creek sampling site |

Photo # 8

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 3 | Oct 16th 2019 | Access to site 3 located at corner of farm field on Richards Trail (road) through deep grassy ditch |

Photo # 9

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 3 | Oct 16th 2019 | Riffle area ~5m infront of cement flow-through culvert easily accessible |

Photo # 10

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 3 | Oct 16th 2019 | View of slippery rock hazard and of water flowing through unobstructed culvert |

Photo # 11

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 3 | Oct 16th 2019 | Access to site 3 located at corner of farm field on Richards Trail (road) through deep grassy ditch |

Photo # 12

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 3 | Oct 16th 2019 | Less desirable side of culvert for sampling potentially due to large boulders limiting invertebrate Hess sampler method |

Photo # 13

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Access to Site 2 through gravel driveway on private property. Nearly 100% canopy cover from mature forest. |

Photo # 14


| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Access to Site 2 on private property “Innisvale” farm |

Photo # 15


| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | M. Van Osch contacted "Holly" at this number @ 12:24HR and permission was granted to access the property for project purposes. |

Photo # 16

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Access through uneven terrain to pink flagging tape seen in background |

Photo # 17

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Potential invansive species (possible bamboo) located in clearing area between driveway and creekside. 3+ plants. |

Photo # 18

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Orange flagging tape marking possible location of sample site. |

Photo # 19

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Riffle and glide habitat types with nearly 100% canopy cover |

Photo # 20

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Frog located on forest floor surrounded by vegetation |

Photo # 21

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 2 | Oct 16th 2019 | Confirmed Red-legged frog species, *Rana aurora aurora*. Gently captured, quickly photographed, and immediately released. No observable issues noted with ambuation after short (<20 seconds) handling duration. |

Photo # 22

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 1 | Oct 16th 2019 | Access to Site 1 via gravel parking area near farm access road. |

Photo # 23

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 1 | Oct 16th 2019 | Level terrain with long grass and canopy cover ~25% |

Photo #24

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 1 | Oct 16th 2019 | Two large cedar trees provide reference for potential sampling location |

Photo # 25

| SITE # | DATE | DESCRIPTION |
|---|---|---|
| 1 | Oct 16th 2019 | Riffle and glide habitat with little vegetation in riparian area resulting in farm field being visible in background. |

# D)
# Data Sheets / Results

Oct 28, 2019

RICHARDS CREEK FIELD MEASUREMENTS

clear, sunny, windy, 10°C

| STATION # | TEMP °C | DO mg/L | WIDTH m | DEPTH cm | TIME s | DISTANCE m |
|---|---|---|---|---|---|---|
| 1 | 7.5 | 11.7 | 1.52m | 12.5 | 12.2 | 5 |
| 2 | 7.5 | 11.7 | | | | |
| 3 | 7.2 | 11.6 | | | | |
| 4 | 7.0 | 1.7 | | | | |

---

Nov 18, 2019

RICHARDS CREEK FIELD MEASUREMENTS

overcast 9.7°C

| STATION # | TEMP °C | DO mg/L |
|---|---|---|
| 1 | 9.4 | 10.6 |
| 2 | 9.9 | 10.8 |
| 3 | 9.9 | 10.3 |
| 4 | 13.3 | 1.3 |

DISCHARGE

WIDTH = 1.8m

DEPTH = 52cm

TIME = 8.5s

DISTANCE = 5m

## INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

| Stream Name: Richards Creek | | Date: Oct 28 |
|---|---|---|
| Station Name: 1 | | Flow status: Low |
| Sampler Used: Hess | Number of replicates: 3 | Total area sampled (Hess, Surber = 0.09 $m^2$) x no. replicates: 0.09 x 3 = $m^2$ |

| Column A<br>Pollution Tolerance | Column B<br>Common Name | Column C<br>Number Counted | Column D<br>Number of Taxa |
|---|---|---|---|
| Category 1<br>Pollution Intolerant | Caddisfly Larva (EPT) | EPT1 4 | EPT4 2 |
| | Mayfly Nymph (EPT) | EPT2 72 | EPT5 3 |
| | Stonefly Nymph (EPT) | EPT3 7 | EPT6 2 |
| | Dobsonfly (hellgrammite) | | |
| | Gilled Snail | | |
| | Riffle Beetle | | |
| | Water Penny | | |
| Sub-Total | | C1 | D1 |
| Category 2<br>Somewhat Pollution Tolerant | Alderfly Larva | 2 | 1 |
| | Aquatic Beetle | | |
| | Aquatic Sowbug | 1 | 1 |
| | Clam, Mussel | 8 | 1 |
| | Cranefly Larva | 4 | 3 |
| | Crayfish | | |
| | Damselfly Larva | | |
| | Dragonfly Larva | | |
| | Fishfly Larva | | |
| | Amphipod (freshwater shrimp) | 18 | 2 |
| | Watersnipe Larva | | |
| Sub-Total | | C2 | D2 |
| Category 3<br>Pollution Tolerant | Aquatic Worm (oligochaete) | 2 | 2 |
| | Blackfly Larva | 62 | 1 |
| | Leech | | |
| | Midge Larva (chironomid) | 2 | 1 |
| | Planarian (flatworm) | | |
| | Pouch and Pond Snails | | |
| | True Bug Adult | | |
| | Water Mite | 3 | 1 |
| Sub-Total | | C3 | D3 |
| TOTAL | | CT | DT |

## INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

| Stream Name: Richards Creek | | Date: Oct 28 |
|---|---|---|
| Station Name: 2 | | Flow status: low |
| Sampler Used: Hess | Number of replicates: 3 | Total area sampled (Hess, Surber = 0.09 $m^2$) x no. replicates: $m^2$ |

| Column A<br>Pollution Tolerance | Column B<br>Common Name | Column C<br>Number Counted | Column D<br>Number of Taxa |
|---|---|---|---|
| Category 1 | Caddisfly Larva (EPT) | EPT1 8 | EPT4 1 |
| | Mayfly Nymph (EPT) | EPT2 28 | EPT5 3 |
| | Stonefly Nymph (EPT) | EPT3 10 | EPT6 2 |
| Pollution Intolerant | Dobsonfly (hellgrammite) | | |
| | Gilled Snail | | |
| | Riffle Beetle | | |
| | Water Penny | | |
| Sub-Total | | C1 | D1 |
| Category 2 | Alderfly Larva | | |
| | Aquatic Beetle | | |
| | Aquatic Sowbug | | |
| | Clam, Mussel | 1 | 1 |
| | Cranefly Larva | 12 | 2 |
| | Crayfish | | |
| Somewhat Pollution Tolerant | Damselfly Larva | | |
| | Dragonfly Larva | | |
| | Fishfly Larva | | |
| | Amphipod (freshwater shrimp) | 10 | 1 |
| | Watersnipe Larva | | |
| Sub-Total | | C2 | D2 |
| Category 3 | Aquatic Worm (oligochaete) | 12 | 1 |
| | Blackfly Larva | | |
| | Leech | | |
| | Midge Larva (chironomid) | | |
| Pollution Tolerant | Planarian (flatworm) | 1 | 1 |
| | Pouch and Pond Snails | 2 | 1 |
| | True Bug Adult | | |
| | Water Mite | 2 | 2 |
| Sub-Total | | C3 | D3 |
| TOTAL | | CT | DT |

## INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

| Stream Name: Richards creek | | Date: oct 28 |
|---|---|---|
| Station Name: 3 | | Flow status: Low |
| Sampler Used: Hess | Number of replicates 3 | Total area sampled (Hess, Surber = 0.09 $m^2$) x no. replicates $m^2$ |

| Column A<br>Pollution Tolerance | Column B<br>Common Name | Column C<br>Number Counted | Column D<br>Number of Taxa |
|---|---|---|---|
| Category 1 | Caddisfly Larva (EPT) | EPT1 3 | EPT4 1 |
| | Mayfly Nymph (EPT) | EPT2 12 | EPT5 1 |
| | Stonefly Nymph (EPT) | EPT3 4 | EPT6 2 |
| Pollution Intolerant | Dobsonfly (hellgrammite) | | |
| | Gilled Snail | | |
| | Riffle Beetle | | |
| | Water Penny | | |
| Sub-Total | | C1 | D1 |
| Category 2 | Alderfly Larva | 1 | 1 |
| | Aquatic Beetle | | |
| | Aquatic Sowbug | | |
| | Clam, Mussel | 6 | 2 |
| | Cranefly Larva | 2 | 1 |
| Somewhat Pollution Tolerant | Crayfish | | |
| | Damselfly Larva | | |
| | Dragonfly Larva | | |
| | Fishfly Larva | | |
| | Amphipod (freshwater shrimp) | 15 | 1 |
| | Watersnipe Larva | | |
| Sub-Total | | C2 | D2 |
| Category 3 | Aquatic Worm (oligochaete) | 20 | 3 |
| | Blackfly Larva | | |
| | Leech | | |
| | Midge Larva (chironomid) | 2 | 1 |
| | Planarian (flatworm) | 3 | 1 |
| Pollution Tolerant | Pouch and Pond Snails | | |
| | True Bug Adult | 2 | 2 |
| | Water Mite | 1 | 1 |
| Sub-Total | | C3 | D3 |
| TOTAL | | CT | DT |

OCT 30

## Station 1

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | mg/L N | 0.27 | |
| Phosphate | mg/L | 0.03 mg/L $PO_4^{3-}$ | |
| Hardness 42 drops | mg/L | 42 | |
| Alkalinity 236 | mg/L | 23.6 | |
| Coliform | | | |
| Turbidity | NTU | 1.84 | |
| Conductivity | µS/cm | 90 | |
| pH | No units | 8.3 | |

NOV 20

Richard's Creek
Nov 18, 2019
Station 1

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | mg/L $NO_3^-$ | 0.52 | |
| Phosphate | | 0.09 mg/L $PO_4^{3-}$ | |
| Hardness | 15 drops | 60 mg/L $CaCO_3$ | |
| Alkalinity | 80 drops | 32 mg/L $CaCO_3$ | |
| Coliform | | | |
| Turbidity | | 1.91 NTU | |
| Conductivity | | 128 us | |
| pH | | 8.3 | |

OCT 30

## Station 2

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | mg/L N | 0.38 | |
| Phosphate $PO_4^{3-}$ | mg/L 0.03 mg/L | | |
| Hardness 15 drops | mg/L 60 | | |
| Alkalinity 80 | mg/L ~~380~~ | ~~32~~ 32 | |
| Coliform | | | |
| Turbidity | NTU ~~0.80~~ | 1.96 | |
| Conductivity | µS/cm 133 | ~~[illegible]~~ | |
| pH | No units | 8.4 | |

NOV 20

Richard's Creek
Nov 18, 2019
Station 2

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | mg/L $NO_3^-$ | 0.64 | |
| Phosphate | | 0.02 mg/L $PO_4^{3-}$ | |
| Hardness | 16 drops | 64mg/L $CaCO_3$ | |
| Alkalinity | 85 drops | 34 mg/L $CaCO_3$ | |
| Coliform | | | |
| Turbidity | | 1.77 NTU | |
| Conductivity | | 148 µs | |
| pH | | 8.4 | |

OCT 30

## Station 3

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | mg/L N | 0.50 | |
| Phosphate | mg/L 0.04 | | |
| Hardness 17 drops | mg/L | 68 | |
| Alkalinity 102 x 0.4 | mg/L | 40.8 | |
| Coliform | | | |
| Turbidity | NTU 1.95 | | |
| Conductivity | µS/cm 141 | ~~[illegible]~~ | |
| pH | No units | 8.1 | |

NOV 20

Richard's Creek
Nov 18, 2019
Station 3

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | | 0.59 | |
| Phosphate | | 0.16 mg/L $PO_4^{3-}$ | |
| Hardness | 18 drops | 72 mg/L $CaCO_3$ | |
| Alkalinity | 117 drops | 46.8 mg/L $CaCO_3$ | |
| Coliform | | | |
| Turbidity | 4.42 NTU | ~~4.67 NTU~~ | |
| Conductivity | | 171 µs | |
| pH | | 8.0 | |

OCT 30

## Station 4

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | mg/L N | 1.01 | |
| Phosphate | mg/L 0.59 mg/L | | |
| Hardness 23 | mg/L | 92 | |
| Alkalinity 95 | mg/L ~~95~~ | 38 | |
| Coliform | | | |
| Turbidity | NTU 1.90 | | |
| Conductivity | µS/cm 205 | [illegible] | |
| pH | No units | 7.6 | |

NOV 20

Richard's Creek
Nov 18, 2019
Station 4

| Parameter | Units | Value | Guideline |
|---|---|---|---|
| Nitrate | | 0.35 | |
| Phosphate | | 0.66 mg/L $PO_4^{3-}$ | |
| Hardness | 22 drops | 88 mg/L $CaCO_3$ | |
| Alkalinity | 125 drops | 50 mg/L $CaCO_3$ | |
| Coliform | | | |
| Turbidity | | 4.51 NTU | |
| Conductivity | | 204 µs | |
| pH | | 7.3 | |

OCT 30

| | | Value ↓ Station 1 REPLICATE | Guideline |
|---|---|---|---|
| Nitrate | mg/L | 0.25 | |
| Phosphate | mg/L | 0.09 mg/L | |
| Hardness 42 | mg/L | 42 | |
| Alkalinity 220 | mg/L | 22.0 | |
| Coliform | CFU/100mL | | |
| Turbidity | NTU 2.02 | | |
| Conductivity | uS/cm | 92 | |
| pH. | Ø | 7.2 | |

| TRIP BLANK | PHOSPHORUS | NITRATE. |
|---|---|---|
| | 0.02mg/L | 0.07mg/L |

NOV 20

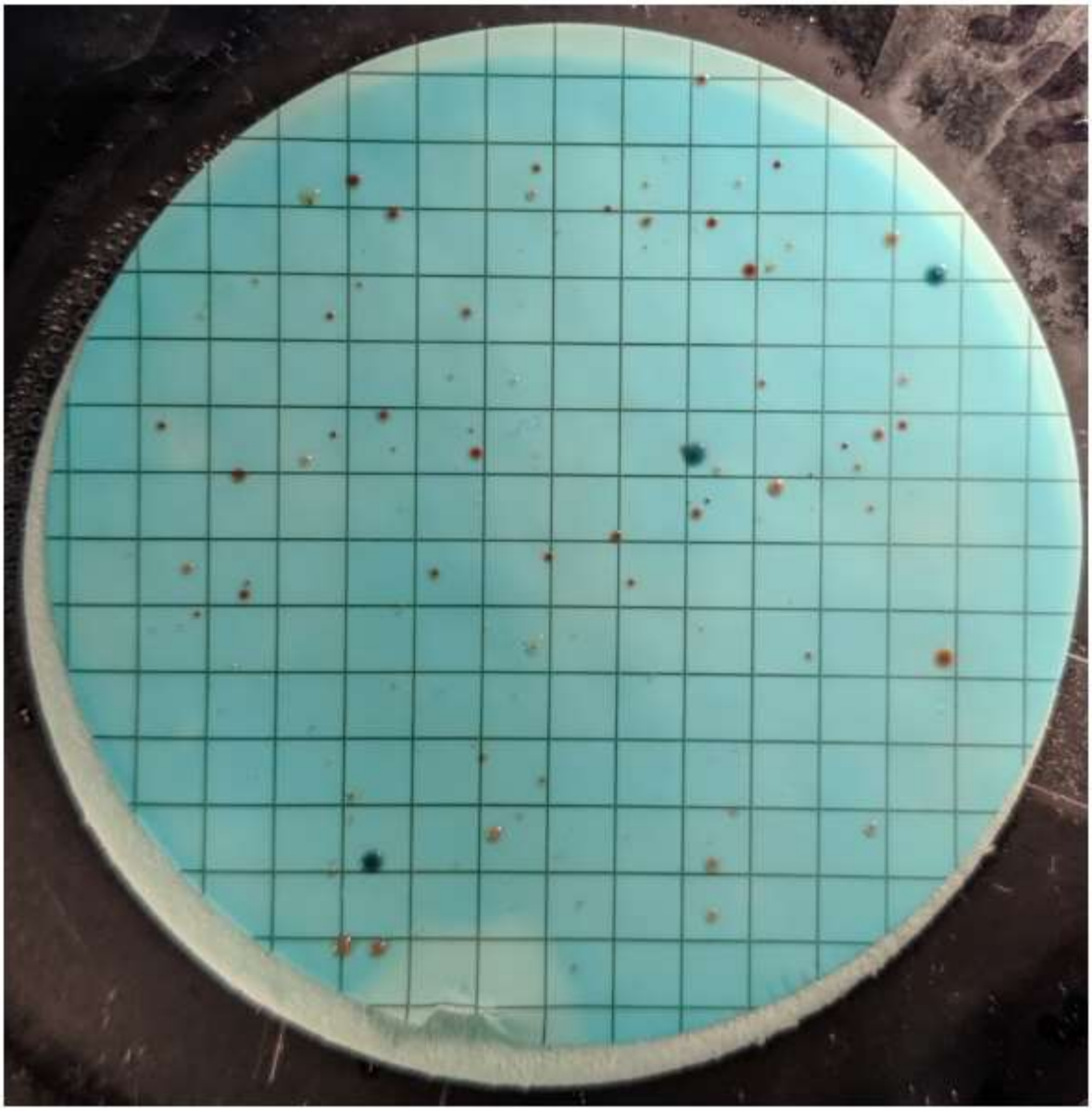
Richard's Creek
Nov 18, 2019
Station 1 Rep

| | Parameter | Units | Value | Guideline |
|---|---|---|---|---|
| O | Nitrate | | 0.22 | |
| O | Phosphate | | 0.04 mg/L $PO_4^{3-}$ | |
| ✓ | Hardness | 17 drops | 68 mg/L $CaCO_3$ | |
| ✓ | Alkalinity | 80 drops. | 32 mg/L $CaCO_3$ | |
| O | Coliform | | | |
| ✓ | Turbidity | | 1.94 NTU | |
| ✓ | Conductivity | | 130 µs | |
| ✓ | pH | | 7.0 | |

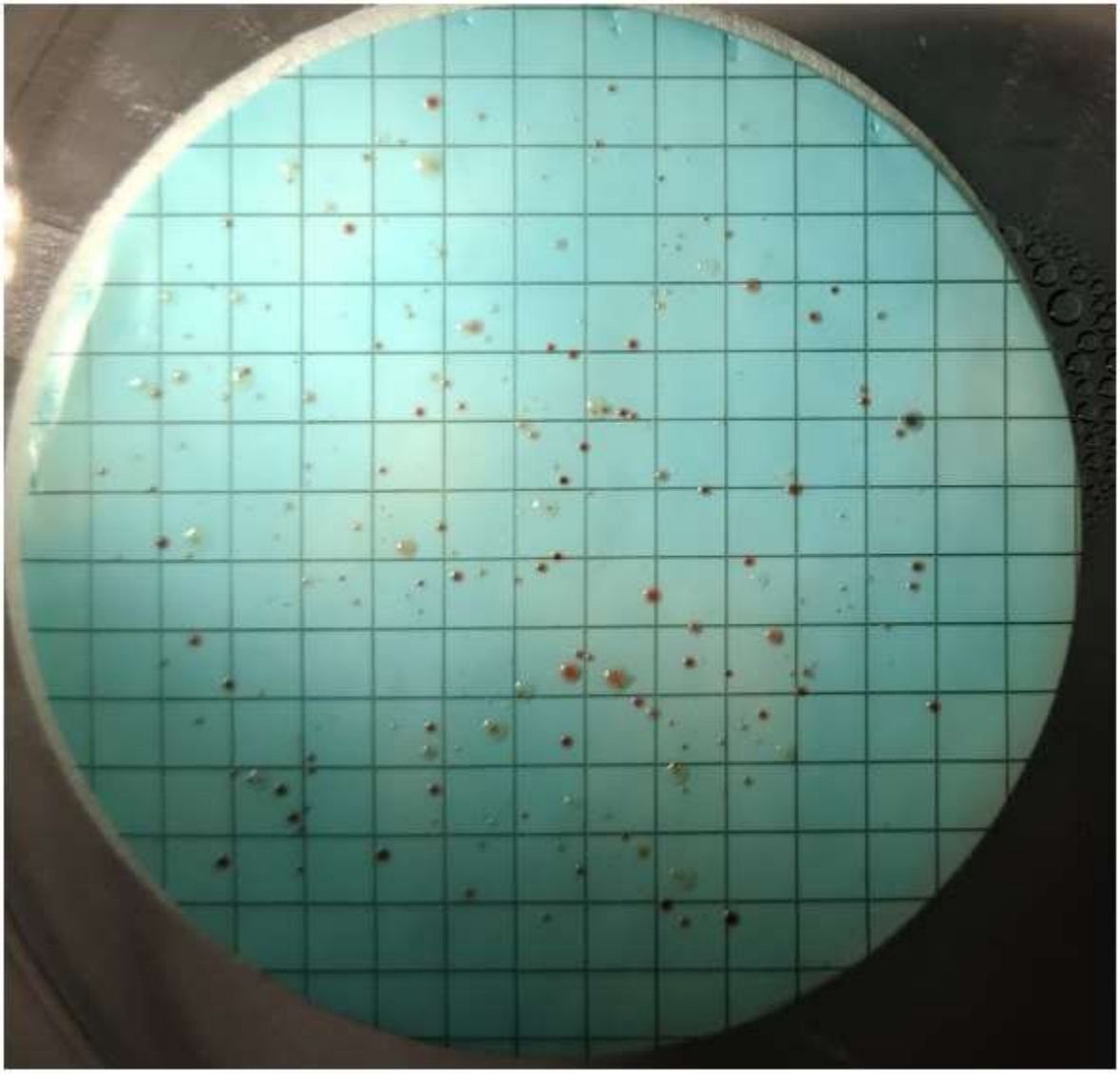
TB – Nitrate 0.65

Phosphate 0.05 mg/L $PO_4^{3-}$

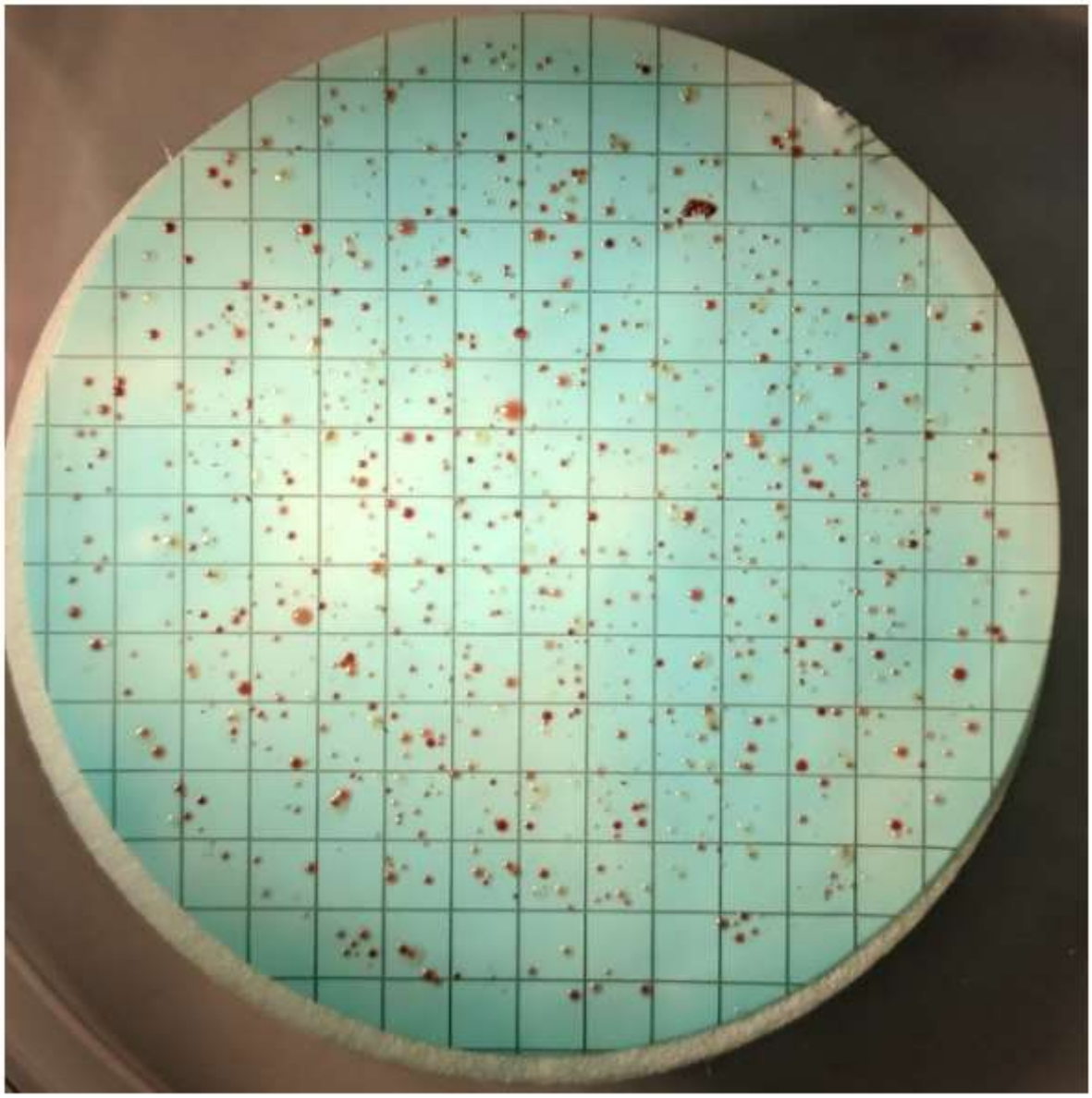
# Station 1 – Coliform Results



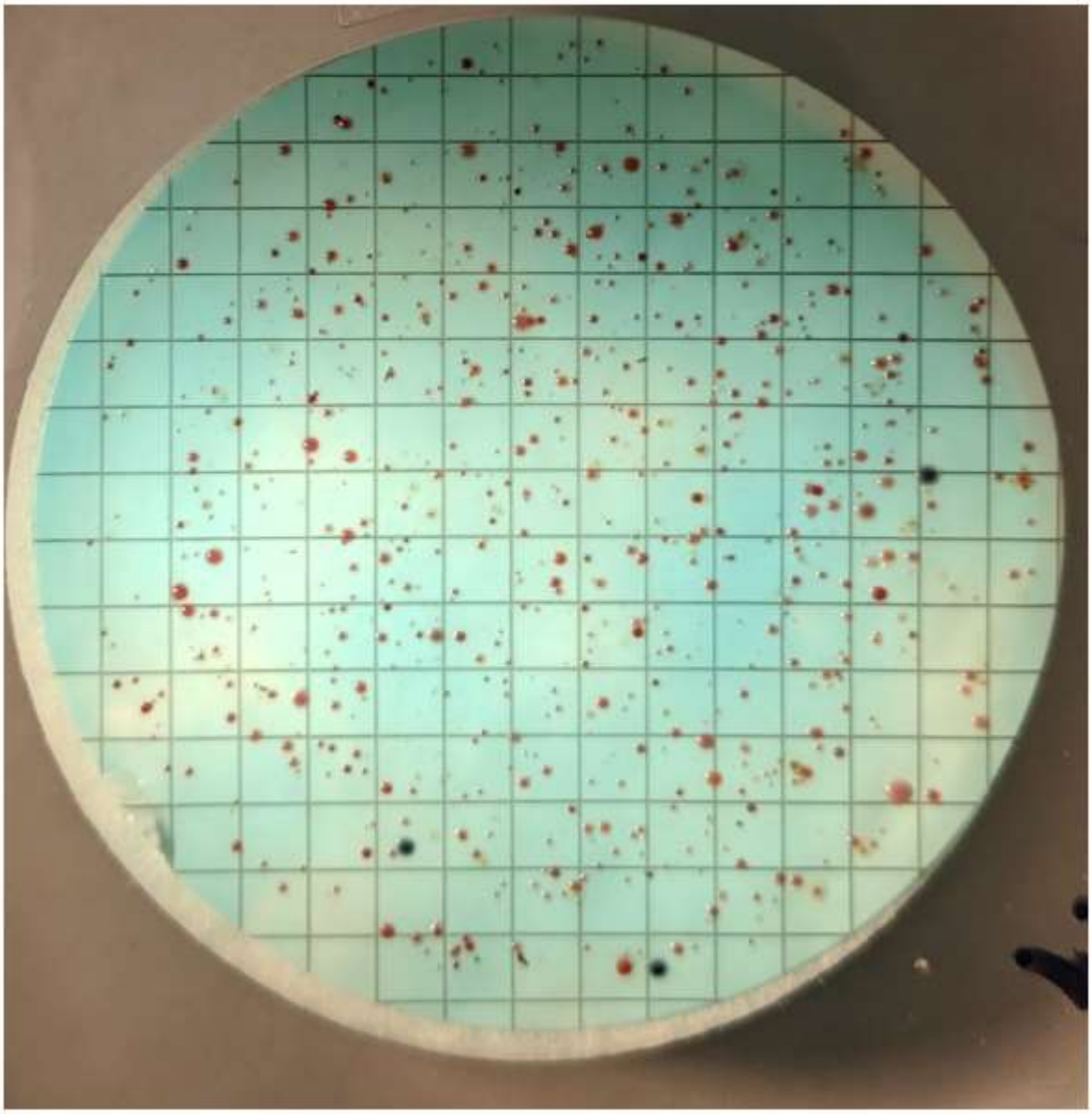
## Station 2 – Coliform Results



## Station 3 – Coliform Results



## Station 4 – Coliform Results



## Replicate (Station 4) – Coliform Results