DATA REPORT

Water Quality and Stream Invertebrate Assessment

for the Millstone River, Nanaimo, BC,

(Fall 2021)

Report Prepared by:

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Executive Summary (Hunter)

As part of the long term and on-going monitoring project perpetuated through the Environmental Monitoring course (RMOT 306) offered at Vancouver Island University, a water quality and invertebrate assessment was conducted on the Millstone River in Nanaimo, British Columbia. To accomplish this task, two sampling events took place with one occurring on October 27 and the other on November 24, 2021. The first sampling event took place during relative low flow, and the latter took place during high flow. It is important to note that the second sampling event took place only a few short days after an abnormally large amount of rainfall which caused massive flooding throughout many parts of British Columbia. Many different parameters were taken and analyzed for each stream site. These parameters include dissolved oxygen (mg/L), pH, temperature (°C), conductivity, (µS/cm), turbidity (NTU), velocity (m/sec), hardness (mg/L as $CaCO_3$), nitrate (mg/L as $CaCO_3$), total alkalinity (mg/L), reactive phosphorus (mg/L PO_4^{3-}), nutrients, and total metals. In addition, stream invertebrates were sampled and analyzed. All these analyses occurred in two laboratories: VIU Nanaimo Campus and ALS in Vancouver. To make sense of all the data, these results were then compared with reports from previous years. The analyses indicated that based on the samples for the water quality parameter taken, the Millstone River was within acceptable ranges. However, two metals analyzed (calcium and aluminum) in both October and November were over the guidelines for aquatic life which could prove to be an issue. When looking at the invertebrate analyses it was found based on the invertebrates collected that generally, the further downstream a sampling site the higher level of suspected pollution. This report and its findings will be forwarded to and shared with the Department of Fisheries and Oceans, Regional District of Nanaimo, British Columbia Conservation Foundation, and the City of Nanaimo.

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1.0 Introduction and Background Information

1.1 Project Overview (Hunter)

To continue a long-term data set, a team of students consisting of Coltan Lorenz, Hunter Jarratt, Megan Kollman, and Luca Sekela completed an environmental monitoring project on the Millstone River in Nanaimo, British Columbia. This project was conducted under the guidance of Owen Hargrove. The two sampling events from which the project data were derived took place on October 27th and November 24, 2021. Before any sampling was conducted, five optimal sampling locations were identified (on October 13), four of which reside in the Millstone River, and one of which is in Benson Creek (a tributary of the Millstone River). During this initial sampling location examination other pieces of information were collected including photos, public vs private access, vegetation, flow conditions, possible sources of contamination, and site safety hazards.

This valuable and beneficial sampling data obtained will be submitted to the Department of Fisheries and Oceans, Regional District of Nanaimo, British Columbia Conservation Foundation, and the City of Nanaimo. The reason this long-term data set from the Millstone River is so indispensable is because environmental monitoring reports of this river have been produced since 2006. Comparing and contrasting the data from previous years and reports to our new findings not only helps better understand the overall health of the river, but it allows us to determine if there are any unforeseen environmental impacts occurring in the Millstone River. To do this, water quality and invertebrate samples were taken including a variety of parameters. The samples taken at each of the five stations were all analyzed at the Nanaimo Vancouver Island University campus, while samples taken at sites one, three and five were analyzed by the Australian Laboratory Services (ALS Labs) in Vancouver, BC.

The environmental monitoring included basic hydrology and invertebrate sampling. This involved noting the amount of dissolved oxygen and temperature at each site, and then collecting samples to be brought back to the lab to be analyzed and assessed for other parameters. Finally, sampling for the aquatic invertebrates was collected at sites one, three, and four. It was originally anticipated to collect the aquatic invertebrates at sampling sites one, three, and five to get a good representation of the stream's invertebrate community. However, on the day of collection it was deemed to be not only unsafe, but impractical to collect invertebrates from site five due to higher than anticipated flow conditions due to heavy rainfall.

1.2 Historical Overview (Hunter)

The Millstone River is a 14km river running from Brannen Lake into the City of Nanaimo's Inner Harbour. This river travels through Bowen Park which is a 36-hectare park in the City of Nanaimo. With an area of approximately 100km2 the Millstone River watershed (**Figure 1**) comprises 26km of streams, 16 tributaries, and 8 lakes (City of Nanaimo, 2008). Overall, the headwaters are mostly privately owned forestlands, in the middle reaches they are agricultural areas, and the lower reaches are urban and residential areas (RDN, 2016). Most of the Millstone River flows gently, but in Bowen Park there is a gradient change (cascading waterfalls), and due to its significance, this causes conditions of relatively high flow. (Ng-Cornish et al. 2019).

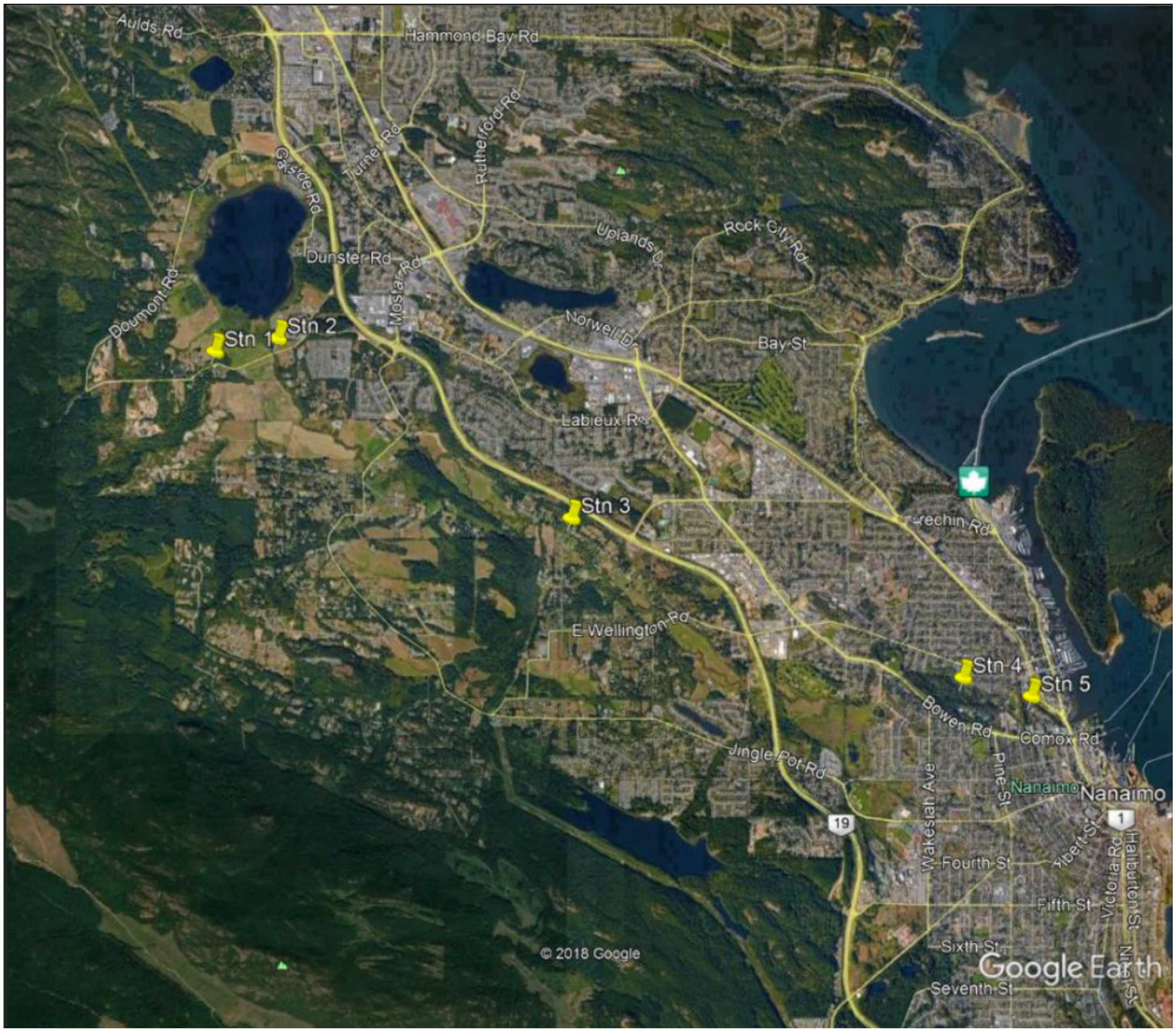

Figure 1: Map of Millstone River and Corresponding Watershed

Historically, when it came to Coho salmon and sea-run trout returning to the Millstone watershed to spawn, there were three significant cascades that created significant and inaccessible barriers for these returning fish, approximately 1-2km above tidewater in Nanaimo (Lanarc Consultants Limited, 1998). Therefore, before any remediation efforts were implemented, this watershed was considered the largest urban watershed on the coast of British

Columbia that was inaccessible to salmon. Fish habitat above these barriers was of high quality due to its biological complexity, numerous lakes, and large, low gradient floodplain and adjoining wetlands (Lanarc Consultants Limited, 1998). Therefore, this was a perfect opportunity to build new runs of Coho salmon and steelhead and so in the fall of 2007 the Millstone Side-Channel was created which involved the blasting and jack hammering of conglomerate and sandstone to achieve the desired channel depth. This was extremely beneficial for salmon habitat, increased community recreation, and educational opportunities (City of Nanaimo, 2008).

1.3 Potential Environmental Concerns (Hunter)

Due to the various land use changes throughout the Millstone River, there are many anticipated environmental concerns including both point source and nonpoint sources. Usage by the forestry industry highlights the possibility of erosion and sedimentation in the Millstone River that would impact aquatic life and water quality. Agricultural activities highlight the possibility of agricultural run-off and the associated effects of eutrophication. Urbanized and residential areas throughout the course of the waterway highlight the possibility of contamination due to chemical pollutants, garbage, sedimentation, and or erosion caused by stormwater effluent. Being aware of these potential impacts and being able to detect them is extremely important because they have the potential to seriously alter the aquatic ecosystem and associated habitat within the Millstone River watershed. Not only would these impacts negatively affect the quality of the water and usage by people, but this would severely impact the plant and animal species that depend on this watershed to survive.

1.4 Project Overview (Hunter)

The main objective for this environmental monitoring project on the Millstone River is to collect the appropriate samples and associated data to provide a better understanding of the overall health of the river and its ability to support aquatic life. These findings, including water quality and stream invertebrate population data, will be used in conjunction with the reports produced since 2007 to compare past data with current data which will strengthen the long-term study. There will be five sampling points (**Figure 1**) of which four are in the Millstone River and one of which will be in Benson Creek, which flows into Brannen Lake, then into the Millstone River. Using these sampling locations, samples will be taken along with measurements of water quality and hydrology, in addition to stream invertebrates for analysis. Water quality analyses will occur at VIU facilities and at the Australian Laboratory Services (ALS) in Vancouver, BC where they will provide general water quality parameters, nutrient analyses, and total metal scan (including ~30 different metals). Results will then be reported and added to the ongoing collection of data for this long-term project.

1.5 Proposed Environmental Sampling and Analytical Procedures

1.51 Habitat Characteristics (Megan)

The land use around our stream sites is a mix between residential area, farmland, and public roads/bridges. Most of the habitat on the banks of our selected sample sites was well covered with large deciduous trees and had thick bushes up to the river. There was minimal large woody debris present at the sites and only site 1 had significant undercut banks present. Sites 1,3 and 5 are the chosen sites for sending water samples to the ALS Laboratory. Therefore, these specific sites are to be the focus for identifying key habitat characteristics.

1.52 Sampling Site Characteristics (Megan + Hunter)

Site #1 (**Figure 2 and 3**) is unlike the other four sampling locations because it is located on Benson Creek which is a tributary of the Millstone River (10 U 422740mE, 5450751mN). This site has public access, with a trail right beside the bridge leading down to Benson Creek. Just upstream of where sampling took place is Camp Caillet which is one of the largest Scouts Canada camps on Vancouver Island. The immediate surrounding areas are nearly all farm fields with some residential properties mixed in. The substrate for this site consisted of 5% Fines, 10% Gravel, 80% Cobble, 5% Boulders, and 0% Bedrock. The main tree species on the left and right sides of the creek consisted of red alder (*Alnus rubra*) with an estimated canopy cover of 25% but other tree species such as big-leaf maple (*Acer macrophyllum)* were present. The creek was quite wide in some sections and had a few undercut banks and large tree roots which could provide salmonids with excellent habitat. The understory plants consisted mostly of Himalayan blackberry (*Rubus armeniacus*) and snowberry (*Symphoricarpos albus*). The instream cover was estimated to be at 10% and there were eleven pieces of large woody debris noted. The gradient at this site was determined to be 2.5%. During our initial site visit on October 13, the flow rate was fairly low for all sites, but we did anticipate higher flows as time went on. Some sources of pollution for this site could include noise pollution, or fuel leaking from vehicles due to the proximity of the road to the creek. Other potential sources include creosote from the bridge which may prove to be harmful to the riparian area, garbage from easy public access, and runoff and eutrophication from the nearby agricultural areas. Some hazards outlined for this sampling location include tripping hazards such as roots or wet rocks. There are also sharp bushes, the possibility of drowning, busy traffic, and possible dangerous animal encounters.

Figure 2: Photo from Site 1 During Low Flow

Figure 3: Photo from Site 1 During High Flow

Site #2 (**Figure 4 and 5**) was the first site we started sampling for the Millstone River and the rest of the locations all take place in the Millstone (10 U 423343mE, 5450840mN). This site had public access by a little trail just off the road by the bridge that goes over the river. Just upstream of this sampling site is Brannen Lake and the Nanaimo Correctional Centre. The immediate surrounding area is slightly forested, and the rest is all farm fields and the Nanaimo Correctional Centre buildings. The substrate for this site consisted of 40% Fines, 30% Gravel, 30% Cobble, 0% Boulders, 0% Bedrock. The site had ample vegetation on both river sides, with tree cover giving us an estimated 10% canopy cover. There were many understory plants such as Himalayan blackberry (*Rubus armeniacus*), hardhacks (*Spiraea douglasii*), and cutleaf blackberry (*Rubus laciniatus*). The instream cover was estimated to be at 45% and there were three pieces of large woody debris noted. The gradient at this site was determined to be 1.5%. Some sources of pollution for this sampling site include runoff and eutrophication from nearby agricultural areas, garbage, and oil from the road and bridge that travel across the river. Some hazards identified for this site include busy traffic as there is no actual parking lot available, and there is a considerable hill on the road that could prove to be slippery in wet or frozen conditions. When getting in and out of vehicles it was important to stay vigilant. Other hazards included tripping on tree roots, sharp bushes, the possibility of drowning, and dangerous animals.

Figure 4: Photo from Site 2 During Low Flow

Figure 5: Photo from Site 2 During High Flow

Site #3 (**Figure 6 and 7**) had easy public access on either side of a bridge that goes across the Millstone River (10 U 426310mE 5448965mN). The immediate surrounding areas are dominated by residential dwellings and some small farming fields. The substrate for this site consisted of 30% Fines, 30% Gravel, 30% Cobble, 5% Boulders, and 5% Bedrock. The dominant trees on the left bank were cherry trees and, on the right, it was a species of cottonwood tree which gave us around 20% for canopy cover. The site had understory vegetation such as skunk cabbage (*Lysichiton americanus*), lady fern (*Athyrium filix-femina*), and invasive Himalayan blackberry (*Rubus laciniatus*). The instream cover was estimated to be at around 45% with some grass-like vegetation growing in the river and there was one piece of large woody debris noted. The gradient at this site was determined to be 1%. Some sources of pollution for this sampling site include pollution from the road and bridge such as oil and creosote from the bridge may prove to have some impact on the river. Other potential impacts include garbage from easy access and nearby residents, or potential runoff and the associated impacts of eutrophication from nearby farmland. Possible impacts from septic tanks may be present. Some hazards identified for this site include tripping hazards, loose substrate, muddy conditions, some sharp bushes, a risk of drowning, and fruit trees nearby on residential properties may attract dangerous animals. The creosote used to treat the bridge may additionally have negative impacts on the riparian area downstream.

Figure 6: Photo from Site 3 During Low Flow

Figure 7: Photo from Site 3 During High Flow

Site #4 (**Figure 8 and 9**) had easy public access through Bowen Park in Central Nanaimo (10 U 430329mE 5447276mN). The immediate surrounding areas were forested but Bowen Park is surrounded by residential housing and developments. The substrate for this site consisted of 30% Fines, 30% Gravel, 20% Cobble, 15% Boulders, and 5% Bedrock. The dominant trees on the left bank were Douglas fir (*pseudotsuga menziesii*) and Western red cedar, while on the right it was mostly red alder trees (*Alnus rubra*). This gave us an estimated 60% canopy cover due to how forested the surrounding areas were. The site had understory vegetation such as invasive English ivy (*Hedera helix*), sword fern (*Polystichum munitum*), ocean spray (*Holodiscus discolor*), and salmonberry (*Rubus spectabilis*). The instream cover was estimated to be at 40% and there were three pieces of large woody debris noted. The gradient at this site was determined to be 1%. Some sources of pollution for this sampling site include pollution from the nearby park parking lot, and garbage from park visitors. Some hazards identified for this site include dangerous animal encounters - Including pets from people on trails, sharp bushes, and of course the possibility of drowning or being swept away by the river.

Figure 8: Photo from Site 4 During Low Flow

Figure 9: Photo from Site 4 During High Flow

Site #5 (**Figure 10 and 11**) had easy public access like the other sites through a small walking path through a forested area with a paved trail in Barsby Park (10 U 431008mE 5447205mN) and was the sampling site closest to the ocean. Although this is a park, it is relatively small, and it is surrounded by developments and high traffic areas. The substrate for this site consisted of 20% Fines, 15% Gravel, 10% Cobble, 30% Boulders, and 25% Bedrock. The dominant trees noted for the right bank were red alder trees (*Alnus rubra*) and this gave us an estimated 10% of canopy cover. Other understory vegetation on site included grass, invasive English ivy (*Hedera helix*), and ocean spray (*Holodiscus discolor*). The instream cover was estimated to be at 35% and there were five pieces of large woody debris noted. The gradient at this site was determined to be 2%. Some sources of pollution for this sampling site include pollution from the busy highway above such as oil, tires, or garbage blowing out of vehicles. There was plenty of garbage already present on site, along with a handful of homeless structures. Some hazards identified for this site include tripping hazards, wet rocks, muddy substrate, a possibility of drowning, needle pricks, there was busy traffic getting to the sampling location, and of course dangerous wildlife encounters.

Figure 10: Photo from Site 5 During Low Flow

Figure 11: Photo from Site 5 During High Flow

1.6 Methods

1.61 Monitoring Frequency (Megan)

To ensure sampling equipment and time in the VIU lab was within the established dates and time frame, so collected samples did not degrade, communication and coordination between peers was important. The two sampling dates were October 27th and November 24th, 2021 with the first sampling event intended to collect data during “low flow” and the latter during “high flow.” As the data in this report will later display, the second sampling event was predicted to show “high flow” but was instead the lower flow between the two sampling events. Sampling the same designated locations took place twice so changes in data with low vs. high water flow could be observed. Sampling twice also ensured human error could become more obvious if sampling data between the two selected dates was significantly different. If a sampling or lab error had occurred, the results could have therefore been investigated more closely and potential errors could have been identified. During the lab analysis of the samples taken from the Millstone River during October 27th and November 24th, 2021 no data appeared to be abnormal or due to the direct result of lab or fieldwork error. During both sampling events water quality and hydrology aspects were sampled and measured to help interpret how healthy the Millstone River is during times of high and low flow. Invertebrate sampling was only able to be completed during the first sampling event due to poor river conditions during the second sampling event.

First Sampling Event (A): October 27, 2021

Second Sampling Event (B): November 24, 2021

Site	**Hydrology**		**Invertebrate Sampling** ***(Replicate)**	**VIU Water Quality** ***(Duplicate)**	**AIS Water Quality**
	Temp	D.O.			
#1	A, B	A	A*	A, B*	A, B
#2	A, B	A		A, B	
#3	A, B	A	A	A, B*	A, B
#4	A, B	A	A*	A, B	
#5	A, B	A		A, B	A, B

Figure 12: Sampling Schedule and Locations Where Data was Collected (Colton)

1.7 Basic Hydrology (Coltan)

While conducting our stream assessment we measured parameters related to the basic hydrology of the Millstone River. This included measuring physical characteristics of the river such as the wetted depth, stream gradient, and available instream cover. These characteristics can affect the water conditions within the river and may be useful in observing how the river changes between our sampling dates.

We recorded the velocity on two occasions (October 27th and November 24th) to capture the river conditions at a low and just after a high flow rate. To measure our velocity at each site we used the "floating object method" outlined in the British Columbia Field Sampling Manual. This measurement involved taking the length of a section of the river that best represents that site and then measuring the time it takes a floating object to travel that distance (Clark 2013). Due to recent high water, we observed a large amount of debris in the river. At our sites near bridges, we observed some of our floating objects got caught in currents or became snagged which we felt impacted some of our velocity measurements. To account for this, we made several measurements to ensure they were consistent.

We had planned to measure the water discharge at each of our sites by wading in to measure the water depths and wetted width, but we were unable to safely cross. During sampling event two, we were able to measure the wetted width of the river using a laser measure. To monitor the discharge of the Millstone River we relied on the Environment Canada Hydrometric Data Station. The station is located at the upstream end of Bowen Park, between sites 2 and 3 and monitors the water level and discharge of the Millstone River and provides that data on their website (Water Level and Flow… 2021). Since we were unable to take the water depth measurements required for discharge calculations, we used this data to supplement our site visits.

To determine stream gradient, we looked at the elevation measurements at our site and compared that to the change in elevation 100m upstream and downstream to hopefully observe if there was a large elevation change through that section.

With the hydrological parameters we collected at each site, we were able to compare the flow characteristics of the Millstone River at different periods in the fall season and we were able to monitor trends throughout the years by comparing our results with previous reports.

1.8 Water Quality

1.81 Field Measurements (Colton)

During our two sampling trips, we took some water quality measurements in the field for convenience and to reduce the chance of sample contamination during transport. These field measurements include D.O. (Dissolved Oxygen), and water temperature (°C). During sampling event one, we used an electric probe signed out from Vancouver Island University to measure temperature and dissolved oxygen. During sampling week two, we unfortunately didn't have the electric probe, so we were unable to take field D.O. measurements but we were still able to measure the water temperature in the field using a mercury thermometer.

1.82 Water Sample Collection (Colton)

When collecting samples in the field we ensured we were prepared and used communication within our team to guarantee quality results. Throughout our sampling events we referred to the sampling guidelines outlined in the British Columbia Field Sampling Manual Part

E which helped us to ensure accurate results as well as to keep sampling consistent throughout all the sites. While we were taking our samples it was important that we used the proper technique, so our samples are a true representation of our site. To keep track of our site samples our planning and preparation included ensuring we had all the sample containers labelled and ready to use. To reduce the possibility of contamination we always worked in an upstream direction; this included starting each sampling day at our farthest downstream site (site 5) and working upstream to site 1. This technique was also utilized when taking multiple samples from a site, working carefully upstream to not take samples from areas contaminated by sediment (Clark 2013).

For the collection of our samples, we were unable to wade into the center of the river due to unsafe conditions. The water level of the river rose significantly from our initial site visit to when we took our samples, so we had to collect all our samples from near the riverbank. However, we were able to take all our necessary measurements near the river edge. While taking our water samples we employed sampling techniques to ensure accurate results, such as flushing the collection bottles three times if they were not cleaned before using them.

After our samples were collected, we stored them in a manner to avoid degradation. During our time sampling everything was stored in a cooler to maintain a steady temperature and keep our samples in a dark place. The water samples collected for the ALS laboratory analyses were transferred into a container for shipping shortly after collection. To reduce biochemical activity within the samples, they were placed into a chilled cooler to help maintain a temperature near 4^{o}C. After collection, parameters such as pH and nutrients degrade over time. Because of this, it was important we scheduled time in the Nanaimo Vancouver Island University laboratory to quickly collect this data (Clark 2013).

1.9 VIU Laboratory Results (Colton)

Our team utilised the Nanaimo Vancouver Island University laboratory to conduct water quality analyses for our sites. Our scheduled time in the lab was within hours of our samples being collected. In the lab we measured the water samples from each of our sites for pH, turbidity (NTU), total alkalinity (mg/L CaCO3), hardness, reactive phosphorus (µg/L, PO_4), nitrate (mg/L NO_3), and conductivity (µs/cm).

1.10 ALS Laboratory Results (Colton)

The purpose of the ALS laboratory analyses is to obtain a more detailed description of the water quality within our sites. Samples were collected by our team from sites 1, 3 and 5 and were sent to ALS (Australian Laboratory Services) located in Vancouver. The result of these analyses provided a detailed breakdown of the conventional parameters including pH, turbidity, and dissolved ions; as well as nutrients and anions including nitrate, nitrite, nitrogen, ammonia, phosphorus; and a breakdown of the total metals which includes thirty-eight metals. Due to the cost and time required to send these samples for analysis, it was important we followed the proper collection and storage guidelines.

1.12 Data Analyses and Comparison to Guidelines (Colton)

Once all samples had been collected for our Millstone River stream assessment, we conducted an analysis to decide on the overall health of the stream. Using both our analyses from the Nanaimo Vancouver Island University lab and the data from ALS lab we compared the results to see if any parameters differed. We were also able to compare our results from both sampling events to determine if any changes occurred, as well as observe any changes that occurred moving downstream. Once we had all our water quality results, we were able to compare them to the approved British Columbia Water Quality Guidelines (BCMOE 2021) and decide if the Millstone River had met the water quality requirements to support aquatic life.

1.13 Stream Invertebrate Communities Methods

1.131 Sampling Stations and Conditions (Luca)

There were five total sample sites used on the Millstone River for the purposes of invertebrate and water quality sampling. All invertebrate sampling took place on October 27, 2021. Of these five sites it was originally planned that sites 1,3, and 5 would have invertebrate samples collected. The staggering of sampling site locations meant the river was going to be accurately represented and provided a higher chance of pinpointing a location of potential environmental disturbance. However, due to the extreme water levels it was deemed unsafe for students to sample for invertebrates at site 5, so therefore site 4 was chosen instead. Locations at each sampling site were chosen by the substrate composition, hydrological conditions, and personal safety. With these conditions in mind, riffles with a substrate of gravel and sand were selected. Cost and time allowed for two replicates at sites 1 and 4 and one replicate at site 3.

1.132 Invertebrate Sample Collection and Lab Analysis (Luca)

At each sampling site a Hess sampler was used for collection purposes. The Hess sampler was used according to the procedures outlined in Taccogna and Munro (1995). All students approached from downstream of each sampling site which prevented invertebrates from being disturbed before collection. Once the appropriate substrate area was found the Hess sampler was pressed down and isolated an area of 0.09-m^2. Then for one minute a student disturbed the substrate within the sampler to direct invertebrates into the attached sample bottle. Once the minute was up, students detached the Hess sampler bottle and removed any large debris inside. Invertebrates were then transferred into a labeled lab sample container with an alcohol preservative. Each lab sample container was transported and stored within a cooler. Once back at the Nanaimo Vancouver Island University Lab each lab sample container was dumped into a large white tray and invertebrates were taken and placed into clear dishes. When examining the tray two students searched for invertebrates. Once all invertebrates had been placed in the dish they were identified using a dissecting microscope.

1.133 Quality Assurance and Quality Control (Luca)

To implement quality assurance and quality control many procedures were conducted both in the field and lab. In the field, quality assurance was accomplished by washing out and verifying the Hess sampler was in working condition before use. Other steps taken included ensuring students stayed downstream of the invertebrate sampling locations to not disturb any invertebrates in the area and using premeasured alcohol preservative to keep samples in an identifiable state. Quality control in the field was implemented by taking replicates at sites 1 and 4 which this accounted for potential bias at sample locations. In the lab, quality control was ensured by using two students to oversee the process of removing invertebrates from the lab sample container and identifying them under a dissecting microscope. Identification was used with reference to an accurate field guide for invertebrates in the area.

1.134 Stream Invertebrate Data Analysis (Luca)

Once all invertebrates were examined in the lab, the data was transferred onto survey data sheets. Once put on these sheets the values of abundance, density, predominant taxon, pollution tolerance index, EPT index, EPT to total ratio index, and diversity could be found and used to calculate overall site assessment ratings. Shannon-Weiner Diversity Indexes were also calculated for each sample site. These indexes are an accurate way to produce diversity results while being sensitive to rare, or uncommon species that may be in an area.

2.0 Results and Discussion

2.1 Hydrology (Colton)

The parameters related to the basic hydrology of the Millstone River include the precipitation, water level, discharge, and velocity. Between our first sampling trip on October 24th and our second trip on November 26th Nanaimo received 313.3mm of rainfall as measured by the weather station located in the Nanaimo City Yard. In comparison to previous years, Nanaimo saw high rainfall in November of 2021 (**Table 1**) and as a result there were high water levels in the Millstone River. During November of 2021 Nanaimo had 345.5mm of rainfall in comparison to 195.3mm in November of 2020 (Climate 2021).

Table 1: Rainfall Comparison Data in Nanaimo BC During November & October of 2020-2021 (Climate 2021)

Month of Measurement	Total Rainfall - 2020 (mm)	Total Rainfall - 2021 (mm)
October	125.9	157.3
November	195.3	345.6

When comparing water discharge data from the time between sampling event one and two, we can see the result of this rainfall on the Millstone River (**Figure 13**). When looking at data from previous years we were able to conclude that water levels in the river were the highest they have been since 2010 (Water Level and Flow… 2021).

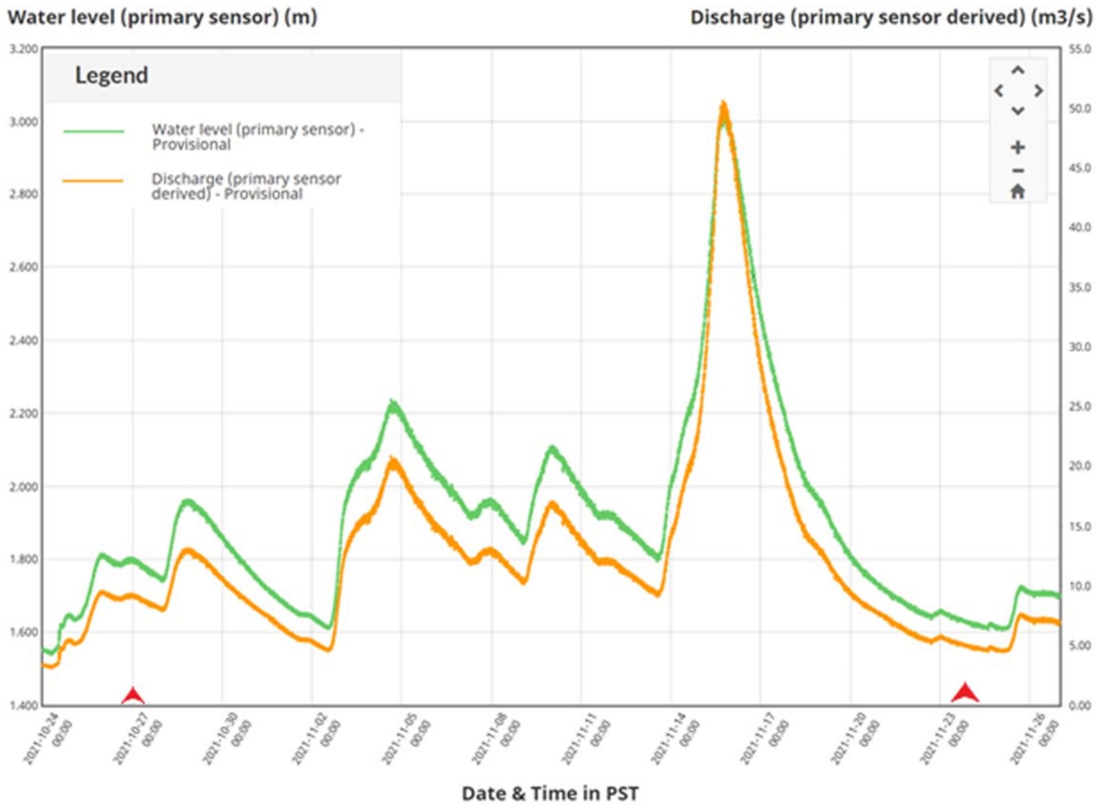

Figure 13: Graph of Water level and Discharge of the Millstone River from October 24, 2021, to November 26, 2021 (Water Level and Flow… 2021)

During sampling event 1, we attempted to capture the state of the river after a period of low flow conditions. At that time the Millstone River was at a water level of 1.77m (**Table 2**). During sampling event two, we attempted to capture the state of the Millstone River after a period of high flow conditions; at the time of sampling the water levels had fallen to a level of 1.61m from a peak of 3.03m (Water Level and Flow… 2021).

Table 2: Water Level and Discharge Data from the Millstone River During our Time Sampling (Water Level and Flow… 2021).

Date Of Measurement (Time)	**Description**	**Water Level** (m)	**Discharge** (m^3/s)
October 27, 2021 (12:00:00)	**LOW FLOW**	1.772	8.60
November 15, 2021 (17:45:00)	**PEAK FLOW**	3.027	50.6
November 24, 2021 (12:20:00)	**HIGH FLOW**	1.611	4.58

Water velocity generally decreased from sampling event one to sampling event two except for site 1 (**Table 3**) which shows change in velocity at each of our sites. Sites 2 through 5 all show an average decrease in water velocity of 11.7% which may relate to the 9.5 % decrease in water levels we observed.

Table 3: Comparison of Velocity Measurements Taken at Sites 1 to 5 on Both Sampling Dates

Site	**Velocity (m/s)**		**% Difference**
	Sampling Date 1	Sampling Date 2	
#1	1.18	1.33	+12%
#2	0.52	0.44	-17%
#3	1.00	0.96	-4%
#4	2.07	1.81	-13%
#5	0.91	0.80	-13%

The outlier in our water velocity measurements was site 1 located in Benson Creek. This site is a tributary that flows into Brannen Lake that feeds the Millstone River. Because of this, this sample site is somewhat isolated from our other sites. It's possible Benson Creek is still experiencing some runoff from the heavy rainfall which could explain the difference from the trend of decreasing velocity. Another possibility is the drastic change in the stream layout after the high waters, which caused a narrower channel to one side of the stream channel.

2.2 Water Quality

2.21 Field Measurements (Megan)

While in the field, dissolved oxygen and temperature was taken directly in the river with the use of an electric probe during the first sampling event and a mercury thermometer during the second sampling event (dissolved oxygen was taken in the Nanaimo Vancouver Island University lab for the November samples). In October dissolved oxygen levels ranged from 9.7mg/L to 11.5mg/L with the highest levels being closer to the headwaters (site 1) and the end of the Millstone River (site 4 and 5) where the gradient of the river changes and overall water velocity increases. Sites 1 and 4 have notably the highest mean velocities of the sampling sites and likely the higher velocity of the water promotes aeration and circulation of dissolved oxygen within the river at these sites. The temperature for the October sampling event also correlates with the sites with the highest dissolved oxygen levels (sites 1,4, and 5). These three sites have both the highest levels of dissolved oxygen and the lowest water temperatures, which follows the general trend that colder water holds more dissolved oxygen within it. The amount of dissolved oxygen within the Millstone River during the November sampling event followed a similar trend as the first sampling event with dissolved oxygen levels ranging between 9.5mg/L and 11.1mg/L. All sites from October to November did not fluctuate more than one degree Celsius and the mean velocity of the river followed a similar trend during both sampling events. The temperature during the November sampling date showed a significant decrease from October fluctuations, likely due to the outside air temperature decreasing as the daylight hours and strength of the sun declined. While October water temperatures ranged from 8.8°C - 11.1°C the November water temperatures of the Millstone dropped to an average of 1°C - 3°C (**Table 4**). According to the BC water quality guidelines, the minimum level of dissolved oxygen needed within a freshwater river or stream to support fish migration, spawning, incubation, and development is 11.0mg/L (Ministry of Environment and Climate Change Strategy 2019). During the sampling in October and November only four of the ten samples taken on dissolved oxygen reveal acceptable levels for fish life cycles, with site 4 being the only site that meets the minimum requirement in both sampling events. Temperature levels during the October sampling event were all within optimum ranges (4.0-16.0 degrees Celsius) to support the life cycle of Coho salmon which have been seen migrating, spawning, and developing in the Millstone River before smolts migrate back to the Pacific Ocean (Ministry of Environment and Climate Change Strategy 2019). However, the temperatures for the November sampling event are below optimum levels which could affect migrating Coho salmon within the Millstone River. It's important to note that the second sampling event did not use an electric probe like the first sampling event did and instead used a mercury thermometer which could yield slightly different results.

Table 4: Millstone River Measurements Taken Over Low Flow and High Flow

Date	Station Number	Dissolved Oxygen (mg/L)	Temperature (°C)	Mean Velocity (m/sec)
October 27	1	11.4	9.1	1.18
	2	9.7	11.1	0.52
	3	10	10.1	1.00
	4	11.5	9.6	2.07
	5	11.5	8.8	0.91
November 24	1	10.1	1	1.33
	2	9.5	3	0.44
	3	10.2	2	0.96
	4	11.1	3	1.81
	5	10	2	0.80

2.3 VIU Laboratory Analysis (Megan)

Water samples collected at both sampling events for the VIU analyses were conducted during scheduled lab time at the Vancouver Island University Nanaimo campus, and the parameters measured included pH, conductivity, alkalinity, hardness, turbidity, nitrate, and phosphate. Bar graphs included within the "*VIU Laboratory Analysis*" section of this report is sampling data from sites 1 to 5 and does not display the data of the duplicates (1B and 3B). Stations "1" and "3" on the following bar graphs represent original data collected from the sites and are designated as "1A" and "3A" (**Figures 14 to 17**). Duplicate samples were not included in the graphs to make fluctuations in the data between the sampling stations easier to distinguish.

Ph: The pH values measured from sampling events one and two were all within the normal freshwater pH values of 6.5 - 9.0 (BCMOE 2021). Sampling stations 1-5 ranged between 7.6 – 7.9 during the first sampling event and 6.8 – 7.5 during the second sampling event.

Between the first and second sampling event the pH of the river fluctuated less than a one whole pH value despite having drastic differences in river water temperature. The water temperature during the first sampling event ranged between 9.5 – 11.1 degrees Celsius and 1-3 degrees Celsius for the second sampling event. The differences in temperature and corresponding minimal change in pH values between the two sampling dates could be due to using an electric thermometer during the first sampling event and a mercury thermometer during the second sampling event (the electronic one was not available). The observed trend in the data shows that site 2, which is slightly downstream of Brannen Lake, was the most acidic site during both sampling events and had a higher ranging temperature overall. This observed data supports the fact that as water temperature increases the pH decreases and the water becomes more acidic, which is displayed at Site 2 (**Figure 14**). Likely, the pH of Brannen Lake directly affects the Millstone River immediately downstream of it, but as the river gets closer to the bottom sampling stations the pH increases and the river becomes less acidic.

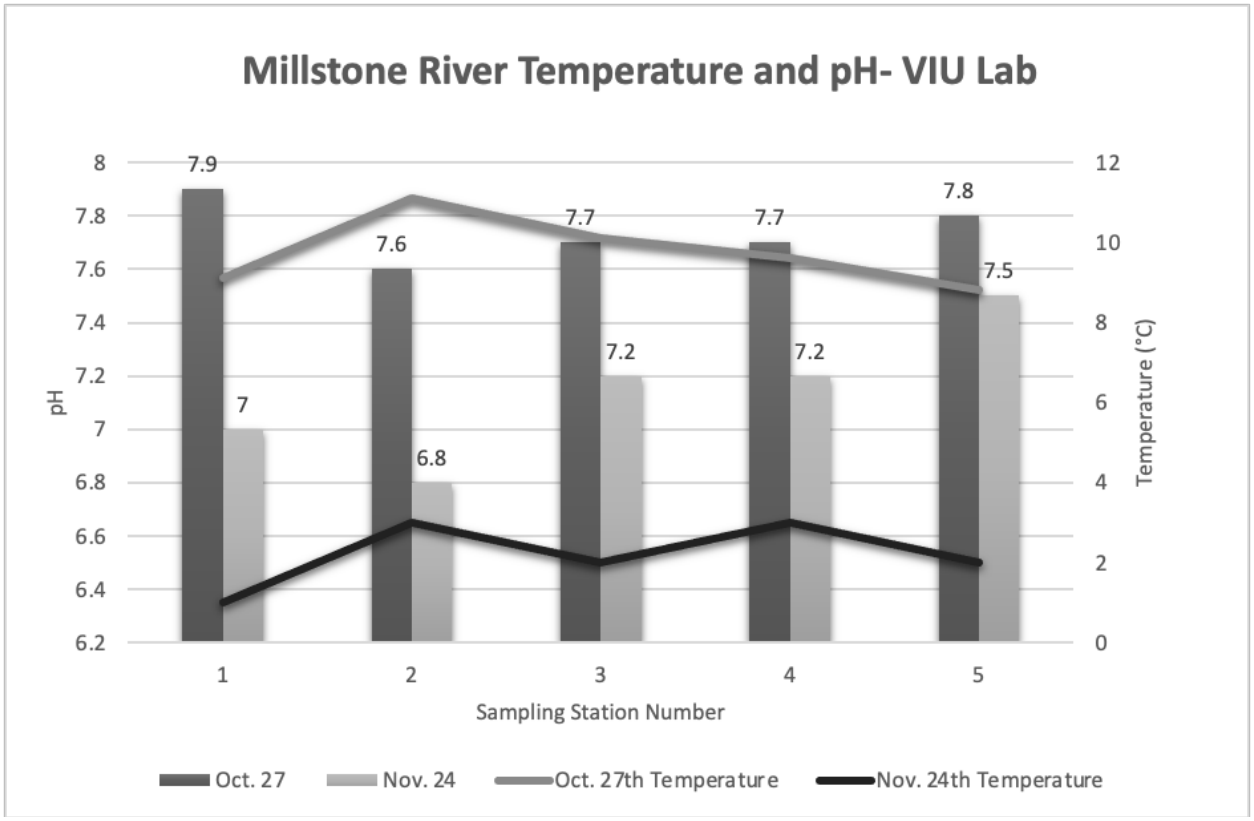

Figure 14: VIU Lab Data Comparison Between Temperature and pH on the Millstone River

Conductivity: The data collected from both sampling events show a significant increase in conductivity and turbidity the further downstream you collect a water sample from (**Figure 15**). This data trend was expected because as water moves down a stream or river it erodes and moves more sediment and solids downriver, and therefore has more of these sediments and solids suspended within it that gives it a higher conductivity and turbidity level. This was also visually noticed while taking samples since water was clearer closer to the headwaters and then became murkier as you got closer to the end of the river. In October, conductivity at site 1 was 33µS/cm and continuously increased to 98µS/cm at site 5 with the most significant increase being from site 1 to 2 (33µS/cm to 102µS/cm). In November, conductivity at site 1 was 30µS/cm and increased to 89µS/cm at site 5. As displayed in the data, the second sampling event also saw a large increase from site 1 to 2 (30µS/cm to 58µS/cm). The drastic increase from these sites is possibly due to Brannen Lake draining into site 2, as the lake likely contributes large amounts of displaced solids and sediments into the Millstone River. Due to our second sampling event being a lower flow than the first event, the data supports why site 2 in October had a significantly higher conductivity level than the November sample. The October flow velocity at site 2 was also visually faster and the water was more "funneled" into a smaller area (small, wetted width) than the November flow which had a larger wetted width, and the velocity was slower. Therefore, more suspended solids and sediments were pushed down the river during the October sampling event due to the stronger current which could move a higher volume of larger sediment. Temperature also plays a role in conductivity with hotter temperatures correlating to a higher water conductivity level. This is consistent with the collected data from October which shows that site 2 had the highest water temperature of any sample site (11.1°C) and had the highest conductivity level during this time (102µS/cm).

Turbidity: As previously discussed, the turbidity and conductivity significantly increased the further down the stream the samples were taken. The change is turbidity was easy to distinguish visually as the Millstone River water at site 5 (last sampling station) appeared to be the "dirtiest" compared to the clear and "clean" conditions at site 1. In October, site 1 had Nephelometric Turbidity Units of 1.66 and they increased to 14.7 NTU at site 5. November's data displayed 1.52 NTU at site 1 and increased to 8.69 NTU at site 5. The higher NTU values in October reflect the larger volume of water passing through the Millstone River as the first sampling event had higher stream discharge than the second sampling event (**Figure 15**).

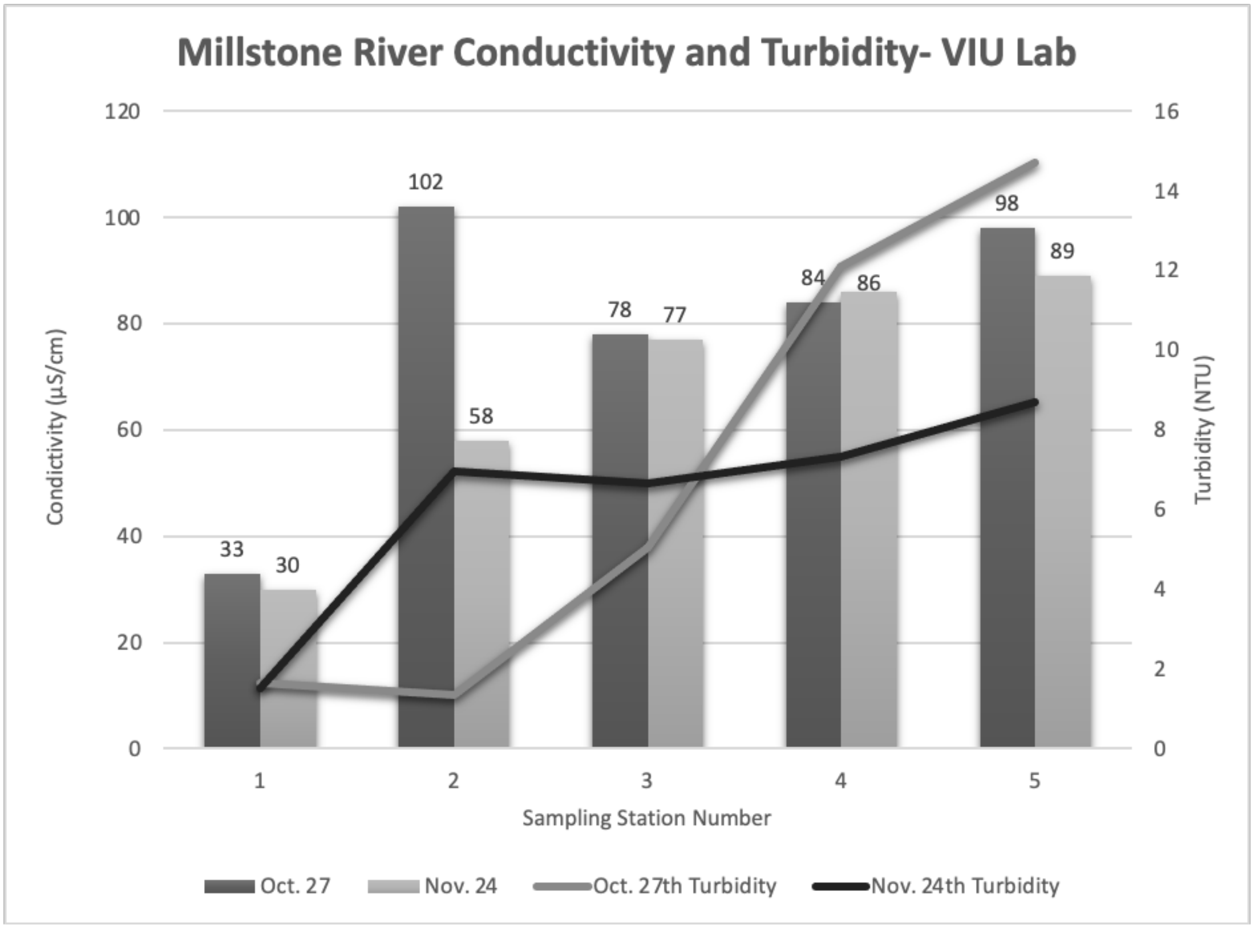

Figure 15: VIU Lab Data Comparison Between Conductivity & Turbidity for the Millstone

Alkalinity: The results from the first sampling event in October ranged from 3 mg/L to 5.2 mg/L as $CaCO_3$ with the most drastic change between site 1 and site 2 (4.8mg/L to 3mg/L). Due to the location of site 2 being directly downstream of Brannen Lake, the sudden drop in alkalinity could represent a lack of $CaCO_3$ coming from the lake. Likely there are more rocks and sediments within the Millstone River than Brannen Lake that contain calcium carbonate, so this may contribute to the increase in alkalinity upstream and further downstream from the lake. The November sampling showed a similar data trend with alkalinity continuing to increase further downstream minus the anomaly seen at site 4 which data analysis showed the test was inconclusive, and the total alkalinity was below the detection limit (**Figure 16**). Besides the results from site 4, the November samples for alkalinity ranged from 1.8mg/L to 3mg/L and had lower $CaCO_3$ levels overall than the October sampling event. It's important to note that the November sampling took place one week after a large rainfall and flood event (**Figure 13**) so likely lots of the $CaCO_3$ within the Millstone River during that time would have been pushed downstream and into the ocean. The data collected on both sampling events overall follows the general trend that there will be an increase in $CaCO_3$ levels as water pushes more calcium carbonate and other minerals downstream. As stated in the British Columbia Approved Water Quality Guidelines for Aquatic Life (**Table 5 and 6**) all alkalinity values from both sampling events were between 0-10mg/L as $CaCO_3$ and all sites tested are considered to have a high acid sensitivity level (BCMOE 2021). This high sensitivity to acid means that the Millstone River during the time of testing didn't have a great ability to neutralize acid that is added to the river, so its buffering capacity was limited. Looking back at the data collected on pH (**Figure 14**) the Millstone River at the time of sampling was within an acceptable pH value that can support freshwater aquatic life (BCMOE 2021). However, if the alkalinity within the Millstone River continues to stay low (future testing will indicate this), the pH could become more acidic and fall outside of the guidelines (BCMOE 2021).

Hardness: The sum of magnesium and calcium concentrations within water or a stream or river contributes to how "hard" or "soft" water is. The guidelines outlined in (BCMOE 2021) classify "soft water" as $CaCO_3$ concentrations less than 60mg/L, "moderate" at 60-120 mg/L, and "hardwater" at any concentration over 120mg/L. The hardness of the Millstone River between both sampling events correlated with both alkalinity, conductivity, and turbidity with all data showing increasing values the further from the headwaters the samples were collected. The first sampling event had concentrations ranging from 22mg/L to 33mg/L with a steady increase from sampling stations 3 to 5. The most substantial increase was displayed at sampling stations 1 to 2 where the hardness of the water increased from 22mg/L to 32mg/L immediately downstream of Brannen Lake (**Figure 16**). Likely at site 2 there was an increase in the number of dissolved cations (such as calcium and magnesium) that entered the Millstone River from the lake and thus contributed to the sharp hardness increase. The second sampling event showed a similar trend with the hardness of the river ranging from 14mg/L to 39mg/L with another sharp increase from site 1 to site 2 (14mg/L to 27mg/L as $CaCO_3$). Due to all samples being less than 60mg/L as $CaCO_3$ during both sampling events, the Millstone River at the time of the sampling was considered to have soft water.

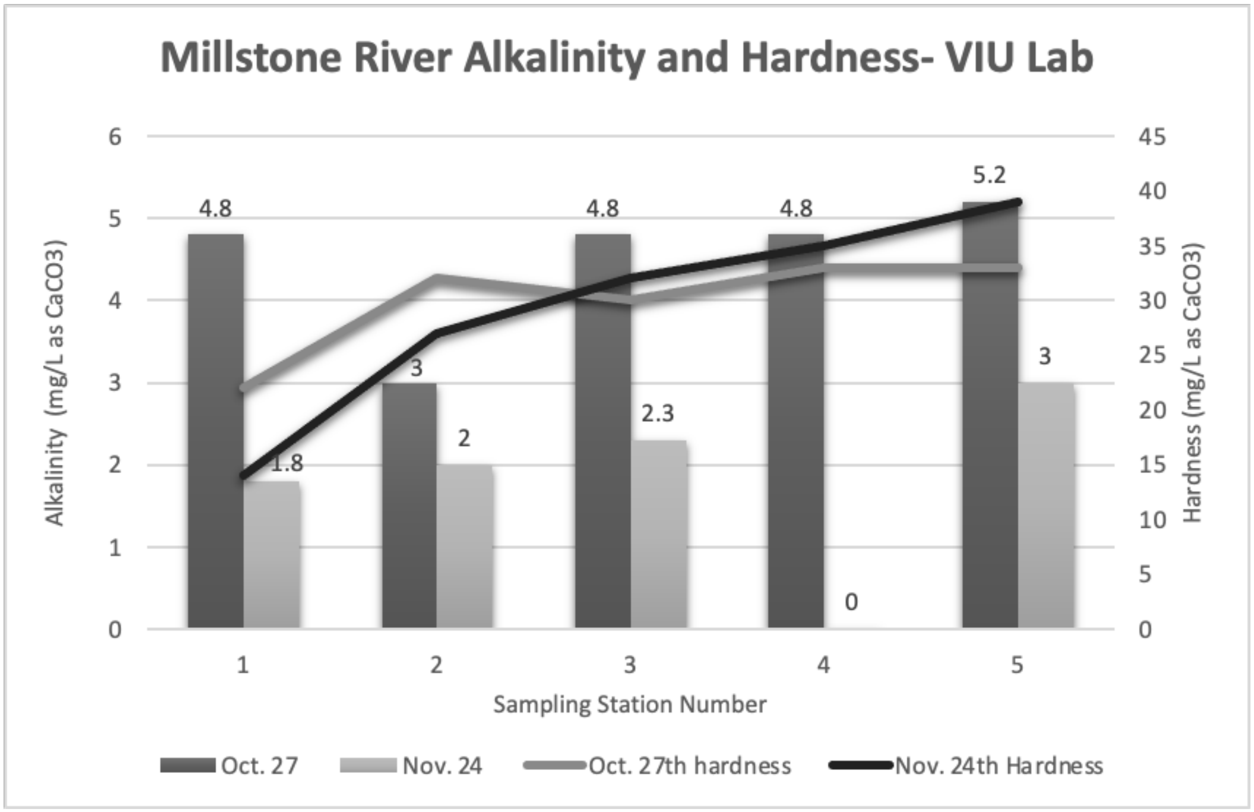

Figure 16: VIU Lab Data Comparison Between Alkalinity and Hardness on the Millstone River

Nitrate: Water samples from the first sampling date show minimal fluctuations between samplings sites and nitrate levels ranged from 0.02mg/L to 0.06mg/L. Once displayed on a bar graph (**Figure 17**) the data does not show a specific pattern when looking at the beginning of the river (site 1) down to the end of it (site 5). Rather the data shows very similar levels of nitrate throughout all the samplings sites and slight decreases do not appear to be correlated with the location on the river (forestry vs. agriculture vs. developed areas). Nitrate levels during the November sampling event increased significantly and data showed a steady increase in nitrate levels the further away from the headwaters of the river you sampled from. Nitrate levels ranged from 0.17mg/L to 87mg/L from sites 1 to 5 and likely increased at such a rate during the second sampling event due to the extreme precipitation event that occurred in the area during the previous week (**Figure 13**). The highest nitrate concentration from November (0.87mg/L) was at the very end of the Millstone River (site 5), and this follows the general trend that the end of the river often has the most nitrate dissolved within the water. This especially makes sense that the bottom of the Millstone River has the highest nitrate levels because the end of the river is in a very densely urbanized and developed land space and has also gone through numerous areas that utilise the land for agricultural practices (nitrate runoff is higher in these areas). Although the nitrate levels appear to be high when looking at the data displayed on the bar graph the BC Water Quality Guideline for aquatic life states that 32.8 mg/L NO – is the maximum acceptable level of nitrate within freshwater, and all data collected from the sampling sites during October and November fall within acceptable levels (MOE, 2019).

Phosphate: In October phosphate levels ranged from 0.06µg/L to 0.11µg/L and gradually increased from site 1 to site 5. The increase in phosphates from sites 1 to 5 likely correlates with the increase in development as you become closer to the ocean, and likely phosphates from soaps and detergents are entering the river at higher levels in heavily populated areas along the Millstone River. During the November sampling event the phosphate levels ranged from 0.04µg/L to 0.13µg/L with the most significant increase being at site 1 to site 2 (0.05µg/L to 0.13µg/L) (**Figure 17**). This data point is significant because site 2 is downstream of Brannen Lake and points to a possibility that the lake greatly impacts phosphate levels within the Millstone River (especially after high precipitation events). Interestingly, the phosphate levels downstream of site 2 steadily decreased to a level of 0.04µg/L at site 5. It is possible that the phosphate concentration at the lower sites (3-5) became diluted during the heavy rain and flooding event, but more extensive testing would have been required at that time to support this hypothesis.

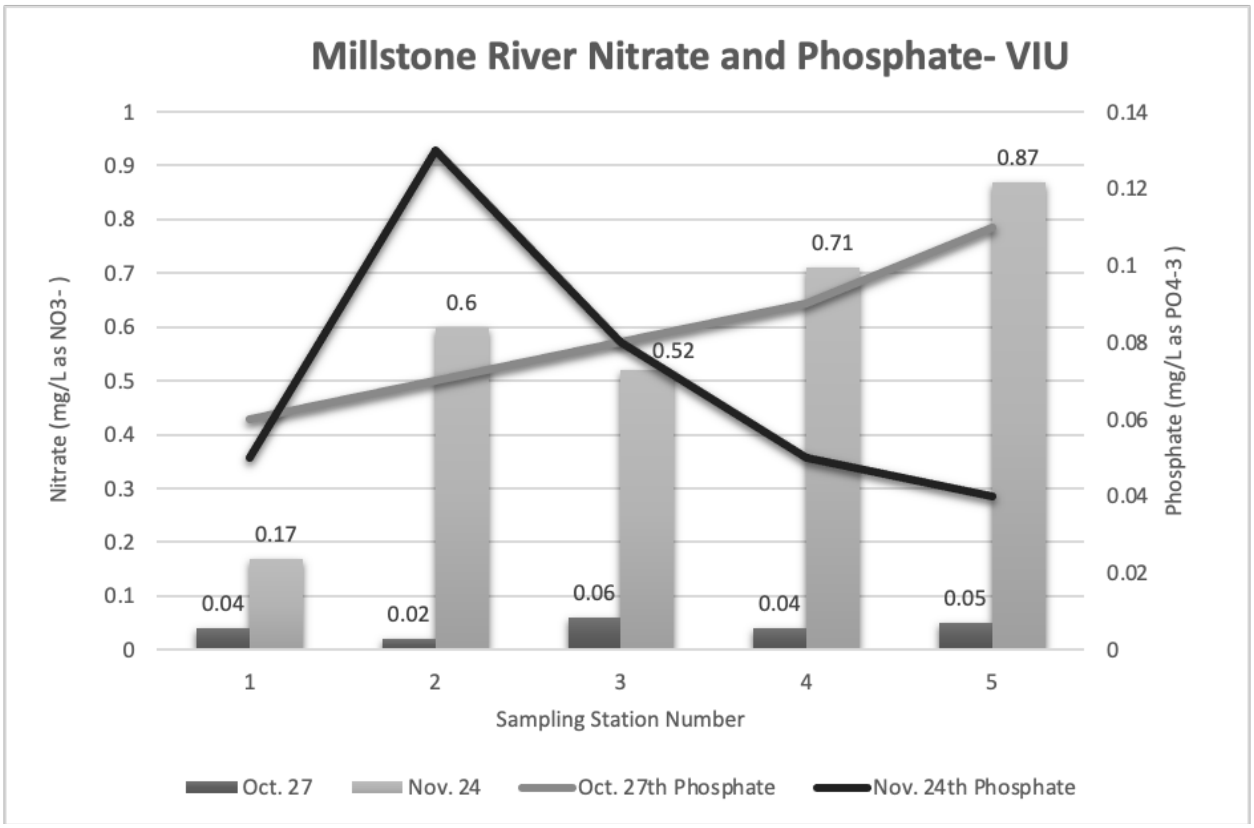

Figure 17: VIU Lab Data Comparison Between Nitrate and Phosphate on the Millstone River

2.4 ALS Laboratory Analysis

2.41 Physical Tests (Megan)

Sites 1, 3 and 5 were analyzed by the ALS laboratory in Vancouver, BC and summarized results from both sampling events have been compiled into charts along with the BC Water Quality Guidelines (**Table 5 and 6**). Overall, the physical tests between conductivity, hardness, and pH during both sampling events stayed consistent and there were no drastic differences between the dates for these specific parameters. Conductivity, hardness, and pH gradually increased from site 1 to site 5 which shows that added minerals and nutrient runoff is the highest at the bottom of the Millstone River. This is where minerals and nutrient runoff have accumulated over the course of the water running down from the headwaters to the ocean. Using the established guidelines, all samples taken from both October and November show the Millstone River as having soft water and the pH levels were within acceptable ranges.

2.42 Nutrients (Megan)

Ammonia at site 3 was 0.0053mg/L in October and increased to 0.0194mg/L during the November samplings which suggests that more ammonia runoff ends up in the Millstone River during high precipitation events. Although the values increased, they are still within an acceptable range of 19.7mg/L to 23.2mg/L. Nitrite within the Millstone River decreased overall in November and nitrite and nitrogen increased slightly in November. Orthophosphate dissolve (P) increased by over double during the November sampling event and both sampling events show the Millstone River was oligotrophic during the times the samples were taken. Total phosphorus increased in November except at site 5 where the Millstone River at this specific site went from 0.0254mg/L (October) to 0.0144mg/L (November).

2.43 Total Metals (Megan)

Total calcium results from both October and November show similar results and didn't fluctuate much between the two sampling events. Sites 1-5 during October and November show a range from 3.51mg/L to 9.30mg/L which is well over the guideline of 4mg/L to 8mg/L (at most sites sampled). Only site 1 during both sampling events was within an acceptable range (3.72mg/L and 3.51mg/L), although it is just barely acceptable. Total aluminum analysis showed that almost all samples taken from both October and November are well above the 0.1mg/L guideline with the highest concentration of total aluminum being at site 5 during the October sampling event (0.539mg/L). Total iron analysis revealed that all samples taken by students during both sampling events were within acceptable levels (1mg/L). Iron within samples 1,3, and 5 ranged from 0.105mg/L to 0.838mg/L during October and 0.047mg/L to 0.481 during November. Generally, there was more iron at sites 1, 3 and 5 during the October sampling and iron levels increased the further from the headwaters the sample was taken from. Both total magnesium and total silicon stayed consistent between the October and November sampling dates and didn't fluctuate greatly. In addition, the total magnesium and total silicon followed the same trend as the other previously noted metals and increased in concentration further down the Millstone River.

Table 5: ALS Laboratory Analysis Results Summarized – October 27, 2021 (Hunter)

Physical tests (Water)	**Unit**	**Stations**			**Guidelines**	**Observation**
		1	**3**	**5**		
Conductivity	µs/cm	34.4	84.6	93.7	-	
Hardness (CaCO3)	mg/L	13.3	30.0	32.8	<60 mg/L	Soft Water
pH	pH	7.10	7.49	7.61	6.5-9.0	
Anions / Nutrients (Water)						
Ammonia, Total (as N)	mg/L	<0.0050	0.0053	0.0124	19.7-23.2	
Nitrate (as N)	mg/L	0.226	0.236	0.295	200	
Nitrite (as N)	mg/L	<0.0010	0.0010	0.0013	0.06	
Total Nitrogen	mg/L	0.328	0.371	0.560	-	
Orthophosphate-Dissolved (P)	mg/L	<0.0010	0.0017	0.0013	-	
Phosphorous (P) – Total	mg/L	0.0021	0.0111	0.0254	<0.10	Oligotrophic
N:P	N/A	156.2	33.4	22	16	
Total Metals						
Calcium (Ca) – Total	mg/L	3.72	8.24	9.06	4-8	Above Guidelines
Aluminum (Al) – Total	mg/L	0.144	0.289	0.539	0.1	Above Guidelines
Iron (Fe) – Total	mg/L	0.105	0.507	0.838	1	
Magnesium (Mg) – Total	mg/L	0.973	2.29	2.46	-	
Silicon (Si) – Total	mg/L	3.73	3.77	4.20	-	

Table 6: ALS Laboratory Analysis Results Summarized – November 24, 2021 (Hunter)

Physical tests (Water)	Unit		Stations		Guidelines	Observation
		1	3	5		
Conductivity	µs/cm	34.0	83.1	94.9	-	
Hardness (CaCO3)	mg/L	12.8	29.8	33.0	<60 mg/L	Soft Water
pH	pH	6.99	7.16	7.44	6.5-9.0	
Anions / Nutrients (Water)						
Ammonia, Total (as N)	mg/L	<0.0050	0.0194	0.0180	19.7-23.2	
Nitrate (as N)	mg/L	0.148	0.377	0.419	200	
Nitrite (as N)	mg/L	<0.0010	0.0018	0.0016	0.06	
Total Nitrogen	mg/L	0.218	0.533	0.621	-	
Orthophosphate-Dissolved (P)	mg/L	<0.0010	0.0037	0.0036	-	Oligotrophic
Phosphorous (P) – Total	mg/L	<0.0020	0.0132	0.0144	<0.10	
N:P	N/A	BDL	40.4	43.1	16	
Total Metals						
Calcium (Ca) – Total	mg/L	3.51	8.40	9.30	4-8	Above Guidelines
Aluminum (Al) – Total	mg/L	0.0862	0.210	0.246	0.1	Above Guidelines
Iron (Fe) – Total	mg/L	0.047	0.476	0.481	1	
Magnesium (Mg) – Total	mg/L	0.977	2.14	2.37	-	
Silicon (Si) – Total	mg/L	3.61	4.26	4.63	-	

2.44 Quality Assurance and Quality Control (Megan)

During sampling and lab analysis, quality control and quality assurance standards were followed in accordance with the British Columbia Field Sampling Manual (Clark 2013). ALS Laboratory bottles were sterile and opened underwater in the Millstone River to decrease contamination, and all applicable information was written on both ALS and VIU sample bottles to avoid mixing up samples. Water quality analysis for the ALS Laboratory was sent within 24 hours of sample collection and VIU lab samples were analyzed within 4 hours of being collected to ensure data could be obtained before samples degraded or expired and gave invalid information. To ensure the quality of the samples taken was as like the river as possible, samplings began at the end of the river (site 5) and concluded at the start (site 1). This method ensured excess sediment did not contaminate samples due to loosened sediment traveling downstream while students waded in the river. VIU water sampling containers were rinsed three times with river water, taken upstream of where the student was wading (to avoid extra sediment in the sample) and then samples were taken in a well flowing spot on the river at the designated sample station. The duplicate samples obtained from sampling sites 1 and 3 were designated as 1B and 3B and analysed in the VIU laboratory to ensure quality and consistency within the results (**Table 7**). The duplicates were taken at the same spot on the river as the originals and within a few minutes of each other. All seven water quality parameters (**Table 7**) were tested on the duplicates and all parameters (except turbidity) between original samples and duplicates came back with minimal fluctuation between samples, meaning tests were analyzed with high precision. The varying results for turbidity between sites 1 and 3 (originals and duplicates) could be the result of different amounts of times the samples were shaken before being tested. The time samples were shaken for could have impacted how many solids or sediments were suspended in the sample during analysis and if the lab equipment was able to register it.

Table 7: Comparison Between Duplicates from the First and Second Sampling Dates

Parameters	October 27th Sampling Sampling Station Number:				November 24th Sampling Sampling Station Number:			
	1A	1B*	3A	3B*	1A	1B*	3A	3B*
pH	7.9	7.9	7.7	7.7	7	7.2	7.2	6.9
Hardness (mg/L as CaCO3)	22	16	30	28	14	14	32	33
Conductivity (µS/cm)	33	35	78	78	30	29	77	84
Turbidity (NTU)	1.66	1.58	5.07	6.84	1.52	1.24	6.64	6.47
Nitrate (mg/L NO3)	0.04	0.04	0.06	0.11	0.17	0.21	0.52	0.50
Total Alkalinity (mg/L)	4.8	4.8	4.8	4.8	1.8	1.8	2.3	2.7
Reactive Phosphorus (µg/L PO4)	0.06	0.04	0.08	0.07	0.05	0.05	0.08	0.06

*Duplicate Sample

2.5 Stream Invertebrates Communities

2.51 Abundance and Density (Luca)

The invertebrate sampling conducted on the Millstone River produced a total of 75 invertebrate individuals and five broad taxonomic groups. Invertebrate density was calculated and site 3 was found to have the highest density at 233.33 animals/m2 (**Figure 21 and 22**). Moving downstream, site 4 had 105.56 animals/m2 which was the lowest of all sample sites (**Figure 23 and 24**). Site 1 fell in between the other two sites with a density of 194.44 animals/m2 (**Figure 19 and 20**). Notably prominent species through all sample sites consisted of aquatic worms, mayfly, and freshwater shrimp. The prominent species for site 1 was mayfly larva, which is a pollutant intolerant species (**Figure 25**). The prominent species for site 3 was freshwater shrimp which are considered somewhat pollution tolerant (**Figure 26**). The prominent species for site 4 was aquatic worms which are pollution tolerant (**Figure 27**). When looking at each of the sites prominent species there is a trend of species becoming more tolerant to pollution as one travels downstream (**Figure 18**). This suggests greater pollution levels further downstream.

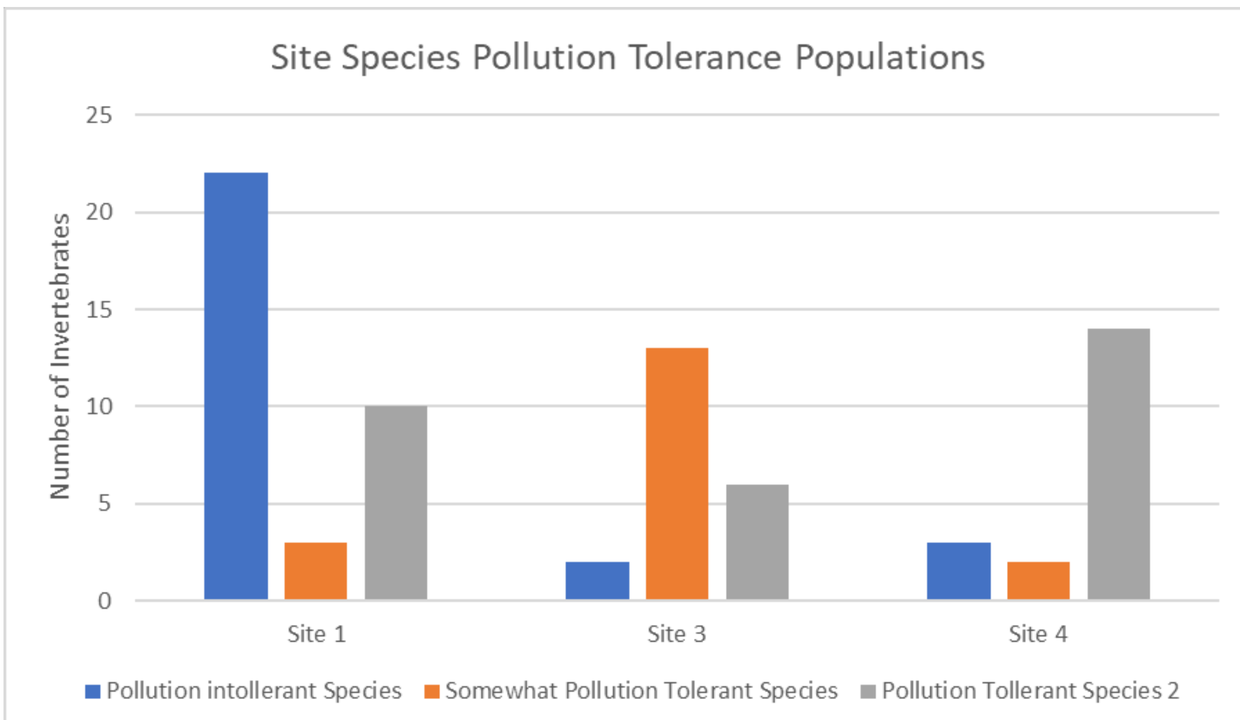

Figure 18: Site Species Pollution Tolerance Populations Chart

2.52 Diversity and Site Ratings (Luca)

When looking at the calculated Shannon Weiner Diversity Index ratings, the maximum possible diversity rating is 1. The highest diversity rating was site 3 which scored .800 (**Table 9**), followed by site 1 which scored 7.24 (**Table 8**). Site 4 received the lowest rating at .616 (**Table 10**). Since site 4 had the lowest rating, it once again suggests that the further downstream you sample, higher pollution levels are noted.

Site assessment ratings were calculated. These ratings use the pollution tolerance index, EPT index, the EPT to total ratio, and the predominant taxon ratio to score the overall health of a site. The range of possible scores is between 1 and 4, with 1 representing "poor" health, and 4 representing "good" health. Site 1 received a "marginal" rating at 2.5 (**Figure 20**). Site 3 received a "Poor" rating at 1.25 (**Figure 22**). Site 4 also received a "Poor" rating at 1.5 (**Figure 24**). These ratings once again suggest that the more downstream a site is the more pollution there may be. Overall, these results suggest that the majority of the Millstone River is in poor condition for supporting invertebrate life with a particular emphasis on areas downstream from Brannen lake. Therefore, significant efforts should be made at remediation in these areas.

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name:	Millstone River	Date:	Oct 27 2021
Station Name:	Site 1	Flow status:	Hi

Sampler Used:	Number of rep	Total area sampled (Hess, Surber = 0.09 m²) x no. replicate
Hess	2	.09x2=.18 m²

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT	3	2
	Mayfly Nymph (EPT)	19	1
	Stonefly Nymph (EPT		
Pollution Intolerant	Dobsonfly (hellgramn		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		22	3
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	1	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwate	2	1
	Watersnipe Larva		
Sub-Total		3	2
Category 3	Aquatic Worm (oligoc	10	3
	Blackfly Larva		
	Leech		
	Midge Larva (chironc		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Sn		
	True Bug Adult		
	Water Mite		
Sub-Total		10	3
TOTAL		35	8

Figure 19: Site 1 Invertebrate Survey Field Data Sheet

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 – ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: 35

DENSITY: Invertebrate density per total area sampled:

From page 1

35 ÷ 0.18 m^2 = 194.44 / m^2

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

SECTION 2 – WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 3 + 2 x 2 + 3 = 16

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

2 + 1 + 0 = 3

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

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

(EPT1 + EPT2 + EPT3) / CT

(3 + 19 + 0) / 35 = 0.63

SECTION 3 – DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 8

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT

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

Col. C for S1 / CT

19 / 35 = 0.54

SECTION 4 – OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

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

Average Rating
Average of R1, R2, R3, R4
2.5

Figure 20: Site 1 Invertebrate Survey Interpretation Sheet

Table 8: Site 1 Shannon Weiner Diversity Index

Shannon Weiner Diversity Index				
Common Name	Column C	*Pi* (C/T)	ln(Pi)	Pi*ln*Pi*
Caddisfly Larva (EPT)	3	0.08571429	-2.4567358	-0.2105774
Mayfly Nymph (EPT)	19	0.54285714	-0.6109091	-0.3316364
Cranefly Larva	1	0.02857143	-3.5553481	-0.1015814
Amphipod (freshwater shrimp)	2	0.05714286	-2.8622009	-0.1635543
Aquatic Worm (oligochaete)	10	0.28571429	-1.252763	-0.3579323
Total		1		-1.1652817
Shannon Weiner Diversity Index				0.724

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: Oct 27 2021	
Station Name: Site 3		Flow status: Hi	
Sampler Used: Hess	Number of replicates 1	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.09 m^2	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)		
	Mayfly Nymph (EPT)	2	1
	Stonefly Nymph (EPT)		
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		2	1
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	13	1
	Watersnipe Larva		
Sub-Total		13	1
Category 3	Aquatic Worm (oligochaete)	6	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		6	1
TOTAL		21	3

Figure 21: Site 3 Invertebrate Survey Field Data Sheet

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 – ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: **21**

DENSITY: Invertebrate density per total area sampled:

From page 1

21 ÷ 0.09 m² = **233.33** / m²

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): **Freshwater Shrimp**

SECTION 2 – WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 1 + 1 = **6**

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

0 + 1 + 0 = **1**

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

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

(EPT1 + EPT2 + EPT3) / CT

(0 + 2 + 0) / 21 = **0.1**

SECTION 3 – DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: **3**

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT

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

Col. C for S1 / CT

13 / 21 = **0.62**

SECTION 4 – OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	1
EPT Index	1
EPT To Total Ratio	1
Predominant Taxon Ratio	2

Average Rating
Average of R1, R2, R3, R4
1.25

Figure 22: Site 3 Invertebrate Survey Interpretation Sheet

Table 9: Site 3 Shannon Weiner Diversity Index

Shannon Weiner Diversity Index				
Common Name	Column C	*Pi*(C/T)	ln(Pi)	Pi*ln*Pi*
Mayfly Nymph (EPT)	2	0.0952381	-2.3513753	-0.2239405
Amphipod (freshwater shrimp)	13	0.61904762	-0.4795731	-0.2968786
Aquatic Worm (oligochaete)	6	0.28571429	-1.252763	-0.3579323
Total		1		0.87875135
Shannon Weiner Diversity Index				0.8

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Millstone River		Date: Oct 27 2021	
Station Name: Site 4		Flow status: Hi	
Sampler Used: Hess	Number of replicates: 2	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: .09x2=.18 m^2	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	1	1
	Mayfly Nymph (EPT)	2	1
	Stonefly Nymph (EPT)		
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		3	2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	2	1
	Watersnipe Larva		
Sub-Total		2	1
Category 3	Aquatic Worm (oligochaete)	14	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		14	1
TOTAL		19	4

Figure 23: Site 4 Invertebrate Survey Field Data Sheet

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 – ABUNDANCE AND DENSITY

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

DENSITY: Invertebrate density per total area sampled:

From page 1

19 ÷ 0.18 m^2 = 105.56 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): Aquatic Worm

SECTION 2 – WATER QUALITY ASSESSMENTS

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

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

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 1 + 1 = 9

EPT INDEX: Total number of EPT taxa.

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

EPT4 + EPT5 + EPT6

1 + 1 + 0 = 2

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

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

(EPT1 + EPT2 + EPT3) / CT

(1 + 2 + 0) / 19 = 0.16

SECTION 3 – DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 4

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

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

Col. C for S1 / CT

14 / 19 = 0.74

SECTION 4 – OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	1
EPT Index	2
EPT To Total Ratio	1
Predominant Taxon Ratio	2

Average Rating
Average of R1, R2, R3, R4
1.5

Figure 24: Site 4 Invertebrate Survey Interpretation Sheet

Table 10: Site 4 Shannon Weiner Diversity Index

Shannon Weiner Diversity Index				
Common Name	Column C	*Pi*(C/T)	ln(Pi)	Pi*ln*Pi*
Caddisfly Larva (EPT)	1	0.05263158	-2.944439	-0.1549705
Mayfly Nymph (EPT)	2	0.10526316	-2.2512918	-0.2369781
Amphipod (freshwater shrimp)	2	0.10526316	-2.2512918	-0.2369781
Aquatic Worm (oligochaete)	14	0.73684211	-0.3053816	-0.2250181
Total		1		0.8539447
Shannon Weiner Diversity Index				0.616

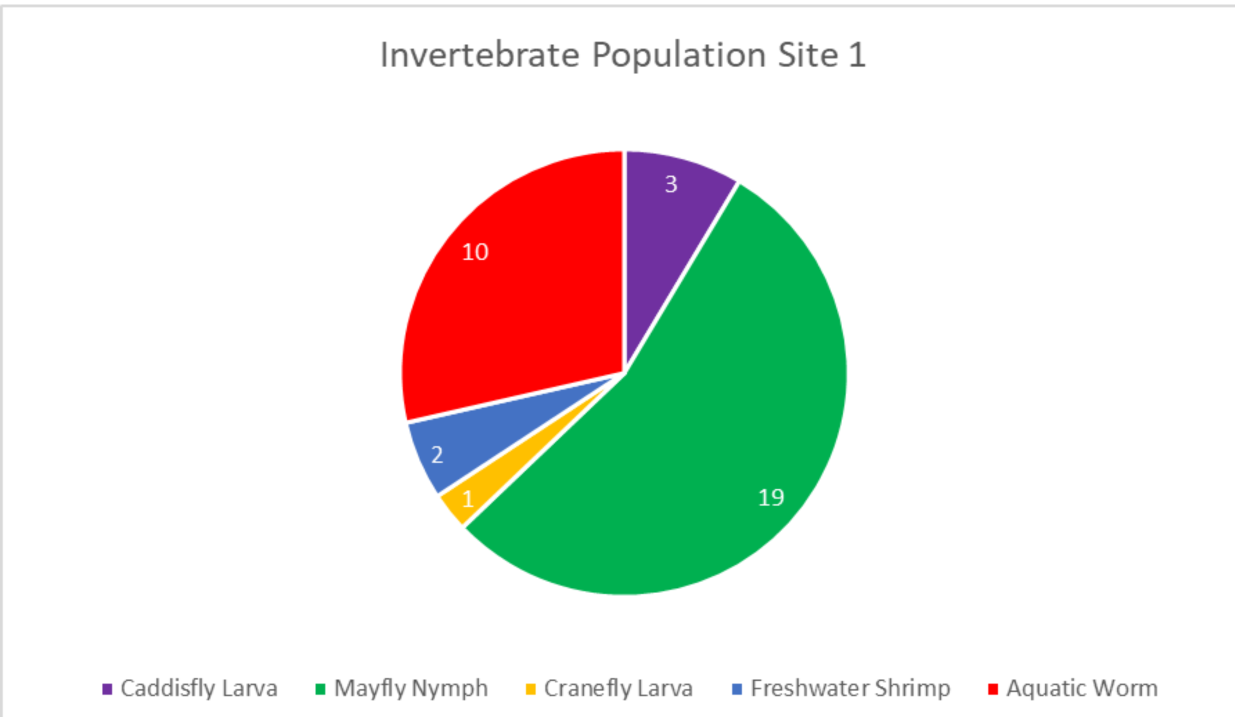

Figure 25: Invertebrate Population Site 1

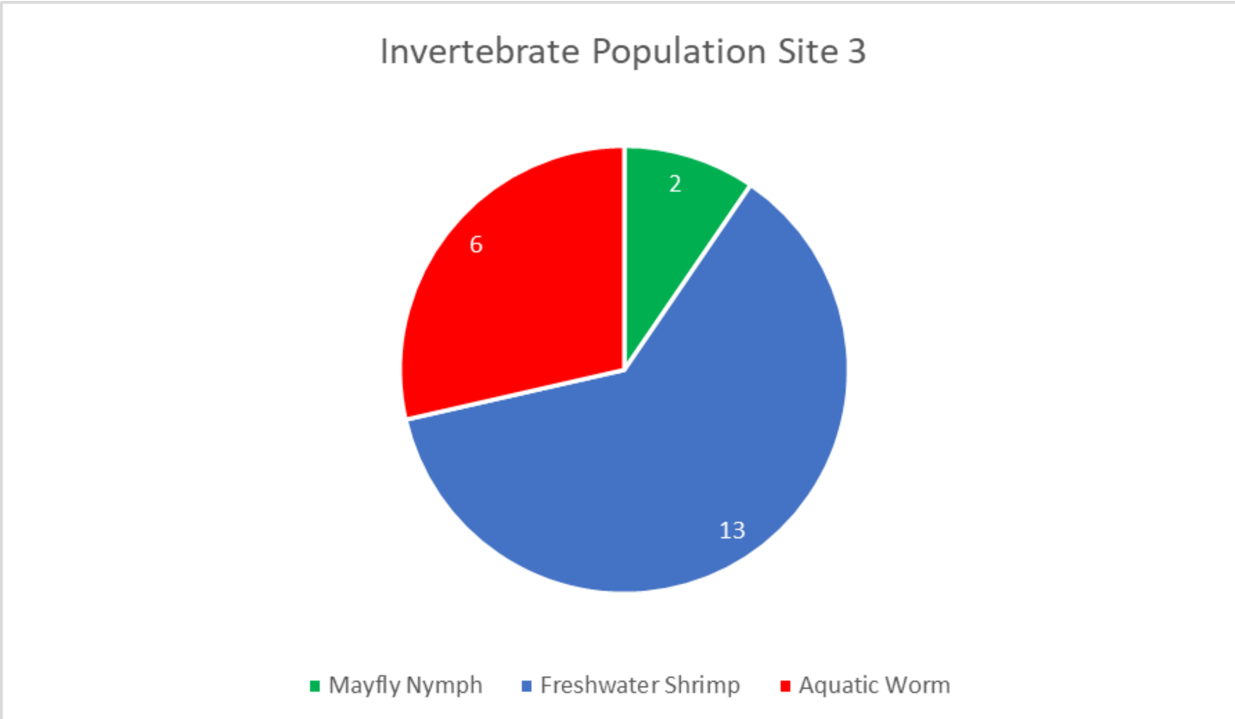

Figure 26: Invertebrate Population Site 3

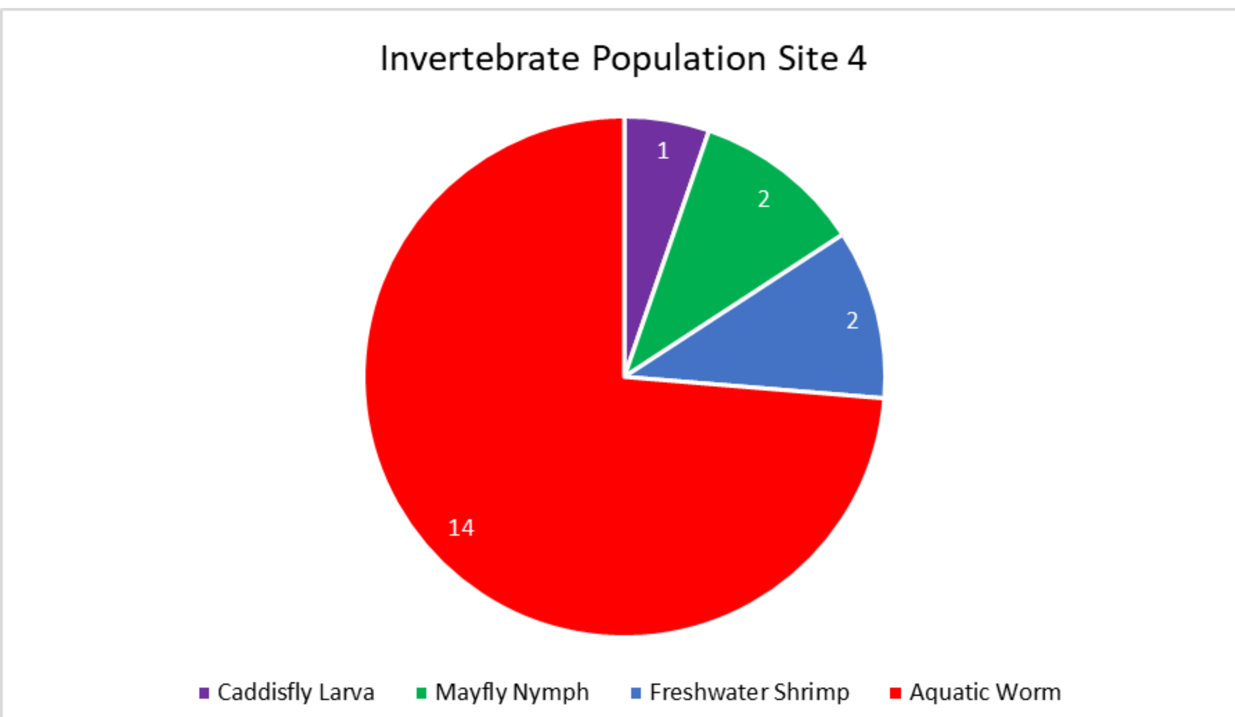

Figure 27: Invertebrate Population Site 4

Site Safety and Hazard Assessment (Luca)

Students are continually aware of their personal safety in the field. Some considerations taken were site water conditions, possible interactions with wildlife or other humans, water conditions, and accessibility hazards (**Table 11**). When possible, students parked well off the road to avoid potential accidents, wore appropriate footwear for slippery conditions, and always had one person watching the area for any other hazards like problem wildlife. Students also adhered by all government mandated Covid 19 guidelines.

Table 11: Site Accessibility and Safety Considerations

Site #	1	2	3	4	5
Water Conditions	Shallow depth Fast Flow	Moderate Depth, Moderate Flow	Shallow depth and fast flow	Shallow depth and fast flow	Deep and fast flow
Access Hazards	Road Traffic, steep slope	Road Traffic, Thick Brush	Road Traffic	Slippery Pathway	Slippery Path, Tripping Hazards
Wildlife/Human Interaction Possibility	Moderate	Low	Low	High	High
Accessibility	Parking Lot	Road	Road	Parking Lot, short walk	Parking Lot, Short Walk

3.0 Conclusion and Recommendations (Hunter)

Looking at the results from our analyses it was encouraging to see that most of the water quality parameters met the guidelines for aquatic life in BC and were acceptable, aside from two metals that were over the guidelines for both sampling events (calcium and aluminium). However, it is important to note that although this is higher than the guidelines, higher than recommend levels of aluminum and calcium have been noted in previous reports completed on the Millstone River. The Millstone River contains salmon, as seen by the students conducting the project. The Millstone River contains both pollution tolerant and pollution intolerant stream invertebrates. As the river becomes more urbanized, and developed in the lower reaches, the stream invertebrate communities change, becoming generally more pollutant tolerant. This indicates a poorer river heath in these lower reaches, and a healthier river closer to the headwaters. This is likely indicative of the various land uses throughout the Millstone River watershed and provides an opportunity for a potential salmon habitat improvement project in these negatively impacted lower reaches. It is imperative that water quality and stream invertebrate reports continue to be produced from the Millstone River so that a more encompassing and complete understanding of the overall health of the Millstone River over the years can be understood.

To improve accuracy in the report there are a few areas that could be worked on. For example, collecting the low flow data a little earlier may provide a more accurate and representative data set. This is because during the low flow data collection, the flow was already flowing at a high velocity due to the intense rains experienced a few days earlier. This would prove to be safer for those collecting samples and other information from the Millstone River, making it easier to cross and wade in. This would make accessing certain sites easier too.

As a final note, an immediate improvement that could be employed to increase the overall health of the Millstone River, would be a garbage clean up in the lower reaches. There is a considerable amount of garbage near site 5 on the sloped bank, leading up to the edge of Terminal Ave. This garbage was visible both in and out of the water.

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