Water Quality and Stream Invertebrate Assessment for the:

Millstone River,

Nanaimo, British Columbia, Canada.

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1.0 Executive Summary

Students of the Bachelor of Natural Resource Protection degree program at Vancouver Island University conducted a stream water quality assessment of the Millstone River located in Nanaimo, British Columbia. Students determined five stations along the Millstone River (an outflow of Brannen Lake) that are a representative of the entire river, and a control station chosen on Benson Creek, which flows into Brannen Lake. Stations that have been previously monitored were chosen for continuity of results. There were two sampling events, one at a low flow period and one during a higher flow period. Results will be compared to previous reports from previous years. Parameters tested and analyzed include: invertebrate populations, microbiology, pH, dissolved oxygen, conductivity, stream nutrients and metals present in stream. Results were analyzed in the field, the Vancouver Island University laboratory, and the ALS laboratory then compared to data from previous years. Overall water analyzed met BC Water Quality Guidelines with the exception of pH and coliform at some stations. Coliform results indicate fecal and total coliform are present in every station, although consistent from other years. The invertebrates collected and are indicative of moderately healthy stream since the EPT index was not significant. In general, metals tested at the ALS laboratory were below detection limits with the exception of some metals including calcium, strontium, magnesium, and several others. The dissolved oxygen levels are high enough to provide a healthy habitat for aquatic life. There are some suggested recommendations in this report to improve the quality of the Millstone River water. The students who conducted this assessment would like to acknowledge the organizations that provided funding for this report as well as Dr. Eric Demerse of Vancouver Island University for assisting the students in conducting the assessment.

Table of Contents

3.0 Introduction and Background Information

Four students currently enrolled in the third year of the Bachelor of Natural Resource Protection at Vancouver Island University conducted an environmental monitoring project on the Millstone River located in Nanaimo, British Columbia, under the direction of Dr. Eric Demers, course instructor for RMOT 306: Environmental Monitoring. The sampling took place on the afternoons of October 27, 2013 and November 17, 2013. The data that has been collected was assessed by the students and will also be added to the catalogue of data that has been accumulated by former students. This study's objective was to assess the river to identify any current environmental impacts, as well as potential impacts from agriculture and development that may occur in the future which may negatively affect the Millstone River in the future.

The Millstone River is in a watershed that encompasses Nanoose to South Wellington and covers approximately 100 square kilometers (Regional District of Nanaimo, 2013). The river itself spans over 14 kilometers through developed land from the south end of Brannen Lake, flowing toward Nanaimo's Inner Harbour into the Strait of Georgia. At the time of the first sampling event (October 27, 2013), the river was low and slow flowing; It was expected that during the second sampling event (November 17, 2013) the water level and velocity would be higher, our theory was proven correct. Six stations were sampled in total; five in which were taken from the Millstone River, as well as one from Benson Creek, which is a tributary that flows into Brannen Lake.

The Millstone River flows through a variety of land use areas that are agricultural, naturally forested, and urbanized. This indicates that, unlike in a more natural undeveloped area, most runoff from rainfall flows straight into the river and tributaries from fields or storm drains. The absence of soil and undergrowth may slow or minimize water filtration causing more harmful chemicals, pollution and garbage to accumulate from roads and urban areas to flow straight into the river (Regional District of Nanaimo, 2013).

In 1982 a fish ladder was constructed in Bowen Regional Park on the Millstone River due to concerns with low flow and obstacles for spawning coho salmon (*Oncorhynchus kisutch*). It was found that the spawning salmon were unable to swim up the ladder due to low flow, so in 2007 a side-channel was constructed in Bowen Regional Park near station 5 (the duck pond). This channel has created habitat not only for thousands of coho salmon juveniles but also for cutthroat trout (*Oncorhynchus clarkii)* and aquatic invertebrate species that are a key food source for salmonids (City of Nanaimo, 2008). There are 21 water licenses assigned at various locations on the Millstone River. Seventeen are for irrigation or for watering, one allows land improvement, and three are assigned to environmental agencies for the purpose of "conservation – stored water" (Government of British Columbia, 2013a). During periods of low flow, these licenses may cause water conservation and flow problems by draining the stream of water that would be valuable in maintaining high quality fish habitat. Livestock using the riparian area or pasture adjacent to the reaches of the Millstone River or its tributaries, as well as run off from fertilizers used in agricultural areas may have impacts on this particular stream.

4.0 Project Objective

The objective of this project is to sample and analyze the results of the Millstone River at a low and high flow period. Data concerning hydrology, invertebrate samples, microbiology, and water quality was collected and analyzed to gain a comprehensive overview of the river's health. The data will also be compared to background information from the last seven years by the public and government agencies to determine the changes in stream health over the long term. The findings are shared to the public, the City of Nanaimo, Nanaimo Regional District, British Columbia Conservation Foundation, and to the Department of Fisheries and Oceans Canada, all of which have funded enhancement projects on the Millstone River, including the aforementioned side channel.

5.0 Methods

5.1 Sampling Stations

We were assigned six sample station locations to assess water quality, microbiology, and invertebrate diversity as part of the environmental monitoring project. Five of these stations were located at various portions of the Millstone River and one location is on Benson Creek. Selection was based on easy vehicle and foot access, similarities in flow and substrate, and stations that provided a general representation of the Millstone River. The 2013 stations remained the same as in 2011 to help provide an accurate stream health history record. A station was recently added in the 2011 station assessment located near the Pryde Vista Golf Course off of Pryde Avenue, Nanaimo, BC. This sample station location was added to the Millstone River stream assessment because of the addition and enhancement of salmon spawning gravel in August 2011. The City of Nanaimo, British Columbia Conservation Foundation, and Department of Fisheries and Oceans funded this enhancement project (Bush, 2011). Students visited all stations on October 19, 2013 to collect initial proposal data.

Station 1 was located at the Biggs Road crossing of Benson Creek (10U0422745mE; 5450710mN) (Figure 1). The samples were taken from downstream of the road crossing. Benson Creek flows into Brannen Lake. Station 1 was surrounded by agricultural land with some riparian area bordering the stream. During Event 1 the stream was observed to be at low flow and substrate consisted of mainly cobble and gravel. The sampling portion includes glide and a riffle with a potential of a pool in increased water level. There was evidence of high flow periods because of potential of the bank full width. During the second event, the stream level was slightly higher. The embankment surrounding the sampling area has a low gradient with an easy trail access from the roadside.

Station 2 was located at the Biggs Road crossing of the Millstone River (10U4023344mE; 5450818mN) (Figure 2). Sampling took place from the downstream portion of the road crossing. This station was also surrounded by agriculture land. Cobble and gravel comprise the substrate in the sampling area, which was classified as a pool. The access was fair due to the embankment being steep with heavy vegetation. Caution is required when walking to the sample location in-stream.

Station 3 was located at the Durnin Road crossing of Millstone River (10U0426304mE; 5448963mN) (Figure 3). The sample location was on the upstream portion of the road crossing. Surrounding the sample station there were rural properties of residential acreage. At the time of the initial station visit, the stream had a medium flow, compared to increased flow later in the season. This sampling station was a combination of a glide and a pool. The substrate was a combination of cobble, gravel, and boulders. The access trail was absent of vegetation, as well as steep and narrow.

Station 4 was located at the southeast corner of the Pryde Vista Golf Course parking lot (10U0429080mE; 5447228mN) (Figure 4). This golf course was located at the south end of Pryde Avenue. The access was good and had an easy trail from the parking lot to the sampling location. The surrounding land use is recreational with a treed riparian area. The substrate contained gravel, cobble, and fines. Due to the addition of spawning gravel in August 2011, the predominant substrate was gravel. At the time of the initial station visit the flow was low. There was also a substantial amount of large woody debris in this section. The sampling area was through a glide portion of the river. Students were aware of the direction that golfers hit their golf balls, as a ball from the adjacent course had been found in the stream upon initial visit.

Station 5 was located at the outflow of the duck pond of the Millstone River Side Channel within Bowen Regional Park. The sample station was located at the downstream portion of the footbridge for the side channel (10U0430244mE; 5447304mN) (Figure 5). The sample station was easily accessible through footpaths within the park. This side channel was man-made and had a low gradual embankment. The substrate consisted of gravel and cobble and the surrounding land use was classified as recreational urban park with vegetation in close proximity to the side channel. The flow of this section was low and consisted of a glide in the first sampling event and a run in the second.

Station 6 was located by the footbridge crossing of the Millstone River at the end of Barsby Avenue, off of Prideaux Street (10U0430955mE; 5447094mN) (Figure 6). The access was rated as fair due to the steep embankment that was covered with heavy vegetation and human litter. Students used caution when walking to the sample location within the stream because of the human refuse observed on the first station visit on October 19, 2013, as well as individuals possibly inhabiting the area below the footbridge. The in-stream footing was fair due to the boulder and cobble substrate. At the initial station visit the flow was medium and comprised of a glide, while during the second event the water was higher and flowed in a run.

5.2 Water Quality and Stream Invertebrate

The sampling events took place on October 27, 2013 and November 17, 2013. On each date a variety of environmental assessments were conducted. Microbiology and aquatic invertebrate samples were conducted on the first sampling date (October 27, 2013) during the low flow period of the Millstone River. Only three stations were sampled for invertebrates, as shown in Table 1. At each station, triplicate samples were collected. On both sampling events (at predicted high and low flow periods) basic hydrology measurements were taken at stations 1, 2 and 5 (Table 1), in addition to samples for water quality samples were collected at all six stations. Basic hydrology measurements were taken to determine current water discharge of the Millstone River during the sampling dates. This was done by measuring the current wetted width, average depth, and water velocity. A metric tape measure was used to measure width and depth. Water velocity (metres per second) was calculated by recording the float-time of a ping-pong ball over a measured distance. By multiplying wetted cross-section area by water velocity an approximate river discharge was determined at both sample stations.

5.3 Parameters Tested

Water quality was determined in the field and laboratory analysis of water samples. At each station an electronic probe was used to determine dissolved oxygen (mg/L) and water temperature (ºC). The water samples were collected in plastic sample bottles at all six stations; these were stored in a fridge and then analyzed at Vancouver Island University (VIU).

Analysis of each sample was conducted to determine alkalinity, hardness, pH, nitrate, phosphate, metal content, turbidity, and conductivity levels. A duplicate sample was taken at one station on both sampling dates. To ensure that water quality testing produces were followed correctly; all members reviewed these procedures before each sampling event.

Additional samples from stations 1, 2, and 5 were collected and sent to the ALS Global Laboratories in Vancouver, B.C. At each sampling station three different bottle types were filled with water from the river. These samples were analyzed for water quality, nutrients and specific metal contents. All data collected was compared to the current B.C. Guidelines for Interpreting Water Quality (Government of British Columbia, 2013b). This will assist in determining if the Millstone River is being affected by any environmental impacts or contamination.

Water samples were collected at all six stations during the first sampling event using sterile 100 ml Whirl-Pak plastic bags. These samples were stored at a consistent temperature and then brought to VIU for laboratory analysis. The samples were analyzed for the amount of coliforms (total and fecal) and specifically *E. coli*. Each sample was filtered through a membrane using 25 ml of the collected water and then incubated at 37ºC for 24 hours in a coliform growth medium. This allowed us to visually assess the amount of coliforms within the 25 ml samples. These samples were multiplied by 4 to get the CFU/ 100ml. Each member reviewed and followed all provided guidelines for this process.

During the first sampling event stations 1, 2, and 5 were sampled for aquatic invertebrates. At each station triplicate samples were taken. Sample areas were in proximity to each other, and in appropriate similar substrate. Each sample was taken by the same student using a Hess sampler in a standardized way, then stored and later analyzed on October 30, 2013 to maintain live species for easier counting and identification. All samples were analyzed and counted individually by two team members to ensure more accurate results. The results were then entered into a categorized data sheet and used to calculate the EPT and biodiversity index of the river.

6.0 Results and Discussion

6.1 Water Quality

6.1.1 Field Measurements

The on-site water quality parameters for Event 1 and Event 2 were recorded into Table 2 and Table 3 respectively. During sampling Event 1, dissolved oxygen (DO) ranged from 10.4 to 11.5 milligrams per liter across all six stations; Event 2 had a slightly higher DO ranging from 10.5 to 12.7 milligrams per liter. The temperature for the five Millstone River stations during Event 1 ranged from 10.3 to 12.5 degrees Celsius (^{0}C) and station 1 on Benson Creek was recorded at 9.2 ^{0}C. Temperatures during Event 2 had a lower range from 7.5 to 8.8 ^{0}C for the Millstone River station and 5.9 ^{0}C for station 1 on Benson Creek. Water volume discharge, cubic meters per second (m^3/s), was calculated from Event 1 at 0.12 m^3/s for station 1, 0.38 m^3/s for station 2 and 0.18 m^3/s station 5. For Event 2 Water discharge was calculated to be higher; 0.37 m^3/s for station 1, 1.22 m^3/s for station 2 and 0.33 m^3/s station 3.

The recorded dissolved oxygen amount from both sampling events for all stations exceeds the BC water quality guideline of the 9.0 mg/l requirement (Government of British Columbia, 2013b). This accounts for fish at all life stages and invertebrates. There was little variation of DO between stations within sampling events. Event 2 had a significant higher DO when comparing averages with Event 1, most likely due to drop in average water temperature 10.7 ^{0}C (October 27, 2013) to 7.6^{0}C (November 17, 2013). In comparison to the Fall 2010 report, the recorded DO and temperature was slightly lower for both sampling events (Clark et al, 2010). This may because of varied sampling dates and weather conditions, with the exception of the control (station 1), which the Fall 2010 report did not use. It should be noted that the control, station 1, shows a significant variation in temperature when compared to the other stations in each sampling event (Tables 2 and 3); a probable explanation being that station 1 is fed from the upper part of the watershed and not Brannen Lake.

There is a significant increase in water discharge from Event 1 to Event 2 for each of the three stations, approximately a 270% averaged increase. This is most likely due to seasonal change in local climate and precipitation. The recorded discharge at station 2 was relatively higher than station 1 and station 5 (Table 2 and 3); Station 2 is the outflow of Brannen Lake which may account for its increased water discharge.

6.1.2 VIU Laboratory Analyses

Both fecal and total coliform were found at all six stations. The levels of fecal coliform were increased (116 CFU/100 millimeters) at station 2, which was the first station from the outfall of Brennan Lake, Nanaimo, BC compared to station 1 (28 CFU/100 millimeters) where Benson Creek emptied into Brannen Lake. The fecal coliform levels increased continuously downstream except for station 3 where the coliform levels dropped to 60 CFU/100 millimeters. There was a maximum of 168 CFU/ 100 millimeters of fecal coliform at station 4. This is near the Pryde Vista Golf Course, and adjacent to Buttertubs Marsh. There is a high concentration of waterfowl in this area that can contribute to the high numbers of fecal colonies. In comparison, the total coliform for station 4 (332 CFU/ 100 millimeters) was not the maximum for all the stations. Station 2 had the maximum total coliform colonies of 404 CFU/ 100 millimeters. Station 5 had 132 CFU/100 millimeters which was the least of all 6 stations. Refer to Table 4 for the specific coliform colonies for every station. The water collected in both the Millstone River and Benson Creek exceed the BC Water Quality Guidelines (Government of British Columbia, 2013b).

Fecal coliform did not change drastically from studies on the Millstone River in 2009 and 2011. In the 2011 and 2009 studies, fecal coliform was observed at a maximum at station 4 (Goeppel et al. 2009; Mc Neill, et al. 2011). Station 4 in this study also had the maximum with 168 CFU/100 ml. In 2011, there was 0 CFU/100 ml at station 1 where as in this study station 1 had 28 CFU/100 ml (Mc Neill, et al. 2011). Total coliform in 2013 was the highest at station 2 with 404 CFU/100 ml. In comparison, total coliform at station 4 in 2011 was highest at 516 CFU/ 100 ml (Mc Neill, et al. 2011). In 2009, the average total comparison between all stations was 519 CFU/ 100 ml (Goeppel et al 2009).

During the first sampling event, all water quality parameters analyzed in the VIU lab met drinking water quality guidelines except pH at the three uppermost stations. All the water was categorized as “soft” during both sampling events, and got softer as the fall progressed to the later sampling event. During the second sampling, all stations met all BC Drinking Water Quality Guidelines (Government of British Columbia, 2013b).

Impreciseness was noted between the replicate and sample taken at station 3 during both sampling events. In Event 1 the parameters nitrate and turbidity had a greater than 25% difference between the sample and replicate. Phosphate and hardness were more than 25% different during Event 2.

Other trends that were noted include pH becoming more basic as stations go downstream. Conductivity, hardness, and turbidity also increased downstream. Phosphate increased during sampling event two. It is hypothesized that alkalinity was higher in sampling event one because the stream flow increased and diluted due to rains and runoff during the second event. This is similar to past data from previous reports (Goeppel et al. 2009; Mc Neill, et al. 2011).

6.1.3 ALS Laboratory Analyses

All the ALS Data from both sampling events was compiled into Table 5. The tables were divided into three parts: physical tests, anions and nutrients, and total metals. This data was collected and analyzed from stations 1, 2 and 5. Recorded conductivity from Event 1 ranged from 40.8-109.0 uS/cm. The recorded conductivity from Event 2 was slightly higher overall, and ranged from 68.1-133.0 uS/cm. Samples from Event 1 resulted in a hardness range of 16.1-38.0mg/L (of $CaCO3-$) compared to the Event 2 hardness range of 27.4-46.1mg/L (of $CaCO3-$). The pH was recorded in both sampling events in a range from 7.43-7.82. Total nitrogen ranges from 0.134-0.38mg/L for both events, with a higher average in Event 1. Total phosphorous results showed a trend of increasing concentrations downstream for both events; Event 1 had a range of 0.0022-0.0296mg/L, while Event 2 showed an increase with a range of 0.005-0.0305mg/L.

The majority of metals tested were below the ALS Laboratory minimum detection limits. The following metals were significantly above the minimum detection limits. Calcium was the most abundant metal, with similar concentration ranges in both events; the lowest calcium level was in Event 1 at 4.49mg/L and the highest was in Event 2 at 13.0mg/L. The results also recorded minimal amounts of certain heavy metals, including Strontium which ranges from 0.0176-0.0954mg/L. Manganese is also present in the samples from station 2 and 5 in low levels, ranging from 0.0197-0.0313mg/L.

The ALS conductivity as stated before, followed an increasing downstream trend. This trend as well as its concentrations' ranges are comparatively similar to results from the Fall 2010 report (Clark et al. 2010). According to the BC water quality guidelines , the hardness results from ALS rates all of the samples as "soft water" having hardness levels less than 60 mg/l of CaCO3 (Government of British Columbia, 2013b). These results were again similar to the ALS results for hardness report by the Fall 2010 report (Clark et al. 2010). The pH levels observed by ALS of all stations for both sampling events fell well within the BC water quality guidelines of 6.5 to 9.0 pH (Government of British Columbia, 2013b). There was also no significant difference between pH levels between this reports' results and the Fall 2010 report results (Clark et al. 2010).

Nutrients amount recorded by ALS were again very similar to the results reported by the Fall 2010 report except for the fish bypass channel stations (Clark et al. 2010). This report's bypass channel station was below the lower duck pond, which may account for the higher amount of total phosphorus and ammonia. According to the BC water quality guidelines the only station rated as eutrophic is station 5 during both samplings events with a total phosphorus amount higher than 0.035 mg/l (Government of British Columbia, 2013b). The nitrogen to phosphorus ratios for station 5 are: 12.8 N to 1 P for Event 1 and 9.2 N to 1 P for Event 2.

The ALS results were compared to the BC water quality guidelines for each of the observed metals and neither exceeds their guidelines (Government of British Columbia, 2013b). Station 1 and station 2 are considered to have a low sensitivity to acidic change and station 5 had a moderate sensitivity during Event 1. For Event 2, only station 2 showed a change in acidic sensitivity from low to moderate. Compared to the Fall 2010 report, the metal amounts share the same detected metal profile (Clark et al. 2010). It should also be noted the minimum detection limits for several of the metals, such as arsenic, aluminum, nickel and silver, reported by ALS are higher than the BC water quality guideline therefore it is undetermined since the ALS cannot detect amounts as minimal as the guidelines.

6.1.4 Stream Invertebrate Communities

The average overall assessment rating was 3.0 out of 4.0 for station 1. The Pollution Tolerance Index was 4.0 or good; meaning the diversity of taxon found was very good in each category. The EPT Index was 3.0 or acceptable, indicating an acceptable amount of pollution intolerant invertebrates (*Ephemeroptera, Plecoptera,* and/or *Trichoptera*). The EPT to Total Ratio of the site was 2.0 or marginal and EPT invertebrates took up 49% of the invertebrates collected. The samples were 41% stonefly nymph which produced a Predominant Taxon Ratio of 3.0 or acceptable.

At station 2 the average overall assessment rating was 2.25 out of 4.0. The pollution Tolerance Index was 4.0 or good; this explains there were a diverse number of taxa found in each of the pollutant tolerance categories. The EPT index was rated 2.0 or marginal. This describes that there was not a significant number of pollutant intolerant invertebrates that constitute the EPT index: The EPT to Total Ratio was 1.0 or poor. This states that the number or EPT invertebrates compared to the total number of invertebrates was found very low; only 5.9% of invertebrates found were in the EPT index. The Predominant Taxon Radio was 2.0 or marginal; furthermore, there were a high number of invertebrates counted in one group compared to the total. Amphipods, or scuds, consisted of 67% the total invertebrates in this station.

At station 5 the average overall assessment rating was 1.5 out of 4.0, this is between marginal and poor. The Pollution Tolerance Index was 3.0; this demonstrates that there was a marginal diversity found in each category of taxa. The EPT Index was rated at 1.0 or poor; meaning there was a very low amount of pollution intolerant taxa (*Ephemeroptera, Plecoptera,* or *Trichoptera*). The EPT to Total Ratio was 1.0 or poor. This states that the number of EPT invertebrates in category 1, the pollution intolerant category, was low. Only 1% of the total invertebrates in this sample were from the EPT invertebrates. Scuds (amphipods) encompass 92% of the invertebrates collected at station 5. This is indicative of a poor diversity sample. The Predominate Taxon Ratio was 1.0 or poor.

At stations 1, 2 and 5 there was a total of 504 invertebrates from 11 different taxonomic groups. All sampling took place on October 27, 2013. It was found that the invertebrate density seemed to increase in the downstream sections of the river. Station 5 had the highest invertebrate density per total area sampled at $1,011/m^2$. Category 1 species were more prominent at stations 1 and 2. The lack of important indicator invertebrates at station 5 may be the result of the river flowing through an urbanized residential area. The majority of invertebrates found were scuds (amphipods), aquatic worms and caddisfly larvae. Overall site assessment rating for all stations ranged from 1.5 to 3.0, or poor/marginal to acceptable. Calculations in the pollution tolerance index concluded that station 5 had the poorest rating. Where as the best rating was found at station 1; the land adjacent to this station was less developed farmland as well as natural undeveloped woodland.

7.0 Conclusion

Overall, it may be concluded that the Millstone River is currently in good health. This salmonids-bearing stream contains organisms, both vertebrates and invertebrates that are sensitive to poor water quality. The guidelines set out for aquatic life by the provincial government are all being met at this time. There is still maintenance required to keep the stream in good health.

8.0 Recommendation

To improve accuracy in data, we suggest multiple sampling events during predicted low to medium to high flow periods. This would be beneficial to analysis because more information, particularly encompassing a larger temporal data set, would give better background for analysis. Ideally, sampling would occur during summer low flow and after first flush.

In addition, the samples taken should be analyzed in a lab that can test with a minimum detection limit that is lower than the maximum concentration level in the BC Guidelines. Also, due to the inaccuracies between the replicates taken from the same station, the authors recommend multiple samples from more than one station.

Overall, the Millstone River appears to be in good health and the best recommendations are to continue monitoring the stream, throughout the seasons with multiple community volunteer and student groups.

9.0 Acknowledgments

The authors would like to acknowledge the Department of Fisheries and Oceans, BC Conservation Foundation, the City of Nanaimo, as well as the Regional District of Nanaimo in all their efforts to continually facilitate this stream assessment by providing us with the funding to be able to have the samples analyzed and processed. Additional support from fellow students enrolled in the course Environmental Monitoring (RMOT 306) at Vancouver Island University is greatly appreciated. Many thanks also to Vancouver Island University's Natural Resource Protection and Biology departments for proving some of the necessary laboratory tools and field instruments needed for analyzing water and invertebrate samples. Notable regard to ALS Laboratory for providing a reduced cost for sample analysis. Lastly thanks to Sarah Greenway, John Morgan and Eric Demers for their guidance, support and help during the field and laboratory process.

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11.0 Appendix

11.1 Figures

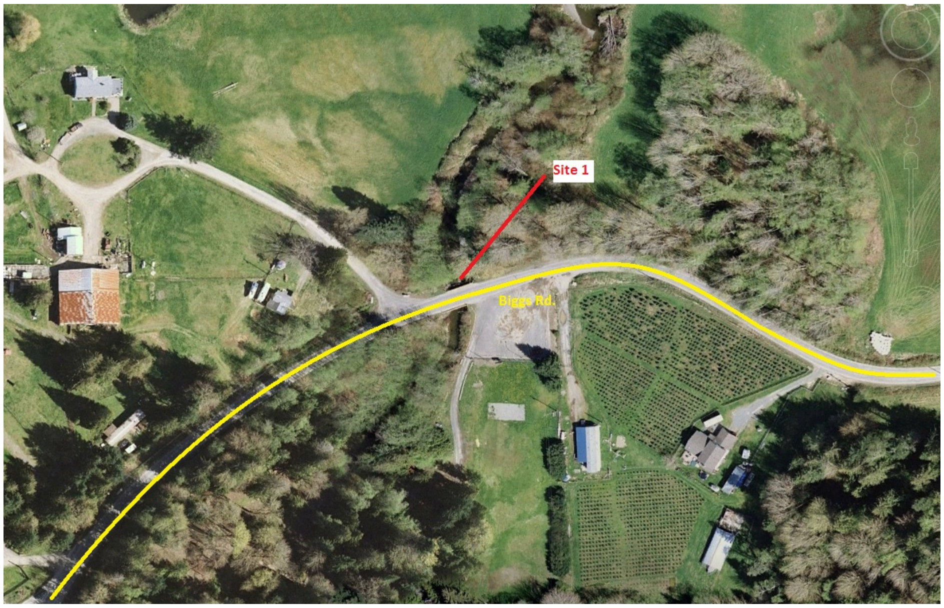

Figure 1: Location of station 1 for water quality environmental monitoring on Benson Creek, Nanaimo, British Columbia.

Figure 2: Location of station 2 for water quality environmental monitoring on the Millstone River, Nanaimo, British Columbia.

Figure 3: Location of station 3 for water quality environmental monitoring on the Millstone River, Nanaimo, British Columbia.

Figure 4: Location of station 4 for water quality environmental monitoring on the Millstone River, Nanaimo, British Columbia.

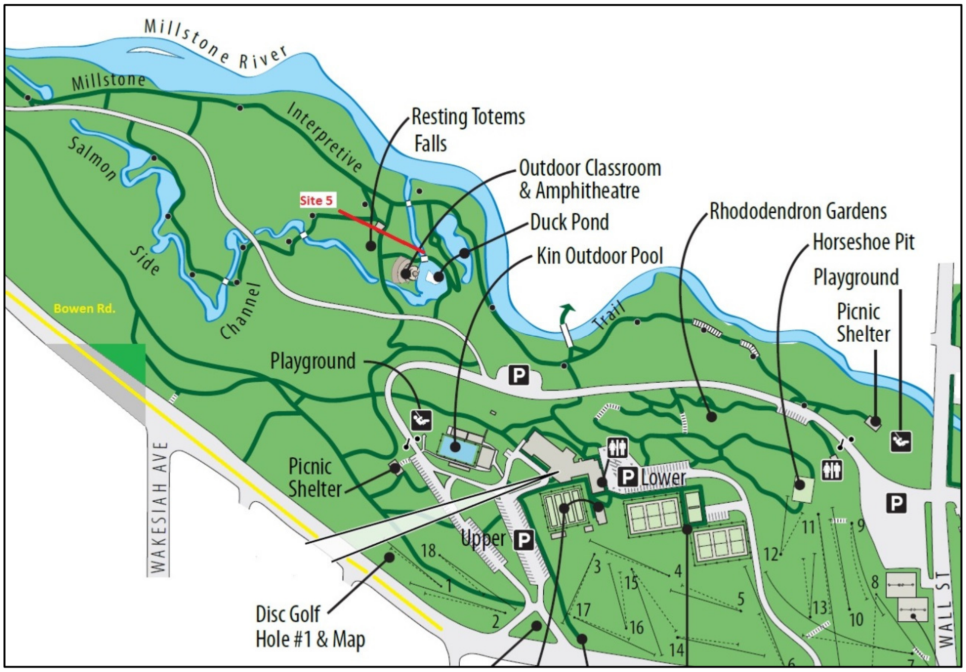

Figure 5: Location of station 5 for water quality environmental monitoring on the Millstone River Side Channel, Nanaimo British Columbia.

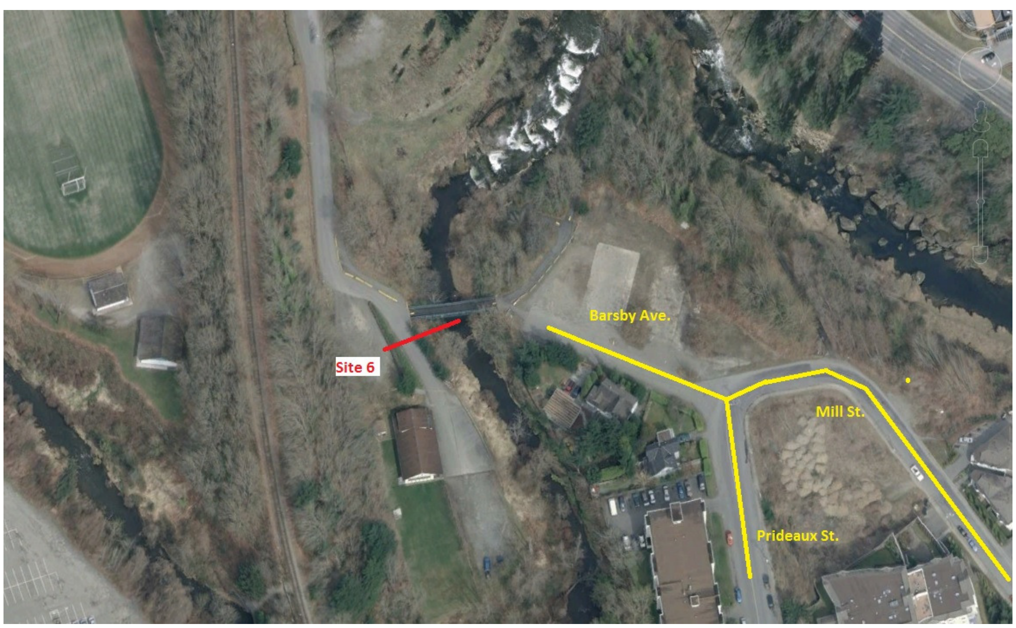

Figure 6: Location of station 6 for water quality environmental monitoring on the Millstone River, Nanaimo, British Columbia.

11.1 Tables

Table 1: Parameters tested for 1st and 2nd sampling events.

Station	Hydrology		Water Quality		Microbiology		Aquatic Invertebrate Sampling	
Sampling Event	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
#1	No	No	Yes	Yes	Yes	No	Yes	No
#2	Yes	Yes	Yes	Yes	Yes	No	Yes	No
#3	No	No	Yes	Yes	Yes	No	No	No
#4	No	No	Yes	Yes	Yes	No	No	No
#5	Yes	Yes	Yes	Yes	Yes	No	Yes	No
#6	No	No	Yes	Yes	Yes	No	No	No

Table 2: Results of field data recorded from Event 1

Sampling Event #1	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Dissolved Oxygen (Mg/L)	11.2	11.0	10.4	10.5	10.8	11.5
Temperature (C)	9.2	12.5	11.0	10.6	10.3	10.6
Mean Wetted Depth (M)	0.10	0.34			0.19	
Wetted Width (M)	2.30	5.90			3.50	
Velocity (M/S)	0.53	0.19			0.27	
Discharge (M^3/S)	0.12	0.38			0.18	

Table 3:Results of field data record from Event 2

Sampling Event #2	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Dissolved Oxygen (Mg/L)	12.8	10.5	11.8	12.1	12.3	12.7
Temperature (C)	5.9	8.8	7.9	7.5	7.6	7.6
Mean Wetted Depth (M)	0.21	0.43			0.25	
Wetted Width (M)	2.30	7.10			3.75	
Velocity (M/S)	0.77	0.40			0.35	
Discharge (M^3/S)	0.37	1.22			0.33	

Table 4: Coliform results from first sampling event

Station	1	2	3	4	5	6
Fecal Coliform	28	116	60	168	124	132
Total Coliform	228	404	220	332	132	220

Table 5: Results from the ALS Laboratory from Event 1 and Event 2

ALS Results	Event 1				Event 2		
	Site 1	Site 2	Site 5		Site 1	Site 2	Site 5
Physical Tests							
Conductivity (uS/CM)	40.8	71.4	109		68.1	74.5	133
Hardness (as CaCO3) (Mg/L)	16.1	28.2	38		27.4	30.2	46.1
pH	7.61	7.45	7.64		7.43	7.61	7.82
Anions and Nutrients							
Ammonia, Total (as N) (Mg/L)	<0.0050	0.0057	0.0382		<0.0050	<0.0050	0.0249
Nitrate (as N) (Mg/L)	0.153	0.0517	0.14		0.0359	<0.0050	0.0224
Nitrite (as N) (Mg/L)	<0.0010	<0.0010	0.0016		<0.0010	<0.0010	<0.0010
Total Nitrogen (Mg/L)	0.216	0.215	0.38		0.134	0.22	0.28
Orthophosphate-Dissolved (as P) (Mg/L)	<0.0010	0.001	0.0036		<0.0010	<0.0010	0.0013
Phosphorus (P)-Total (Mg/L)	0.0022	0.0068	0.0296		0.005	0.0101	0.0305
Total Metals							
Aluminum (Al)-Total (Mg/L)	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20
Antimony (Sb)-Total (Mg/L)	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20
Arsenic (As)-Total (Mg/L)	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20
Barium (Ba)-Total (Mg/L)	<0.010	<0.010	0.012		<0.010	<0.010	0.015
Beryllium (Be)-Total (Mg/L)	<0.0050	<0.0050	<0.0050		<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total (Mg/L)	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20
Boron (B)-Total (Mg/L)	<0.10	<0.10	<0.10		<0.10	<0.10	<0.10
Cadmium (Cd)-Total (Mg/L)	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Calcium (Ca)-Total (Mg/L)	4.49	7.59	10.6		7.61	8.04	13
Chromium (Cr)-Total (Mg/L)	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Cobalt (Co)-Total (Mg/L)	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Copper (Cu)-Total (Mg/L)	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Iron (Fe)-Total (Mg/L)	<0.030	0.12	0.369		0.037	0.21	0.442
Lead (Pb)-Total (Mg/L)	<0.050	<0.050	<0.050		<0.050	<0.050	<0.050
Lithium (Li)-Total (Mg/L)	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Magnesium (Mg)-Total (Mg/L)	1.18	2.24	2.78		2.04	2.47	3.33
Manganese (Mn)-Total (Mg/L)	<0.0050	0.0192	0.0211		<0.0050	0.0197	0.0313
Molybdenum (Mo)-Total (Mg/L)	<0.030	<0.030	<0.030		<0.030	<0.030	<0.030
Nickel (Ni)-Total (Mg/L)	<0.050	<0.050	<0.050		<0.050	<0.050	<0.050
Phosphorus (P)-Total (Mg/L)	<0.30	<0.30	<0.30		<0.30	<0.30	<0.30
Potassium (K)-Total (Mg/L)	<2.0	<2.0	<2.0		<2.0	<2.0	<2.0
Selenium (Se)-Total (Mg/L)	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20
Silicon (Si)-Total (Mg/L)	3.55	3.29	3.78		4.3	3.25	3.57
Silver (Ag)-Total (Mg/L)	<0.010	<0.010	<0.010		<0.010	<0.010	<0.010
Sodium (Na)-Total (Mg/L)	<2.0	3.4	7.4		3.1	3.8	9.9
Strontium (Sr)-Total (Mg/L)	0.0176	0.0288	0.0737		0.0281	0.0284	0.0954
Thallium (Tl)-Total (Mg/L)	<0.20	<0.20	<0.20		<0.20	<0.20	<0.20
Tin (Sn)-Total (Mg/L)	<0.030	<0.030	<0.030		<0.030	<0.030	<0.030
Titanium (Ti)-Total (Mg/L)	<0.010	<0.010	0.013		<0.010	<0.010	0.015
Vanadium (V)-Total (Mg/L)	<0.030	<0.030	<0.030		<0.030	<0.030	<0.030
Zinc (Zn)-Total (Mg/L)	<0.0050	<0.0050	<0.0050		<0.0050	<0.0050	<0.0050