Water Quality Assessment on the C.W. Young Channel of the Englishman River, Parksville, British Columbia

Report prepared by:
Jillian Bjarnason and Keighley Doerksen

Report prepared for:
Dr. Eric Demers, Vancouver Island University
December 14, 2018

Executive Summary

The Englishman River located in Parksville, British Columbia, provides quality habitat for anadromous salmon and resident trout species. In 1992, the C.W. Young Channel was constructed within Englishman River Regional Park in an effort to enhance salmon habitat. The 4.1 kilometre channel runs parallel to the river's mainstem and has evolved into some of the most important salmon spawning and rearing habitat along the central island.

Annual assessments of the channel have taken place since 2008 in order to analyse water quality and overall stream health. In previous years, overall health was determined by conducting water quality analyses, microbiology (coliform) testing, and invertebrate sampling. The results obtained have assisted in monitoring potential environmental impacts of increased agricultural, recreational, and industrial activities within the watershed. In addition, the project has provided an opportunity for Vancouver Island University (VIU) students to practice skills and apply knowledge in a field and laboratory setting.

This report focusses on water quality parameters at four sites along the C.W. Young Channel. Sample collection took place in the C.W. Young Channel located within Englishman River Regional Park and laboratory analyses were conducted at the VIU Laboratory under the supervision of Dr. Eric Demers. Confirmation of these results were supported by tests run concurrently by ALS Laboratories located in Vancouver, British Columbia. Overall, water quality results obtained by VIU and verified by ALS, in conjunction with field observations and measurements, indicate that the C.W. Young Channel is in good health and will continue to support aquatic life.

Table of Contents

List of Tables 1

List of Figures 1

1.0 Introduction and Background 3
- **1.1 Project Overview** 3
- **1.2 Background** 4
- **1.3 Historical Review** 5
- **1.4 Potential Environmental Concerns** 5

2.0 Project Objectives 6

3.0 Environmental Sampling and Analytical Procedures 6
- **3.1 Sampling Program** 6
  - 3.1.1 Sampling Locations 6
  - 3.1.2 Habitat Characteristics 7
  - 3.1.3 Sampling Frequency 8
- **3.2 Basic Hydrology** 9
- **3.3 Water Quality** 9
  - 3.3.1 Field Measurements 9
  - 3.3.2 Water Sample Collection 10
  - 3.3.3 VIU Laboratory Analyses 10
  - 3.3.4 ALS Laboratory Analyses 11
  - 3.3.5 Quality Assurance/Quality Control 11
  - 3.3.6 Data Analyses, Comparison to Guidelines 11

4.0 Results and Discussion 12
- **4.1 General Field Conditions** 12
  - 4.1.1 Hydrology 12
- **4.2 Water Quality** 13
  - 4.2.1 Field Measurements 13
  - 4.2.2 VIU Laboratory Analyses 16
  - 4.2.3 ALS Laboratory Analyses 22
  - 4.2.4 Quality Assurance/Quality Control 25

5.0 Conclusion and Recommendations 25

6.0 Acknowledgments 26

7.0 References 27

8.0 Appendices 28
- **8.1 Appendix A** 28
- **8.2 Appendix B** 30

List of Tables

Table 1. Water quality and stream invertebrate sampling conducted at Site 1 through 4 on the C.W. Young Channel on the Englishman River, during October (A) and November (B) 2018. 9

Table 2. Hydrology measurements at Site 2 on the C.W. Young Channel taken on sampling event 1 (October 31, 2018) and sampling event 2 (November 21, 2018). 13

Table 3. Field measurements of temperature and dissolved oxygen taken at four sites along the C.W. Young Channel on October 31st, 2018. 14

Table 4. Field measurements of temperature and dissolved oxygen taken at four sites along the C.W. Young Channel on November 21st, 2018. 14

Table 5. VIU water quality results for five parameters tested on October 31st, 2018. 16

Table 6. VIU water quality results for five parameters tested on November 21st, 2018. 17

Table 7. Sampling containers and preservatives used for ALS water quality samples taken at the C.W. Young Channel. 22

Table 8. ALS Laboratory results for water samples collected at three sites on the C.W. Young Channel on October 31, 2018 and November 21, 2018. 24

List of Figures

Figure 1. Location of the C.W. Young Channel (orange) in proximity to the Englishman River (blue). 3

Figure 2. Location of Englishman River watershed on the central east coast of Vancouver Island. 4

Figure 3. Approximate locations of sampling sites on the C.W. Young Channel of the Englishman River. 7

Figure 4. Comparative graph of temperature and dissolved oxygen level at four sites along the C.W. Young Channel taken during two sampling events (October 31, 2018 and November 21, 2018). 15

Figure 5. Comparative graph of pH and alkalinity of five water samples from the C.W. Young Channel taken from four sites during two sampling events (October 31, 2018 and November 21, 2018). 18

Figure 6. Comparative graph showing decreased turbidity levels from the first sampling event (October 31, 2018) to the second sampling event (November 21, 2018). 19

Figure 7. Comparative graph showing conductivity levels from the first sampling event (October31, 2018) and the second sampling event (November 21, 2018). 20

Figure 8. Comparative graph showing hardness levels from the first sampling event (October 31, 2018) and the second sampling event (November 21, 2018). 21

1.0 Introduction and Background

1.1 Project Overview
(Keighley Doerksen)

Jill Bjarnason and Keighley Doerksen, students at Vancouver Island University, proposed the task of conducting an environmental monitoring assessment on the Englishman River in Parksville, British Columbia. The specific location of the monitoring took place on the C.W. Young Channel (Figure 1), located southwest of Parksville in Englishman River Regional Park. Under the supervision of Dr. Eric Demers, the water sampling occurred between October 27 and November 21, 2018. Two visits took place during this time period; one in a low-flow setting and the other in a high-flow setting, in order to collect samples to test water quality and invertebrate community health. The C.W. Young Channel of the Englishman River has been tested for water quality since 2008 by various agencies such as Regional District of Nanaimo, Department of Fisheries and Oceans, British Columbia Conservation Foundation, and Vancouver Island University (VIU) Students enrolled in an Environmental Monitoring class. Having conducted this environmental monitoring assessment, we are able to contribute to the data collected in previous years, by providing results of water quality and invertebrate community health analyses, and provide some insight on possible complications that the channel may face in the future.

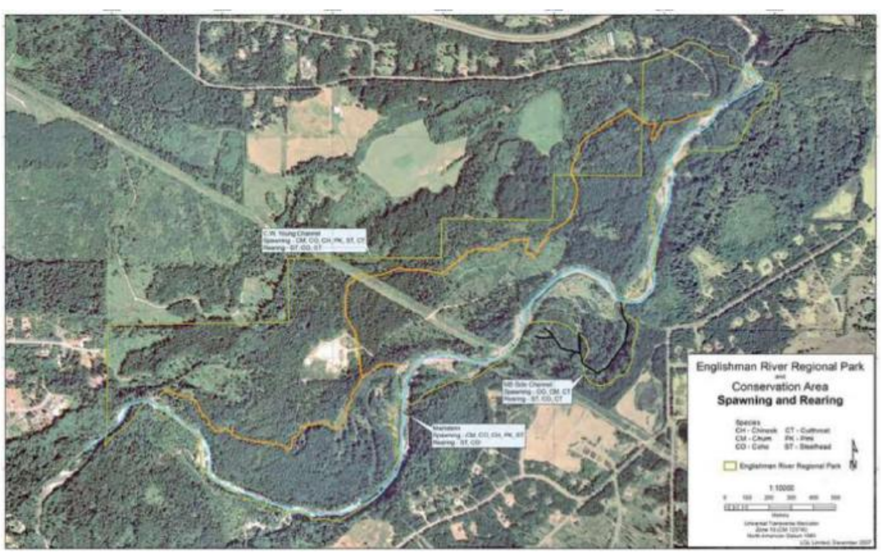


Figure 1. Location of the C.W. Young Channel (orange) in proximity to the Englishman River (blue). Both systems are found within the Englishman River Regional Park boundary (yellow) (Hawkes et al. 2008)

1.2 Background
(Keighley Doerksen)

Situated on the eastside of Vancouver Island and southwest of Parksville, British Columbia, the Englishman River runs about 28 kilometers in length. It flows from Mount Arrowsmith towards the northeast, and drains into the Georgia Strait north of Craig Bay. With a total watershed area (Figure 2) of 324km² drained from the Englishman River, there are four main tributaries that flow into the Englishman River. These include South Englishman River, Centre Creek, Morison Creek and Shelley Creek (Decker et al. 2003). All five species of anadromous salmon as well as rainbow and cutthroat trout can be found in the Englishman River, which easily makes it one of the most important salmon bearing streams on the central eastside of Vancouver Island (McCulloch 2005). About 16 kilometers upstream from the mouth of the river, Englishman River Falls creates a natural barrier to the migration of the anadromous fish. Most of the juvenile salmonid habitat is provided in the lower 8 kilometers of the Englishman River, which is low gradient (< 2%). Over the years populations of salmonids in the Englishman river have decreased, due to clear-cut logging, urbanization, overfishing, and poor ocean survival (Decker et al. 2003).

Figure 2. Location of Englishman River watershed on the central east coast of Vancouver Island (Silvestri 2007).

1.3 Historical Review
(Keighley Doerksen)

Although most of the Englishman River watershed is privately owned for the production of timber (Decker et al. 2003), it does include the Englishman River Provincial Park (97 ha) as well as the Englishman River Regional Park (207 ha) where it is used frequently for a variety of recreational uses such as camping, swimming, hiking, biking and fishing. The Englishman River is located within the Nanaimo Lowland ecoregion established by the Ministry of Environment for Vancouver Island. The portion of the Englishman River which includes the C.W. Young Channel is found to be in the Coastal Douglas-fir (CDF) and Coastal Western Hemlock (CWH) biogeoclimatic zones (Barlak et al. 2010). In the Englishman River watershed, approximately 90% of the land base has been logged in the past 50 years, leaving the watershed to consist mostly of second growth coniferous forest (Decker et al. 2003).

1.4 Potential Environmental Concerns
(Keighley Doerksen)

There are many potential environmental concerns in the Englishman River area that would affect the quality of the water in the channel greatly. Human related concerns include timber harvesting, agriculture, rural and urban residential, light industrial development, and recreation. Natural concerns that would affect the quality of the water would include natural erosion and the presence of wildlife (Barlak et al. 2010). The stream channels in the Englishman River have suffered through slope instability, landslides, altered run-off patterns and sediment loading due to reduced forest cover and wide-spread road construction. Subsequently, the Englishman River then experienced low summer flows, winter flooding, unstable channels and the deterioration of riparian cover (Decker et al. 2003). As timber harvesting and recreational activities continue to take place in the Englishman River watershed, it is likely that the condition of the stream and the organisms inhabiting it will remain in a fragile state.

2.0 Project Objectives
(Keighley Doerksen)

The main objective of this assessment was to monitor the environmental impacts on the C.W. Young Channel of the Englishman River. Four sites along the C.W. Young Channel were visited twice (On October 31, 2018 and November 21, 2018) and samples were taken to test the hydrology, water quality, microbiology, and stream invertebrate community health in the channel. After collection of the samples, they were analysed at VIU Laboratory located in Nanaimo, British Columbia, as well as tested at ALS Laboratories located in Vancouver, British Columbia. Results of the analysed samples have been compared and added to the data collected in the previous years, dating back to 2008. These results will be used to determine the overall water quality of the C.W. Young Channel. The data obtained from this assessment supports the long-term study of the Englishman River and the C.W. Young Channel, as well as reveals any changes in overall stream health from past years.

3.0 Environmental Sampling and Analytical Procedures

3.1 Sampling Program
(Keighley Doerksen)

3.1.1 Sampling Locations

There were four sites (Figure 3) located along the C.W. Young Channel of the Englishman River that were visited to complete this assessment. These four sites have been chosen previously based on accessibility and data from these sites can provide an accurate assessment of the channel as they adequately cover the length of the C.W. Young Channel. These four sites have also been consistently monitored for environmental impacts every year since 2008 (Demers 2016).

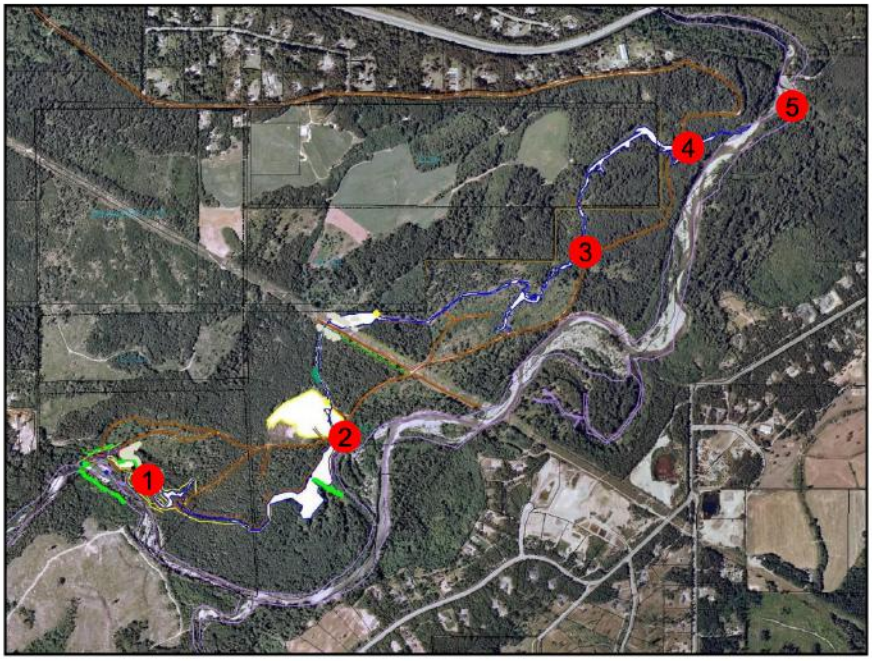


Figure 3. Approximate locations of sampling sites on the C.W. Young Channel of the Englishman River (Demers 2016).

3.1.2 Habitat Characteristics

An initial assessment of the C.W. Young Channel of the Englishman River and the four sampling sites was conducted on October 17, 2018. All four sites were easily accessible by the access road in Englishman River Regional Park.

Site 1 is located at the intake valve where water enters the C.W. Young channel from the Englishman River (10 U 405267 m E, 5459846 m N). Samples were taken on the dock side of the metal gate, as it was shallower than the pool where the intake valve is found. Substrate at this site consist mostly of coarse gravel. This site is open with not much canopy cover, and very little large woody debris is found in the swamp-like pool. The path to the sampling spot is steep and slippery with a bit of a drop to get into the water.

On the right side of the main access road there is pool that flows into a culvert that passes underneath the road (10 U 406143 m E, 5459962 m N). Site 2 is on the left side of the road where there is a riffle that flows from the culvert. Samples were taken in the riffle section of the channel just behind the culvert. Substrate at this site consist of coarse gravel, cobble, and some boulders. There is low to medium riparian and canopy cover at this site, and lots of large woody debris within the channel. This site is close to the main access road, but enough to the side to ensure safety.

Site 3 is located to the left of the main access road, and can be accessed by a trail located between the two root wads of fallen trees (10 U 407089 m E, 5460663 m N). Samples were taken in the rocky substrate downstream from the riffle. The substrate at this site consists mostly of coarse gravel and cobble. The canopy cover at this site is very open, and there is lots of large woody debris within the channel. There is easy access into the stream, however some risk exists at this site, as bears have been known to frequent this location.

Site 4 is located to the right of the main access road. There is a metal bridge and cement structure at this site (10 U 407495 m E, 5461056 m N). Samples were taken in the riffle downstream of the metal bridge. The substrate at this site consist mostly of large cobble, with some boulders and coarse gravel. There is low riparian cover, and an almost closed canopy cover. There is easy access into the stream, however the rocks surrounding the channel can be slippery when the weather is rainy.

3.1.3 Sampling Frequency

For this assessment of the C.W. Young Channel of the Englishman River, two sampling events took place (Table 1). In an effort to obtain samples in both a low-flow and high-flow setting, the samples were taken approximately three weeks apart. The dates when samples were taken were October 31, 2018 and November 21, 2018. These dates coincided with the dates the laboratory was available at VIU. During the first sampling event, hydrology was sampled at one site on the C.W. Young Channel and water quality was sampled at all four sites. During the second sampling event, hydrology was sampled at one site, while water quality was sampled at all four sites.

Table 1. Water quality and stream invertebrate sampling conducted at Site 1 through 4 on the C.W. Young Channel on the Englishman River, during October (A) and November (B) 2018.

Water Quality					
Site	**Field Measurements**	**VIU Analyses**	**ALS Lab Analyses**	**Microbiology**	**Stream Invertebrates**
1	A, B	A, B	A, B	A	A
2	A, B	A, B	A, B	A	-
3	A, B	A, B	-	A	-
4	A, B	A, B	A, B	A	A

3.2 Basic Hydrology
(Jillian Bjarnason)

In order to assess the movement (flow), distribution, and quality of the habitat in the C. W. Young channel, measurements of bank full width, wetted width, gradient, velocity, water depth and discharge were taken at site 2. A measuring tape and metre stick was used to assess the wetted width, bank full width, and water depth, whereas velocity and discharge was calculated using the float method. Measurements of gradient combined with discharge provide a correlation between a stream's erosion power and the distribution of suspended sediments, nutrients, streambed material, and particulate organic matter.

Furthermore, crown cover, riparian cover, and substrate was noted for each sample station and used in conjunction with channel measurements to determine overall channel health.

3.3 Water Quality
(Jillian Bjarnason)

3.3.1 Field Measurements

Water quality measurements including onsite water temperature (°C) and dissolved oxygen (mg/L) was determined in the field at each sample station. Testing for these parameters was performed with a Oxyguard Handy Polaris electronic probe provided by VIU. All other testing for water quality criterion was conducted in laboratory facilities provided by VIU located in Nanaimo, British Columbia and ALS Laboratories located in Vancouver, British Columbia.

3.3.2 Water Sample Collection

In order to minimize contamination, specific methodology outlined by the ambient freshwater and effluent sampling manual (Cavanagh et al. 1997) was followed which included sampling the furthest downstream location first (sample site 4), followed by sample site 3, sample site 2, and lastly the furthest upstream location (sample site 1). Additionally, samples were taken in pre-labelled plastic water bottles provided by VIU, and taken from a representative section of the station, mid-stream, below the water surface. Each sample bottle was rinsed three times by the sampler to prevent contamination.

Samples for analysis by ALS Laboratories was taken at sites 1, 2, and 4 and three sample bottles were filled at each station. The bottles were labelled with client name, project, station ID, and the date/time. The white plastic bottle sample was analysed for general parameters, the white plastic bottle sample was analysed for total metals, and the amber glass bottle sample was analysed for total nutrients. These bottles came pre-rinsed and did not need to be rinsed in the field. All bottles were filled to “shoulder” level to ensure there was enough space to add the appropriate preservative (sulphuric acid for nutrients, nitric acid for metals). All samples were stored in a cooler with ice during transportation from the field to the lab. Upon arrival at the lab, the samples were removed from the cooler and placed in a fridge (4 ºC) to inhibit biochemical activity and alteration of chemical parameters.

3.3.3 VIU Laboratory Analyses

Laboratory analyses of water samples were conducted at the VIU Nanaimo Campus by Keighley Doerksen and Jillian Bjarnason within four days of collection. Water samples from the four sample sites were tested for pH, conductivity (µs/cm), and turbidity (NTU). The pH was tested using the Oakton pHTestr 10 (nearest 0.1 pH unit), conductivity was tested using the Pinpoint Conductivity Metre (nearest 1 µs/cm), and turbidity was tested using the HACH 2100 (nearest 0.1 NTU). Hardness (mg/L as $CaCO_3$) and alkalinity (mg/L as $CaCO_3$) were assessed using the HACH HA-4P test kit (nearest 1mg/L) and the HACH AL-DT digital titration method (nearest 0.1 mg/L), respectively.

3.3.4 ALS Laboratory Analyses

A separate set of water samples were collected and sent, within 48 hours of collection, to a private analytical lab (ALS Laboratories) located in Vancouver, BC. The water samples from each sample station were tested for general water quality parameters including pH, conductivity (µs/cm), hardness (mg/L $CaCO_3$), reactive phosphorus (mg/L PO_4^{3-}), and nitrate (mg/L NO_3-), as well as a nutrient analyses and total metal scan were completed.

3.3.5 Quality Assurance/Quality Control

To ensure quality assurance and quality control is maintained, all samples were taken from the same locations as in previous sampling years (2008-2017), with the exception of sampling site 5, where no sample was taken. Where possible, samples were taken consistently from the same location at each site during the first and second sampling events and were taken in accordance with the established sampling methodologies outlined by the ambient freshwater and effluent sampling manual (Cavanagh et al. 1997). Samplers were responsible for quality assurance and had clean hands while collecting the water samples and rinsed the sample containers three times in order to reduce the likelihood of contamination. A trip blank was present during both sampling events and replicate samples were taken at a frequency of 10% of samples taken (1 replicate sample at any one station). Replicate samples were analysed at the VIU Laboratory in order to assess sample quality integrity.

3.3.6 Data Analyses, Comparison to Guidelines

Results obtained from laboratory analysis conducted at VIU and ALS was compiled and compared to the parameters prescribed by the Province of British Columbia through the Approved Water Quality Guidelines for Aquatic Life, Wildlife and Agriculture (BCAWQG 2018). These guidelines provide a measurement for safe levels of substances and sediment quality in order to protect different water users. In this case, the C.W. Young channel supports anadromous and non-anadromous species of fish, and therefore the results yielded can be compared to the above guidelines to ensure parameters are being met or fall below the prescribed maximum allowable concentrations. The measurements provide insight into the overall health and ability of the channel to support aquatic life.

4.0 Results and Discussion
(Jillian Bjarnason)

4.1 General Field Conditions

The initial site assessment took place on October 24, 2018 at 09:00. The weather was sunny with blue skies and the ambient air temperature was 12.1 ºC (The Weather Network 2018). During the first sampling event on October 31, 2018, the mean air temperature among the four monitoring sites was 10.5 ºC and it had rained the night before. Rainfall between the initial site assessment and the first sampling event totaled 33.2 mm over a 7-day period. During the final sampling event, which took place on November 21, 2018 at 08:30, the rain had ceased directly prior to sampling and the air temperature was 10.2 ºC. Throughout the 21-day period between sampling sessions, 31.6 mm of precipitation was reported in the Parksville area (The Weather Network 2018).

The sampling dates were chosen to capture a low flow and high flow event as average rainfall trends show an increase in precipitation between the month of October and November resulting in increased discharge and turbidity within the channel (Parksville Public Works 2018). However, flow into the C.W. Young Channel from the Englishman River is controlled by a pipe and valve which restricts discharge fluctuations. Nonetheless, water quality within the C.W. Young Channel can be influenced by inflowing water quality from the Englishman River (Demers 2016).

4.1.1 Hydrology

Due to limited man-power, hydrology measurements including wetted width (m), bank full width (m), maximum depth (cm), average depth (cm), and average velocity (m/s) were taken at one site (site 2) along the C.W. Young Channel; discharge (m^3/s) was also calculated at a later date. These hydrology measurements were taken during both sampling events in order to compare results from a low flow and high flow event (Table 2).

Table 2. Hydrology measurements at Site 2 on the C.W. Young Channel taken on sampling event 1 (October 31, 2018) and sampling event 2 (November 21, 2018).

Sampling Event	Wetted Width (m)	Bank full Width (m)	Maximum Depth (cm)	Average Depth (cm)	Average Velocity (m/s)	Discharge (m^3/s)
1	3.8	5.5	40.9	34.4	.38	0.572
2	3.7	5.25	45	39.3	.38	0.640

At Site 2 it appears that the wetted and bank full widths decreased slightly whereas the maximum and average depths increased. This may be a result of a slight increase in water volume causing erosion of the stream bed to take place. However, due to restricted outflow wetted widths and discharge did not increase significantly as expected, and the average water velocity remained constant. Although measurements of the other three sites were not taken, observations were made regarding water volume. In particular, Site 3, which is located on a sharp curve of the channel and along an open grassy area, experienced a significant rise in water levels. The increased water caused much of the grassy vegetation, which was exposed during the first sampling event, to become submerged during the second sampling event. The measuring tape located on a footbridge at Site 4 was also an indicator of rising water levels. During the first sampling event the water was reaching the 0.31 m mark whereas during the second sampling event the water reached the 0.36 m mark.

4.2 Water Quality

4.2.1 Field Measurements

Temperature (ºC) and dissolved oxygen (mg/L and %) were measured at all four sites during the first sampling event on October 31st (Table 3) and the second sampling event on November 21st (Table 4) using an Oxyguard Handy Polaris electronic probe.

Table 3. Field measurements of temperature and dissolved oxygen taken at four sites along the C.W. Young Channel on October 31st, 2018.

Site	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
1	8.9	11.4	99
2	9.6	10.6	92
3	9.8	10.9	95
4	11.3	10.3	94

Table 4. Field measurements of temperature and dissolved oxygen taken at four sites along the C.W. Young Channel on November 21st, 2018.

Site	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)
1	6.1	12.0	98
2	5.7	11.6	93
3	6.7	11.4	94
4	7.3	11.5	96

Between the first and second sampling event, water temperature decreased between 2 and 4 ºC at each of the four sites; which is consistent with the drop in ambient air temperature. Correspondingly, an increase in dissolved oxygen was observed as the water temperature decreased (Figure 4). In addition, a trend can be detected along on the channel where Site 1 consists of lowest temperatures and highest dissolved oxygen content and Site 4 consists of highest temperatures and lowest dissolved oxygen content (not shown).

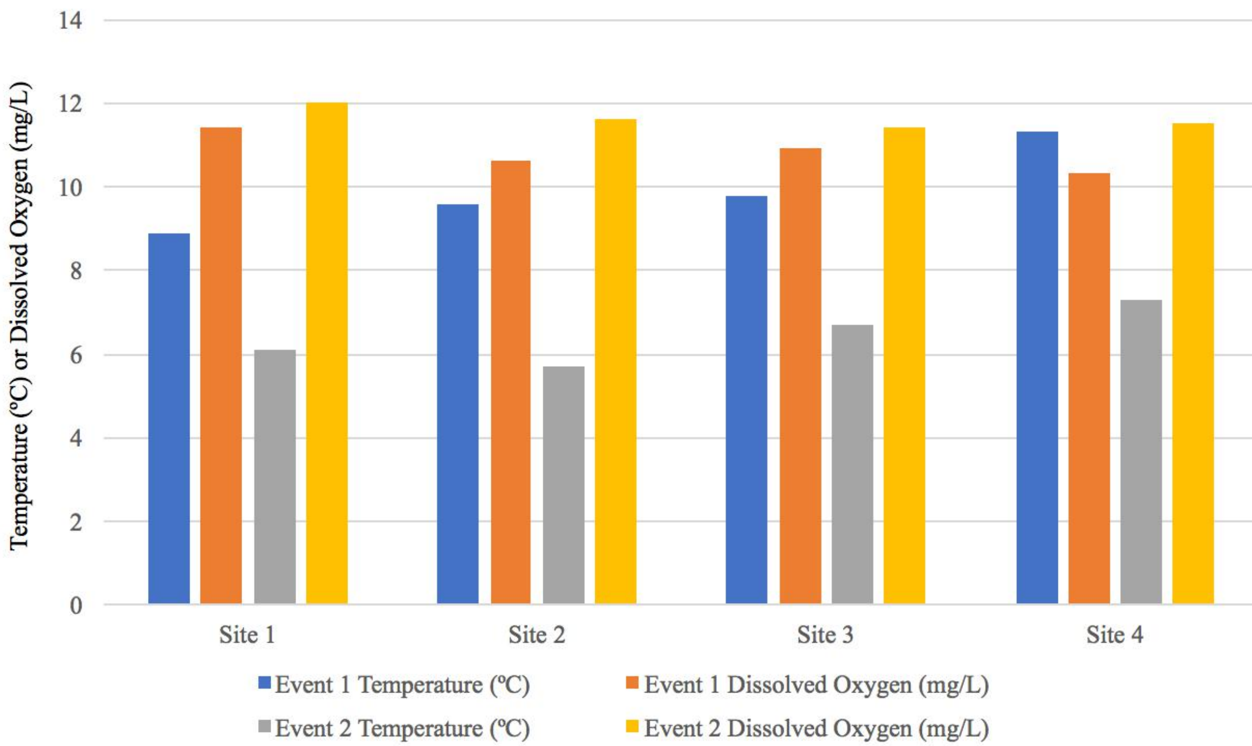


Figure 4. Comparative graph of temperature and dissolved oxygen level at four sites along the C.W. Young Channel taken during two sampling events (October 31, 2018 and November 21, 2018).

According to the British Columbia Water Quality Guidelines for Aquatic Life most organisms require a minimum of 4.0 mg/L of dissolved oxygen and early fish stages require above 9.0 mg/L (BCWQG 2018; RISC 1998). Results from both sampling events show a dissolved oxygen content above 9.0 mg/L which indicates that the C.W. Young Channel is excellent habitat capable of supporting a number of fish and invertebrate species.

By comparing these results to data compiled over an 8-year period (2008-2015), it was found that temperature measurements taken during the October sampling event were slightly elevated, ranging between 8.9 and 11.3 ºC, whereas the previous average range was reported to be between 5.5 and 9.0 ºC. During the second sampling event on November 21st temperatures ranged between 5.7 and 7.3 ºC and were well within the normal reported levels of 1.5 to 7.6 ºC (Demers 2016).

A slight discrepancy was found when comparing dissolved oxygen content to previous years' data. Antecedently, the 8-year report described a low range of 10.5 mg/L of dissolved oxygen whereas results during the first sampling event on October 31st exhibited a low of 10.3 mg/L (Site 4). The remaining sites (Site 1, 2, and 3) all contained above 10.5 mg/L of dissolved oxygen. Additionally, all four sites contained within normal levels during the second sampling event on November 21st, 2018 ranging between 11.4 and 12.0 mg/L.

4.2.2 VIU Laboratory Analyses

Water samples were taken in plastic 500 ml sample bottles. One bottle was filled at each site during both sampling events and a replicate sample was taken at site 2; one during each sampling event. Additionally, a trip blank was filled prior to sampling and was present during both the October and the November sampling events. Samples were collected in the morning on October 31st and November 21st and were subsequently placed in a cooler with ice for transportation to the VIU Laboratory located in Nanaimo, BC. Upon arrival at the laboratory each of the five samples and the replicates were tested for pH level, turbidity (NTU), conductivity (μS/cm), alkalinity (mg/L), and hardness (mg/L $CaCO_3$). All VIU water quality parameters were tested on October 31st (Table 5) and November 21st (Table 6). Due to limited resources, nitrate and phosphate levels were not tested at the VIU Laboratory.

Table 5. VIU water quality results for five parameters tested on October 31st, 2018.

Parameters	Site 1	Site 2	Site 3	Site 4	Replicate (Site 2)	Water Quality Guidelines
pH	7.5	7.3	7.2	7.1	7.2	6.5 – 9.0
Conductivity (μS/cm)	60	60	60	70	60	< 100
Turbidity (NTU)	0.6	1.4	1.7	1.9	1.6	< 9.4
Alkalinity (mg/L)	13.6	18.6	22.2	17.7	19.2	> 20
Hardness (mg/L $CaCO_3$)	27	29	30	38	27	< 60 = soft water

Table 6. VIU water quality results for five parameters tested on November 21st, 2018.

Parameters	Site 1	Site 2	Site 3	Site 4	Replicate (Site 2)	Water Quality Guidelines
pH	7.3	7.3	7.3	7.2	7.3	6.5 – 9.0
Conductivity (µS/cm)	59	64	61	74	61	< 100
Turbidity (NTU)	0.8	1.4	1.6	1.6	1.3	< 9.4
Alkalinity (mg/L)	17.0	18.2	18.4	24.0	19.3	> 20
Hardness (mg/L $CaCO_3$)	31	32	32	32	30	< 60 = soft water

4.2.2.1 pH and Alkalinity

Most lakes throughout B.C. report to have a pH of 7.0 or greater. On the other hand, coastal streams tend to be more acidic and commonly have a lower pH value ranging between 5.5 and 6.5. In order to support aquatic life, pH levels should be above 6.5 but not exceed 9.0; lethal effects on aquatic life occur at pH levels below 4.5 and above 9.5 (RISC 1998). Over two sampling events, pH levels at sites 1 through 4 ranged from 7.1 to 7.5 (Figure 5). The October results were more variable in comparison to the November results, where the average pH ranged from 7.2 to 7.3. These results coincide with averages determined over the 8-year sampling period, while no particular trend was detected, all reported pH measurements were near neutral and were well within the guidelines for aquatic life (Demers 2016).

Total alkalinity, which is a measurement of the water's ability to neutralize acids, ranged from 13 to 22 mg/L as $CaCO_3$ during the late October event and from 17 to 25 mg/L $CaCO_3$ during the November event. The values indicate that the alkalinity levels ranged between "moderate" (10-20 mg/L as $CaCO_3$) to "low" (>20 mg/L as $CaCO_3$) acidification sensitivity ratings and are within normal levels for a coastal B.C. stream (RISC 1998). Variation among the first and second sampling events appear to be fairly consistent with a difference of 9 mg/L as $CaCO_3$ and

8 mg/L as $CaCO_3$, respectively. Measurements taken from previous years suggest that there is higher variation during the first sampling event in October as opposed to the second sampling event in November, which may be correlated with river discharge (Demers 2016).

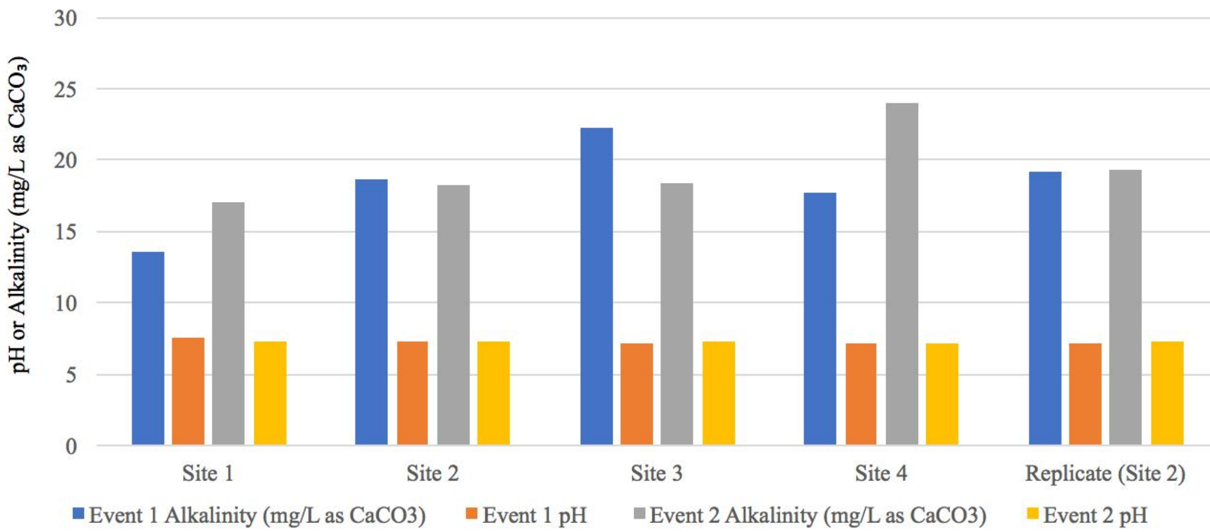


Figure 5. Comparative graph of pH and alkalinity of five water samples from the C.W. Young Channel taken from four sites during two sampling events (October 31, 2018 and November 21, 2018).

4.2.2.2 Turbidity and Conductivity

Past studies of this Channel have shown a general increase in turbidity between the first and second sampling events (Demers 2016). Elevated turbidity is usually associated with increased precipitation, increased sediment levels from runoff and erosion, and increased river discharge causing the mobilization of suspended solids. The data compiled in the 8-year report show a background range of 0.2 to 4.4 NTU during the October event and from 1.1 to 5.2 NTU during the November event (Demers 2016). However, the measurements taken during this study illustrate a decrease in overall turbidity between the first and second event; values during the first event ranged between 0.6 and 1.9 NTU whereas values during the second event ranged between 0.8 and 1.6 NTU (Figure 6). This may be a result of 33.2 mm of rainfall recorded in the 7-day period before the first sampling event, and only 31.6 mm of rainfall recorded over the 21-day period between sampling events.

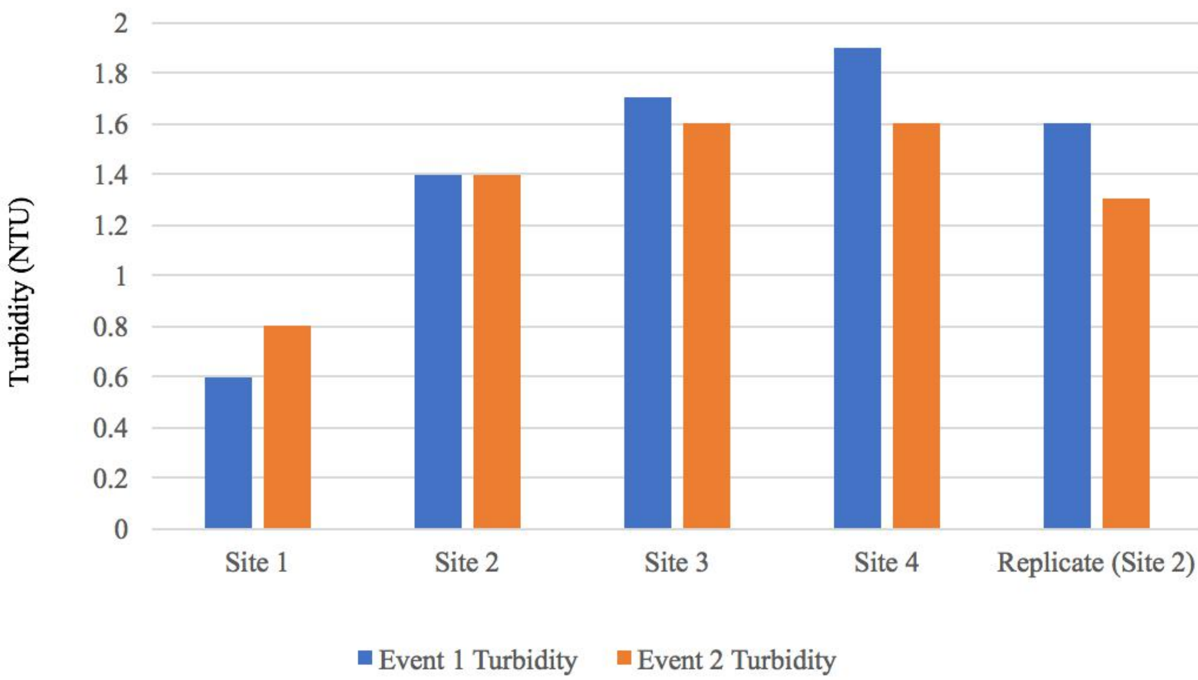


Figure 6. Comparative graph showing decreased turbidity levels from the first sampling event (October 31, 2018) to the second sampling event (November 21, 2018).

The guideline for turbidity suggests that it can only rise 5 NTUs above the background level before it has detrimental effects on aquatic plants and fish (RISC 1998). As a result, background levels extrapolated from the previous eight years of studies are taken in to account in order to determine the maximum turbidity level for each sampling event. Considering that average background levels were between 0.2 and 4.4 NTUs during late October and 1.1 and 5.2 NTUs during mid-November, then the guidelines suggest that turbidity should not rise above 9.4 NTUs and 10.2 NTUs respectively (Demers 2016). Based on these parameters, the turbidity results from both the first and second sampling event meet the criteria for aquatic life.

Conversely, conductivity increased and was more variable during the second sampling event in mid-November (Figure 7). This data contradicts that of previous years where conductivity was generally higher and more variable during late October. However, a weak negative correlation between conductivity and discharge was detected. In events of higher discharge, whether in

October or November, a decrease in overall conductivity occurred as a result of the dilution effect (Demers 2016).

Throughout the 8-year study of the C.W. Young Channel, average conductivity ranged from 40 to 89 µS/cm during late October and from 36 to 63 µS/cm during mid- November. Considering that the first sampling event produced results ranging from 60 to 70 µS/cm, it appears that conductivity is consistent with average levels for late October. On the other hand, the second sampling event produced results ranging from 59 to 74 µS/cm; which is 23 µS/cm higher at the lower range and 11 µS/cm higher at the higher range (Demers 2016). This was likely due to slightly increased levels of dissolved calcium, iron, silicon, and sodium ions. There is no specific guideline for conductivity, however, most coastal B.C. streams present with a conductivity <150 µS/cm. Although the second sampling event produced slightly higher than normal results, all four sites had within normal levels for a coastal stream (RISC 1998).

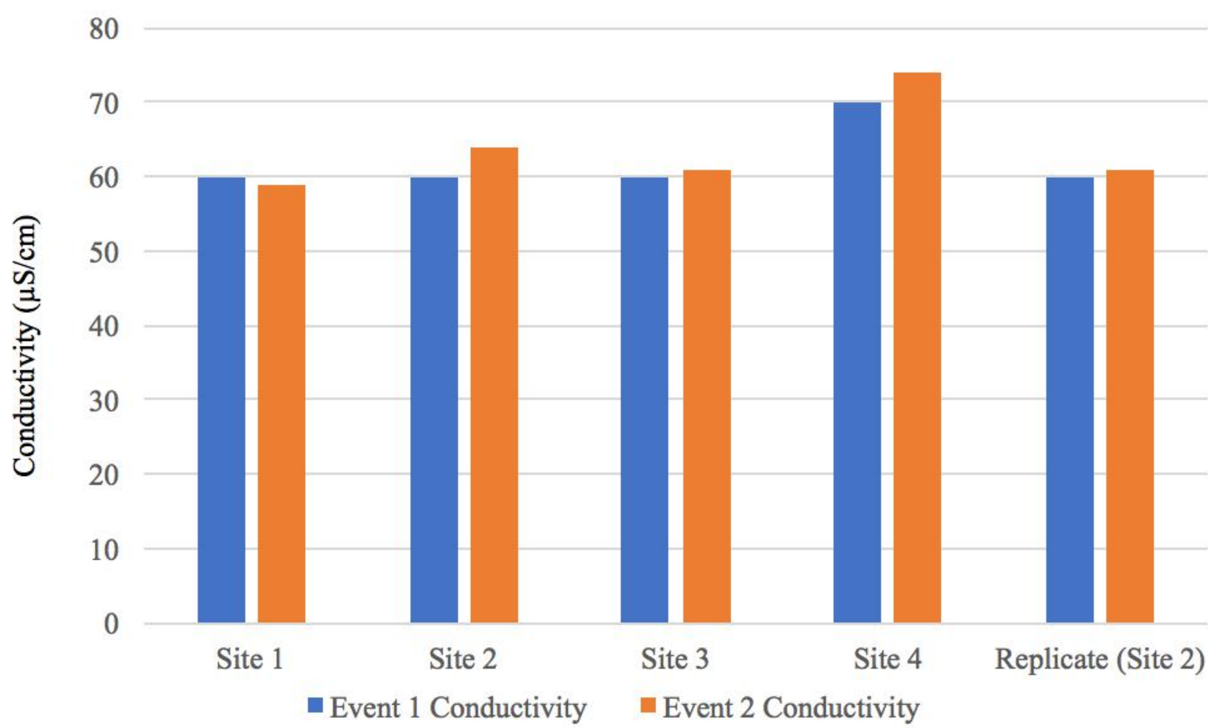


Figure 7. Comparative graph showing conductivity levels from the first sampling event (October 31, 2018) and the second sampling event (November 21, 2018).

4.2.2.3 Hardness

Hardness values recorded at all four sites ranged from 27 to 38 mg/L as $CaCO_3$. These values are below the 60 mg/L as $CaCO_3$ guideline which indicates that the water within the C.W. Young Channel is soft (RISC 1998). While soft water is acceptable for aquatic life, it is more susceptible to metal toxicity. At sites 1, 2, and 3 all hardness values increased during the second event which correlate with the increase in conductivity. In contrast, site 4 experienced a decrease in hardness from 38 mg/L as $CaCO_3$ to 32 mg/L as $CaCO_3$ during the second event (Figure 8). Similar studies conducted by VIU Environmental Monitoring students in 2016 and 2017 found that hardness levels were also much higher at site 4; site 4 nearly doubled from the other sites during one event in 2017 (Harper et al. 2017). This difference may be a result of the geology of the specific site. However, during the second event levels did decrease to match other sites.

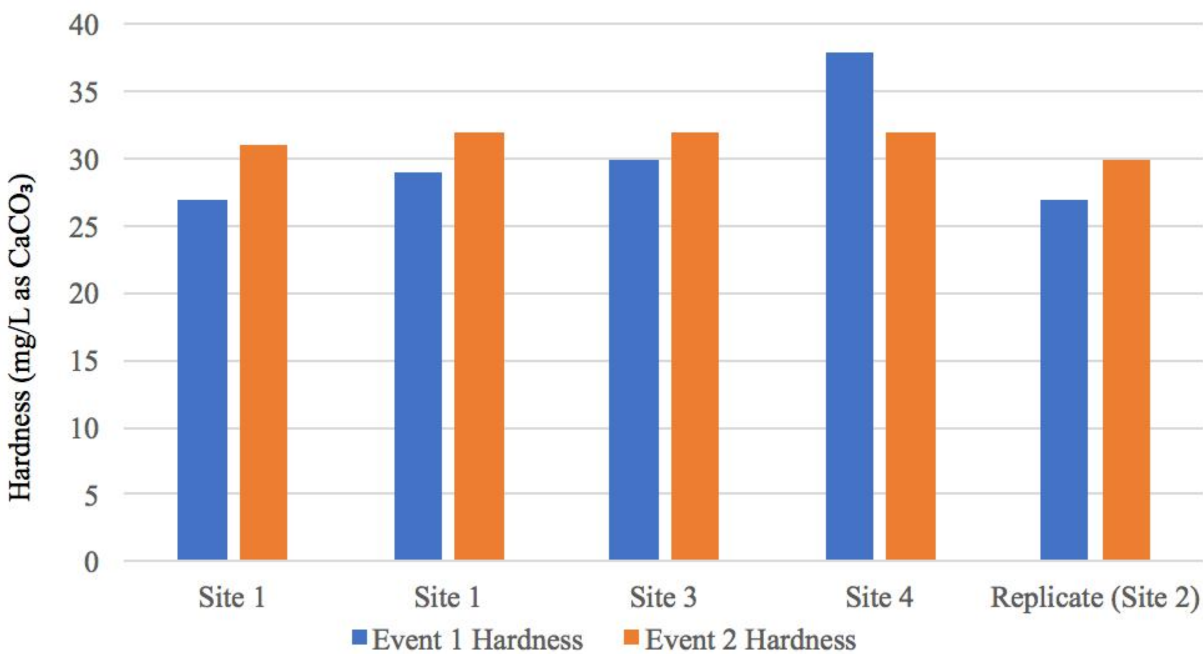


Figure 8. Comparative graph showing hardness levels from the first sampling event (October 31, 2018) and the second sampling event (November 21, 2018).

4.2.3 ALS Laboratory Analyses

Water samples were collected at sites 1, 2, and 4 on October 31st and November 21st using three clean, pre-labelled sample containers provided by ALS Laboratories (Table 7) (Demers 2016). Samples were taken carefully in order to prevent contamination and samples for nutrient and metal analysis were preserved using sulphuric and nitric acid, respectively. The samples were placed in a cooler with ice and shipped to ALS Laboratories located in Vancouver, British Columbia. Tests were performed in order to determine conductivity, hardness, pH, anions, nutrients, and total metals present at each of the three stations during both sampling events. Results were submitted back to VIU in order for comparison to the BC Water Quality Guidelines (Table 8). Comparing the ALS results to the BC Water Quality Guidelines for aquatic life and to VIU Laboratory results will help to identify potential habitat quality concerns and will provide insight as to possible sources of error throughout laboratory procedures.

Table 7. Sampling containers and preservatives used for ALS water quality samples taken at the C.W. Young Channel.

Physical Parameters	Container	Preservative	Analysed by
Alkalinity, turbidity	500 ml plastic	None	VIU Laboratory
Conductivity, pH, hardness	1 L plastic	None	ALS Laboratories
Anions and nutrients	250 ml amber glass	Sulphuric acid	ALS Laboratories
Total metals	250 ml plastic	Nitric acid	ALS Laboratories

Conductivity and pH values from the first sampling event are comparable between VIU and ALS, although they were slightly higher on average. Values for pH at VIU ranged from 7.1 to 7.5 and ALS pH values ranged from 7.3 to 7.5. During the second sampling event ALS pH results were considerably higher ranging from 7.6 to 7.7 whereas VIU pH results ranged from 7.2 to 7.3. Event 1 conductivity results from ALS are comparable and are within the same range as those obtained by VIU. The second set of ALS results from the second sampling event showed higher levels ranging between 71.5 µS/cm and 81.8 µS/cm whereas VIU results reported the range to be between 59 µS/cm and 74 µS/cm. Overall, both sets of results show the same general trend of increasing conductivity values from the late October to mid-November sampling event. In contrast, ALS hardness results were lower than those recorded by VIU during both sampling events. However, this did not alter the final determination of the C.W. Young Channel containing soft water.

Anion and nutrients were not tested at the VIU Laboratory. Tests for these parameters were performed by ALS Laboratories. In general, both nitrate and total phosphorus ranges increased between the late October and mid-November event from 0.0693 - 0.0764 mg/L to 0.0973 - 0.116 mg/L and 0.0029 – 0.0078 mg/L to 0.0046-0.0097 mg/L, respectively. This data is concurrent with that of the 8-year data report for the C.W. Young Channel. Furthermore, this data supports previous years' data in that total phosphorus levels increased with distance downstream. (Demers 2016). Both nitrate and phosphorus levels fall within the guidelines for aquatic life. Phosphorus levels at all sites are below 0.010 mg/L categorizing the C.W. Young Channel system as "oligotrophic" (< 0.010 mg/L) (RISC 1998).

ALS reported that all metals from the two sampling events were below the water quality guidelines for aquatic life or were below minimum detection limits. A similar study conducted in 2017 yielded aluminum levels of between 0.24 mg/L in early November and 0.64 mg/L in mid to late November (Harper et al. 2017). These results suggest that a high flow event occurred causing an increase in runoff and input of contaminants into the system. Industrial and agricultural lands surrounding the Englishman River watershed likely contribute aluminum contaminants to the channel which causes fluctuations in input and concentrations during high rainfall and high flow events.

Table 8. ALS Laboratory results for water samples collected at three sites on the C.W. Young Channel on October 31, 2018 and November 21, 2018.

	Minimum Detection Limit		Site 1	Site 2	Site 4	Site 1	Site 2	Site 4
Date Sampled		Units	31-Oct-2018	31-Oct-2018	31-Oct-2018	21-Nov-2018	21-Nov-2018	21-Nov-2018
Physical Tests (Water)								
Conductivity	2.0	uS/cm	60.9	62.0	71.5	72.6	71.5	81.8
Hardness (as CaCO3)	0.50	mg/L	24.1	24.8	30	25.6	25.6	31.5
pH	0.10	pH	7.50	7.35	7.42	7.64	7.63	7.70
Anions and Nutrients (Water)								
Ammonia, Total (as N)	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	0.0075	0.0150
Nitrate (as N)	0.0050	mg/L	0.0764	0.0693	0.0699	0.105	0.0973	0.116
Nitrite (as N)	0.0010	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Nitrogen	0.030	mg/L	0.124	0.135	0.165	0.174	0.184	0.226
Orthophosphate-Dissolved (as P)	0.0010	mg/L	<0.0010	<0.0010	0.0011	0.0017	0.0018	0.0039
Phosphorus (P)-Total	0.0020	mg/L	0.0029	0.0063	0.0078	0.0046	0.0076	0.0097
N:P	N/A	N/A	42.8	21.4	21.2	37.8	24.2	23.3
Total Metals (Water)								
Aluminum (Al)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony (Sb)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	0.10	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total	0.050	mg/L	8.32	8.52	9.47	8.62	8.56	9.69
Chromium (Cr)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	0.030	mg/L	0.043	0.131	0.228	0.070	0.150	0.218
Lead (Pb)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	0.10	mg/L	0.80	0.85	1.53	1.00	1.02	1.76
Manganese (Mn)-Total	0.0050	mg/L	<0.0050	0.0055	0.0064	<0.0050	0.0059	0.0074
Molybdenum (Mo)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	0.050	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	0.30	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	2.0	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total	0.10	mg/L	2.40	2.50	3.06	2.97	3.04	3.59
Silver (Ag)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total	2.0	mg/L	3.4	3.5	3.7	4.1	3.9	4.1
Strontium (Sr)-Total	0.0050	mg/L	0.0356	0.0375	0.0406	0.0377	0.0370	0.0394
Thallium (Tl)-Total	0.20	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium (V)-Total	0.030	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	0.0050	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

4.2.4 Quality Assurance/Quality Control

Replicate samples were taken at site 2 during the October and mid-November sampling events in order to verify quality assurance and control of field and laboratory procedures. Tests were performed on the replicate samples and all results are fairly consistent with water quality samples taken at site 2 indicating no presence of contamination. A trip blank was present during both sampling events, however, due to limited resources it was not tested for contamination.

Samples shipped to ALS Laboratories were placed in a cooler with ice to ensure no degradation of the samples occurred. Furthermore, the samples were accompanied by a chain of custody form and were signed for upon arrival in Burnaby. As a professional facility, ALS has properly trained staff, standardized procedures, and specific testing methodology. A more thorough description of these procedures can be found in the report provided by ALS. Quality control lots were completed on samples taken from both the October and November sampling events and indicate that Data Quality Objectives were met. ALS recommends that pH and conductivity be tested in the field as the samples have often exceeded the hold time before arrival at the laboratory which can alter measurement reliability.

5.0 Conclusion and Recommendations

After comprehensive testing of water quality parameters from two separate events, it was determined that the C.W. Young Channel continues to provide quality habitat for fish and invertebrate species. There was no glaring deficiency in water quality at any of the four sites as all water quality parameters were found to meet the criteria outline by the B.C. Water Quality Guidelines for aquatic life. Notwithstanding, slightly elevated aluminum concentrations during previous studies, as well as the potential environmental impacts as a result of development within the watershed, justifies the need for continuous monitoring. While the water quality may not be deteriorating, continued monitoring at the same locations around the same time of the year will allow for a more comprehensive data set and may provide insight into specific trends among individual parameters.

6.0 Acknowledgments

The authors would like to thank Dr. Eric Demers for providing us with the knowledge and necessary skills to complete this monitoring project. In addition, thank you to Kim Ives for her expertise and thoughtful guidance throughout this process. In addition, a special thank you to the Regional District of Nanaimo for facilitating site access. Furthermore, thank you to Vancouver Island University's Resource Management Officer Technology and Science- Biology departments for supplying the necessary field and laboratory equipment needed to conduct this project.

7.0 References

Barlak R, Epps D, Phippen B. 2010. Water Quality Assessment and Objectives for the Englishman River Community Watershed. British Columbia Ministry of Environment Technical Report. 87p.

British Columbia Approved Water Quality Guidelines (BCAWQG). Summary of Water Quality Guidelines: Aquatic Life, Wildlife, and Agriculture. https://www2.gov.bc.ca/gov/conte

Decker AS, Lightly MJ, Ladwig AA. 2003. The contribution of two constructed side-channels to coho salmon colt production in the Englishman river. Canadian Technical Report of Fisheries and Aquatic Sciences. 2442: 53p.

Demers E. 2016. Water Quality and Stream Invertebrate Assessments for the C. W. Young Channel, Englishman River, BC, 2008-2015. Prepared for the Regional District of Nanaimo and Fisheries and Oceans Canada by Dr. Eric Demers and Vancouver Island University Environmental Monitoring Students: Nanaimo, BC. 89p.

Hawkes VC., Gaboury M., Fenneman JD. 2008. Management plan for the Englishman River Regional Park, a conservation area along the river corridor: inventory of natural resources. LGL Project EA1988. Unpublished report by LGL Limited environmental research associates for Regional District of Nanaimo, Nanaimo, BC. 53p.

McCulloch MP. 2005. Construction of Artificial Fish Habitat in the Englishman River, 2004. Greater Georgia Basin Steelhead Recovery Plan. 34p. nt/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines Accessed October 20, 2018.

Parksville Public Works. 2018. City of Parksville Rainfall Records for Year 2018. http://www.parksville.ca/cms/wpattachments/wpID192atID8410.pdf Accessed 4 December 2018.

Resource Industry Standards Committee (RISC). 1998. Guidelines for Interpreting Water Quality Data. Resources Information Standards Committee, Victoria, BC.

Silvestri SW. 2007. Fish Habitat Rehabilitation in the Englishman River, 2006. British Columbia Conservation Foundation Technical Report. 10p.

The Weather Network. 2018. Parksville, BC https://www.theweathernetwork.com/ca/monthly/british-columbia/parksville?year=2018&month=10&dispt=chart-container-monthly&autod=1 Accessed 3 December 2018.

8.0 Appendices

8.1 Appendix A

Figure A1: Site 1, located in the C.W. Young Channel

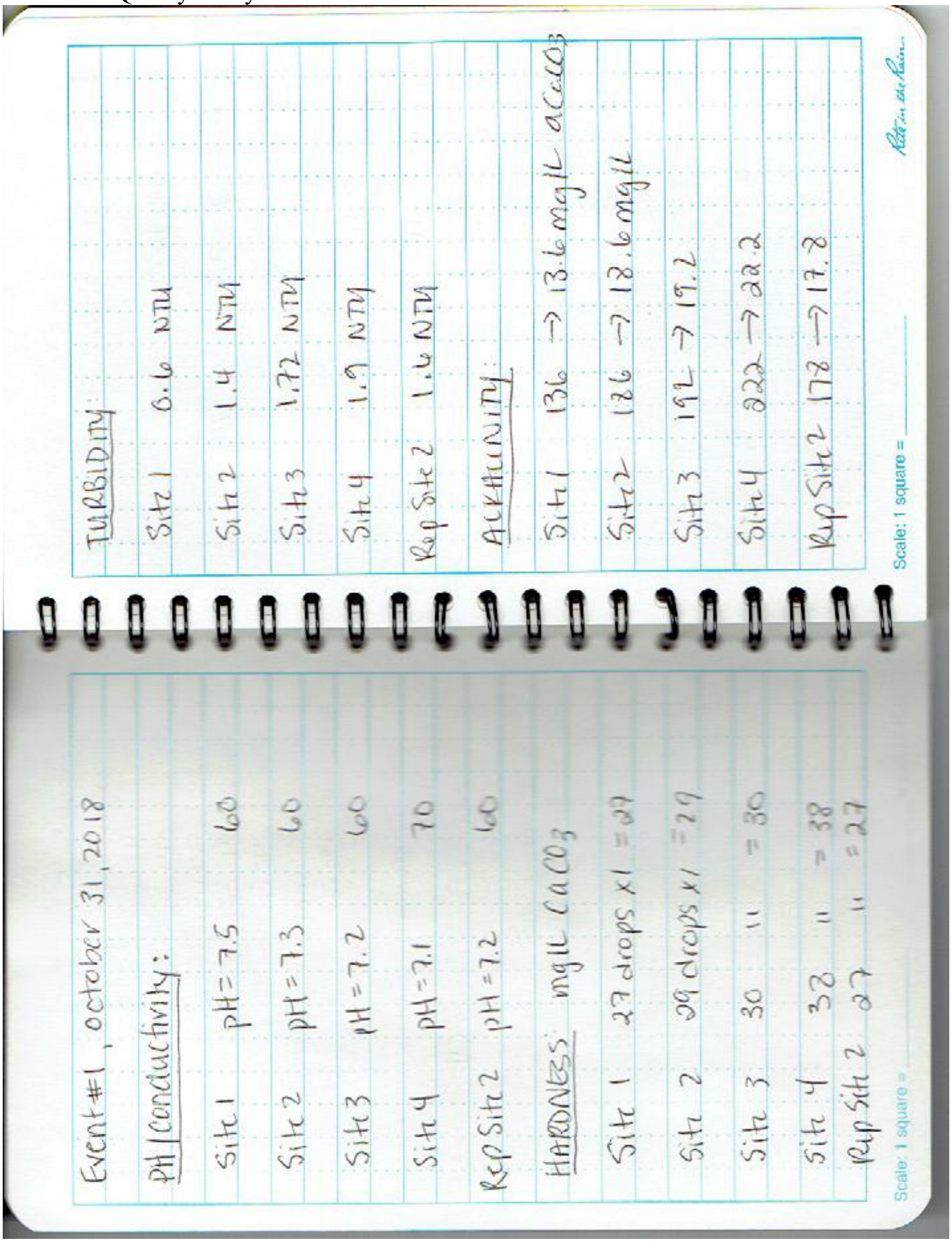
Figure A2: Site 2, located in the C.W. Young Channel

Figure A3: Site 3, located in the C.W. Young Channel

Figure A4: Site 4, located in the C.W. Young Channel

8.2 Appendix B

Lab Water Quality Analysis: Event 1



Event #1, October 31, 2018

PH/conductivity:

Site 1 pH = 7.5 60
Site 2 pH = 7.3 60
Site 3 pH = 7.2 60
Site 4 pH = 7.1 70
Rep Site 2 pH = 7.2 60

HARDNESS: mg/L $CaCO_3$

Site 1 27 drops x1 = 27
Site 2 29 drops x1 = 29
Site 3 30 " = 30
Site 4 38 " = 38
Rep Site 2 27 " = 27

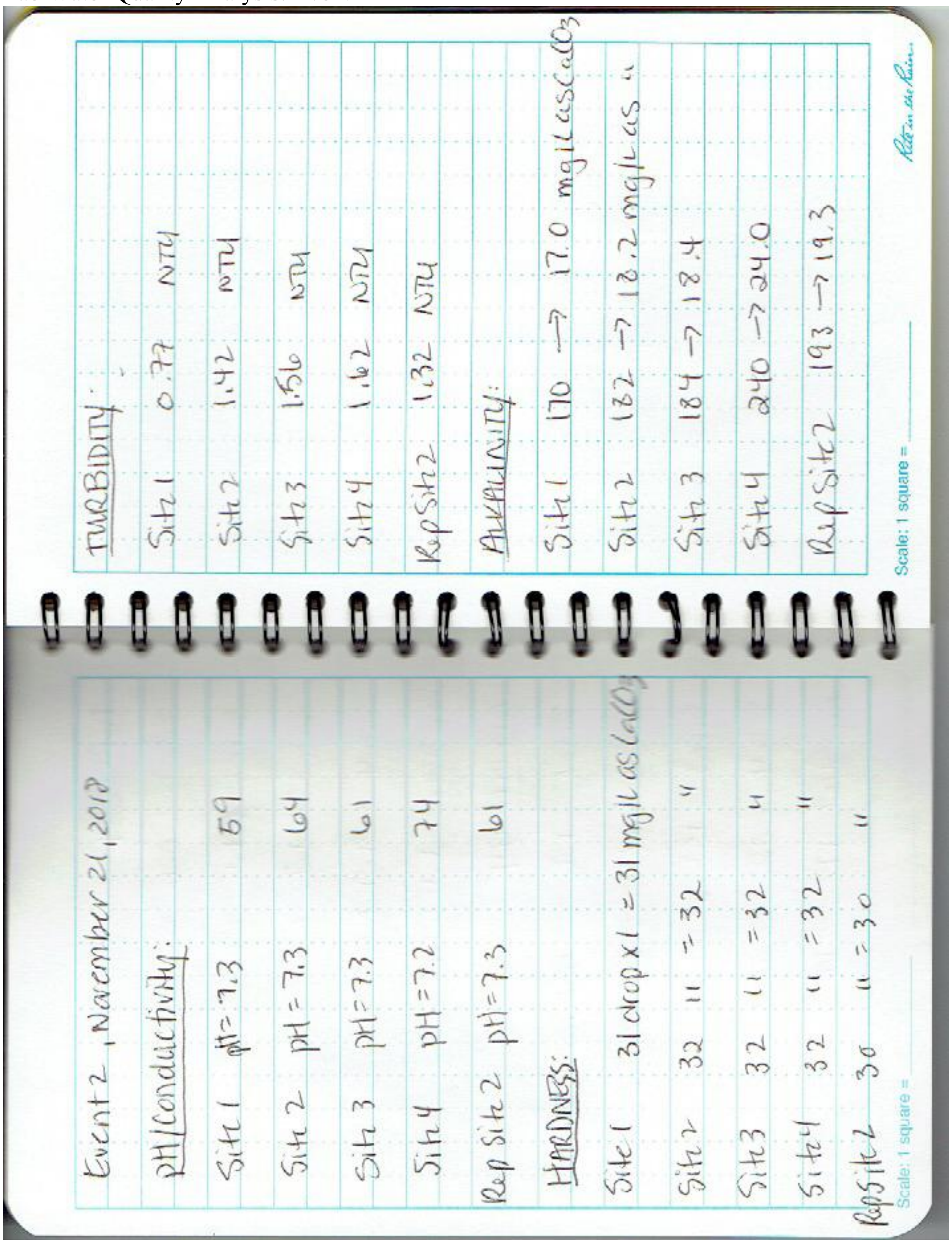
TURBIDITY:

Site 1 0.6 NTU
Site 2 1.4 NTU
Site 3 1.72 NTU
Site 4 1.9 NTU
Rep Site 2 1.6 NTU

ALKALINITY:

Site 1 136 → 13.6 mg/L $CaCO_3$
Site 2 186 → 18.6 mg/L
Site 3 192 → 19.2
Site 4 222 → 22.2
Rep Site 2 178 → 17.8

Lab Water Quality Analysis: Event 2



Event 2, November 21, 2018

pH/conductivity:

Site 1 pH = 7.3 59

Site 2 pH = 7.3 64

Site 3 pH = 7.3 61

Site 4 pH = 7.2 74

Rep Site 2 pH = 7.3 61

HARDNESS:

Site 1 31 drop x 1 = 31 mg/L as $CaCO_3$

Site 2 32 " = 32 "

Site 3 32 " = 32 "

Site 4 32 " = 32 "

Rep Site 2 30 " = 30 "

Scale: 1 square =

TURBIDITY:

Site 1 0.77 NTU

Site 2 1.42 NTU

Site 3 1.56 NTU

Site 4 1.62 NTU

Rep Site 2 1.32 NTU

ALKALINITY:

Site 1 170 → 17.0 mg/L as $CaCO_3$

Site 2 182 → 18.2 mg/L as "

Site 3 184 → 18.4

Site 4 240 → 24.0

Rep Site 2 193 → 19.3

Scale: 1 square =

Rite in the Rain