Environment

University Endowment Lands

Water Quality & Benthic Sampling

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Project Number:

60222155

Date:

July 2016

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July 11, 2016

Graham Walker, P.Eng.
3292 Production Way
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Dear Graham,

Project No: 60222155
Regarding: Water Quality and Benthic Sampling

AECOM is pleased to present our 2015 Water Quality and Benthic Sampling within University Endowment Lands (UEL). This report provides a compilation of the results from the dry sampling which occurred between August to September 2015 and wet period sampling occurring from November to December 2015.

If there are any questions or comments on this report, please contact the undersigned. Thank you for the opportunity to work on this project.

Sincerely,

AECOM Canada Ltd.

Melissa Mukai, R.P.Bio., P.Biol., EP
Aquatic Biologist
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Distribution List

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1	Yes	University Endowment Lands (UEL)
1	Yes	AECOM

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	MM	2016/07/04	Final revisions following workshop with UEL

AECOM Signatures

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1. Introduction

1.1 Overview

The University Endowment Lands (UEL) area falls within the jurisdiction of four levels of government, including federal, provincial, regional (Metro Vancouver) and municipal (University Endowment Lands), with all levels containing enforceable legislation. UEL was required to develop and implement an Integrated Stormwater Management Plan (ISMP) under Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (MV ILWRM; Metro Vancouver 2010) as a member body of the Greater Vancouver Sewerage & Drainage District (GVS&DD). The regulatory requirements of the ISMP include a variety of planning, engineering and environmental components, which is reflective of the multi-disciplinary nature of integrated stormwater management planning.

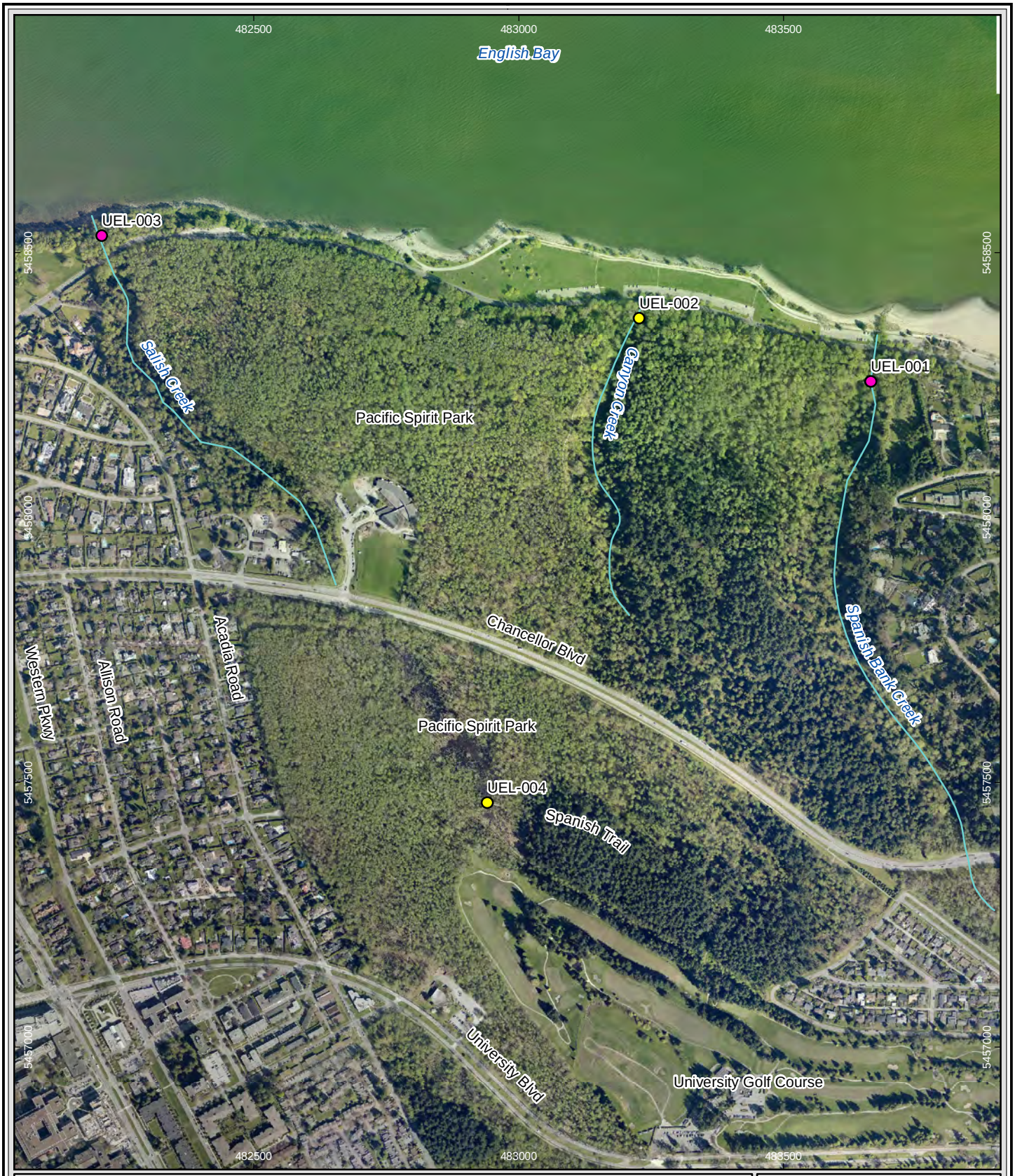
The provincial *Environmental Management Act* is the primary regulatory instrument of environmental protection in British Columbia. The Act allows municipalities to develop community specific solutions to manage the environmental risks of liquid waste streams such as sanitary sewage and stormwater runoff. Metro Vancouver has delegated the responsibility of managing environmental risks of stormwater runoff to its member municipalities (UEL). Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRM) require member municipalities to manage these risks through the development and implementation of Integrated Stormwater Management Plans for the watersheds within their jurisdiction. An Integrated Stormwater Management Plan is an over-arching, long-term strategy that focuses on the protection and enhancement of watershed health. ISMPs combine concepts of urban planning, stormwater management and environmental management to facilitate sustainable development within a watershed.

The UEL retained AECOM to develop the University Endowment Lands ISMP in line with the requirements of the Metro Vancouver LWRMP and the *Environmental Management Act*. As part of the ISMP, AECOM conducted benthic macroinvertebrate and water quality studies for the UEL over the course of one sampling year (wet and dry season). The sampling program was conducted while the implementation of the ISMP for the watersheds was being undertaken. The objective was to collect data representative of existing conditions to be used to monitor temporal changes (both impacts and improvements) in the UEL study area, identify factors potentially impacting environmental health and to determine the overall health of the watercourses. Baseline conditions were established through sampling that included water quality and benthic macroinvertebrates during different seasons. This report describes the studies conducted in 2015 in UEL watercourses including, Spanish Bank Creek, Canyon Creek, Salish Creek and a wetted area along Spanish Trail in Pacific Spirit Park (Spanish Trail watercourse, Figure 1).

1.2 Study Area

The Study Area includes three streams, Spanish Bank Creek, Canyon Creek and Salish Creek, which flow into the Burrard Inlet at Spanish Banks. Sampling sites were selected to collect baseline information for each of the stream systems; in addition an upstream ponded area of Salish Creek was included. The UEL consists of approximately 1,200 hectares of land between the City of Vancouver and the University of British Columbia. The majority of the land, approximately 920 ha (77%), is forested with the remaining 280 ha (23%) is developed for residential, commercial, and institutional land uses. The developed community within the UEL is commonly referred to as University Hill. The ISMP study area consists of University Hill and the drainage channels which the stormwater infrastructure discharges. University Hill is divided into four areas (Figure 2):

- Area A: bordered by Chancellor Boulevard, Acadia Road, University Boulevard, and Wesbrook Mall;
- Area B: between Chancellor Boulevard and NW Marine Drive;
- Area C: between Blanca St., 6th Ave, Tasmania Crescent and College Highroad; and,
- Area D: between University Boulevard, Agronomy Road, Toronto Road, and Wesbrook Mall; and includes Block F.



Basemapping from Government of BC, Natural Resources Canada, Metro Vancouver and AECOM 2016.

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Legend

- Water Quality Sampling Location
- Water Quality and Benthic Sampling Location
- Public Trails (Active) - Metro Vancouver

Overview Map

University Endowment Lands
Water Quality and Bentic Sampling
Location: University Endowment Lands

University Endowment Lands Sampling Locations

28 June 2016

AECOM

Figure 1

File Location: P:\60222155\900-Work\920-GIS\03 Maps\ISMP Figures\2016-02-03\Fig1-2016-02-03-SampleLocation60222155-001.mxd Date Revised: June 28, 2016 Reviewed by: MM
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The Village is the commercial centre of UEL located in Area D. This area includes Block 97 (bordered by University Boulevard, Western Parkway, Dalhousie Road and Allison Road), and the Regent College site (located on the south side of University Boulevard between Western Parkway and Wesbrook Mall).

The population of the UEL is estimated at 7,816 residents according to the 2001 Canadian Census with a total of 2,874 private dwellings. UEL has identified a group of properties, primarily residential rental apartments built in the 1940's and 1950's, that may be redeveloped and increase housing density within Area 'D'. Current zoning allows for an increase in density for an estimated additional 200 units. The estimated population growth following redevelopment is approximately 304 people. Further densification of existing developments in University Hill is not expected; however, there are plans to develop a new parcel of land referred to as 'Block F'. The population of Block F following build-out of the development is estimated at 2,500. The total projected population of the UEL is 10,620. The ISMP study area contains a number of high-volume roads that serve transportation between the City of Vancouver and the University of British Columbia, including Chancellor Boulevard, University Boulevard, and West 16th Avenue. There are no significant projects proposed within the study area that influence the ISMP.

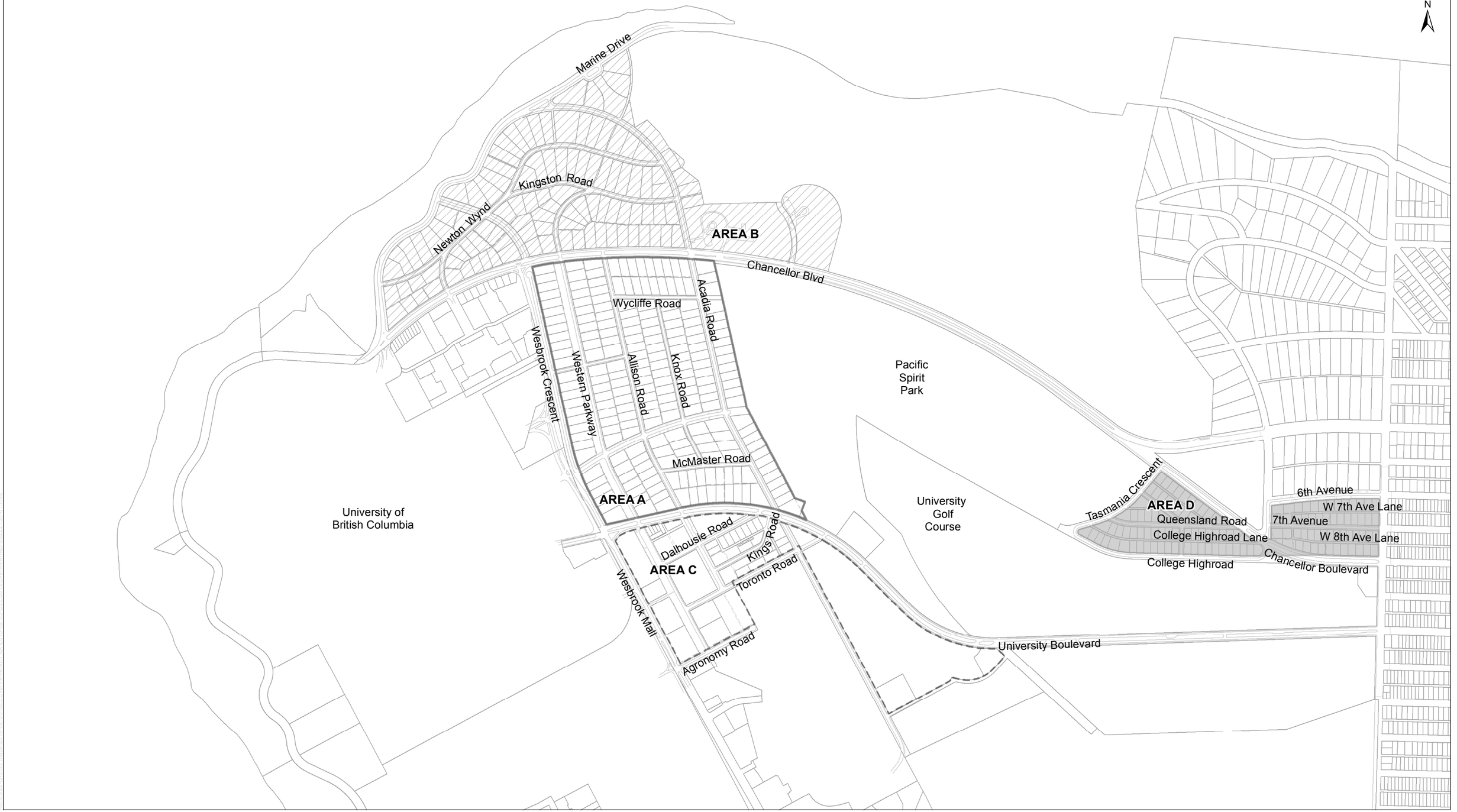
The study area is divided into seven main catchments (four University Hill development areas contained within these catchments), all of which discharge to English Bay via various creeks and ravines. The elevation varies from a high of approximately 90 m to a low of 10 m. The topography of the study area generally slopes northwards towards English Bay. The slope is steepest north of Chancellor Boulevard at a grade of approximately 9% and more gradual south of Chancellor Boulevard with slopes of less than 3%. There is a localized high point near the intersection of College Highroad and Wesbrook Crescent.

1.3 Study Objectives

The overall objective of the 2015 water quality and benthic invertebrate study was to collect data that will be used to characterize baseline conditions in the University Endowment Lands. Condition 7 of the BC Minister of Environment's approval of the Integrated Liquid Waste Resource Management Plan (ILWRMP) requires that municipalities, with the coordination of Metro Vancouver, develop a monitoring and adaptive management framework for assessing watershed health and the effectiveness of Integrated Stormwater Management Plans (ISMPs). To meet this requirement, Metro Vancouver formed a technical working group composed of members of the Stormwater Interagency Liaison Group, the Environmental Monitoring Committee and the Ministry of Environment (MOE). The group produced a Monitoring and Adaptive Management Framework (MAMF; Metro Vancouver 2014) for monitoring stormwater, assessing the effectiveness of ISMPs, and recommending adaptive management practices.

The MAMF outlines a framework to enable municipalities to track changes occurring within watersheds. Based on the stream types identified within the watershed, the MAMF recommends that a combination of water quality and benthic invertebrate sampling be used as a monitoring system tool. The specific scope of work for the 2015 water quality and benthic studies included the following:

- Conduct sampling at four locations within the University Endowment Lands;
- Undertake benthic macroinvertebrate sampling to develop a Benthic Index of Biotic Integrity (B-IBI) baseline that was conducted in late summer during a dry weather water quality sampling event;
- Conduct water quality sampling according to the following:
  - Collect water samples at each of the established sampling stations;
  - Collect five water samples during the dry season (August-September) within a 30 day period; and,
  - Collect five water samples during the wet season (November-December) within a 30 day period.



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Legend

- Parcel Lot
- Area A
- Area B
- Area C
- Area D

University Endowment Lands
Overview of Utility System

Figure 2

2. Methods

2.1 Dates and Locations of Aquatic Benthic Studies

Sample sites were located in three high gradient stream reaches and one low gradient stream reach (Table 1; Figure 1). The system type was classified according to criteria outlined in the MAMF. Sample sites were selected to provide an accurate representation of the watershed. Sampling for benthic marcoinvertebrates was conducted on 24 August 2015; however, samples were not obtained from site UEL-002 due to stream flow levels being too low to allow adequate flow through the surber sampling device and UEL-004 due to system type (lower gradient) not requiring invertebrate sampling.

Water quality samples were collected weekly for five weeks between August and September for the dry season and November to December for the wet season. Sampling dates are provided in Table 2.

Generally, all 10 weeks of water quality sampling occurred at the same location depicted in Figure 1, in order to allow for comparisons between water quality and benthic invertebrate data. Table 3 provides the coordinates of the aquatic sampling locations. Appendix D1 contains site photos of all the water quality sampling locations and site photos taken during benthic invertebrate sampling are provided in Appendix D2.

Table 1. List of UEL Watercourse Sampling Stations

Station ID	Location	System Type	Parameters	Rationale
UEL-001	Lower Spanish Bank Creek	High Gradient	Water Quality, Benthos	Reflects the impact of residential within the area.
UEL-002	Lower Canyon Creek	High Gradient	Water Quality	Reflects the impact of residential within the area.
UEL-003	Lower Salish Creek	High Gradient	Water Quality, Benthos	Reflects the impact residential and institutional (i.e. school, trail, works yard) within the area.
UEL-004	Upper Salish Creek	Low Gradient	Water Quality	Characterizes the impacts from the golf course.

Table 2. Water Quality Sampling Dates at UEL Watercourses, 2015

Sampling Period	Week	UEL Watercourses
Dry	1	24-August-2015
	2	01-September-2015
	3	09-September-2015
	4	15-September-2015
	5	22-September-2015
Wet	1	18-November-2015
	2	26-November-2015
	3	02-December-2015
	4	10-December-2015
	5	16-December-2015

Table 3. Water Quality and Benthic Invertebrate Sampling Location, 2015

Stream	Sample Location	Sample Type	UTM Coordinates
Spanish Bank Creek	UEL-001	Water, Benthic Invertebrates	483665 5458256
Canyon Creek	UEL-002	Water	483228 5458375
Salish Creek	UEL-003	Water, Benthic Invertebrates	482214 5458531
Spanish Trail Watercourse	UEL-004	Water	482941 5457461

2.2 Sample Collection and Data Analysis

2.2.1 Water Quality

All surface water samples taken from the watercourses were grab samples, collected in mid-stream below the surface with the bottle mouths facing upstream. All bottles, preservatives and materials were provided by the laboratory. All samples were kept on ice in a cooler but not allowed to freeze and transported to Maxxam Analytics in Burnaby, BC, immediately following sample collection. Maxxam Analytics is accredited by the Canadian Association for Environmental Analytical Laboratories. Chain of Custody forms accompanied all samples.

The minimum required water quality parameter list outlined in the MAMF was used, and included nitrate, E. coli, fecal coliforms and total metals. Detection limits for each of the parameters is provided in Table 4. For metals analysis, it was assumed that high level metal analysis would be sufficient based on the expected urban stream profile.

In situ data was obtained using a YSI Pro Plus metre for dissolved oxygen (DO), temperature, pH and conductivity, and a Lamotte turbidity metre. Samples for general parameters were collected in a 120 ml plastic bottle. Samples for analysis of total metals only were collected and placed in 120 mL acid-washed plastic bottles and preserved in the field with nitric acid. A separate glass vial preserved with hydrochloric acid was required for mercury analysis. Samples for nutrients were collected in 120 mL bottles. Microbiological parameters were collected in sterile plastic bottles that contained laboratory preserved sodium thiosulfate.

For the purposes of this report, the reportable detection limits (RDL) as provided by the laboratory were used in the analysis and values below the RDL used the RDL as the values for calculations. Mean values for the dry and wet sampling periods were calculated for all water quality parameters for each site sampled (Appendix A). For *E.coli* and fecal coliforms geometric means were calculated instead of the mean as per guideline comparison requirements.

Table 4. Water Quality Parameters and Detection Limits, 2015

Parameter	Units	RDL	Parameter	Units	RDL
Physical			**Total Metals Con'd**		
Conductivity	µS/cm	1	Copper	ug/L	0.5
pH	pH units	-	Iron	ug/L	10
Calculated Parameters			Lead	ug/L	0.2
Total Hardness	mg/L $CaCO_3$	0.5	Lithium	ug/L	5
Nitrate	mg/L	0.02	Magnesium	mg/L	0.05
Anions			Manganese	ug/L	1
Nitrite (N)	mg/L	0.005	Mercury	ug/L	0.01
Nutrients			Molybdenum	ug/L	1
Nitrate plus Nitrite (N)	mg/L	0.02	Nickel	ug/L	1
Microbiological Parameters			Potassium	mg/L	0.05
E. Coli	CFU/100 mL	1	Selenium	ug/L	0.1
Fecal Coliforms	CFU/100 mL	1	Silicon	ug/L	100
Total Metals			Silver	ug/L	0.02
Aluminum	ug/L	3	Sodium	mg/L	0.05
Antimony	ug/L	0.5	Strontium	ug/L	1
Arsenic	ug/L	0.1	Sulphur	mg/L	3
Barium	ug/L	1	Thallium	ug/L	0.05
Beryllium	ug/L	0.1	Tin	ug/L	5
Bismuth	ug/L	1	Titanium	ug/L	5
Boron	ug/L	50	Uranium	ug/L	0.1
Cadmium	ug/L	0.01	Vanadium	ug/L	5
Calcium	mg/L	0.05	Zinc	ug/L	5
Chromium	ug/L	1	Zirconium	ug/L	0.5
Cobalt	ug/L	0.5			

Results analysis included comparisons with various available water quality guidelines for the measured parameters. Guidelines used to compare against measure water quality results included:

- BC Approved Water Quality Guidelines
- A Compendium of Working Water Quality Guidelines for British Columbia
- CCME Canadian Environmental Quality Guidelines
- Health Canada Guidelines for Canadian Recreational Water Quality

To provide context in terms of the amount of precipitation received leading up to the sampling dates, daily total precipitation was obtained for the entire sampling month and sample date total precipitation were downloaded from the UBC Climate Station (UBC 2016). A comparison of the 2015 data was completed for the dry and wet period months with data for the previous decade using data from the same UBC Climate Station.

2.2.2 Benthic Macro Invertebrates

Stream benthic invertebrates were collected from sites UEL-001 and UEL-003 in Spanish Bank Creek and Salish Creek in late summer. Sampling was conducted following benthic invertebrate sampling protocols outlined in Metro Vancouver Monitoring and Adaptive Management Framework report (Metro Vancouver 2014). Sampling was conducted in riffle habitat along sections of stream to sample habitat favourable to *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT). The EPT taxa are sensitive to environmental stress and therefore provide an important measure of stream health. Samples were collected using a surber sampler with 250 µm mesh with substrate cleaning lasting for 3 minutes for each placement. Each placement sampled an area of 0.09 m^2 and each sample was a composite sample from 3 riffle surber placements. Each of the composite samples was filtered through a 250 µm screen and the sampler thoroughly washed. Washed samples were transferred to pre labeled plastic sample containers and preserved with 80% ethanol. GPS waypoints were taken at each of the locations.

Stream samples of benthic invertebrates were shipped to Biologica in Victoria, British Columbia. As specified in the MAMF report, benthic invertebrates should be analyzed to the lowest practice level; however, previous Metro Vancouver guidance document (Page *et al*. 2008) suggested using protocol outlined by Plotnikoff & White (1996), which identified *Chironomidae* to Family, *Oligochaeta* to Class, *Acari* to Class, Molluscs to Genus, and the remainder to species where possible. Benthic invertebrates were analyzed following Plotnikoff & White (1996). Laboratory analysis and QA/QC procedure were in compliance with protocols outlined in the MAMF.

Total density of benthic invertebrates collected by the surber sampler was calculated by total number of organisms collected from a sample divided by the total area sampled of 0.27 m^2.

2.2.2.1 Benthic Invertebrate Results Assessment

The scoring system overview that was used for the benthic invertebrate analysis was derived from the MAMF and recommended ten B-IBI scoring system, which consisted of the following (Fore *et al.* 1994):

1. Total number of taxa
2. Number of mayfly (*Ephemeroptera*) taxa
3. Number of stonefly (*Plecoptera*) taxa
4. Number of caddisfly (*Trichoptera*) taxa
5. Number of long-lived taxa, defined as living at least 2-3 years in the immature state
6. Number of intolerant taxa
7. Percent of individuals in tolerant taxa
8. Percent of predator individuals
9. Number of clinger taxa
10. Percent dominance: the sum of individuals in the three most abundant taxa, divided by the total number of individuals found in the sample (top 3 taxa)

Each of the above metrics scores are assigned based on range values provided in Table 5.

Table 5. B-IBI Metric Guideline Scores Used to Determine Stream Quality

Metric	Scoring Category		
	1	3	5
Taxa Richness & Composition			
Total number of taxa	0 to <15	15 to <28	≥28
Number of mayfly (Ephemeroptera) taxa	0 to <4	4 to 8	>8
Number of stonefly (Plecoptera) taxa	0 to 3	>3 to 7	>7
Number of caddisfly (Trichoptera) taxa	0 to <5	5 to <10	≥10
Number of long-lived taxa	0 to 2	>2 to 4	>4
Pollution Tolerance			
Number of Intolerant taxa	0 to 2	>2 to 3	>3
Tolerant individuals (%)	≥50	>19 to 50	0 to 19
Feeding Ecology			
Predator individuals (%)	0 to <10	10 to <20	≥20
Population Attributes			
Number of clinger taxa	0 to 8	>8 to 18	>18
Dominance % (3 taxa)	≥80	60 to <80	0 to <60

Source: Page *et al*. 2008

Scoring category interpretation is based on the following descriptions:

- 1: results expected in severely degraded sites
- 3: somewhat degraded sites
- 5: undisturbed sites

Total B-IBI scores were obtained by summing the scoring for each of the ten metric categories from Table 5. Interpretation of the total scoring results can be interpreted using Table 6 range values. Some range values contain gaps between each of the categories, so professional judgement can be applied to select the most appropriate category classification.

Table 6. Range B-IBI Scoring Results Interpretation Values

Metric B-IBI Score Totals	Stream Condition
46-50	Excellent
38-44	Good
28-36	Fair
18-26	Poor
10-16	Very poor

Source: Metro Vancouver 2014

2.3 QA/QC

2.3.1 Water Quality

Field QA/QC

All field equipment was maintained in good working condition and instruments were calibrated prior to use. The pH probe was calibrated prior to each field trip using prepared solutions with pH levels of 4 and 7, and the conductivity meter was checked prior to each field trip using the standard 1,413 µS/cm conductivity solution.

All water samples were collected using industry standard sampling protocols. Appropriate measures were taken to reduce potential for sample contamination. Field staff wore disposable nitrile gloves when sampling and used bottles and preservative supplied by the analytical laboratory. All stream samples were collected with the mouth of the sampling bottle facing upstream and the sampler standing downstream of the sample bottle. Care was taken to ensure that no upstream disturbances occurred within the creek bed prior to sampling.

Water quality samples were collected by a qualified aquatic biologist. No field or trip blanks were collected as part of the program.

Laboratory QA/QC

A quality check was conducted by the Maxxam Analytics, which included using a spiked sample as an estimate of accuracy of analysis. To meet the QA/QC standard, the results from a spiked matrix must be within 80% to 120% of the known concentration. Table 7 shows the sample that did not meet the spiked matrix criteria. While the following parameters in the sample set did not meet the quality control limits, Maxxam concluded that overall the quality control results indicated that the analysis met the quality standards.

Table 7. Summary of Spiked Matrix Results Outside the 80-120% Criteria, Maxxam

Sample Date	Spiked Matrix outside of 80-120% Criteria
1 September 2015	Total Titanium (125%)
8 September 2015	Total Aluminum (176%)

2.3.2 Benthic Invertebrates

Biologica is a Canadian aquatic bioassessment firm based in Victoria, British Columbia. The laboratory services include taxonomic analysis of invertebrate communities, including benthos, zooplankton, and phytoplankton from both marine and freshwater environments. Biologica has expertise in aquatic habitats throughout Western Canada, the Pacific Northwest and the Arctic, and has worked on projects from around the world.

Biologica staff are recognized as the taxonomic experts of the Pacific Northwest and certified in freshwater taxonomy (EPT and *Chironomidae*) by the Society for Freshwater Science. Biologica processes approximately 5000 samples per year from various aquatic habitats every year with strict attention to client timelines and budgets.

Biologica has a rigorous sorting procedure that guarantees 95% removal of organisms from all debris sorted. For all samples, a spot check of 25% of the samples was completed. The quality assurance (QA) re-sorts were done after internal quality control (QC) and were selected randomly from all the QC samples. Additionally, a reference collection was created for potential third party verification if necessary. Sorting occurred with 10% of the samples with an overall average of 97.9% efficiency and a subsampling precision of 9.4%. Typically the acceptable criteria for subsampling protocol are a subsampling precision of less than 20% (EC 2013). Additionally, no disagreements were reported from review of referenced specimens (100% agreement).

3. Results and Discussion

3.1 Water Quality

Appendix A provides the results of all water quality samples taken during the five weeks of dry period sampling and five weeks of wet period from 24 August to 18 December 2015. Appendix tables were grouped according to sample sites and include dry period mean and wet period mean (geometric mean for microbiological parameters). All parameters with higher concentrations than the criteria for the protection of aquatic life have been highlighted in the tables accordingly.

3.2 General Water Quality Parameters

3.2.1 Data Analysis

General water quality parameters include temperature, dissolved oxygen (DO), conductivity, total dissolved solids, salinity, pH, turbidity and hardness. Generally, differences were noted in the water quality parameters between site UEL-004 and all other sampling types. The difference is due to the differences in watercourse morphology. Sites UEL-001, UEL-002 and UEL-003 are stream systems and UEL-004 is best characterized as a ponded, forest area that is channelized in sections.

Neutral to alkaline lab pH conditions were observed at all sampling locations, with pH averaging between 6.9 to 8.0 throughout the sampling program. The pH values in the dry sampling period were higher than the wet period, which would be expected due to the higher acidic input of rain during the wet sampling period. The lowest mean pH values were measured at UEL-002 during both sampling periods.

Total hardness in Spanish Bank Creek (UEL-001) averaged 65.3 mg/L as calcium carbonate in the dry season and 40.5 mg/L in the wet season. Canyon Creek (UEL-002) averaged 20.9 mg/L in the dry season and 14.8 mg/L in the wet season. Salish Creek (UEL-003 averaged 46.8 mg/L in the dry season and 43.9 mg/L in the wet season. The Spanish Trail watercourse site (UEL-004) averaged 97.3 mg/L in the dry season and 46.7 mg/L in the wet season. Higher total hardness was observed in the dry season when compared to the wet season. Site UEL-002 measured the lowest total hardness overall than the other sites and UEL-004 had the highest hardness during the dry period and decreased to having similar levels during the wet season. Water hardness in the area is generally considered to be soft.

Conductivity was generally higher at all sites in the dry period over the wet period, with exception to sample site UEL-002. Specific conductivity values of BC Coastal streams typically are at the 100 µS/cm range. Mean turbidity in all sites during all sample periods ranged from 0- 41 NTU. Both, UEL-001 and UEL-002 had an overall mean of less than 1 NTU (0.96 and 0.76 NTU), UEL-003 measured below 2 NTU (1.9 NTU) and UEL-004 had the highest turbidity with a mean of 16.8 NTU. Site UEL-004 was consisted of a wetted area which contained higher total dissolved solid and conductivity levels than all other sampling sites.

3.2.2 Comparison with Water Quality Guidelines

The only *in situ* parameter that exceeded guidelines was pH; the guidelines specify a range of 6.0 to 9.0 with values outside this range to be investigated. The pH values were outside the range for the *in situ* readings at UEL-002 and UEL-004, primarily during the wet sampling seasons. Lower pH results at UEL-002 were measured and could be due to the lower buffering capacity from acidic inputs as indicated by the low total hardness values measured. Measurements outside the lower guideline limit at UEL-002 occurred during the wet sampling period when the stream received higher proportions of rain.

3.3 Nutrients

3.3.1 Data Analysis

Nutrient concentrations as measured by nitrogen compounds for this study generally displayed variable trends during the program sampling periods, with higher values measured in the wet sampling period. The nutrient parameters consisted of nitrite, nitrate and nitrate plus nitrite, which were recommended parameters listed in the MAMF document. During the wet sampling period, the mean nitrate value measured at site UEL-002 was the highest (2.42 mg/L), with all other sites being relatively similar (average range 1.23-1.44 mg/L). Nitrate levels at UEL-001 remained similar between the wet and dry sampling periods; however, decreased at all other sites during the dry sampling period.

3.3.2 Comparison with Water Quality Guidelines

Nutrient concentrations in all systems were within the water quality guidelines.

3.4 Microbiological Indicators

3.4.1 Data Analysis

Microbiological parameters obtained during the course of the wet and dry sampling periods included fecal coliforms and E.coli. Sampling for the parameters occurred at each of the four sampling locations.

Fecal coliforms are common bacteria found in the intestinal tracts of both human and warm-blooded animals and are an indicator of human and animal waste inputs to watercourses. Levels of fecal coliform varied depending on the site. Spanish Bank Creek (UEL-001) and Salish Creek (UEL-003) had higher fecal coliform levels during the wet period, whereas Canyon Creek (UEL-002) and the Spanish Trail watercourse site (UEL-004) had higher levels during the dry period. Mean fecal coliform levels at Spanish Bank Creek (UEL-001) was the highest during the wet period (geometric mean 1214 CFU/100 ml) compared to the other sites during the wet period (UEL-002 geometric mean of 5 CFU/100 ml, UEL-003 geometric mean of 682 CFU/100 ml, and UEL-004 geometric mean of 24 CFU/100 ml). During the dry period the mean fecal coliform levels at Salish Creek (UEL-003) was the highest (geometric mean 290 CFU/100 ml) compared to the other sites during wet sampling period (UEL-001 geometric mean of 115 CFU/100 ml, UEL-002 geometric mean of 88 CFU/100 ml, and UEL-004 geometric mean of 46 CFU/100 ml).

Similar to fecal coliforms, E. coli concentrations varied depending on the site. Both sites Spanish Bank Creek (UEL-001) and Salish Creek (UEL-003) had higher fecal coliform levels during the wet period, whereas Canyon Creek (UEL-002) and the Spanish Trail watercourse site (UEL-004) had higher levels during the dry period. Levels of E. coli were highest at Spanish Bank Creek (UEL-001) during the wet period with a mean of 298 CFU/100 ml. Additionally, the lowest mean observed for E.coli was also observed in Canyon Creek (UEL-002) during the wet period with a mean of 3 CFU/100 ml.

3.4.2 Comparison with Water Quality Guidelines

Various microbiological indicator guidelines exist for fecal and E. coli parameters with guideline values being dependent on the use of the water being sampled. The most appropriate guidelines for fecal coliform comparisons to BC Water Quality Recreational Primary Contact for fecal coliform and Health Canada Guidelines for Canadian Recreational Water Quality (2012) for E. coli.

Health Canada guidelines for E. coli based on recreational primary contact levels are $\leq$200/100 mL for geometric mean values and $\leq$400 E.coli/100 mL maximum. BC Water Quality guidelines for E. coli based on recreational primary contact levels are $\leq$77/100 mL geometric mean. E. coli levels at UEL-004 remained below guidelines for recreational primary contact use during both the wet and dry period. The E.coli guideline was exceeded during the wet season by 4 times the guideline. E. coli monthly guideline values were exceeded during both the wet and dry

season at UEL-003. E. coli geometric mean values were higher in the dry sampling period at UEL-003 when compared to the wet season.

BC Water Quality guideline for fecal coliform for recreational primary contact water use is ≤200/100 mL geometric mean. Fecal coliform at UEL-004 remained below recommended guidelines during both the wet and dry period. The fecal coliform guideline was exceeded during the wet season by 6 times the guideline value. Fecal coliform guideline value was exceeded during both the wet and dry season at UEL-003. Fecal coliform values were higher at UEL-003 during the wet sampling period.

3.5 Metals

3.5.1 Data Analysis

The concentrations of total metals in the samples were variable between wet and dry sampling periods and sampling locations. The wetland site (UEL-004) contained a higher proportion of metal concentrations than the all other sample sites. Comparatively, UEL-001 and UEL-003 were similar in metal concentrations with UEL-002 having the lowest general values. Generally, higher total metal concentrations were measured in the wet period when compared to the dry period levels. The majority of total metal parameters measured were below RDL levels during both the wet and dry sampling periods at all sites. Key metal parameters identified in the MAMF guidance document are iron, cadmium, copper, lead and zinc. Of these key parameters, copper and zinc levels tended to be higher at the sites in the MAMF monitoring ranges levels (see Section 3.6), than all other parameters. Further investigation of watershed delineation and upper watershed sampling should be considered for future sampling programs to determine whether levels are natural or from specific point sources.

3.5.2 Comparison with Water Quality Guidelines

Aluminum, copper, iron and manganese were reported to exceed either one or both of the CCME and BC Water Quality Guidelines (maximum and/or chronic, 30-day guidelines) at the most of water quality sampling locations. Additionally, the wetland site (UEL-004) had exceedances of manganese and the 30 day guideline for zinc during the wet sampling period. Tables 8 to 10 below outline the values obtained at each of the sites and highlights the samples that exceeded criteria displayed in bold. Sample criteria exceedances apply to any available guidelines, for details on which specific guideline is being exceeded, refer to Appendix A. Total copper guideline values are dependent on water hardness, which varies between each sample.

Table 8. Total Aluminum (µg/L) Concentration at UEL Sampling Locations, 2015

Sample Period	Sample Date	Sample Location			
		UEL-001	UEL-002	UEL-003	UEL-004
Dry	24 August 2015	46.8	**160**	35	**567**
	1 September 2015	**155**	**126**	43.2	**734**
	8 September 2015	60.2	**148**	29.2	59.8
	15 September 2015	43.4	96.3	28.1	**324**
	22 September 2015	36.4	**104**	23.7	**197**
Wet	18 November 2015	**235**	**280**	**103**	**121**
	26 November 2015	**122**	**133**	54.6	66.6
	2 December 2015	**212**	**205**	**124**	**358**
	10 December 2015	**343**	**330**	**236**	**1500**
	16 December 2015	**225**	**291**	**122**	**243**

Bolded values exceed guidelines

Table 9. Total Copper (µg/L) Concentration at UEL Sampling Locations, 2015

Sample Period	Sample Date	Sample Location			
		UEL-001	UEL-002	UEL-003	UEL-004
Dry	24 August 2015	1.07	**2.4**	1.72	2.44
	1 September 2015	**5.44**	**2.31**	**4.38**	**9.42**
	8 September 2015	1.91	**2.12**	**3.1**	**2.79**
	15 September 2015	1.16	**2.4**	**2.56**	2.49
	22 September 2015	1.38	1.54	**4.05**	**3.23**
Wet	18 November 2015	**2.48**	1.08	**3.51**	**2.1**
	26 November 2015	**2.23**	1.12	**3.27**	**2.01**
	2 December 2015	**3.96**	**3.35**	**6.81**	**7.14**
	10 December 2015	**3.74**	1.81	**4.93**	**6.16**
	16 December 2015	**2.89**	1.58	**3.59**	**3.61**

Guideline value based on sample hardness; bolded values exceed guidelines

Table 10. Total Iron (µg/L) Concentration at UEL Sampling Locations, 2015

Sample Period	Sample Date	Sample Location			
		UEL-001	UEL-002	UEL-003	UEL-004
Dry	24 August 2015	269	**572**	264	**4840**
	1 September 2015	288	**326**	209	**5620**
	8 September 2015	254	**390**	212	**5670**
	15 September 2015	235	**376**	209	**16700**
	22 September 2015	172	**306**	228	**10300**
Wet	18 November 2015	245	120	**333**	**703**
	26 November 2015	193	83	217	**1830**
	2 December 2015	268	199	**463**	**1870**
	10 December 2015	**341**	124	**406**	**7070**
	16 December 2015	288	160	**313**	**1530**

Bolded values exceed guidelines

Elevated water quality concentrations in relation to established guidelines were reported for the following parameters in the all three systems:

- **Aluminum**: Total aluminum values were exceeded on at least four sampling event at all sites. A higher proportion of exceedances resulted in the wet sampling period with the highest overall exceedances occurring at site UEL-002 (Table 8). Aluminum is not considered a serious threat to public health as it can precipitate out of solution but is important for areas with acidic inputs since it can cause deformation of embryos at low pH (RISC 1998).
- **Copper**: Guideline exceedances for copper concentrations were present during all sample sites during at least five sampling events. The highest overall sampling exceedances occurred at UEL-003 (Table 9). The maximum CCME guideline and BC Water Quality 30-day average guideline for copper was exceeded for all sampling sites. Copper is essential for all plant and animal nutrition; however, copper is acutely toxic to most forms of aquatic life at relatively low concentrations (RISC 1998). It should be noted that total copper as a water quality indicator includes a large fraction of that may be in forms that are biologically unavailable and total copper may overestimate toxicity, especially in a turbid waterbody with high complexing capacity.
- **Iron**: CCME Guideline exceedances for iron concentrations were present in all sites and varied between sites during the wet and dry periods. A higher proportion of exceedances occurred at the wetland site

(UEL-004), which also exceeded BC Water Quality Guidelines of 1000 µg/L (Table 10). None of the other sites exceeded the BC Water Quality Guideline for Iron. In certain circumstance, total iron concentration in water may exceed the recommended guideline of 1.0 mg/L due to natural cases, which is often caused by high load of suspended material in water during high flow conditions and the association of total iron content with the suspended materials (MOE 2008). The suspended material may be the reason for the iron concentration exceedances, particularly during the wet period exceedances. Canyon Creek (UEL-002) had exceedances during the dry period only and wetland site (UEL004) had exceedance during both wet and dry periods.

- **Manganese:** Total Manganese exceeded guidelines at wetland site (UEL-004) on two sampling occasions (15 September and 22 September 2015) and exceeded the 30 Day Maximum BC Water Quality Guideline for the dry period.
- **Zinc:** The total zinc 30 day average guideline value of 7.5 µg/L was exceeded during the wet sampling period. This exceedance was primarily due to the levels measured during the December 2 and December 10 sampling events. Zinc is relatively non-toxic to terrestrial organisms but is acutely and chronically toxic to aquatic organisms, particularly fish. Zinc toxicity decreases with increasing hardness and temperature, and increases with decreasing dissolved oxygen (RISC 1998).

3.6 Water Quality Assessment Approach for Adaptive Management

The MAMF includes a water quality assessment approach that provides municipalities with a simplified screening system to identify where water quality conditions are good and where there may be concerns with water quality. This assessment includes an assessment of stream health in watersheds that are potentially at risk from urban land use and non-point source pollution. When evaluating UEL watercourses utilizing the adaptive management system, all sites individual sampling results were pooled to provide a single wet and dry period mean. The MAMF was developed to provide a simplified approach to water quality assessment by allowing each parameter to be classified into categories for each parameter by season. This tool provides a generalized approach to water quality assessment and Appendix A should be referenced to evaluate water quality parameters in more detail for each site. Table 12 provides a summary of key parameters used to evaluate the overall stream health of the UEL watersheds.

The MAMF rating system using UEL water quality data is presented in Table 12. To provide a simplified approach, the water quality assessment table allows each parameter to be classified into three categories based on the average water quality for each parameter by season. This summary system does not account for site specific conditions (e.g. total hardness) and represents an average stream health assessment. Values in the table were calculated using means for each of the season, with exception to bacteriological parameters, which used a geometric mean.

Table 11. Adaptive Framework Management Rating System for Key Water Quality Parameters in UEL Sample Creeks

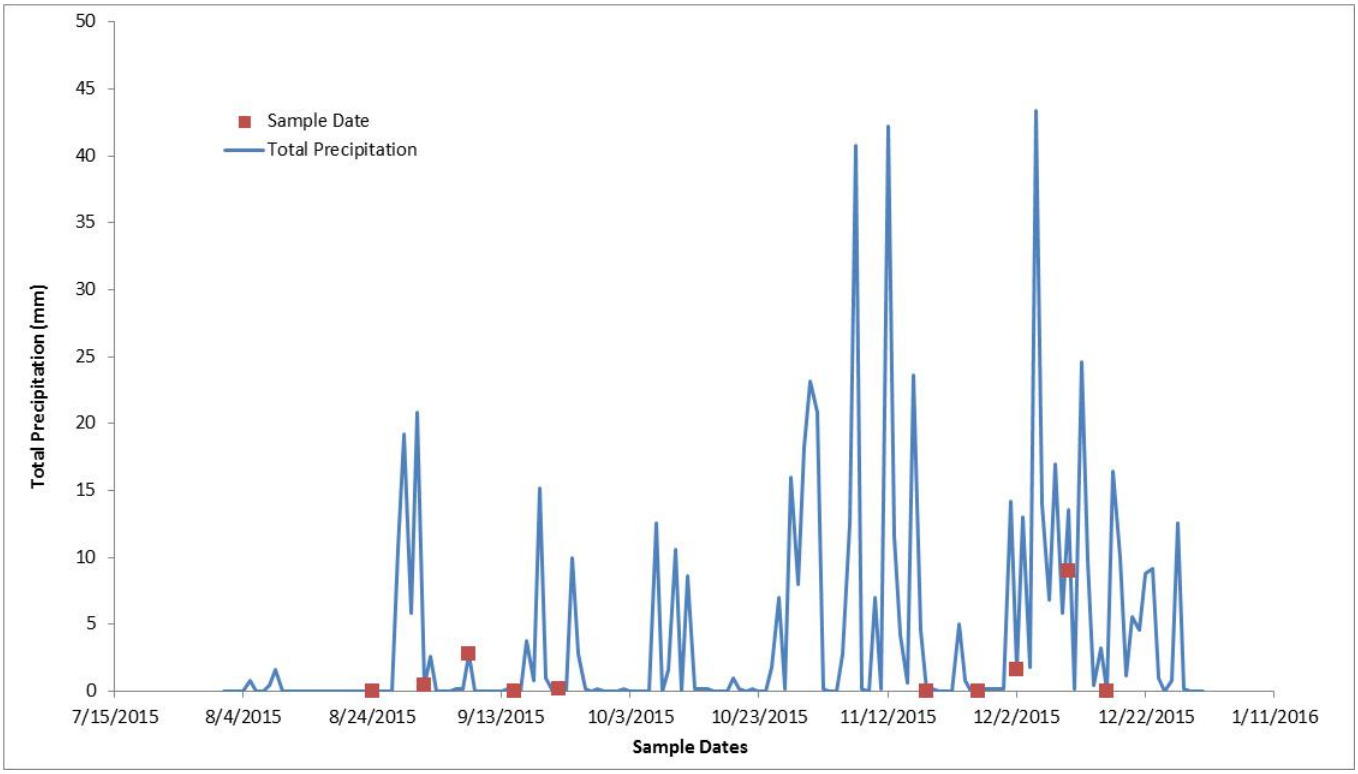
Parameter	Units	AMF Ranking System	UEL-001			UEL-002			UEL-003			UEL-004		
			Wet Mean	Dry Mean	AMF Rank	Wet Mean	Dry Mean	AMF Rank	Wet Mean	Dry Mean	AMF Rank	Wet Mean	Dry Mean	AMF Rank
Dissolved Oxygen (DO)	mg/L	11 = Good 6.5 to 11 = Satisfactory <6.5 = Need Attention	11.50	10.5	Good (wet), Satisfactory (dry)	11.91	9.6	Good (wet), Satisfactory (dry)	11.96	12.0	Good	6.20	0.8	Needs Attention
pH	pH units	6.5-9.0 = Good <6.5 to 6.0 or >9.0 to 9.5 = Satisfactory <6.0 or >9.5 = Need Attention	7.70	7.9	Good	6.89	7.6	Good	7.85	8.0	Good	7.66	7.8	Good
Temperature	°C	<16 (Dry) or 7-12 (wet) = Good 16-18 (Dry) or 5-7 (wet) or 12-14 (wet) = Satisfactory >18 (dry) or <5 or >14 (wet) = Need Attention	7.2	12.0	Good	6.4	12.6	Satisfactory (wet), Good (dry)	6.8	11.2	Satisfactory (wet), Good (dry)	5.6	14.4	Satisfactory (wet), Good (dry)
Conductivity	µS/cm	<50 = Good 50-200 = Satisfactory >200 = Need Attention	129	184.2	Satisfactory	82	66.8	Satisfactory	136	150.0	Satisfactory	142	237.6	Satisfactory (wet), Needs Attention (dry)
Turbidity	NTU	0-5 = Good 5-25 = Satisfactory >25 = Need Attention	1.76	0.3	Good	0.93	0.6	Good	3.36	0.7	Good	11.96	20.7	Satisfactory
Nitrate	Mg/L	<2 = Good 2-5 = Satisfactory >5 = Need Attention	1.44	1.3	Good	2.42	0.5	Satisfactory (wet), Good (dry)	1.29	0.5	Good	1.23	0.3	Good
Fecal Coliform	CFU/100 ml	<200 = Good 201-1000 = Satisfactory >1000 = Need Attention	14018	246.2	Needs Attention (wet), Satisfactory (dry)	8	325.0	Good (wet), Satisfactory (dry)	694	240.0	Satisfactory	27	65.8	Good
E. coli	CFU/100 ml	<77 = Good 78-386 = Satisfactory >385 = Need Attention	1236	127.2	Needs Attention (wet), Satisfactory (dry)	5	306.8	Good (wet), Satisfactory (dry)	193	192.0	Satisfactory	13	36.2	Good
Iron (total)	µg/L	<800 = Good 800-5000 = Satisfactory >5000 = Need Attention	267.0	243.6	Good	137	394.0	Good	346	218.5	Good	2601.0	8626.0	Satisfactory (wet), Needs Attention (dry)
Cadmium (total)	µg/L	<0.06 = Good 0.06-0.34 = Satisfactory >0.34 = Need Attention	0.020	0.011	Good	0.027	0.013	Good	0.019	0.010	Good	0.031	0.013	Good
Copper (total)	µg/L	<3 = Good 3-11 = Satisfactory >11 = Need Attention	3.06	2.2	Satisfactory (wet), Good (dry)	1.79	2.2	Good	4.42	3.3	Satisfactory	4.20	4.1	Satisfactory
Lead (total)	µg/L	<5 = Good 5-30 = Satisfactory >30 = Need Attention	0.3	0.2	Good	0.2	0.2	Good	0.3	0.2	Good	1.0	0.7	Good
Zinc (total)	µg/L	<6 = Good 6-40 = Satisfactory >40 = Need Attention	5.7	5.0	Good	6.1	5.0	Satisfactory (wet), Good (dry)	10.0	5.0	Satisfactory (wet), Good (dry)	8.1	6.1	Satisfactory

Overall, at sites UEL-002 (Canyon Creek) and UEL-003 (Salish Creek) the AMF rankings were either good or satisfactory for all parameters. At site UEL-001 (Spanish Bank Creek) key parameters that require attention according to the AMF ranking were fecal coliform and E.coli (wet period only) and at Site UEL-004 (Spanish Trail watercourse site) dissolved oxygen (wet and dry period), conductivity (dry period) and total iron (dry period).

3.7 Regional Precipitation

Precipitation data was obtained through climate@ubc, which is managed by the UBC Faculty of Land and Food Systems (LFS; UBC 2016). The UBC Climate Station is located on Totem Field at the Vancouver Campus. Figure 3 shows precipitation data in relation to the wet period and dry period creek sampling dates (August to December 2015). For the Dry Period, low flows occurred during most sampling periods with the exception of week 3 having some total precipitation (under 5 mm). For the Wet Period, the majority of the sampling dates occurred during dry dates; however, rain events occurred before the sampling dates (Figure 3).

Figure 3. Regional Total Precipitation during both Wet and Dry Period UEL Sampling Program 2015



The eleven-year average from the UBC Climate Station (UBC 2016) for the months August to December from 2004 to 2014 are compared to the 2015 average daily precipitation data from the corresponding sampling months in Figure 4 to Figure 7. The average daily precipitation data for August was 1 mm, and for 2015 was 1.9 mm.

Figure 4. Regional Precipitation during Sampling in August, in Relation to Climate Normal near UEL

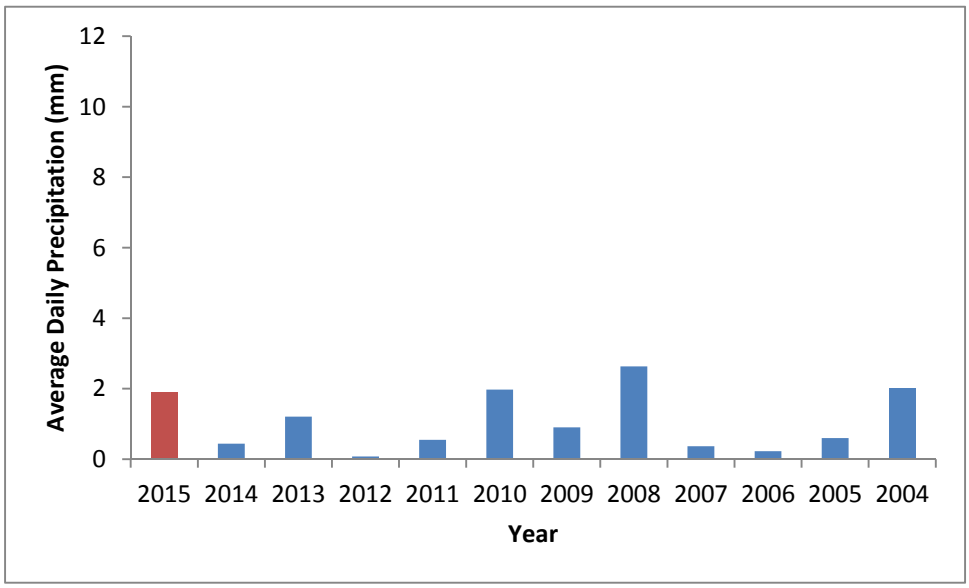


Figure 5. Regional Precipitation during Sampling in September, in Relation to Climate Normal near UEL

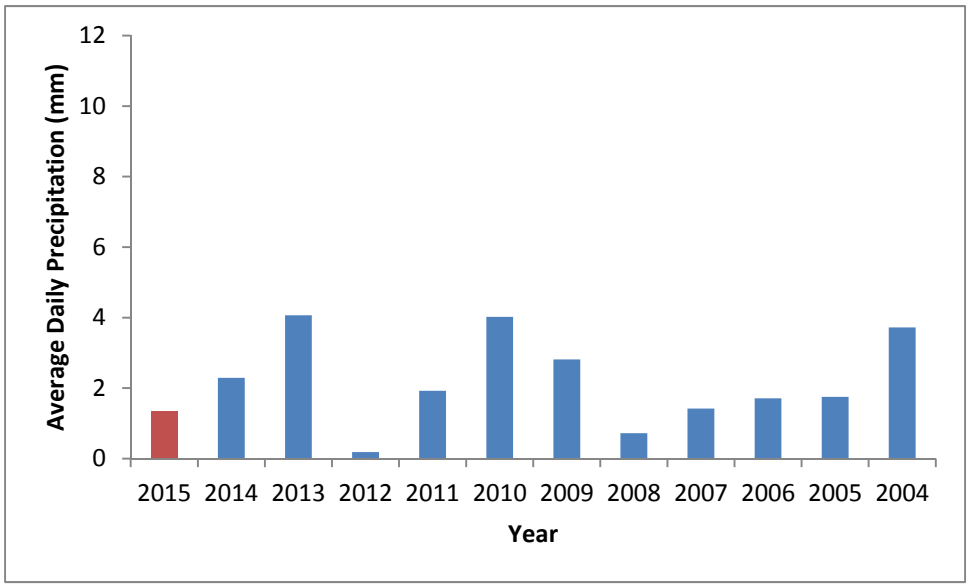


Figure 6. Regional Precipitation during Sampling in November, in Relation to Climate Normal near UEL

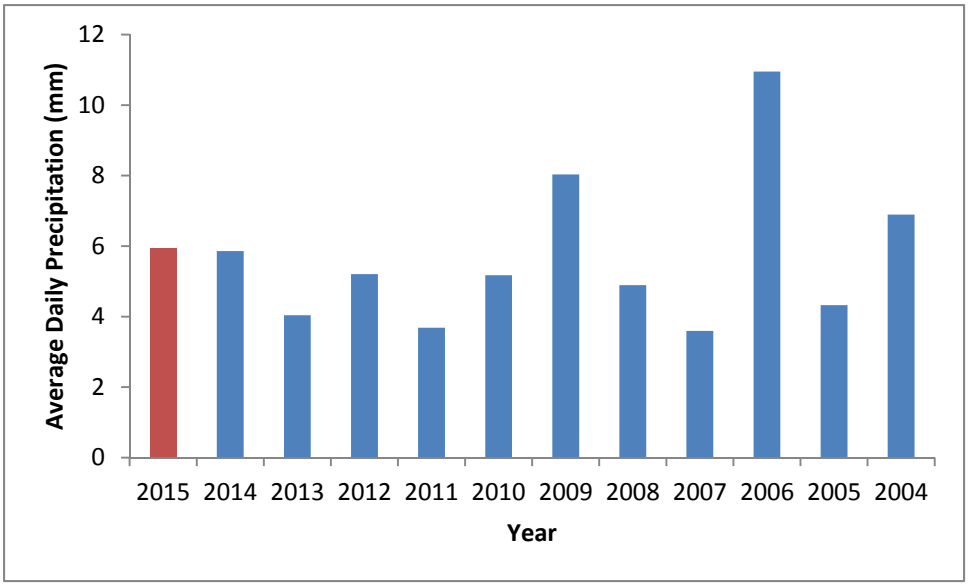
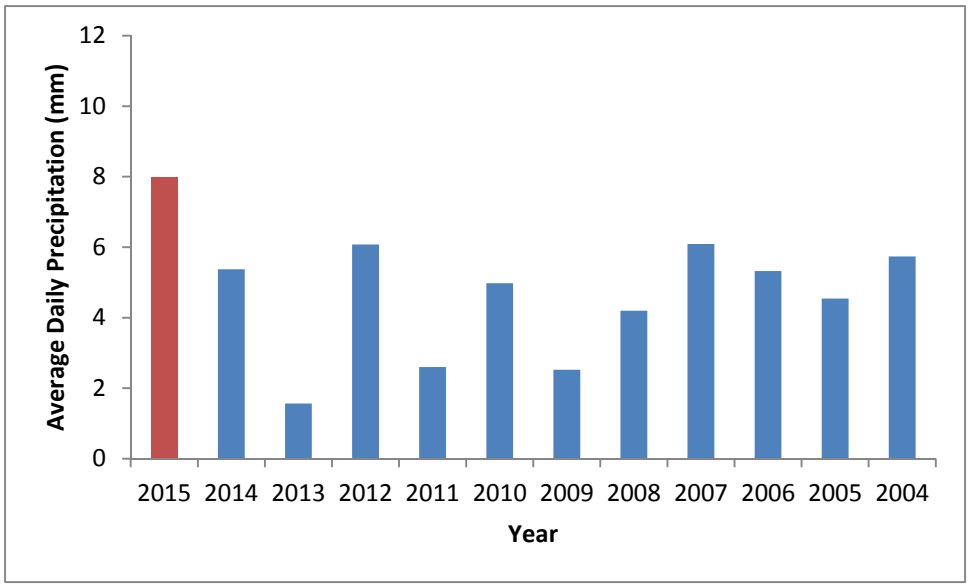


Figure 7. Regional Precipitation during Sampling in December, in Relation to Climate Normal near UEL



3.8 Benthic Invertebrates

3.8.1 Benthic Invertebrate Metrics

The total number of benthic invertebrate taxa for the UEL watercourse sample sites in 2015 are provided in Appendix B. Figure 8 represents the total benthic invertebrate densities obtained at each sample site and Figure 9 presents the benthic invertebrate species richness at each of the sample sites. Density was higher at site UEL-003 than UEL-001, whereas the opposite was true for taxon richness. Table 13 provides a summary of the percentage composition of the benthic invertebrate community at each riffle within a sampling site. *Simuliidae* (blackflies) dominated at both sites, UEL-001 and UEL-003. Similarly, the Spanish Bank Streamkeepers observed that the benthic invertebrate community in Spanish Bank Creek (UEL-001) was predominately blackflies whereas in Salish Creek (UEL-003) was predominately mayflies (Spanish Banks Streamkeepers 2010). Percentage of *Ephemoptera* (mayflies), *Plectoptera* (stoneflies) and *Trichoptera* (caddisflies; EPT %) was higher at site UEL-001 (average 30%) compared to site UEL-003 (average 21%).

Figure 8. Mean Density of Benthic Invertebrates, UEL Project, August 2015

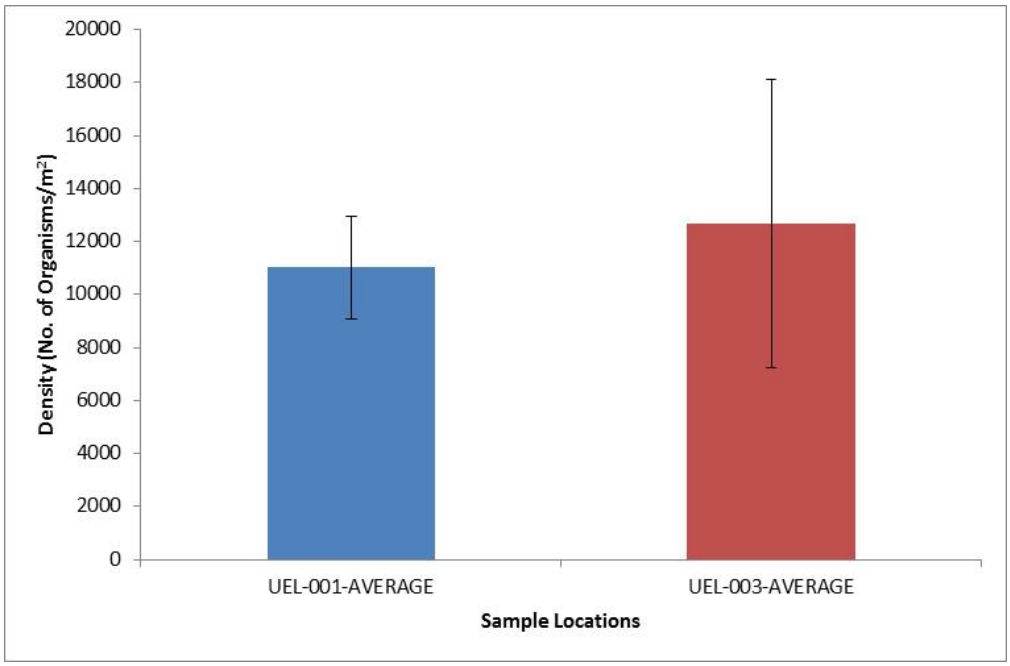


Figure 9. Species Richness of Benthic Invertebrates, UEL Project, August 2015

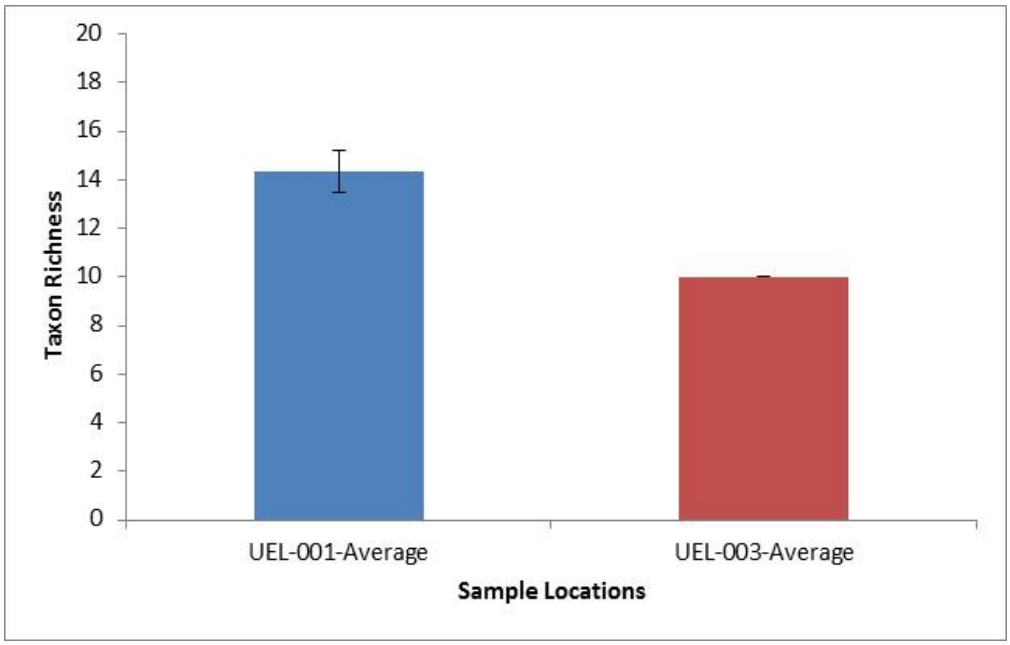


Table 12. Percentage Composition of Benthic Invertebrate Communities, UEL Project, August 2015

Family/Species	UEL-001-Average	UEL-003-Average
Oligochaeta indet.	1.10	0.40
Acari indet.	1.24	4.38
Anisogammaridae	2.34	0.00
Crangonyctidae	0.00	0.33
Amphipoda indet.	0.22	0.20
Elmidae	1.02	0.20
Chironomidae	17.04	25.94
Dixidae	1.83	0.60
Empididae	0.66	0.20
Simuliidae	**42.34**	**45.11**
Tipulidae	0.44	0.50
Baetidae	11.70	11.34
Heptageniidae	1.61	0.00
Ephemeroptera indet.	3.14	1.00
Nemouridae	7.97	0.00
Plecoptera indet.	0.22	0.00
Glossosomatidae	3.62	0.20
Hydropsychidae	0.95	1.06
Trichoptera indet.	1.90	7.96
Pisidiidae	0.66	0.20
Physidae	0.00	0.40

Bolded values=dominant taxon

3.8.2 Benthic Index of Biological Integrity (B-IBI)

Appendix C provides the details of the B-IBI scoring for the samples obtained in the UEL Project sampling locations. Table 14 provides the final stream condition ratings obtained for the sampling locations based on the B-IBI scores. Condition ratings in both creek systems were rated as very poor at both sites, UEL-001 and UEL-003. Spanish Bank Streamkeepers have conducted benthic invertebrates surveys in Spanish Bank Creek since 2001 and the site assessment ratings based on the streamkeeper protocols have rated Spanish Bank Creek between marginal and acceptable (Spanish Banks Streamkeepers 2010).

Table 13. B-IBI Range Scores Obtained for the UEL Project Sampling Program, 2015

Metric Scores	UEL-001	UEL-003
Metric Score	16	16
Stream Condition Rating	Very Poor	Very Poor

4. Summary

The information presented below is a summary of observations in the watersheds and seasonal differences from the results measured during the water quality and benthic invertebrate sampling program conducted between August to December 2015 for UEL water quality and benthic sampling program.

- Sampling in UEL creeks was completed for UEL during the development of the Integrated Stormwater Management Plan (ISMP) for the area. This sampling program was completed according to the methodology outline in the Monitoring and Adaptive Management Framework for Stormwater (Metro Vancouver 2014).
- Benthic macro invertebrate density was highest at UEL-001 sample location whereas taxon richness was highest at UEL-003 with the *Simuliidae* being the dominant benthic invertebrate community for both sample locations. Percentage of *Ephemoptera* (mayflies), *Plectoptera* (stoneflies) and *Trichoptera* (caddisflies; EPT %) was higher at site UEL-003 compared to site UEL-001, due primarily to the presence of *Trichoptera*.
- Benthic macro invertebrate B-IBI scoring provided an overall rating of very poor stream condition for the both sampling locations, UEL-001 and UEL-003.
- Bacteriological analyses were based on Health Canada guidelines for recreational primary contact levels. E.coli guideline values were exceeded at UEL-001 and UEL-003 sampling locations. Both fecal coliform and E. coli levels exceeded at these two sites during the wet sampling period. Exceedances for the two bacteriological parameters during the dry period only occurred at UEL-003.
- Aluminum, copper, iron, manganese and zinc exceeded either one or both of the CCME and BC Water Quality Guidelines (maximum and/or 30-day) at the UEL watercourse water quality sampling locations.
- The MAMF guidance document's simplified water quality screening system was applied and determined that the overall water quality in the watershed was rated as satisfactory to good condition. Fecal coliform (wet period) was identified as the only parameter in the assessment that required was in the Need Attention category rating. Parameters that were considered satisfactory in the watersheds include DO, temperature (wet period), conductivity, turbidity (dry period), fecal (dry period), E.coli, total iron, total copper (wet period), and total zinc (wet period).

5. Recommendations

The follow are final recommendations for further considerations in future water quality and benthic sampling occurring within UEL.

- Further sampling should be conducted to determine potential point sources for all water quality parameters that were exceeded during the dry and wet sampling periods. As part of further investigations, more parameters such as nutrients and parameters associated with roadway runoff could be added to the program to aid in the identification of point sources for water quality exceedances.
- Recommend including QA/QC water quality sampling to ensure overall quality of data collection and sample analysis of the program, such as duplicate and field and travel blanks.
- Considered alternative B-IBI protocols for some or all of the sample locations. One alternative recommended is the Canadian Aquatic Biomonitoring Network (CABIN) Protocol (EC 2012). The CABIN protocol is the national biomonitoring program developed by Environment Canada that provides a standardized sampling protocol and a recommended assessment approach called the Reference Condition Approach (RCA) for assessing aquatic ecosystem condition. CABIN provides the tools necessary to conduct consistent, comparable, and scientifically credible biological assessments of streams. This methodology would be beneficial for UEL-002 which had too low water levels for use of the surber sampler and samples were not able to be collected in this watercourse.
- Benthic studies should be conducted in the watersheds every 3 to 5 years in order to track long term trends in the area. The MAMF recommends that sampling be conducted every 5 years at a minimum. Particular attention to B-IBI ratings and water quality guideline exceedances should be utilized as overall health monitoring indicators.
- Consider adding a sample site location for future monitoring downstream of UEL-004 and upstream of UEL-003, near University Hill Elementary School and the UEL Public Works Yard. In general, a better understanding of watershed delineation and determination of upper watershed water quality sampling information is required at all sampling locations.
- Determine point source for elevated occurrences of fecal coliforms and E. coli upstream of the UEL-001 and UEL-003 sampling locations.

6. References

Environment Canada (EC). 2012. Canadian Aquatic Biomonitoring Network Field Manual for Wadeable Streams. http://publications.gc.ca/collections/collection_2012/ec/En84-87-2012-eng.pdf

Environment Canada (EC). 2013. Revised Guidance for Sampling Sorting and Subsampling Protocols for EEM Benthic Invertebrate Community Surveys. https://www.ec.gc.ca/esee-eem/default.asp?lang=En&n=F919D331-1&offset=2&toc=show

Fore L. S., J. R. Karr, and L. L. Conquest (1994), Statistical properties of an index of biotic integrity used to evaluate water resources. Canadian Journal of Fisheries and Aquatic Sciences 51: 212-231.

Health Canada. 2012. Guidelines for Canadian Recreational Water Quality, Third Edition. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch. Health Canada, Ottawa, Ontario. (Catalogue No H129-15/2012E). http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/water-eau/guide_water-2012-guide_eau/guide_water-2012-guide_eau-eng.pdf

Metro Vancouver. 2010. Integrated Liquid Waste and Resource Management: A liquid Waste Management Plan for the Greater Vancouver Sewerage & Drainage District and Member Municipalities. May 2010. http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/IntegratedLiquidWasteResourceManagementPlan.pdf

Metro Vancouver. 2014. Monitoring and Adaptive Management Framework for Stormwater. Integrated Liquid Waste and Resource Management. September 2014.

Page, N. A., L. S. Fore, M. Eymann, and C. Johnston. 2008. Assessment of the use of B-IBI in Greater Vancouver streams (2003–2006). Report prepared for Metro Vancouver. 58 pp. + appendices.

Plotnikoff, R.W. and J.S. White. 1996. Taxonomic Laboratory Protocol for Stream Macroinvertebrates Collected by the Washington State Department of Ecology. Washington State Department of Ecology. Publication No. 96-323.

RISC. 1998. Guidelines for Interpreting Water Quality Data. Prepared by Ministry of Environment, Lands and Park. LandData BC, Geographic Data BC for the Land Use Task Force, Resources Inventory Committee. Version 1.0. http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/interp/index.htm

Spanish Banks Streamkeepers. 2010. Spanish Bank Creek Invertebrate Surveys. https://spanishbankstramkeepers.wordpress.com/

University of British Columbia (UBC). 2016. Climate@UBC. Climate Station Data Download. http://137.82.254.122/DataExport.aspx

Appendix A

Water Quality Data

Appendix A - UEL Project, Water Quality Sampling, 2015

UEL-001

RESULTS OF CHEMICAL ANALYSES OF WATER																		
				Sampling Period	Dry Sampling					Wet Sampling					BC or CCME 30 Day Water Guidelines	Dry Mean	Wet Mean
				Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-15			
Parameter Name	Units	RDL	CCME[a]	BC Water Guidelines	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001			
In Situ																	
Temperature	°C	-			12.4	13.9	12.5	11.0	10.4	8.3	5.4	7.1	8.3	6.9		12.0	6.9
Dissolved Oxygen (%)	%	-			98.2	98.1	95.2	104.6	92.6	90.2	98.4	95.6	89.5	102.0		97.7	102
Dissolved Oxygen (mg/L)	mg/L	-			10.47	10.12	10.14	11.56	10.33	10.60	12.43	11.59	10.51	12.39		10.52	12.39
Specific Conductivity	uS/cm	-			207.7	166.8	170.1	186.1	187.4	122.7	144.8	150.0	107.0	116.7		183.6	116.7
Conductivity	uS/cm	-			157.7	131.4	129.4	136.1	135.6	83.60	90.50	98.70	73.00	76.40		138.0	76.4
Total Dissolved Solids	g/L	-			135.2	108.6	110.5	120.9	122.2	80.0	-	97.5	69.6	76.1		95.1	76.1
Salinity	ppt	-			0.10	0.08	0.08	0.09	0.09	0.06	-	0.07	0.05	0.05		0.09	0.05
pH	pH units	-	6.5 - 9.0	6.5 -9.0	7.15	6.95	7.13	6.95	7.42	6.61	6.87	6.55	7.03	7.04		7.12	7.04
Turbidity	NTU	-			0.07	0.56	0.15	0.54	0.31	1.48	-	3.71	0.76	1.08		0.32	1.08
Physical Properties																	
Conductivity	uS/cm	1.0			196	164	185	193	183	120	156	146	109	116		184	116
pH	pH	-	6.5 - 9.0	6.5 -9.0	7.91	7.63	8	8	7.9	7.61	7.78	7.69	7.72	7.68		7.89	7.68
Anions																	
Nitrite (N)	mg/L	0.0050	0.06		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050		0.0050	0.0050
Calculated Parameters																	
Nitrate (N)	mg/L	0.020	550 Acute; 13 Chronic[h]	32.8	1.41	1.92	1.28	1.05	0.966	1.83	1.43	1.37	1.33	1.23	3.0	1.33	1.23
Total Hardness (CaCO3)	mg/L	0.50			68.8	57.4	68.3	71.4	60.5	36.9	58.4	36.1	34.2	37		65.3	37.0
Nutrients																	
Nitrate plus Nitrite (N)	mg/L	0.020			1.41	1.92	1.28	1.05	0.966	1.83	1.43	1.37	1.33	1.23		1.33	1.23
Microbiological Param.																	
E. coli	CFU/100mL	1			26	420	84	79	27	60	5000	240	840	39	77	72[y]	298.2[y]
Fecal Coliforms	CFU/100mL	1			47	940	100	99	45	79	67000	770	1900	340	200	115[y]	1214[y]
Total Metals by ICPMS																	
Total Aluminum (Al)	ug/L	3.0	100		46.8	155	60.2	43.4	36.4	235	122	212	343	225		68	225
Total Antimony (Sb)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	9[v]	0.50	0.50
Total Arsenic (As)	ug/L	0.10	5	5	0.59	0.87	0.67	0.5	0.56	0.48	0.43	0.48	0.46	0.41		0.64	0.41
Total Barium (Ba)	ug/L	1.0			12.0	19.3	14.1	12.3	12.1	19.8	25.5	19.0	20.1	21.0	1000[v]	14.0	21.0
Total Beryllium (Be)	ug/L	0.10			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13[v]	0.10	0.10
Total Bismuth (Bi)	ug/L	1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Boron (B)	ug/L	50	29000(Acute); 1500 (Chronic)	1200	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50		50	50
Total Cadmium (Cd)	ug/L	0.010	0.71-1.49[c]		<0.010	0.016	0.011	<0.010	<0.010	0.018	0.017	0.021	0.024	0.022	0.07-0.11[o]	0.011	0.022
Total Calcium (Ca)	mg/L	0.050			15.6	15.3	16.4	16.4	14.3	10.6	16.2	10.3	10.2	10.5		15.6	10.5
Total Chromium (Cr)	ug/L	1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Cobalt (Co)	ug/L	0.50		110	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	4	0.50	0.50
Total Copper (Cu)	ug/L	0.50	2[e]	5.2-8.7[u]	1.07	5.44	1.91	1.16	1.38	2.48	2.23	3.96	3.74	2.89	0.04-2[u]	2.19	2.89
Total Iron (Fe)	ug/L	10	300	1000	269	288	254	235	172	245	193	268	341	288		244	288
Total Lead (Pb)	ug/L	0.20	1 - 2.07[f]	20.8-53.2[l]	<0.20	0.34	<0.20	<0.20	<0.20	0.28	0.22	0.35	0.47	0.29	4.32-5.16[l]	0.23	0.29
Total Lithium (Li)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Magnesium (Mg)	mg/L	0.050			7.27	4.65	6.66	7.41	6.01	2.52	4.38	2.50	2.11	2.59		6.40	2.59
Total Manganese (Mn)	ug/L	1.0		916.9-1326.8[n]	15.4	13.3	14.9	15.6	11.7	17.1	13.0	12.6	20.9	20.2	892.2-783.3[n]	14.2	20.2
Total Mercury (Hg)	ug/L	0.010	0.026 (inorganic)		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0.010	0.010
Total Molybdenum (Mo)	ug/L	1.0	73	2000	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1000	1.0	1.0
Total Nickel (Ni)	ug/L	1.0	25 - 74[g]	25 - 74[v]	<1.0	<1.0	<1.0	<1.0	<1.0	1.1	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Potassium (K)	mg/L	0.050			3.35	3.99	3.50	3.38	2.81	2.53	3.20	2.13	2.05	2.21		3.41	2.21
Total Selenium (Se)	ug/L	0.10	1		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	2	0.10	0.10
Total Silicon (Si)	ug/L	100			18400	12600	17200	19700	15600	7330	13500	6550	6250	7270		16700	7270
Total Silver (Ag)	ug/L	0.020	0.3	0.1 [p]	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.043	<0.020	<0.020	0.05[p]	0.020	0.020
Total Sodium (Na)	mg/L	0.050			8.94	11.20	9.56	9.76	8.48	8.14	11.20	9.10	6.65	7.47		9.59	7.47
Total Strontium (Sr)	ug/L	1.0			123.0	107.0	119.0	121.0	105.0	64.2	129.0	66.6	66.0	75.4		115.0	75.4
Total Sulphur (S)	mg/L	3.0			7.0	62.6	6.1	3.8	5.2	4.6	6.3	<3.0	<3.0	3.3		16.9	3.3
Total Thallium (Tl)	ug/L	0.050	0.8		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		0.050	0.050

Appendix A - UEL Project, Water Quality Sampling, 2015

UEL-001

RESULTS OF CHEMICAL ANALYSES OF WATER															BC or CCME 30 Day Water Guidelines	Dry Mean	Wet Mean
				Sampling Period	Dry Sampling					Wet Sampling							
				Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-15			
Parameter Name	Units	RDL	CCME[a]	BC Water Guidelines	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001	UEL-001			
Total Tin (Sn)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Titanium (Ti)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	7.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Uranium (U)	ug/L	0.10	33 (Acute); 15 (Chronic)		0.21	<0.10	0.13	0.19	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	8.5[v]	0.15	0.10
Total Vanadium (V)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Zinc (Zn)	ug/L	5.0	30	33 [t]	<5.0	5.1	<5.0	<5.0	<5.0	5.3	<5.0	5.8	7.6	5.0	7.5[t]	5.0	5.0
Total Zirconium (Zr)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50		0.50	0.50

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. http://www.ccme.ca/publications/ceqg_rcqe.html
b) Guideline based on range from field pH and temperature; CCME guideline converted to mg/L total ammonia-N by multiplying value by 0.08224.
c) 0.11 µg/L at hardness <5.3 mg/L; calculated as $10^{\{1.016(\log[\text{hardness}]) - 1.71\}}$ at hardness ≥5.3 mg/L to ≤360 mg/L; 7.7 µg/L at hardness >360 mg/L
d) Guideline values represent concentrations of the chloride ion for CCME standards and NaCl chloride for BC WQ Guidelines
e) 2 µg/L at hardness <82 mg/L; calculated as $e^{\{0.8545[\ln(\text{hardness})]-1.465\}}$x0.2 at hardness ≥82 mg/L to ≤180 mg/L; 4 µg/L at hardness >180 mg/L
f) 1 µg/L at hardness <60 mg/L; calculated as $e^{\{1.273[\ln(\text{hardness})]-4.705\}}$ at hardness >60 mg/L to ≤180 mg/L; 7 µg/L at hardness >180 mg/L
g) 25 µg/L at hardness ≤60 mg/L; calculated as $e^{\{0.76[\ln(\text{hardness})]+1.06\}}$ at hardness >60 mg/L to ≤180 mg/L; 150 µg/L at hardness >180 mg/L
h) Guideline values represent concentrations of the nitrate in ion form, must multiply cc
i) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs. Should not increase more than 10% of background levels when > 80 NTUs.
j) Guideline is short term maximum of 100 µg/L at pH ≥6.5 and long term average of 50 µg/L
k) 0.4 mg/L at hardness 10mg/L; calculate -51.73+92.57log10(hardness) x 0.01
l) 3 ug/L at hardness ≤ 8 mg/L; $e^{(1.273\ 1n\ [\text{hardness}])-1.460\}}$ at hardness > 8 mg/L; expressed as total hardness of samples; 30 day guideline (3.31+e(1.273 1n mean hardness)-4.704)
m) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow: Maximum increase of 25 mg/L from background levels at any one time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when ≥250 mg/L.
n) Instantaneous maximum calculated from 0.01102(hardness) + 0.54; expressed using total hardness of samples; 30 day guideline calculated from 0.0044(hardness)+0.605
o) CCME Longterm - 0.04 µg/L at hardness >0 to 17 mg/L; calculated as $10^{\{0.83(\log[\text{hardness}]) - 2.46\}}$ at hardness ≥17 mg/L to ≤280 mg/L; 0.37 µg/L at hardness >280 mg/L
p) 0.1 ug/L at hardness ≤ 100mg/L; 3 ug/L at hardness >100mg/L; 30-d mean guideline 0.05 ug/L at hardness ≤ 100mg/L; 1.5 ug/L at hardness >100mg/L
q) Guideline for total sulphate; 128 mg/L at hardness 0-30 mg/L; 218 mg/L at hardness 31-75 mg/L; 309 mg/L at hardness 76-180; 429 at hardness 181-250 mg/L
r) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximumchange of 5 NTUs from background levels at any one time when background levels are between 8 and 50 NTUs. Should not change more than 10% of background levels when > 50 NTUs.
s) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 10 mg/L from background at any one time when background levels are between 25 and 100 mg/L. Should not increase more than 10% of background levels when ≥100 mg/L.
t) 33 ug/L at hardness of ≤90 mg/L (Acute); and 33+0.75(hardness mg/L -90) for hardness that exceeds 90 mg/L; 30 day guideline 7.5 ug/L at hardness <90 mg/L and 7.5+0.75(hardness mg/L -90) for hardness that exceeds 90 mg/L
u) calculated as 0.094 (hardness) +2; expressed using total hardness of samples; 30 day is 2 ug/L for hardness <50 mg/L and 0.04(avg hardness) for hardness >50 mg/L
v) A compendium of working water quality guidelines for British Columbia, 2006. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html
w) Calculated as e[1.03*ln(hardness)-5.274] short term and e[0.736*ln(hardness)-4.943] long term; expressed using total hardness of samples
x) Guidelines represent total chloride concentrations; 150 mg/L long term average; 600 mg/L short term maximum
y) Geometric Mean reported here

"<"	Less than detection limit.
0.125	Value exceeds CCME guideline.
0.125	Value exceeds BC WQ guidelines
0.125	Value exceeds both CCME and BC WQ guidelines
0.125	Value exceeds BC 30 Day WQ guidelines

RDL = Reportable Detection Limit

Appendix A - UEL Project, Water Quality Sampling, 2015

UEL-002

RESULTS OF CHEMICAL ANALYSES OF WATER																		
				Sampling Period	Dry Sampling					Wet Sampling					BC 30 Day Water Guidelines	Dry Mean	Wet Mean
				Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-15			
Parameter Name	Units	RDL	CCME[a]	BC Water Guidelines	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002			
In Situ																	
Temperature	°C	-			14.0	14.0	13.1	11.3	10.4	7.6	4.1	6.1	7.9	6.1		12.6	6.4
Dissolved Oxygen (%)	%	-			92.0	91.4	88.9	82.0	94.7	91.1	101.1	96.6	89.3	103.6		89.8	96.3
Dissolved Oxygen (mg/L)	mg/L	-			9.53	9.42	9.37	8.98	10.55	10.88	13.22	12.00	10.60	12.85		9.57	11.91
Specific Conductivity	uS/cm	-			71.6	66.2	63.7	64.4	70.0	69.7	78.5	135.5	61.8	65.2		67.2	82.1
Conductivity	uS/cm	-			-	42.3	49.3	47.5	50.5	46.6	47.1	86.4	41.6	41.7		47.4	52.7
Total Dissolved Solids	g/L	-			46.8	42.3	41.6	41.6	45.5	45.5	51.4	87.8	40.3	42.2		34.5	53.4
Salinity	ppt	-			0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.06	0.03	0.03		0.03	0.04
pH	pH	-	6.5 - 9.0	6.5 -9.0	7.28	7.00	7.12	7.15	7.26	5.87	6.35	6.47	6.56	6.36		7.16	6.32
Turbidity	NTU	-			0.18	0.84	-	0.96	0.40	1.16	-	1.95	0.21	0.41		0.60	0.93
Physical Properties																	
Conductivity	uS/cm	1.0			67.2	65.2	68.9	67.0	65.7	68.3	84.0	132.0	63.0	64.5		66.8	82.4
pH	pH	-	6.5 - 9.0	6.5 -9.0	7.52	7.45	7.67	7.71	7.67	6.56	7.02	7.14	6.88	6.84		7.60	6.89
Anions																	
Nitrite (N)	mg/L	0.0050	0.06		<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050		0.005	0.005
Calculated Parameters																	
Nitrate (N)	mg/L	0.020	550 Acute; 13 Chronic[h]	32.8	0.351	0.933	0.581	0.324	0.407	3.16	2.78	1.88	2.34	1.92	3.0	0.519	2.42
Total Hardness (CaCO3)	mg/L	0.50			19.0	21.0	21.8	21.2	21.4	15.2	16.9	15.5	12.8	13.8		20.9	14.8
Nutrients																	
Nitrate plus Nitrite (N)	mg/L	0.020			0.351	0.933	0.581	0.324	0.407	3.16	2.78	1.88	2.34	1.92		0.519	2.33
Microbiological Param.																	
E. coli	CFU/100mL	1			1400	61	33	31	9	3	<2	18	<1	1	77	60[y]	3[y]
Fecal Coliforms	CFU/100mL	1			1400	120	54	34	17	5	8	21	2	2	200	88[y]	5[y]
Total Metals by ICPMS																	
Total Aluminum (Al)	ug/L	3.0	100		160.0	126.0	148.0	96.3	104.0	280.0	133.0	205.0	330.0	291.0		126.9	247.8
Total Antimony (Sb)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	9[v]	0.50	0.50
Total Arsenic (As)	ug/L	0.10	5	5	0.32	0.27	0.31	0.22	0.14	<0.10	<0.10	0.15	<0.10	0.15		0.25	0.12
Total Barium (Ba)	ug/L	1.0			18.3	20.4	19.2	16.4	17.3	30.6	28.8	28.9	28.1	32.2	1000[v]	18.3	29.7
Total Beryllium (Be)	ug/L	0.10			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13[v]	0.10	0.10
Total Bismuth (Bi)	ug/L	1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Boron (B)	ug/L	50	29000(Acute); 1500 (Chronic)	1200	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50		50	50
Total Cadmium (Cd)	ug/L	0.010	0.26-0.45[c]		0.012	0.016	0.015	<0.010	<0.010	0.032	0.020	0.019	0.028	0.034	0.04[o]	0.013	0.027
Total Calcium (Ca)	mg/L	0.050			4.68	5.25	5.38	5.38	5.25	4.18	4.60	4.11	3.60	3.77		5.19	4.05
Total Chromium (Cr)	ug/L	1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Cobalt (Co)	ug/L	0.50		110	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	4	0.50	0.50
Total Copper (Cu)	ug/L	0.50	2[e]	3.2-4.0[u]	2.4	2.31	2.12	2.4	1.54	1.08	1.12	3.35	1.81	1.58	2[u]	2.15	1.79
Total Iron (Fe)	ug/L	10	300	1000	572	326	390	376	306	120	83	199	124	160		394	137
Total Lead (Pb)	ug/L	0.20	1-11[f]	6.0-11.7[l]	0.27	<0.20	0.24	<0.20	<0.20	<0.20	<0.20	0.29	0.26	0.27	3.7-7.1[l]	0.22	0.24
Total Lithium (Li)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Magnesium (Mg)	mg/L	0.050			1.77	1.91	2.02	1.89	2.01	1.15	1.31	1.26	0.932	1.07		1.92	1.14
Total Manganese (Mn)	ug/L	1.0		681.1-780.2[n]	40.5	36.7	27.8	23.5	20.1	29.6	13.1	16.4	28.2	27.1	696.9-670.3	29.7	22.9
Total Mercury (Hg)	ug/L	0.010	0.026 (inorganic)		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0.010	0.010
Total Molybdenum (Mo)	ug/L	1.0	73	2000	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1000	1.0	1.0
Total Nickel (Ni)	ug/L	1.0	25[g]	25[v]	<1.0	<1.0	<1.0	<1.0	<1.0	1.1	<1.0	1.2	<1.0	<1.0		1.0	1.1
Total Potassium (K)	mg/L	0.050			1.65	2.06	1.97	1.75	1.83	0.892	1.06	1.05	0.751	0.789		1.85	0.908
Total Selenium (Se)	ug/L	0.10	1		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	2	0.10	0.10
Total Silicon (Si)	ug/L	100			14700	14400	14800	16600	15700	6010	8680	6310	5710	6340		15240	6610
Total Silver (Ag)	ug/L	0.020	0.3	0.1[p]	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.05[p]	0.020	0.020
Total Sodium (Na)	mg/L	0.050			4.76	5.13	4.94	4.88	4.82	5.82	9.63	19.40	4.94	5.96		4.91	9.15
Total Strontium (Sr)	ug/L	1.0			57.8	58.4	57.9	56.4	58.3	44.9	57.9	48.8	40.7	46.4		57.8	47.7
Total Sulphur (S)	mg/L	3.0			3.0	5.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0		3.4	3.0
Total Thallium (Tl)	ug/L	0.050	0.8		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		0.050	0.050

Appendix A - UEL Project, Water Quality Sampling, 2015

UEL-002

RESULTS OF CHEMICAL ANALYSES OF WATER																		
				Sampling Period	Dry Sampling					Wet Sampling					BC 30 Day Water Guidelines	Dry Mean	Wet Mean
				Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-15			
Parameter Name	Units	RDL	CCME[a]	BC Water Guidelines	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002	UEL-002			
Total Tin (Sn)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Titanium (Ti)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Uranium (U)	ug/L	0.10	33 (Acute); 15 (Chronic)		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	8.5[v]	0.10	0.10
Total Vanadium (V)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Zinc (Zn)	ug/L	5.0	30	33[t]	<5.0	<5.0	<5.0	<5.0	<5.0	6.5	<5.0	6.2	6.3	6.4	7.5[t]	5.0	6.1
Total Zirconium (Zr)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50		0.50	0.50

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. http://www.ccme.ca/publications/ceqg_rcqe.html
b) Guideline based on range from field pH and temperature; CCME guideline converted to mg/L total ammonia-N by multiplying value by 0.08224.
c) 0.11 µg/L at hardness <5.3 mg/L; calculated as $10^{\{1.016(\log[\text{hardness}]) - 1.71\}}$ at hardness ≥5.3 mg/L to ≤360 mg/L; 7.7 µg/L at hardness >360 mg/L
d) Guideline values represent concentrations of the chloride ion for CCME standards and NaCl chloride for BC WQ Guidelines
e) 2 µg/L at hardness <82 mg/L; calculated as $e^{\{0.8545[\ln(\text{hardness})]-1.465\}}$x0.2 at hardness ≥82 mg/L to ≤180 mg/L; 4 µg/L at hardness >180 mg/L
f) 1 µg/L at hardness <60 mg/L; calculated as $e^{\{1.273[\ln(\text{hardness})]-4.705\}}$ at hardness >60 mg/L to ≤180 mg/L; 7 µg/L at hardness >180 mg/L
g) 25 µg/L at hardness ≤60 mg/L; calculated as $e^{\{0.76[\ln(\text{hardness})]+1.06\}}$ at hardness >60 mg/L to ≤180 mg/L; 150 µg/L at hardness >180 mg/L
h) Guideline values represent concentrations of the nitrate in ion form,
i) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs. Should not increase more than 10% of background levels when > 80 NTUs.
j) Guideline is short term maximum of 100 µg/L at pH ≥6.5 and long term average of 50 µg/L
k) 0.4 mg/L at hardness 10mg/L; calculate -51.73+92.57log10(hardness) x 0.01
l) 3 ug/L at hardness ≤ 8 mg/L; $e^{(1.273\ 1n\ [\text{hardness}])-1.460)}$ at hardness > 8 mg/L; expressed as total hardness of samples; 30 day guideline (3.31+e(1.273 1n mean hardness)-4.704)
m) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow: Maximum increase of 25 mg/L from background levels at any one time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when ≥250 mg/L.
n) Instantaneous maximum calculated from 0.01102(hardness) + 0.54; expressed using total hardness of samples; 30 day guideline calculated from 0.0044(hardness)+0.605
o) CCME Longterm - 0.04 µg/L at hardness >0 to 17 mg/L; calculated as $10^{\{0.83(\log[\text{hardness}]) - 2.46\}}$ at hardness ≥17 mg/L to ≤280 mg/L; 0.37 µg/L at hardness >280 mg/L
p) 0.1 ug/L at hardness ≤ 100mg/L; 3 ug/L at hardness >100mg/L; 30-d mean guideline 0.05 ug/L at hardness ≤ 100mg/L; 1.5 ug/L at hardness >100mg/L
q) Guideline for total sulphate; 128 mg/L at hardness 0-30 mg/L; 218 mg/L at hardness 31-75 mg/L; 309 mg/L at hardness 76-180; 429 at hardness 181-250 mg/L
r) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximumchange of 5 NTUs from background levels at any one time when background levels are between 8 and 50 NTUs. Should not change more than 10% of background levels when > 50 NTUs.
s) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 10 mg/L from background at any one time when background levels are between 25 and 100 mg/L. Should not increase more than 10% of background levels when ≥100 mg/L.
t) 33 ug/L at hardness of ≤90 mg/L (Acute); and 33+0.75(hardness mg/L -90) for hardness that exceeds 90 mg/L; 30 day guideline 7.5 ug/L at hardness <90 mg/L and 7.5+0.75(hardness mg/L -90) for hardness that exceeds 90 mg/L
u) calculated as 0.094 (hardness) +2; expressed using total hardness of samples; 30 day is 2 ug/L for hardness <50 mg/L and 0.04(avg hardness) for hardness >50 mg/L
v) A compendium of working water quality guidelines for British Columbia, 2006. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html
w) Calculated as e[1.03*ln(hardness)-5.274] short term and e[0.736*ln(hardness)-4.943] long term; expressed using total hardness of samples
x) Guidelines represent total chloride concentrations; 150 mg/L long term average; 600 mg/L short term maximum
y) Geometric Mean reported here

"<"	Less than detection limit.
0.125	Value exceeds CCME guideline.
0.125	Value exceeds BC WQ guidelines
0.125	Value exceeds both CCME and BC WQ guidelines
0.125	Value exceeds BC 30 Day WQ guidelines

RDL = Reportable Detection Limit

Appendix A -UEL Project, Water Quality Sampling, 2015

UEL-003

RESULTS OF CHEMICAL ANALYSES OF WATER																		
				Sampling Period	Dry Sampling					Wet Sampling					BC 30 Day Water Guidelines	Dry Mean	Wet Mean
				Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-16			
Parameter Name	**Units**	**RDL**	**CCME[a]**	**BC Water Guidelines**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**			
In Situ																	
Temperature	°C	-			13.3	14.1	13.3	11.5	10.9	7.8	4.8	6.4	8.4	6.4		11.2	6.8
Dissolved Oxygen (%)	%	-			104.7	99.3	99.7	110.8	107.4	91.5	103.7	99.7	90.1	104.1		109.1	97.8
Dissolved Oxygen (mg/L)	mg/L	-			10.96	10.21	10.44	12.06	11.85	10.9	13.29	12.29	10.5	12.84		11.96	11.96
Specific Conductivity	uS/cm	-			157.2	167.2	129.1	144.2	158.5	138.9	141.1	196.2	115.5	126.8		151.4	143.7
Conductivity	uS/cm	-			121.5	132.3	100.2	107.1	116.0	93.2	86.7	149.5	78.9	81.7		111.6	98.0
Total Dissolved Solids	g/L	-			101.4	108.6	83.9	93.6	102.7	90.3	91.7	96.9	75.8	82.5		46.9	87.4
Salinity	ppt	-			0.07	0.08	0.06	0.07	0.08	0.07	0.07	0.07	0.05	0.06		0.08	0.06
pH	pH	-	6.5 - 9.0	6.5 -9.0	7.91	7.75	7.82	7.80	7.86	7.36	7.35	7.19	7.43	7.41		7.83	7.35
Turbidity	NTU	-			1.11	1.41	0.00	0.54	0.94	1.8	-	4.64	3.09	3.905		0.74	3.36
Physical Properties																	
Conductivity	uS/cm	1.0			144	168	140	149	151	137	152	145	119	125		150	136
pH	pH	-	6.5 - 9.0	6.5 -9.0	7.89	7.73	7.99	8.01	7.91	7.8	7.83	7.89	7.89	7.83		7.96	7.85
Anions																	
Nitrite (N)	mg/L	0.0050	0.06		<0.0050	0.0077	<0.0050	<0.050 (1)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050		0.0050	0.0050
Calculated Parameters																	
Nitrate (N)	mg/L	0.020	550 Acute; 13 Chronic[h]	32.8	0.813	1.24	0.823	<0.200	0.715	1.69	1.34	0.859	1.31	1.23	3.0	0.458	1.29
Total Hardness (CaCO3)	mg/L	0.50			44.9	51.0	42.2	45.6	47.9	44.6	51.4	45.2	36.3	42.0		46.8	43.9
Nutrients																	
Nitrate plus Nitrite (N)	mg/L	0.020			0.813	1.25	0.823	<0.20 (1)	0.715	1.69	1.34	0.859	1.31	1.23		0.715	1.27
Microbiological Param.																	
E. coli	CFU/100mL	1			29	1100	500	340	44	54	46	46	490	330	77	189[y]	113[y]
Fecal Coliforms	CFU/100mL	1			57	1500	500	340	140	540	690	670	950	620	200	290[y]	682[y]
Total Metals by ICPMS																	
Total Aluminum (Al)	ug/L	3.0	100		35.0	43.2	29.2	28.1	23.7	103.0	54.6	124.0	236.0	122.0		25.9	127.9
Total Antimony (Sb)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	9[v]	0.50	0.50
Total Arsenic (As)	ug/L	0.10	5	5	0.52	3.32	2.39	0.71	1.51	0.66	1.06	1.47	2.02	0.73		1.11	1.19
Total Barium (Ba)	ug/L	1.0			7.3	10.8	8.5	7.1	7.9	16.1	16.5	15.4	14.5	18.2	1000[v]	7.5	16.1
Total Beryllium (Be)	ug/L	0.10			<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13[v]	0.10	0.10
Total Bismuth (Bi)	ug/L	1.0			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Boron (B)	ug/L	50	29000(Acute); 1500 (Chronic)	1200	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50		50	50
Total Cadmium (Cd)	ug/L	0.010	0.75-1.07[c]		<0.010	0.01	<0.010	<0.010	<0.010	0.014	0.013	0.029	0.015	0.022	0.08[o]	0.010	0.019
Total Calcium (Ca)	mg/L	0.050			9.85	12.80	10.10	10.30	11.10	13.90	15.40	13.50	11.30	12.80		10.70	13.38
Total Chromium (Cr)	ug/L	1.0			<1.0	1.5	1.6	<1.0	<1.0	<1.0	<1.0	<1.0	1.1	<1.0		1.0	1.0
Total Cobalt (Co)	ug/L	0.50		110	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	4	0.50	0.50
Total Copper (Cu)	ug/L	0.50	2[e]	5.4-6.8[u]	1.72	4.38	3.1	2.56	4.05	3.51	3.27	6.81	4.93	3.59	2[u]	3.31	4.42
Total Iron (Fe)	ug/L	10	300	1000	264	209	212	209	228	333	217	463	406	313		219	346
Total Lead (Pb)	ug/L	0.20	1[f]	22.5-35.0[l]	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.35	0.35	0.21	3.97[l]	0.20	0.26
Total Lithium (Li)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Magnesium (Mg)	mg/L	0.050			4.93	4.64	4.15	4.83	4.92	2.40	3.15	2.78	1.95	2.46		4.88	2.55
Total Manganese (Mn)	ug/L	1.0		940.0-1106.4[n]	6.5	4.8	5.4	4.7	4.9	9.5	4.6	12.8	15.7	11.6	798.2-810.7[n]	4.8	10.8
Total Mercury (Hg)	ug/L	0.010	0.026 (inorganic)		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0.010	0.010
Total Molybdenum (Mo)	ug/L	1.0	73	2000	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1000	1.0	1.0
Total Nickel (Ni)	ug/L	1.0	25[g]	25[v]	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Potassium (K)	mg/L	0.050			3.02	2.90	2.62	2.73	2.70	2.12	2.64	2.00	1.80	2.03		2.72	2.12
Total Selenium (Se)	ug/L	0.10	1		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	2	0.10	0.10
Total Silicon (Si)	ug/L	100			19800	13300	17800	19100	20300	6940	9850	6640	5470	6860		19700	7152
Total Silver (Ag)	ug/L	0.020	0.3	0.1[p]	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.05[p]	0.020	0.020
Total Sodium (Na)	mg/L	0.050			12.00	11.10	10.50	11.80	11.50	7.74	11.10	11.80	6.81	8.05		11.65	9.10
Total Strontium (Sr)	ug/L	1.0			80.6	86.8	67.6	70.6	77.4	79.0	117.0	81.5	70.8	92.3		74.0	88.1
Total Sulphur (S)	mg/L	3.0			4.1	4.1	<3.0	<3.0	3	<3.0	4.9	<3.0	<3.0	3.1		3.0	3.4
Total Thallium (Tl)	ug/L	0.050	0.8		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		0.050	0.050
Total Tin (Sn)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Titanium (Ti)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Uranium (U)	ug/L	0.10	33 (Acute); 15 (Chronic)		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	8.5[v]	0.10	0.10
Total Vanadium (V)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0

Appendix A -UEL Project, Water Quality Sampling, 2015

UEL-003

RESULTS OF CHEMICAL ANALYSES OF WATER																		
				Sampling Period	Dry Sampling					Wet Sampling					BC 30 Day Water Guidelines	Dry Mean	Wet Mean
				Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-16			
Parameter Name	**Units**	**RDL**	**CCME[a]**	**BC Water Guidelines**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**	**UEL-003**			
Total Zinc (Zn)	ug/L	5.0	30	33[t]	<5.0	5.8	<5.0	<5.0	<5.0	6.4	5.6	19.6	10	8.6	7.5[t]	5.0	10.0
Total Zirconium (Zr)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50		0.50	0.50

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. http://www.ccme.ca/publications/ceqg_rcqe.html
b) Guideline based on range from field pH and temperature; CCME guideline converted to mg/L total ammonia-N by multiplying value by 0.08224.
c) 0.11 µg/L at hardness <5.3 mg/L; calculated as $10^{\{1.016(\log[\text{hardness}]) - 1.71\}}$ at hardness ≥5.3 mg/L to ≤360 mg/L; 7.7 µg/L at hardness >360 mg/L
d) Guideline values represent concentrations of the chloride ion for CCME standards and NaCl chloride for BC WQ Guidelines
e) 2 µg/L at hardness <82 mg/L; calculated as $e^{\{0.8545[\ln(\text{hardness})]-1.465\}}$x0.2 at hardness ≥82 mg/L to ≤180 mg/L; 4 µg/L at hardness >180 mg/L
f) 1 µg/L at hardness <60 mg/L; calculated as $e^{\{1.273[\ln(\text{hardness})]-4.705\}}$ at hardness >60 mg/L to ≤180 mg/L; 7 µg/L at hardness >180 mg/L
g) 25 µg/L at hardness ≤60 mg/L; calculated as $e^{\{0.76[\ln(\text{hardness})]+1.06\}}$ at hardness >60 mg/L to ≤180 mg/L; 150 µg/L at hardness >180 mg/L
h) Guideline values represent concentrations of the nitrate in ion form, must
i) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs. Should not increase more than 10% of background levels when > 80 NTUs.
j) Guideline is short term maximum of 100 µg/L at pH ≥6.5 and long term average of 50 µg/L
k) 0.4 mg/L at hardness 10mg/L; calculate -51.73+92.57log10(hardness) x 0.01
l) 3 ug/L at hardness ≤ 8 mg/L; $e^{(1.273\ 1n\ [\text{hardness}])-1.460)}$ at hardness > 8 mg/L; expressed as total hardness of samples; 30 day guideline (3.31+e(1.273 1n mean hardness)-4.704)
m) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow: Maximum increase of 25 mg/L from background levels at any one time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when ≥250 mg/L.
n) Instantaneous maximum calculated from 0.01102(hardness) + 0.54; expressed using total hardness of samples; 30 day guideline calculated from 0.0044(hardness)+0.605
o) CCME Longterm - 0.04 µg/L at hardness >0 to 17 mg/L; calculated as $10^{\{0.83(\log[\text{hardness}]) - 2.46\}}$ at hardness ≥17 mg/L to ≤280 mg/L; 0.37 µg/L at hardness >280 mg/L
p) 0.1 ug/L at hardness ≤ 100mg/L; 3 ug/L at hardness >100mg/L; 30-d mean guideline 0.05 ug/L at hardness ≤ 100mg/L; 1.5 ug/L at hardness >100mg/L
q) Guideline for total sulphate; 128 mg/L at hardness 0-30 mg/L; 218 mg/L at hardness 31-75 mg/L; 309 mg/L at hardness 76-180; 429 at hardness 181-250 mg/L
r) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximumchange of 5 NTUs from background levels at any one time when background levels are between 8 and 50 NTUs. Should not change more than 10% of background levels when > 50 NTUs.
s) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 10 mg/L from background at any one time when background levels are between 25 and 100 mg/L. Should not increase more than 10% of background levels when ≥100 mg/L.
t) 33 ug/L at hardness of ≤90 mg/L (Acute); and 33+0.75(hardness mg/L-90) for hardness that exceeds 90 mg/L; 30 day guideline 7.5 ug/L at hardness <90 mg/L and 7.5+0.75(hardness mg/L-90) for hardness that exceeds 90 mg/L
u) calculated as 0.094 (hardness) +2; expressed using total hardness of samples; 30 day is 2 ug/L for hardness <50 mg/L and 0.04(avg hardness) for hardness >50 mg/L
v) A compendium of working water quality guidelines for British Columbia, 2006. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html
w) Calculated as e[1.03*ln(hardness)-5.274] short term and e[0.736*ln(hardness)-4.943] long term; expressed using total hardness of samples
x) Guidelines represent total chloride concentrations; 150 mg/L long term average; 600 mg/L short term maximum
y) Geometric Mean reported here

"<"	Less than detection limit.
0.125	Value exceeds CCME guideline.
0.125	Value exceeds BC WQ guidelines
0.125	Value exceeds both CCME and BC WQ guidelines
0.125	Value exceeds BC 30 Day WQ guidelines

RDL = Reportable Detection Limit
(1) RDL raised due to sample matrix interference.

Appendix A -UEL Project, Water Quality Sampling, 2015

UEL-004

RESULTS OF CHEMICAL ANALYSES OF WATER																		
					Sampling Period	Dry Sampling					Wet Sampling					BC 30 Day Water Guidelines	Dry Mean	Wet Mean
					Sampling Date	24-Aug-15	1-Sep-15	8-Sep-15	15-Sep-15	22-Sep-15	18-Nov-15	26-Nov-15	2-Dec-15	10-Dec-15	16-Dec-16			
Parameter Name	Units	RDL	CCME[a]	BC Water Guidelines		UEL-004	UEL-004	UEL-004	UEL-004	UEL-004	UEL-004	UEL-004	UEL-004	UEL-004	UEL-004			
In Situ																		
Temperature	°C	-				17.0	15.2	14.3	13.2	12.1	6.8	3.4	5.0	7.5	5.1		14.4	5.6
Dissolved Oxygen (%)	%	-				10.7	15.0	6.4	4.2	4.5	42.7	36.7	56.6	-	52.4		8.2	47.1
Dissolved Oxygen (mg/L)	mg/L	-				1.03	1.51	0.65	0.44	0.48	5.21	4.91	7.23	6.98	6.66		0.82	6.20
Specific Conductivity	uS/cm	-				371.2	136.3	224.8	305.7	224.1	119.1	171.8	183.1	122.8	114.0		252.4	142.2
Conductivity	uS/cm	-				313.9	110.6	178.8	237.1	168.8	77.7	100.9	113	81.8	70.8		201.8	88.8
Total Dissolved Solids	g/L	-				241.2	88.4	146.3	198.9	154.6	77.4	118.0	119.0	80.0	74.1		135.0	93.7
Salinity	ppt	-				0.18	0.06	0.11	0.15	0.11	0.06	0.08	0.09	0.06	0.05		0.12	0.07
pH	pH	-	6.5 - 9.0	6.5 -9.0		7.24	6.39	6.66	6.88	6.73	6.21	6.48	6.49	6.38	6.50		6.78	6.41
Turbidity	NTU	-				41.20	22.80	4.47	15.70	19.37	2.05	-	13.60	25.30	6.88		20.71	11.96
Physical Properties																		
Conductivity	uS/cm	1.0				353	135	216	282	202	116	183	177	122	112		238	142
pH	pH	-	6.5 - 9.0	6.5 -9.0		7.85	7.21	7.97	7.91	7.99	7.66	7.66	7.69	7.8	7.49		7.79	7.66
Anions																		
Nitrite (N)	mg/L	0.0050	0.06			0.0072	<0.050 (1)	0.0059	<0.0050	0.0081	0.0074	0.0118	0.0157	0.0066	0.0084		0.0066	0.0102
Calculated Parameters																		
Nitrate (N)	mg/L	0.020	550 Acute; 13 Chronic[h]	32.8		<0.020	0.95	<0.020	0.661	<0.020	1.77	0.991	0.615	1.52	1.27	3.0	0.33	1.23
Total Hardness (CaCO3)	mg/L	0.50				128.0	52.8	89.1	121.0	95.4	35.8	61.6	51.5	40.3	44.1		97.3	46.7
Nutrients																		
Nitrate plus Nitrite (N)	mg/L	0.020				<0.020	0.95 (1)	<0.020	0.661	<0.020	1.78	1	0.631	1.53	1.28		0.18	1.11
Microbiological Param.																		
E. coli	CFU/100mL	1				70	56	6	7	42	7	<2	40	6	8	77	23[y]	8[y]
Fecal Coliforms	CFU/100mL	1				100	150	19	16	44	20	26	54	12	24	200	46[y]	24[y]
Total Metals by ICPMS																		
Total Aluminum (Al)	ug/L	3.0	100			567	734	59.8	324	197	121	66.6	358	1500	243		376	458
Total Antimony (Sb)	ug/L	0.50				<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	9[v]	0.50	0.50
Total Arsenic (As)	ug/L	0.10	5	5		0.98	0.83	0.62	1.21	0.89	0.16	0.16	0.30	0.66	0.22		0.91	0.30
Total Barium (Ba)	ug/L	1.0				75.2	38.2	50.0	83.6	64.0	30.9	39.6	32.6	44.1	38.9	1000[v]	62.2	37.2
Total Beryllium (Be)	ug/L	0.10				<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.13[v]	0.10	0.10
Total Bismuth (Bi)	ug/L	1.0				<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		1.0	1.0
Total Boron (B)	ug/L	50	29000(Acute); 1500 (Chronic)	1200		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50		50	50
Total Cadmium (Cd)	ug/L	0.010	0.74-2.70[c]			<0.010	0.022	0.011	0.01	0.012	0.018	0.019	0.037	0.06	0.023	0.08-0.15[o]	0.013	0.031
Total Calcium (Ca)	mg/L	0.050				33.6	15.0	25.3	34.5	27.1	10.9	18.6	15.6	12.3	12.9		27.1	14.1
Total Chromium (Cr)	ug/L	1.0				<1.0	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0		1.0	1.1
Total Cobalt (Co)	ug/L	0.50		110		0.72	0.58	0.86	2.51	1.40	<0.50	<0.50	<0.50	0.74	<0.50	4.00	1.21	0.55
Total Copper (Cu)	ug/L	0.50	2-4[e]	5.4-14.0[u]		2.44	9.42	2.79	2.49	3.23	2.10	2.01	7.14	6.16	3.61	0.04-2[u]	4.07	4.20
Total Iron (Fe)	ug/L	10	300	1000		4840	5620	5670	16700	10300	703	1830	1870	7070	1530		8626	2601
Total Lead (Pb)	ug/L	0.20	1 - 4.4[f]	22.1-111.8[l]		0.78	1.52	0.27	0.58	0.47	<0.20	<0.20	0.70	3.16	0.49	6.4-4.2[l]	0.72	0.95
Total Lithium (Li)	ug/L	5.0				<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Magnesium (Mg)	mg/L	0.050				10.70	3.73	6.30	8.56	6.70	2.09	3.66	3.05	2.32	2.87		7.20	2.80
Total Manganese (Mn)	ug/L	1.0		934.5-1950.5[n]		1410	347	1320	3750	2300	101	240	384	260	188	810.3-1032.9[n]	1825	235
Total Mercury (Hg)	ug/L	0.010	0.026 (inorganic)			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0.010	0.010
Total Molybdenum (Mo)	ug/L	1.0	73	2000		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1000	1.0	1.0
Total Nickel (Ni)	ug/L	1.0	25 - 115.3[g]	25 - 115.3[v]		1.0	1.5	<1.0	1.3	<1.0	<1.0	<1.0	1.0	1.8	<1.0		1.2	1.2
Total Potassium (K)	mg/L	0.050				4.94	6.46	5.34	4.69	4.71	1.99	2.67	2.38	1.99	2.37		5.23	2.28
Total Selenium (Se)	ug/L	0.10	1			0.18	<0.10	<0.10	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	2	0.12	0.10
Total Silicon (Si)	ug/L	100				4830	4340	5400	6550	5630	5040	6440	4350	6540	5600		5350	5594
Total Silver (Ag)	ug/L	0.020	0.3	0.1-3[p]		<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.05[p]	0.020	0.020
Total Sodium (Na)	mg/L	0.050				13.70	5.07	7.61	10.80	8.15	6.07	12.10	14.10	6.25	6.66		9.07	9.04
Total Strontium (Sr)	ug/L	1.0				337	109	211	300	235	71	143	101	84	103		238	100
Total Sulphur (S)	mg/L	3.0				<3.0	4.8	3.4	<3.0	<3.0	<3.0	3.2	<3.0	<3.0	<3.0		3.4	3.0
Total Thallium (Tl)	ug/L	0.050	0.8			<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		0.050	0.050

Total Tin (Sn)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Titanium (Ti)	ug/L	5.0			22.2	22.1	<5.0	6.9	<5.0	<5.0	<5.0	14.6	53.7	5.4		12.2	16.7
Total Uranium (U)	ug/L	0.10	33 (Acute); 15 (Chronic)		<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	8.5[v]	0.10	0.10
Total Vanadium (V)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0		5.0	5.0
Total Zinc (Zn)	ug/L	5.0	30	33-61.5[t]	6.4	9.2	<5.0	<5.0	<5.0	<5.0	<5.0	11.3	13.7	5.7	7.5[t]	6.1	8.1
Total Zirconium (Zr)	ug/L	0.50			<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50		0.50	0.50

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. http://www.ccme.ca/publications/ceqg_rcqe.html
b) Guideline based on range from field pH and temperature; CCME guideline converted to mg/L total ammonia-N by multiplying value by 0.08224.
c) 0.11 µg/L at hardness <5.3 mg/L; calculated as $10^{\{1.016(\log[\text{hardness}]) - 1.71\}}$ at hardness ≥5.3 mg/L to ≤360 mg/L; 7.7 µg/L at hardness >360 mg/L
d) Guideline values represent concentrations of the chloride ion for CCME standards and NaCl chloride for BC WQ Guidelines
e) 2 µg/L at hardness <82 mg/L; calculated as $e^{\{0.8545[\ln(\text{hardness})]-1.465\}}$x0.2 at hardness ≥82 mg/L to ≤180 mg/L; 4 µg/L at hardness >180 mg/L
f) 1 µg/L at hardness <60 mg/L; calculated as $e^{\{1.273[\ln(\text{hardness})]-4.705\}}$ at hardness >60 mg/L to ≤180 mg/L; 7 µg/L at hardness >180 mg/L
g) 25 µg/L at hardness ≤60 mg/L; calculated as $e^{\{0.76[\ln(\text{hardness})]+1.06\}}$ at hardness >60 mg/L to ≤180 mg/L; 150 µg/L at hardness >180 mg/L
h) Guideline values represent concentrations of the nitrate in ion form, must multiply c
i) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs. Should not increase more than 10% of background levels when > 80 NTUs.
j) Guideline is short term maximum of 100 µg/L at pH ≥6.5 and long term average of 50 µg/L
k) 0.4 mg/L at hardness 10mg/L; calculate -51.73+92.57log10(hardness) x 0.01
l) 3 ug/L at hardness ≤ 8 mg/L; $e^{(1.273\ 1n\ [\text{hardness}])-1.460)}$ at hardness > 8 mg/L; expressed as total hardness of samples; 30 day guideline (3.31+e(1.273 1n mean hardness)-4.704)
m) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow: Maximum increase of 25 mg/L from background levels at any one time when background levels are between 25 and 250 mg/L. Should not increase more than 10% of background levels when ≥250 mg/L.
n) Instantaneous maximum calculated from 0.01102(hardness) + 0.54; expressed using total hardness of samples; 30 day guideline calculated from 0.0044(hardness)+0.605
o) CCME Longterm - 0.04 µg/L at hardness >0 to 17 mg/L; calculated as $10^{\{0.83(\log[\text{hardness}]) - 2.46\}}$ at hardness ≥17 mg/L to ≤280 mg/L; 0.37 µg/L at hardness >280 mg/L
p) 0.1 ug/L at hardness ≤ 100mg/L; 3 ug/L at hardness >100mg/L; 30-d mean guideline 0.05 ug/L at hardness ≤ 100mg/L; 1.5 ug/L at hardness >100mg/L
q) Guideline for total sulphate; 128 mg/L at hardness 0-30 mg/L; 218 mg/L at hardness 31-75 mg/L; 309 mg/L at hardness 76-180; 429 at hardness 181-250 mg/L
r) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximumchange of 5 NTUs from background levels at any one time when background levels are between 8 and 50 NTUs. Should not change more than 10% of background levels when > 50 NTUs.
s) Clear flow: Maximum increase of 25mg/L from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from for a longer term exposure (e.g., 30-d period).
High flow or turbid waters: Maximum increase of 10 mg/L from background at any one time when background levels are between 25 and 100 mg/L. Should not increase more than 10% of background levels when ≥100 mg/L.
t) 33 ug/L at hardness of ≤90 mg/L (Acute); and 33+0.75(hardness mg/L -90) for hardness that exceeds 90 mg/L; 30 day guideline 7.5 ug/L at hardness <90 mg/L and 7.5+0.75(hardness mg/L -90) for hardness that exceeds 90 mg/L
u) calculated as 0.094 (hardness) +2; expressed using total hardness of samples; 30 day is 2 ug/L for hardness <50 mg/L and 0.04(avg hardness) for hardness >50 mg/L
v) A compendium of working water quality guidelines for British Columbia, 2006. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html
w) Calculated as e[1.03*ln(hardness)-5.274] short term and e[0.736*ln(hardness)-4.943] long term; expressed using total hardness of samples
x) Guidelines represent total chloride concentrations; 150 mg/L long term average; 600 mg/L short term maximum
y) Geometric Mean reported here

"<"	Less than detection limit.
0.125	Value exceeds CCME guideline.
0.125	Value exceeds BC WQ guidelines
0.125	Value exceeds both CCME and BC WQ guidelines
0.125	Value exceeds BC 30 Day WQ guidelines

RDL = Reportable Detection Limit
(1) RDL raised due to sample matrix interference.

Appendix B

Benthic Invertebrate Data

Appendix: B Benthic Invertebrate Data, UEL Project, 2015

					Site	UEL Project					
					Station	UEL-001			UEL-003		
					Client Sample #	UEL-001-1	UEL-001-2	UEL-001-3	UEL-003-1	UEL-003-2	UEL-003-3
Family	**Taxon**	**Voltinism**	**Tol/Intol**	**Clinger**	**Feeding**	**Count**	**Count**	**Count**	**Count**	**Count**	**Count**
	Oligochaeta indet.	Uv-Sv	0	no	CG	6		4	2	2	
	Acari indet.	Mv	0	no	PA	9	7	1	5	18	43
Anisogammaridae	Ramellogammarus sp.	Uv	T	no	CG	2	5	25			
Crangonyctidae	Crangonyctidae indet.	Uv	T	no	CG						
Crangonyctidae	Crangonyx sp.	Uv	T	no	CG				3	1	1
(blank)	Amphipoda indet.	Uv	T	no	CG			1	1		
Asellidae	Asellidae indet.	Uv	T	no	CG						
Asellidae	Caecidotea sp.	Uv	T	no	CG						
Elmidae	Lara sp.	LL	0	yes	SH	2	5	4			1
Elmidae	Narpus sp.	LL	0	yes	CG			1			
	Coleoptera indet.	UN	UN	UN	UN						
Ceratopogonidae	Bezzia/Palpomyia sp.	Uv	0	no	PR						
Ceratopogonidae	Ceratopogonidae indet.	Uv	0	no	PR						
Chironomidae	Chironomidae indet.	Uv-Mv	0	no	CG	97	71	65	110	162	119
Dixidae	Dixa sp.	Uv	0	no	CG	5	3	17	3		
Dixidae	Dixidae indet.	Uv	0	no	CG						
Empididae	Empididae indet.	Uv	0	no	PR		1			1	1
Empididae	Hemerodromia sp.	Uv	0	no	PR						
Empididae	Hemerodromia sp.	Uv	T	no	PR						
Empididae	Metachela/Chelifera sp.	Uv	0	no	PR						
Empididae	Neoplasta sp.	Uv	0	no	PR	2					
Empididae	Wiedemannia sp.	Uv	0	no	PR						
Psychodidae	Maruina sp.	Uv	0	yes	SC						
Simuliidae	Simuliidae indet.	Uv	0	yes	CF	100	151	168	180	181	181
Simuliidae	Simuliium sp.	Uv	0	yes	CF	42	59	59	25	86	27
Tipulidae	Dicranota sp.	Uv	0	no	PR	2				2	3
Baetidae	Baetidae indet.	Uv-Mv	0	no	CG	22	35	23	56	13	38
Baetidae	Baetis sp.	Uv-Mv	0	no	CG	27	20	33	19	23	22
Ephemerellidae	Ephemerellidae indet.	Uv	0	yes	CG						
Heptageniidae	Heptageniidae indet.	Uv	0	yes	SC	6	5	11			
Leptophlebiidae	Leptophlebiidae indet.	Uv	0	no	CG						
Leptophlebiidae	Paraleptophlebia sp.	Uv	0	no	CG						
	Ephemeroptera indet.	UN	0	no	UN	20	13	10			5
Sialidae	Sialis sp.	Uv	0	no	PR						
Leuctridae	Despaxia augusta	Uv	I	no	SH						
Nemouridae	Malenka sp.	Uv	0	no	SH	1	1				
Nemouridae	Zapada cinctipes	Uv	0	no	SH	34	37	17			
Nemouridae	Zapada oregonensis group sp.	Uv	0	no	SH	1					
Nemouridae	Zapada sp.	Uv	0	no	SH	2	8				
Perlodidae	Perlodidae indet.	Uv	0	no	PR						
Perlodidae	Skwala sp.	Uv	0	no	PR						
Pteronarcyidae	Pteronarcys sp.	LL	0	yes	OM						
	Plecoptera indet.	UN	UN	UN	UN	1					
Brachycentridae	Brachycentrus sp.	LL	0	yes	OM						
Glossosomatidae	Glossosomatidae indet.	Uv	0	yes	SC	28		5	1		
Hydropsychidae	Hydropsyche sp.	Uv-Mv	0	yes	CF						
Hydropsychidae	Hydropsychidae indet.	Uv-Mv	0	yes	CF				2	5	2
Hydropsychidae	Parapsyche sp.	Uv-Mv	0	yes	CF	5	3	5	1	2	4
Limnephilidae	Dicosmoecus sp.	Uv	0	no	OM						
Rhyacophilidae	Rhyacophila sp.	LL	0	yes	PR						
(blank)	Trichoptera indet.	Uv	0	no	UN	2	16	8	23	16	81
Pisidiidae	Pisidiidae indet.	LL	0	no	CG		4	2			1
Ancylidae	Ferrissia sp.	Uv	T	no	SC						
Physidae	Physidae indet.	Uv	T	no	CG				1	3	
Planorbidae	Planorbidae indet.	Uv	T	no	SC						
	Nemertea indet.	Uv	T	no	PR						
	Platyhelminthes indet.	Mv	0	no	CG						
					Subsample Total	**416**	**444**	**459**	**432**	**515**	**529**
					Total Abundance Extrapolated for whole sample*	**1993**	**3552**	**3672**	**1152**	**3090**	**6348**
					Densities	**7151**	**12,745**	**13,175**	**4133**	**11,087**	**22,777**

*UEL-001-1 split 5/24, UEL-001-2 split 1/8, UEL-001-3 split 1/8, UEL-003-1 split 3/8, UEL-003-2 split 1/6, UEL-003-3 split 1/1

Voltinism — Refers to length of life cycle (generation). Can vary by region for any given taxon.
Uv = univoltine, one generation/year
Mv= multivoltine, numerous generations/year
Sv= Semivoltine, generation takes more than one year
LL = long lived (semivoltine in region of interest)

Tol/Intol — Tolerance to pollution
I- Intolerant
T-Tolerant
0 - neither tolerant or intolerant

Clinger — Macroinvertebrates that cling to substrates, **yes/no**

Feeding
CG - Collector-Gatherer
PR - Predator
CF - Collector-Filterer
PA - Parasite
SC - Scraper
SH - Shredder
OM - omnivore

Appendix C

B-IBI Data

Appendix C: B-IBI Data, UEL Project, 2015

Site	UEL Project							
Station	UEL-001				UEL-003			
Client Sample #	UEL-001-1	UEL-001-2	UEL-001-3	UEL-001-Average	UEL-003-1	UEL-003-2	UEL-003-3	UEL-003-Average
Metrics								
Taxon Richness	16	13	14	14.33	10	10	10	10.00
E richness	2	2	2	2.00	1	1	1	1.00
P richness	3	2	1	2.00	0	0	0	0.00
T richness	2	1	2	1.67	2	1	1	1.33
Intolerant Richness	0	0	0	0.00	0	0	0	0.00
Clinger Richness	5	4	6	5.00	3	2	3	2.67
Long-Lived Richness	1	2	3	2.00	0	0	2	0.67
% Tolerant	0.48	1.13	5.66	2.42	1.16	0.78	0.19	0.71
% Predator	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00
%Dominance (3)	57.45	63.29	63.62	61.45	80.09	83.30	72.02	78.47
B-IBI Values								
Taxon Richness	3	1	1	1	1	1	1	1
E richness	1	1	1	1	1	1	1	1
P richness	1	1	1	1	1	1	1	1
T richness	1	1	1	1	1	1	1	1
Intolerant Richness	1	1	1	1	1	1	1	1
Clinger Richness	1	1	1	1	1	1	1	1
Long-Lived Richness	1	1	3	1	1	1	1	1
% Tolerant	5	5	5	5	5	5	5	5
% Predator	1	1	1	1	1	1	1	1
%Dominance (3)	5	3	3	3	1	1	3	3
B-IBI Sample Score	**20**	**16**	**18**		**14**	**14**	**16**	
B-IBI Site Score				**16**				**16**
B-IBI Site Category				**Very Poor**				**Very Poor**
Community Composition								
%EPT	35.82	31.08	24.40	30.43	23.61	11.46	28.73	21.27
%Chironomidae	23.32	15.99	14.16	17.82	25.46	31.46	22.50	26.47
%Isopods	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%Oligochaetes	1.44	0.00	0.87	0.77	0.46	0.39	0.00	0.28

Appendix D1

Water Quality Sampling Photolog

Photograph 1. ↑
UEL-001 looking downstream during the dry sampling period, September 8, 2015.

Photograph 2. ↑
UEL-001 looking downstream during the wet sampling period, November 18, 2015.

Photograph 3. ↑
UEL-002 looking downstream during the dry sampling period, September 8, 2015.

Photograph 4. ↑
UEL-002 looking downstream during the wet sampling period, December 10, 2015.

Photograph 5. ↑
UEL-003 looking upstream during the dry sampling period, September 15, 2015.

Photograph 6. ↑
UEL-003 looking upstream during the wet sampling period, December 12, 2015.

Photograph 7. ↑
UEL-004 looking downstream during dry the sampling period, September 15, 2015.

Photograph 8. ↑
UEL-004 looking downstream during the wet sampling period, December 10, 2015.

Appendix D2

Benthic Invertebrate Sampling Photolog

Photograph 1.
UEL-001, Replicate 2 benthic invertebrate sampling, August 24, 2015.

Photograph 2.
UEL-002 benthic invertebrate sampling, August 24, 2015.
Not enough water to sample with Surber.

Photograph 3.
UEL-003, Replicate 2 benthic invertebrate sampling, August 24, 2015.