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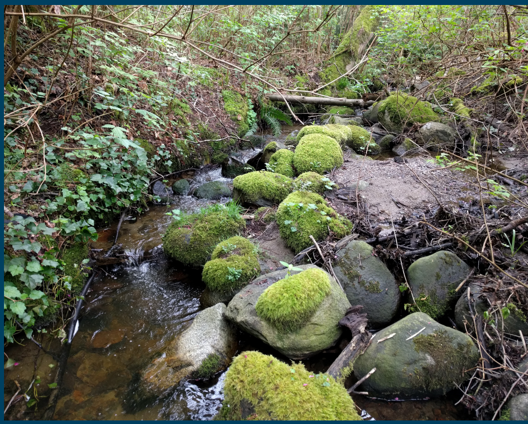
BRITISH COLUMBIA

Integrated Stormwater Management Plan

University Endowment Lands

January 2018



AECOM

University Endowment Lands

Integrated Stormwater Management Plan

Prepared by:

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Project Number:

60222155

Date:

January, 2018

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January 22, 2018

Jonn Braman
Manager
University Endowment Lands
5495 Chancellor Boulevard
Vancouver, BC V6T 1E3

Dear Jonn:

Project No: 60222155
Regarding: Integrated Stormwater Management Plan

Please find attached the Integrated Stormwater Management Plan for the northward draining stormwater catchment area of the University Endowment Lands.

Please contact me if you have any questions about the information presented within this report.

Sincerely,
AECOM Canada Ltd.

Graham Walker
Project Manager
Graham.walker2@aecom.com

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
5	1	The University Endowment Lands

Version Log

Version #	By	Date	Description
1	Semyon Chaymann	2017-08-28	Draft
2	Semyon Chaymann	2017-09-12	Draft for UEL Review
3	Semyon Chaymann	2018-01-19	Revised based on UEL draft version review
4	Semyon Chaymann	2018-01-22	Final

AECOM Signatures

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JAN 2 2 2018

Executive Summary

An Integrated Stormwater Management Plan (ISMP) is an over-arching, long-term strategy that focuses on the protection and enhancement of a watershed's health. ISMPs combine concepts of urban planning, stormwater management and environmental management to facilitate sustainable development within a watershed.

The University Endowment Lands ("the UEL") has retained AECOM Canada Inc. to develop the Integrated Stormwater Management Plan ("the ISMP") in line with the requirements of Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRMP) and British Columbia's Environmental Management Act. Development of the ISMP occurred in four stages and is based on the approach outlined in Chapter 9: Developing and Implementing an ISMP in Stormwater Planning: A Guidebook for British Columbia.

Table 1: Summary of ISMP Approach

Stage	Question Answered	Description of tasks	Relevant ISMP Sections
1	What do we have?	Review background information and summarize existing conditions	• Study Area • Regulatory Context • Land Use • Hydrology • Stormwater System • Hydrogeology and Soils • Environment • Hydraulic Modelling and Assessment
2	What do we want?	Establish the vision for future development	• Vision and Goals
3	How do we put this into action?	Development of an implementation plan, funding and enforcement strategies	• Implementation Plan
4	How do we stay on target?	Development of a monitoring and assessment program	• Adaptive Management Plan

UEL Integrated Stormwater Management Plan

During Stage 1 of the UEL ISMP, AECOM reviewed background information and summarized existing conditions of stormwater management within the UEL, as well as highlighted the gaps in stormwater regulation, land use planning, and stormwater infrastructure. The Stage 1 report includes a water quality and benthic sampling report that provides an understanding of "current" baseline conditions within the existing creeks.

In Stage 2 of the ISMP, the UEL and the key stakeholders (Metro Vancouver, City of Vancouver, Spanish Bank Streamkeepers, the University Golf Course, and the University of British Columbia), established five (5) goals to guide the stormwater management for the UEL:

Goal 1: The UEL community is engaged in stormwater management.
Goal 2: Healthy streams and a natural environment are part of the UEL.
Goal 3: Stormwater infrastructure provides an adequate level of service, while protecting life and property.
Goal 4: The UEL provides guidelines and a regulatory framework for stormwater management.
Goal 5: Stormwater management at UEL adapts to change.

These goals were established to achieve the vision of "A stormwater management plan that protects the natural and built environment through enhancement of natural watercourses, and provides opportunities for collaboration and engagement with community and residents on stormwater issues".

The Implementation Plan document (Stage 3) identifies opportunities to develop planning, environmental, and engineering controls that would allow the UEL to achieve the stormwater management vision and goals. There are ten (10) action items that UEL should consider for implementation:

1. Promote stormwater management awareness and engagement opportunities.
2. Continue with the combined sewer separation strategy in Area B.
3. Manage the quantity of road runoff.
4. Treat stormwater runoff from the roadways and upgrade stormwater treatment at the UEL Works Yard.
5. Identify stormwater infrastructure that is poorly located for maintenance and develop plans for management or replacement (i.e. the 300mm diameter storm sewer in Pacific Spirit Park east of Acadia Road).
6. Continue to upgrade system capacity and renew aging infrastructure in a proactive manner through the capital planning process.
7. Develop mitigation measures to address slope stability in Area B.
8. Integrate stormwater asset maintenance with work order management using a GIS-centric system.
9. Develop Erosion and Sediment Control requirements.
10. Limit the rate of stormwater runoff from private properties.

The Adaptive Management Plan document (Stage 4) provides guidelines for monitoring and tracking water quality, quantity, and instream habitat through the lens of the UEL Watershed Health Monitoring and Adaptive Management Framework. The proposed Framework is a condensed version of the Metro Vancouver's Monitoring and Adaptive Management Framework document and consists of recommendations that are most applicable to the UEL.

The ISMP contains long-term goals and objectives that have a planning horizon of up to 30 years. Changes in factors such as the economy, technology, policy, land-use and public opinion over the long term horizon can be addressed through an Adaptive Management approach in which the ISMP is periodically updated to ensure that it remains relevant and applicable. The adaptive process is iterative, as shown in Figure 1 - the last stage in the cycle focuses on monitoring, and will generate new information that should be reviewed in the first stage of the next cycle.

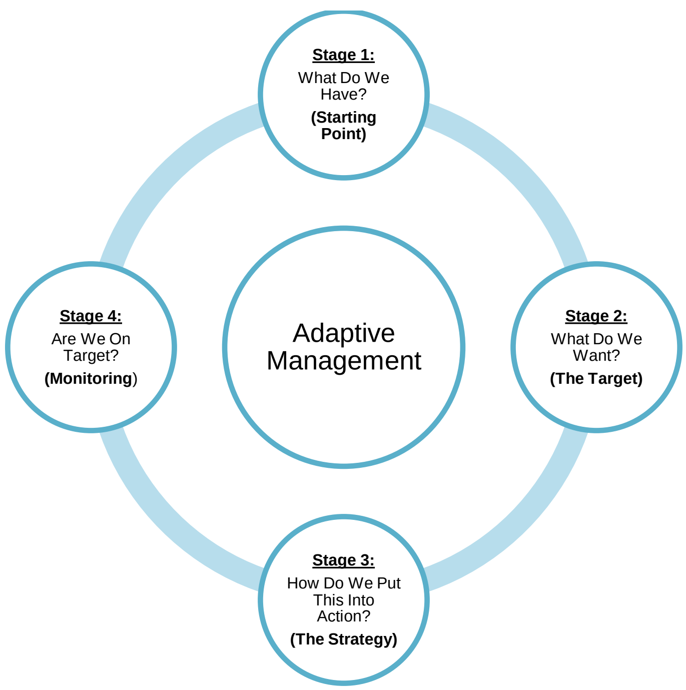

Figure 1: ISMP Adaptive Management Process

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1. Introduction

The 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. Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRM) requires 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 (ISMP) 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 University Endowment Lands ("the UEL") retained AECOM to develop the University Endowment Lands ISMP ("the ISMP") in line with the requirements of the Metro Vancouver LWRMP and the Environmental Management Act. The ISMP relates to the UEL area that drains north into the English Bay.

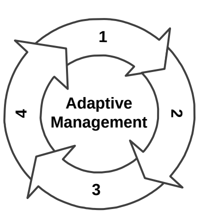
The primary, over-arching goals of the ISMP are as follows:

- Alleviate existing and/or potential drainage, erosion, and flooding concerns
- Protect and/or restore stream health including riparian and aquatic habitat
- Remediate existing and/or potential water quality issues

The ISMP focus is on the integration of stormwater management and land use planning. An ISMP is an integral component of a local government's land development and growth management strategy because upstream activities including land use change have downstream consequences including flood and environmental risks.

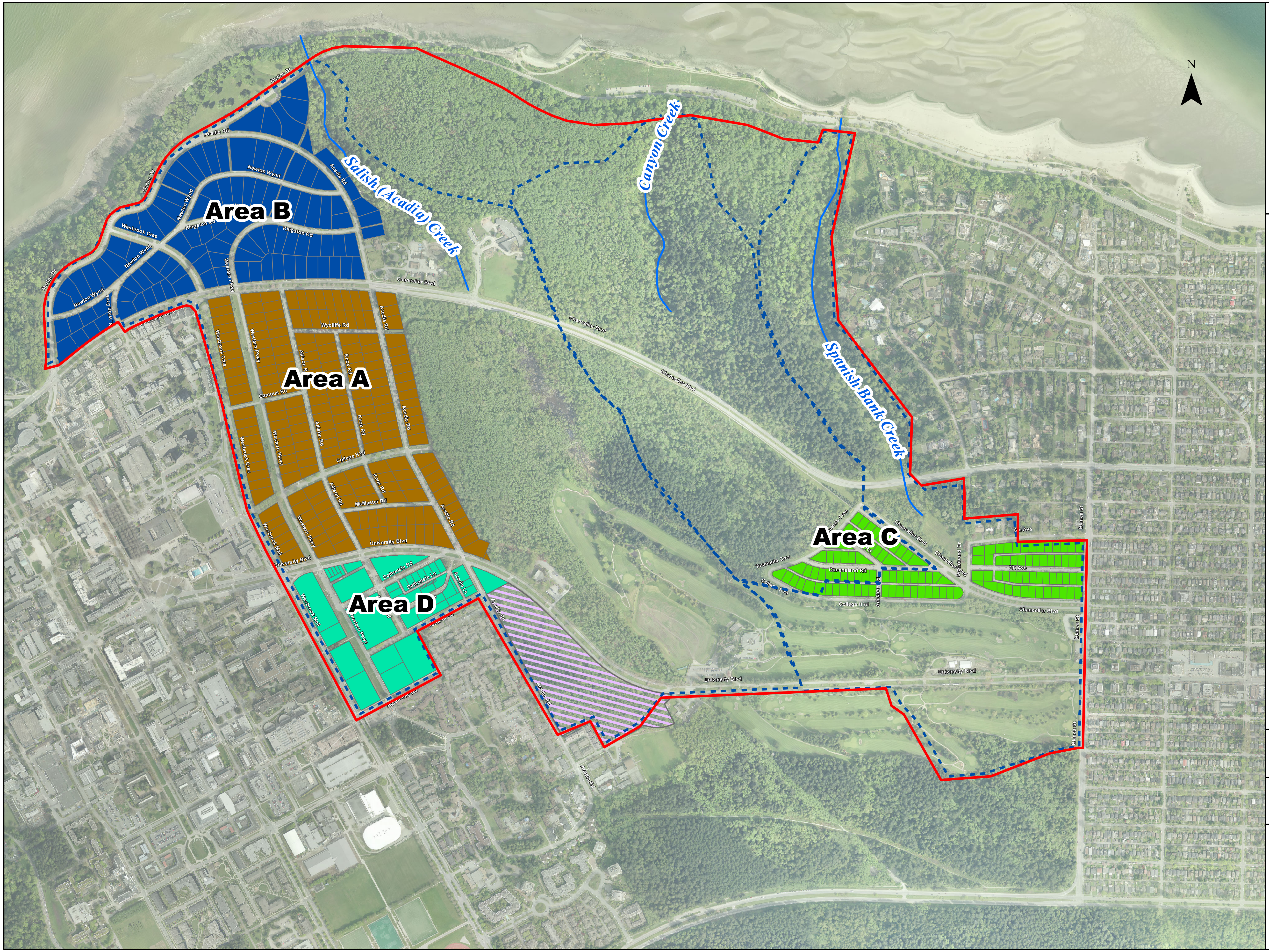
Development of the ISMP will occur in four stages and was based on the approach outlined in Chapter 9: Developing and Implementing an ISMP in Stormwater Planning: A Guidebook for British Columbia.

Stage 1	What do we have?	Review background information and summarize existing conditions
Stage 2	What do we want?	Establish the vision for future development
Stage 3	How do we put this into action?	Development of an implementation plan, funding and enforcement strategies
Stage 4	How do we stay on target?	Development of a monitoring and assessment program



The ISMP contains long-term goals and objectives that have a planning horizon of up to 30 years. Predicting changes in factors such as the economy, technology, policy, land-use and public opinion over the long term horizon is challenging.

Subsequently, an Adaptive Management approach is proposed, in which the ISMP is periodically updated to ensure that it remains relevant and applicable. The adaptive process is cyclical - the last stage in the cycle focuses on monitoring, and will generate new information that should be reviewed in the first stage of the next cycle.



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Study Area
- Watershed Boundary
- Watercourses

Areas

- Area A
- Area B
- Area C
- Area D
- Block F

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Meters
0 100 200 400

Project No.	Date
60222155	August 2017

UEL ISMP Study Area

Figure 2

2. Stage 1 Summary – "What do we have?"

Study Area

The UEL consist 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 or 77%, is forested with the remaining 280 Ha, or 23%, 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 and streams which the stormwater infrastructure discharges to. Figure 2 provides an overview of the ISMP study area.

University Hill is divided into four areas:

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

The Village is the UEL's centre for commercial activity located in Area D. This area includes a high density, mixed commercial and residential use development (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 development of Block F includes new municipal water, sewer, parks, and transportation infrastructure. The development consists of a 22 acre parcel of land bounded by Acadia Rd, University Boulevard, Toronto Road, and Ortona Rd. The parcel is currently zoned for multi-family residential townhouse development but with approval for rezoning will include a community center and some commercial occupancy. The development of Block F will require various improvements to the existing infrastructure as well as new infrastructure.

Overall, the population and impervious area in the study area are likely to increase, with the development of Block F and as redevelopment occurs in Area D.

The full version of the Stage 1 Report is attached in Appendix A.

Legislative Context

The study area falls within the jurisdiction of Provincial (British Columbia) level of government that enforces legislative requirements relevant to the ISMP. The most significant regulatory items are the BC Environmental Management Act, and the Metro Vancouver Integrated Liquid Waste and Resource Management Plan, which are the drivers for developing the ISMPs in the region. It will be important to monitor changes in legislation relating to environmental management, water, and flood management to ensure that the ISMP remains compliant.

The UEL Works and Services (W&S) Bylaw was approved and implemented in 2016. The W&S Bylaw specifies the minimum standards for engineering design, including stormwater management and project execution in municipal infrastructure. The UEL currently lacks an Erosion and Sedimentation Control Bylaw to ensure that the engineered and natural drainage system is adequately protected during construction.

Land Use Planning

The University Hill community consists of primarily single family homes in Areas A, B, and C. Area D consists of a mix of low and high-rise apartments, townhouses, mixed-use, and commercial development. A significant development is planned on the Block F property southeast of the existing Area D development. Other than the Block F property, the UEL Community has been built out. It is expected that there may be further densification of some properties within Area D when they are eventually redeveloped. Pacific Spirit Park, which contains a number of environmentally sensitive areas, is within the study area.

Hydrology

The developed portion of the study area is made up of eight distinct catchments, most of which drain north towards English Bay through various creeks and ravines. Approximately 1 acre of Block F drains south to Cut Throat Creek and is addressed through Musqueam Integrated Stormwater Management Plan. Climate change may cause more frequent and extreme storm or longer periods of drought than have historically occurred; this has been identified as a long term concern for the UEL and the Pacific Spirit Park.

Existing Drainage System

Within developed areas, the drainage system consists mainly of streets with curbs, gutters, catch basins and gravity storm sewers. Within the Pacific Spirit Park and University Golf course the system consists mainly of a network of ditches, creeks, and culverts. A small section of the UEL (north of Chancellor Boulevard) is served by a combined sewer system, which is being separated as the sewers are replaced (Figure 3).

All properties within the UEL that have been developed in the last 10 years have been required to limit discharge during a 5 year storm to a rate of 8 litres per second. Hydraulic modelling of the existing drainage system was completed and recommendations addressing drainage deficiencies are summarized in Appendix A.

The storm sewer system is regularly inspected with CCTV, and was last inspected in 2012-2013. Sewers in poor condition have been slated for repair/replacement within the UEL 10 Year Capital Plan (2012-2021).

Hydrogeology and Soils

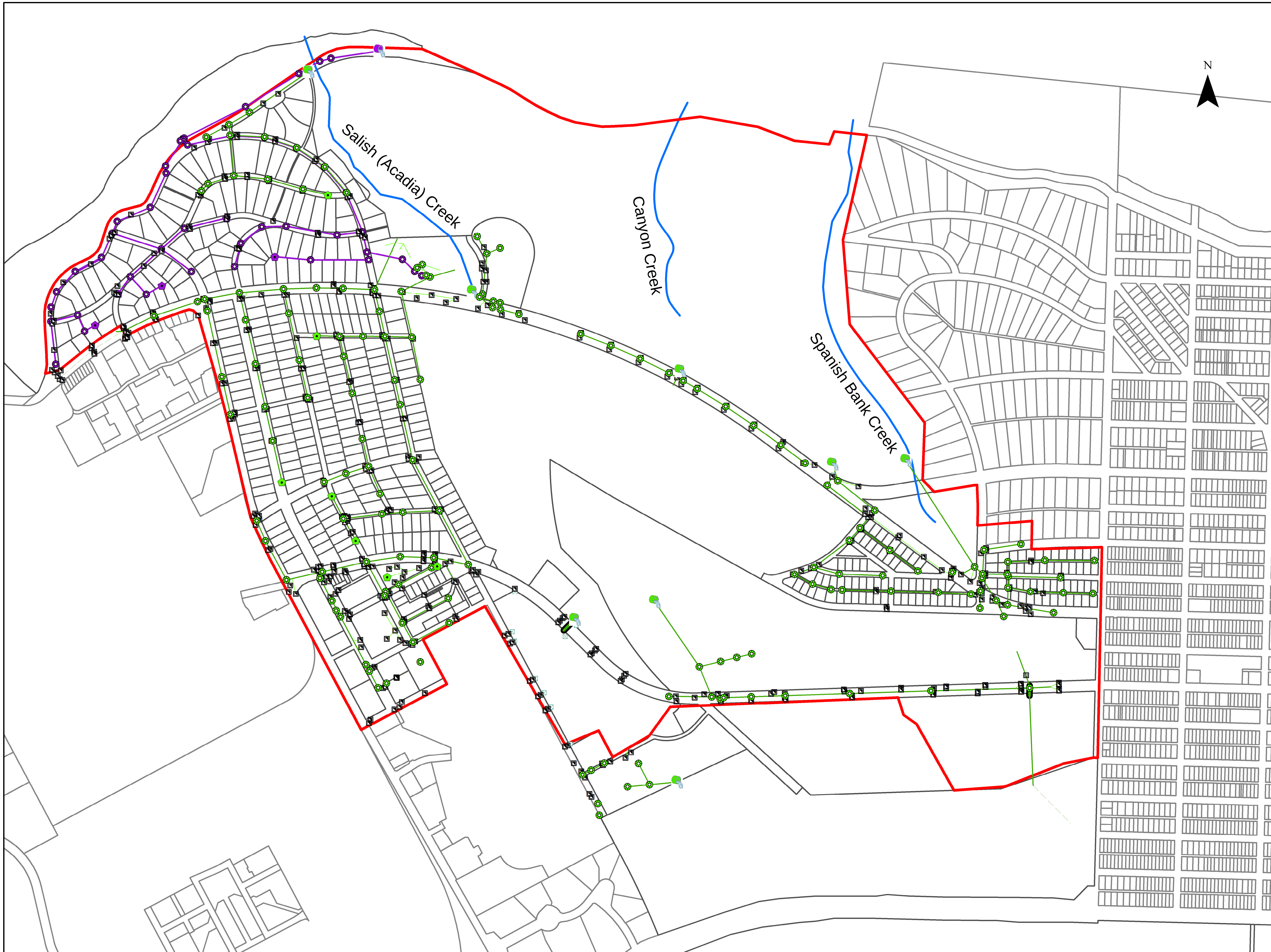
Most of the study area is directly underlain by low permeability till which limits the ability of infiltration as a method of reducing storm water runoff. Groundwater flow in the Upper Aquifer discharges from the cliff faces along Spanish Banks resulting in mass wasting and erosion. Increasing infiltration is generally not recommended in the vicinity of these cliffs. Existing wells show the aquifer ground water table is located at approximately 50-95 metres below the surface depending on location; however, there is conflicting information from nearby shallow water wells showing ground water depth as high as 3.8 metres below surface.

Environment

Sampling in UEL creeks was completed during the development of the 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).

Both fecal coliform and E. coli levels exceeded regional guidelines at the Spanish Bank Creek and Salish Creek sampling locations during the wet sampling period. Exceedances for the two bacteriological parameters during the dry period only occurred in Salish Creek. The point sources for these contaminations should be determined. 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. Urban areas can have high metal concentrations primarily during wet season sampling due to roadway runoff. Benthic macro invertebrate scoring provided an overall rating of very poor stream condition for both sampling locations, at Spanish Bank Creek and Salish Creek. 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.

Coho Salmon, Chum Salmon, and Cutthroat Trout have been observed in Spanish Bank Creek; and Coho Salmon has been observed in Salish Creek. It should be assumed that these fish species are also present in Canyon Creek. The majority of Spanish Bank, Canyon and Salish Creeks, north of Chancellor Boulevard, have retained their 30 metre riparian setback, but there are some areas where this is reduced to 15 metres or less.



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Storm Outfall
- Storm Cleanout
- Storm Manhole
- Junction Box
- Catch Basin
- Culvert Headwall
- Abandoned Main
- Storm Sewer
- Culvert
- Catchbasin Lead
- Combined Cleanout
- Combined Manhole
- Combined Outfall
- Combined Sewer
- Study Area
- Watercourses

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Existing Stormwater and Combined Sewer Infrastructure

Figure 3

3. Stage 2 – "What do we want?"

AECOM conducted five ISMP progress briefings and visioning input consultations with stakeholders; one with the UEL Community Advisory Council, one with City of Vancouver and Metro Vancouver staff, one with Spanish Bank Streamkeepers and Pacific Spirit Part Society staff, one with University of British Columbia Campus and Community Planning staff, and one with University Golf Course management staff.

3.1 Summary of Progress Briefings and Input Consultations with Stakeholders

UEL Community Advisory Council

On October 17, 2016, a brief overview of the findings of the ISMP Stage 1 report and a Stage 2 overview information sheet were presented to the UEL Community Advisory Council (CAC). The ISMP Stage 1 report was made available on the UEL website for review by the community and an open invitation was given for input into further stages of the ISMP development process. The CAC accepted the Stage 1 report for review and requested to be provided with further updates and information as the ISMP is further developed.

City of Vancouver and Metro Vancouver Visioning Workshop

On June 24, 2016 a workshop was held at the University Endowment Land Administrative Office. AECOM and the UEL presented the Stage 1 report findings and obtained input from participants on the potential vision and goals of the ISMP. The meeting was attended by staff members from both the City of Vancouver and Metro Vancouver in order to gain insight from their past experiences. The follow items were discussed as part of the development of vision and goals:

Engagement with the community

- Education for residents regarding stormwater best management practices
- Utilize resources and studies conducted within the watershed to benefit stormwater management
- A library, or repository, of local knowledge about the watercourses and parks that is accessible for public
- Pursue concepts of connected community and sharing of information
- Engage Golf Course in stormwater planning, Best Management Practices (BMPs), and water conservation practices

Protect Water Quality

- Protect, enhance, and improve streams
- Protect and respect the Pacific Spirit Park area
- Implement stormwater BMPs where applicable
- Understanding of water flow patterns through the Park
- New Developments/Redevelopments
    - Increase in impermeable area is a concern
    - Infiltration is not always the best option

Protect Water Quantity

- Maintain flows in watercourses for fish habitat
- Investigate water flow from Regent College into the stormwater system and its contribution to Salish Creek and maintaining of fish habitat

Protect Life and Property

- Erosion along NW Marine Dr.
- Maintain or improve current fish values

Natural Environment

- Tree protection and management
- New developments/ redevelopments
    - o Keep significant and/or valuable trees

Resiliency to Climate Change

- Increased peak flows
- Increased storm frequency

Consider Developing Bylaws

- Tree Protection
- Erosion and Sediment Control

Spanish Bank Streamkeepers and Pacific Spirit Park Society Visioning Consultation

On September 8, 2016, the Spanish Bank Streamkeepers and representative from the Pacific Spirit Park Society met with AECOM and the UEL staff to discuss issues and concerns regarding stormwater management.

The Spanish Bank Streamkeepers volunteer group is actively involved in monitoring, assessing, and safeguarding the Spanish Bank Creek, Canyon Creek, and Salish Creek. The group receives support from the Pacific Streamkeepers Federation and members are encouraged to get the Streamkeeper Certification, which provides training in watercourse monitoring and assessment. The Spanish Bank Streamkeepers have provided educational opportunities for the public, including school children programs and summer camps. The Streamkeepers have also taken on investigative work in assessing water quantity variability in Salish Creek. Together with the UEL Operations staff, the Spanish Bank Streamkeepers have discovered that, during the dry summer months, Regent College is discharging groundwater directly into the UEL storm drains after it is utilized for the building cooling system. The flow discharges into Salish Creek at the box culvert below Acadia Circle. The Streamkeepers are eager to determine the impact of the flow from the Regent College on the ecology in Salish Creek, and have contacted the Pacific Streamkeepers Federation to provide further guidance on the next steps.

The Streamkeepers have noted that with presence of salmon in Spanish Bank Creek and Salish Creek it is important to provide a healthy stream habitat through:

- Maintaining sufficient stream flow in the summer/drought months, and controlling high storm flows in the rainy/winter seasons; and,
- Identifying if water quality is an issue, specifically concerning the size of the insects in Salish Creek as compared to Spanish Bank Creek, and especially during the “first flush” events.

University of British Columbia ISMP Consultation

Similar to the UEL, the University of British Columbia is undertaking the development of an Integrated Stormwater Management Plan. This presents an opportunity for collaboration between the UEL and the UBC with respect to stormwater management. On July 28, 2016, AECOM and UEL staff met with UBC Campus and Community Planning staff to discuss the challenges and opportunities for development of an ISMP, gather information, and build on the lessons learned.

Key challenges that the UBC is facing as it develops their stormwater strategy were identified as follows:

- The underlying clay soils that limit infiltration options and lead to development of detention and system optimization options
- Stormwater outfalls are located outside UBC's jurisdictional boundaries, therefore there are opportunities for collaboration between the UBC and the UEL to minimize impact of the Point Grey Campus on adjacent lands
- Stability of slopes at ravines, outfalls and coastal cliffs area a concern due to the potential for damage to life and property. Erosion continues to be a focus of studies and development of a management plan.

The result of the consultation with the UBC is the understanding that future stormwater management work can be done in a collaborative approach through open communication and sharing of information.

University Golf Course ISMP Consultation

The University Golf Course (UGC) has accommodated UEL's effort to gain further information regarding drainage and water consumption within the golf course property. During the meeting with UGC management on August 16, 2016, AECOM was able to introduce UEL ISMP project and request information that will help better understand the drainage and water use within the UEL.

The University Golf Course is located in the headwaters of the study area watershed, and a series of culverts, drainage lines, and open ditches, discharge from UGC property into the Salish Creek and Spanish Bank Creek. Block F, located upstream of the UGC, discharges through the UGC into Salish Creek. Based on the drainage information acquired after the meeting, the headwaters of the watershed delineation was able to be improved because it was discovered that a portion of the golf course property south of University Boulevard drains southward to the Musqueam and Cutthroat Creeks. Additionally, the consultation with the University Golf Course resulted in a better understanding of water use through UGC's Water Use Plan as well as information about the pesticide use through the UGC's Integrated Pest Management (IPM) Plan. According to the UGC, changes in the provincial Integrated Pest Management regulation require a licence for application of pesticides on landscaped areas of private lands. Businesses, such as UGC, are required to have certified staff that obtain a licence and who use IPM, follow environmental protection requirements, and keep records of all pesticide applications.

3.2 Vision, Goals, and Objectives

Based on the input of the key stakeholders, the vision of the UEL ISMP can be summarized as:

"*The University Endowment Lands' Integrated Stormwater Management Plan protects the natural and built environment through enhancement of natural watercourses, and provides opportunities for collaboration and engagement with community and residents on stormwater issues"*

The UEL Community Advisory Council, City of Vancouver, Metro Vancouver, the Spanish Bank Streamkeepers, the Pacific Spirit Park Society, the University Golf Course, and the University of British Columbia have identified the following goals to enhance stormwater management in the University Endowment Lands.

Goal 1: The UEL community is engaged in stormwater management

- Residents and homeowners within the UEL ISMP study area are engaged in stormwater management at UEL.
- Engagement of Pacific Spirit Park users, neighbouring communities and stakeholder organizations. There is capacity for key stakeholders to share and access stormwater related information (i.e. water quality reports).

Goal 2: Healthy streams and a natural environment are part of UEL

- UEL employs stormwater Best Management Practices where applicable.
- New development or redevelopment projects at UEL abide by Erosion and Sediment Control requirements.
- Remaining combined sewers at UEL are separated respectively with implementation of Low Impact Development and stormwater Best Management Practices.

Goal 3: Stormwater infrastructure provides adequate level of service and protects life and property

- UEL storm sewer infrastructure sufficiently conveys run-off from the 5 year design storm within the drainage system without causing significant flooding, slope stability issues or significant environmental issues.
- UEL aims for a proactive asset management program to track the state of its infrastructure.
- UEL strives towards reducing erosion and potential damage in the areas with steep slopes. Geotechnical expertise required to study areas contributing to erosion and slope instability.

Goal 4: The UEL provides guidelines and a regulatory framework for stormwater management

- Section 20 of the W&S Bylaw requires stormwater management for new developments and redevelopment of existing properties in accordance with the standards established under Section 13 of W&S Bylaw
- UEL protects its watercourses and natural environment from deleterious substances generated by construction activity through implementation of Erosion and Sediment Control best practices.
- UEL integrates the Schedule C (specifications for boulevard trees and landscaping) of the W&S Bylaw with the stormwater management plans.
- UEL guidelines and regulatory frameworks are in line with regional stormwater management policies.

Goal 5: Stormwater management at UEL adapts to change

- UEL adapts its stormwater management to changes in climate and regulatory environments.
- The UEL ISMP is a living document and is revisited through future iterations.

4. Stage 3 – "How do we put this into action?"

4.1 Stormwater Management Plan Action Items

The following action items were identified and are proposed in order for the UEL to meet the goals and vision set out during the stormwater visioning process.

Table 2: Summary of Stormwater Management Plan Action Items

Action Item #	Description	Related ISMP Goals
1	Promote stormwater management awareness and engagement opportunities	*1*
2	Continue with the combined sewer separation strategy in Area B	*2, 3*
3	Manage the quantity of road runoff	*2*
4	Treat stormwater runoff from the roadways and upgrade stormwater treatment at the UEL Works Yard	*2*
5	Identify stormwater infrastructure that is poorly located for maintenance and develop plans for management or replacement (i.e. the 300mm diameter storm sewer in Pacific Spirit Park east of Acadia Road)	*3, 5*
6	Continue to upgrade system capacity and renew aging infrastructure in a proactive manner through the capital planning process	*3*
7	Develop mitigation measures to address slope stability in Area B	*3*
8	Integrate stormwater asset maintenance with work order management using a GIS-centric system	*2, 3, 5*
9	Develop Erosion and Sediment Control requirements	*2, 4*
10	Limit the rate of stormwater runoff from private properties	*2, 3, 4*

In addition to the above listed action items, Appendix D of this report provides Best Management Practices (BMPs) for stormwater management on single-family residential lots to help support Action Item #10.

The following section of this report provides details regarding the action items outlined above.

Action Item #1: Promote stormwater management awareness and engagement opportunities

One of the goals of the UEL ISMP is to increase awareness of stormwater management and stormwater related issues at the UEL (**Goal 1**). This can be achieved through support of education and community engagement efforts within the UEL that focus on stormwater management. The Spanish Bank Streamkeepers currently provide community engagement and volunteer opportunities. The UEL should promote such Streamkeepers activities and collaborate on stream related projects where possible.

To increase public awareness of stormwater issues, the UEL should:

- Promote and encourage support for Streamkeepers activities and volunteer opportunities on the UEL's website and newsletter.
- Provide a link to the Streamkeepers webpage on the "Links" page of the UEL website.
- Future ISMP iterations should identify opportunities for collaboration on stormwater management with the University Golf Course and Pacific Spirit Park Society.

To increase capacity of understanding and sharing of knowledge of stormwater management, the UEL should:

- Retain all stormwater related reports and results of studies on record.
- Allow key stakeholders to submit studies, reports, and other stormwater related findings and retain copies on record.
- Strive to achieve an easily accessible repository of stormwater information.
- Allow access to stormwater related studies, reports, and findings to key stakeholders.
- Work towards creating an Environmental page or tab on the UEL website that provides access to the above mentioned reports, studies, and findings.

Cost

There is no capital cost associated with this Action Item. The Streamkeepers are a volunteer organization. The support of the Streamkeepers' activities does not go beyond the regular UEL commitment and cost (staff time) of maintaining content on the website and generating the newsletter.

Implementation Considerations

In order to better liaise with the Streamkeepers, the UEL should have a Stormwater Champion who would act as a point of contact. A Stormwater Champion should be a UEL staff member who is directly involved in stormwater projects at the UEL.

Figure 4: In-stream Chum salmon incubation at Spanish Bank Creek (source Dick Scarth)

Action Item #2: UEL continues to implement its combined sewer separation strategy

Combined sewers convey wastewater (e.g. from toilet flushing) along with stormwater runoff in one single pipe. This combined flow is then conveyed to Metro Vancouver's Iona Wastewater Treatment Plant. During large storms, the capacity of the combined sewer system and/or Wastewater Treatment Plant may be exceeded, resulting in combined sewage overflowing into large receiving bodies (i.e. combined sewer overflows into English Bay and the Fraser River) with the potential for sewage backing up into basements in low lying areas if there isn't a properly operating backflow device. To reduce the risk of combined sewer overflows and basement flooding, municipalities within Metro Vancouver that have combined sewers are working towards replacing them with separate storm and sanitary sewers.

Another benefit to replacing combined sewers with separate storm and sanitary sewers is that stormwater runoff can then follow its natural drainage pathways and contribute to local streams. However, due to increased imperviousness of the watershed, the natural flow regime of the stormwater runoff is altered and stormwater BMPs should be considered in conjunction with sewer separation to manage the quantity and quality of stormwater runoff before it is conveyed to local streams.

The UEL is currently in the implementation phase of the separation of its remaining 4 km of existing combined sewers within Area B. This sewer separation strategy falls in line with the goals identified in the UEL ISMP visioning consultations; namely: to maintain healthy streams and a natural environment; and to protect property (**Goal 2 and Goal 3**). One of the objectives of the combined sewer separation strategy is to eliminate stormwater from entering Metro Vancouver's wastewater system by providing dedicated sanitary and storm sewers. The following table presents the timelines of projects identified as part of the Area B storm/sanitary sewer separation strategy as identified in the Capital Plan 2015 Update.

Table 3: Combined and Storm Sewer Capital Projects for Area B - 2015 Update

Project No	Asset Class	Project Type	Project Description	Location	Project Cost	Status
2014-04	Combined	Planning / Design	Design of Combined sewer separation on Wesbrook Cres (N/ Chancellor)	Wesbrook Cres (Area B)	$25,000	Complete
2014-17	Combined	Planning / Design	Design of Combined sewer separation on Acadia Rd (N/ Chancellor Blvd)	Acadia Rd (Area B)	$30,000	Complete
2014-18	Combined	Planning / Design	Area B Combined Sewer Separation Strategy	Area B	$8,000	Complete
2014-25	Various	Planning / Design	Design of Water, Sewer and Road replacement on Newton Wynd (W/ Acadia Rd)	Newton Wynd (Area B)	$25,000	Complete
2015-02	Various	Construction	Construction of stormwater/sanitary sewer separation on Wesbrook Cres (N/ Chancellor)	Wesbrook Cres (Area B)	$352,331	Complete
2018-01	Combined	Construction	Construction of Sanitary / Stormwater sewer separation on Acadia Rd (N/ Chancellor Blvd)	Acadia Rd (Area B)	$682,666	-
2019-03	Storm	Construction	Design and Construction of Storm sewer on Western Cres and Kingston Rd (B/W Chancellor Blvd and Acadia Rd)	Western Cres, Kingston Rd (Area B)	$346,500	-

Project No	Asset Class	Project Type	Project Description	Location	Project Cost	Status
2020-03	Combined	Construction	Design and Construction of Sanitary / Stormwater sewer separation on Chancellor Blvd (bet. Western Cres and Acadia Rd)	Chancellor Blvd (Area B)	$303,600	-

Cost

A portion of the total capital costs associated with the combined sewer separation strategy have been included as part of the 10-year Capital Plan. Table 3 provides cost estimates for proposed sewer separation in Area B. By scheduling the sewer separation projects at the end of a combined sewer's life (i.e. when the pipe needs to be replaced in any case due to anticipated failure), the actual cost of sewer separation can be minimized.

Implementation Considerations

Because of the increase in "hard surfaces" (or imperviousness) at the UEL in comparison to pre-developed conditions, the stormwater that is returned to the creeks after combined sewer separation shall meet the quantity and quality recommendations set by Canada's Department of Fisheries and Oceans (DFO). This creates an opportunity for the UEL to implement stormwater BMPs such as rain gardens in the areas of newly separated sewers to showcase that the UEL's awareness of the implications of increased imperviousness on the neighbouring fish bearing creeks. Any BMPs implemented in Area B may need to be designed without infiltration due to slope stability concerns (see Action Item #7).

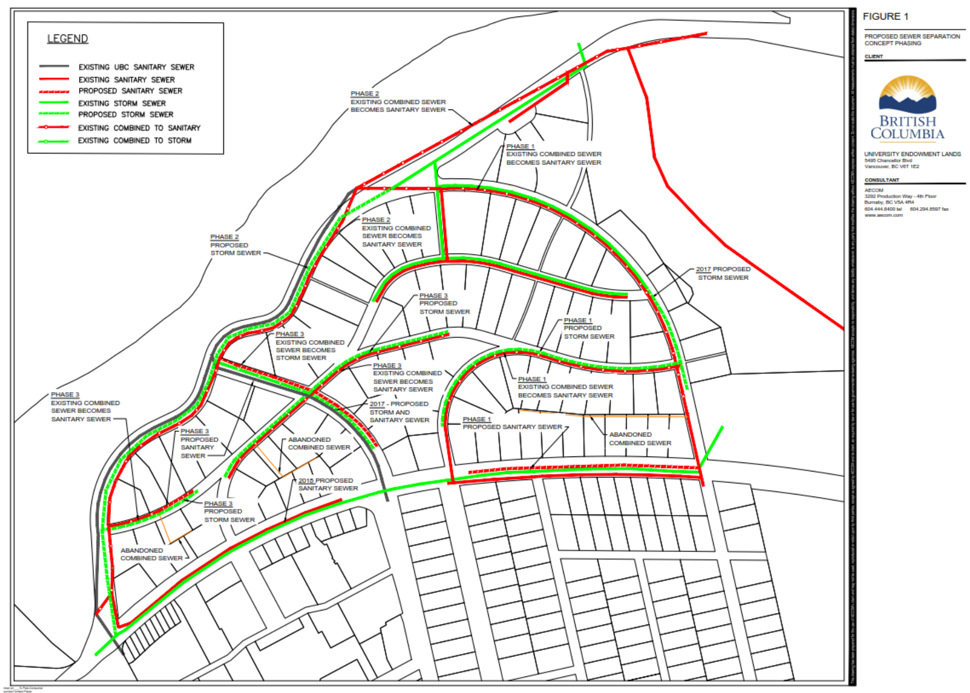

Figure 5: Existing Combined Sewers in Area B

Action Item #3: Manage the quantity of road runoff

Managing the quantity of water that is discharged to the fish-bearing creeks within the UEL was identified as an important step in achieving healthy streams (**Goal 2**). Increases in the amount of hard surfaces (e.g. roadways, roofs etc.) will alter the natural water cycle by increasing the amount of runoff during storms and decreasing the amount of rainfall that soaks into the ground. This can cause an increase in stream erosion and a decrease in stream base flows, which can have a detrimental effect on a stream's ability to support aquatic life.

Currently there are provincial and federal stormwater discharge criteria for controlling the runoff from urbanised areas to limit the impact on natural receiving waterbodies. Metro Vancouver's Stormwater Source Control Design Guidelines document provides a detailed summary of the provincial and federal stormwater criteria and makes recommendations on how to achieve these criteria. The guidelines present a number of source controls, such as rain gardens, which can be used either in roadways or on private property to achieve the stormwater discharge criteria. Not only do rain gardens reduce the volume of stormwater runoff from roadways, but they can also help replenish aquifers, increase summer base flows in creeks, remove some contaminants from the road runoff, be implemented in conjunction with traffic calming features (bump-outs), and provide a visually pleasing landscaped feature.

The UEL should consider implementing curbside rain gardens (see Figure 6) within its roadways, particularly in conjunction with infrastructure renewal projects. As outlined in Metro Vancouver's Stormwater Source Control Design Guidelines, for every 30 square metres of roadway, at least 1 square metre of rain garden should be installed to mitigate the negative impacts on stormwater runoff.

Cost

The cost for a rain garden is approximately $250 per square metre. If the UEL were to install 1 square metre of rain garden for every square metre of roadway (127,000 m^2) then then the total cost of rain gardens to mitigate the UEL's entire roadway system is approximately $1 million. For a "standard block" of roadway (100 metre long by 8 metres wide) then the cost would be approximately $7,000 (in addition to the standard curbing etc.). This does not include Provincial roads such as Chancellor Boulevard that traverse the UEL.

Implementation Considerations

Implementation of BMPs on NW Marine Drive, University Boulevard and Chancellor Boulevard would have to be coordinated with the BC Ministry of Transportation and Infrastructure (MoTI). Rain gardens within Area B may need to be designed to not include infiltration due to slope stability concerns (see Action Item #7).

Figure 6: Example of Curbside Rain Garden in Residential Area

Action Item #4: Treat stormwater runoff from the roadways and upgrade stormwater treatment at the UEL Works Yard

Arterial roadways and maintenance works yards can be significant sources of pollutants such as metals, sediments, chlorides and hydrocarbons. Water quality monitoring that was conducted in Stage 1 of the ISMP showed high concentration of metals that typically come from motor vehicles. Further investigation to identify sources of metal pollution was recommended by the water quality report.

The arterial roadways within the UEL are part of the provincial road network. So any effort to treat the runoff from these roadways would need to be in done in conjunction with the MoTI. Action Item #3 recommends the implementation of rain gardens within the remaining roads at the UEL. This would help address water quality issues associated with these roadways. Further water quality testing will be recommended in Stage 4, particularly at the UEL's maintenance yard. Currently, the UEL works yard employs a stormwater chamber to collect the sediments running off the maintenance yard (Figure 7 and Figure 8). Based on the results of further water quality testing, the UEL can decide whether it should upgrade its stormwater treatment system to mitigate the potential pollution from the works yard activities. This could provide a good opportunity for the UEL to showcase its commitment to maintaining healthy streams and a natural environment (**Goal 2**).

A possible upgrade of the current treatment system is installation of an Oil/Grit Separator (OGS). The OGS units are commonly used in municipalities and other industries to remove hydrocarbons, litter, and large sediments from stormwater runoff. Many pollutants, such as metals, tend to adhere to sediments; so by removing sediments, one will likely remove other pollutants as well. Stormwater treatment technologies such as membrane filters and bioretention facilities can remove finer sediments and other substances such as phosphorous, but these technologies tend to cost more and are therefore only used where more rigorous treatment is required.

Sediment and associated pollutants can be removed from the stormwater system through best operational practices such as regular catch basin cleaning and street sweeping. Catch basins should be inspected and/or cleaned at least once per year and street sweeping should be done twice per year (more often on arterial roadways). Increases in winter sanding and salt use may require an increase in frequency of catch basin cleaning and street sweeping practices.

Cost

Advanced OGS units such as the Stormceptor STC models (Figure 9) that remove particles from 20 to 2000 microns in size, free oil, heavy metals and sediments, range in cost from $11,000 to $90,000, depending on the size of the unit (range from 1.2m to 2.4m in diameter). Conventional Oil/Water Separators and Oil Interceptors (e.g. API style or Coalescing Plate style) range from $2,000 to $20,000 but require a larger footprint and a sump. The prices listed above are estimated unit costs only and do not include detailed design, shipment of materials, and installation.

Implementation Considerations

OGS installations on arterials (e.g. NW Marine Drive, Chancellor Blvd or University Boulevard) need to be done in consultation with the MoTI who own and operate these roadways.

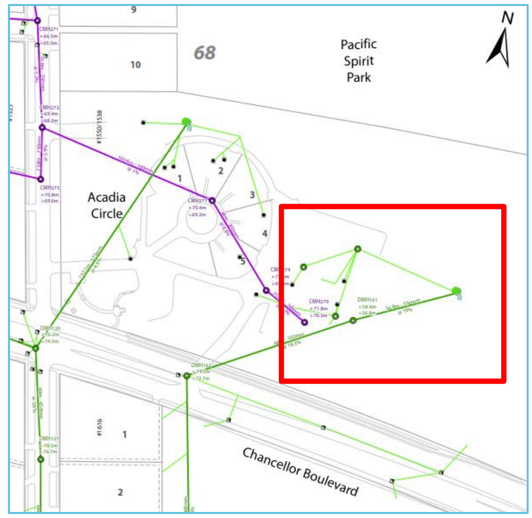

Figure 7: UEL Works Yard Sediment Chamber

Figure 8: Location of the UEL Works Yard

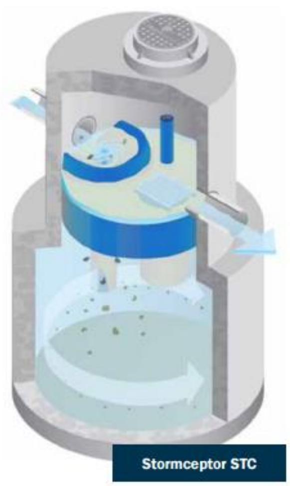

Figure 9: Stormceptor STC by Imbrium Systems

Action Item #5: Identify stormwater infrastructure that is poorly located for maintenance and develop plans for management or replacement (i.e. the 300mm diameter storm sewer in Pacific Spirit Park east of Acadia Road).

A naturalised area located east of the properties on the eastern side of Acadia Road north of College High Road, contains 280m of a 300mm diameter storm sewer that collects storm flow from the adjacent properties (as shown on Figure 10). The challenge for the UEL is associated with access and responsibility for the maintenance and renewal of this storm sewer as it is located within a vegetated area with limited vehicle access. This action item aligns with UEL's **Goal 3** of the stormwater vision.

As the houses on the east side of Acadia Road are redeveloped they should be connected to the 450mm diameter storm sewer on Acadia Road to permit the eventual decommissioning of the 300 mm diameter storm sewer in Pacific Spirit Park. This would increase the total flow in the 450mm diameter storm sewer. However, based on the preliminary hydraulic modelling results identified in Stage 1 of this ISMP, and recommendations that stem from those results, the UEL should upgrade 300m of the existing 450mm diameter storm sewer on Acadia Road south of Chancellor Boulevard to 600mm diameter storm sewer when the sewer is renewed. As the houses are reconnected to the 450mm diameter storm sewer (or newly upgraded 600mm diameter storm sewer) on Acadia Rd., UEL can disconnect these properties from the 300mm diameter storm sewer that runs parallel to Pacific Spirit Park. This presents UEL with an opportunity to decommission the 300mm diameter storm sewer in the right-of-way and 70m of a 300mm diameter storm sewer that connects it to Acadia Road. However, further investigation and a management plan are required to address the existing ditch at the back of the properties on the east side of Acadia Road to mitigate any flooding potential and opportunity to daylight the existing buried storm system.

Cost

Capital cost of upgrading the storm sewer along Acadia Road between College Highroad and Chancellor from 450mm to 600mm diameter main is approximately $400,000. If it is decided that the 300 mm diameter storm sewer is to be decommissioned, the pipe should be capped at Chancellor Boulevard, manholes should be filled with gravel and risers/lids removed. The approximate cost of decommissioning the 550m of the 300mm diameter storm sewer is $15,000.

Figure 10: Existing 300mm Storm Sewer behind Acadia Road

Action Item #6: Continue to upgrade system capacity and renew aging infrastructure in a proactive manner through the capital planning process

One of the goals articulated by the UEL was to maintain stormwater infrastructure in order to provide an adequate level of service and protect life and property (**Goal 3**). The UEL's 10-Year Capital Plan, as described in the Phase 1 Report of the UEL's Integrated Stormwater Management Plan, recommended a number of sewer upgrades to address insufficient capacity and/or structural failures.

As part of the capital plan development, AECOM conducted a hydraulic modelling analysis by simulating the impact of a 5-year 30-minute design storm to assess the constraints in the sewer network. The most urgent pipe upgrades were included within the 2012 – 2021, 10 year capital plan but future capital plans will need to consider the remaining capacity issues. As steps are taken to reduce the amount of stormwater in the existing system through sewer separation, by limiting the runoff from individual properties and controlling runoff from roadways, the need to increase the capacity of the existing combined/storm systems is reduced.

Table 4: 10-Year Capital Plan Stormwater Projects

Project Reference #	Description
2015-02	Construction of stormwater/sanitary sewer separation on Wesbrook Cres, north of Chancellor Blvd
2016-02	Construction of storm sewer replacement on Wesbrook Cres, south of Chancellor Blvd.
2016-01	Construction of new storm sewer on Alison Rd between Campus Rd and College Highroad, and on Western Parkway between College Highroad and University Blvd
2017-02	Design and construction of storm sewer replacements on lane north of College Highroad
2018-01	Construction of sanitary/stormwater separation on Acadia Rd, north of Chancellor Blvd
2018-02	Design and construction (reline) of storm sewer on Drummond Dr and College Highroad
2021-01	Construction of Water, Sewer and Road replacement on Newton Wynd between Acadia Rd and Kingston Rd
TBC-02	Construction of storm sewer replacement on lane north of Wycliffe Rd

In summary, it is recommended that the UEL:

- Continue to implement its 10 year capital plan; and
- Continue to use the hydraulic model to review the capacity of its combined/stormwater system before any infrastructure upgrades are finalised and any development is approved. Confirm that upgrades and development are in conjunction with future capital planning efforts.

Cost

The capital costs associated with the stormwater projects outlined above in Table 4 have been included as part of the 10-year Capital Plan. Since the UEL already has a stormwater model, periodic reviews and updates are minimal in cost.

Implementation Considerations

As the UEL upgrades its storm sewer system or changes the allowable discharge per property, the hydraulic model needs to be updated accordingly.

Action Item #7: Develop mitigation measures to address slope stability in Area B

A recent study for UBC by Golder Associates on erosion along the UBC cliffs highlights continuing concern with slope stability along NW Marine Drive and within Salish (Acadia) Creek. From previous project experience and consultation with a senior hydrogeologist at AECOM it has been noted that increased infiltration of water in close proximity to the cliffs may increase erosion potential and slope instability. With high potential for erosion along the cliff face, it is best to take the precautionary approach and to only allow infiltration facilities if geotechnical and hydrogeological assessments are completed in advance.

The UEL should retain a consultant to delineate areas requiring geotechnical/hydrogeological assessment prior to implementation of infiltration facilities and areas to exclude infiltration as a means of stormwater management. Potential scope of work required to conduct this study would include a review and assessment of available background information and data, field inspections and assessment by a qualified hydrogeologist and a geotechnical engineer, development of the conceptual model, and preparation of Geographic Information System (GIS) maps to present the results.

Cost

The estimated cost of retaining a consultant to delineate areas of no infiltration is $45,000. This includes assessments by a professional hydrogeologist and geotechnical engineer, and design and preparation of technical maps by a GIS professional.

Implementation Considerations

The UEL is collaborating in a multi-agency working group aimed at addressing slope stability concerns in this area. Without timely mitigation measures, Metro Vancouver parkland, UBC sanitary sewer, MoTI road, UEL storm sewer and private property upslope are at risk for potential damage caused by eroding slopes. The UBC Integrated Stormwater Management Plan and the UBC Cliff Erosion Study are two primary documents that provide recommendations to UBC regarding maintaining slope stability and further prevention of cliff erosion.

Figure 11: Salish (Acadia) Creek Riparian Setback, UEL ISMP Stage 1 Report, 2016

Action Item #8: Integrate stormwater asset maintenance with work order management using a GIS-centric system

A GIS-centric asset management system means that the stormwater asset records are fully integrated with GIS mapping and all stormwater asset records can be accessed and updated using map locations. Stormwater infrastructure maintenance activities play an integral part in keeping sidewalks, roads and properties safe from flooding, maintaining slope stability, checking that stormwater assets are functioning as designed and protecting natural streams. Developing an asset management system for easy tracking of asset maintenance and related work order management activities will help the UEL reach the envisioned goals of protecting life and property while providing an adequate level of service. A GIS-centric, integrated, system could contain asset information such as year of installation, condition assessments, maintenance records, and remaining expected service life. This consolidated information could then be used to develop future capital plans.

Cost

Integration of asset maintenance plans with the work order management processes in a GIS-centric system for stormwater infrastructure has an estimated cost of $42,000. However, additional savings are envisioned if the UEL should undertake similar integration of water and sanitary sewer infrastructure in addition to stormwater. An estimated cost to integrate water, sanitary and storm infrastructure is $90,000. The above mentioned estimate includes the cost of labour to migrate asset inventory data into a GIS-centric system and link to a future Computerized Maintenance Management System (CMMS). The estimated cost above does not account for the GIS license and CMMS license costs.

Implementation Considerations

The UEL has made good progress in digitizing most of the storm sewer infrastructure and already has a good inventory in its GIS program. This will cut down on the time required to migrate asset data.

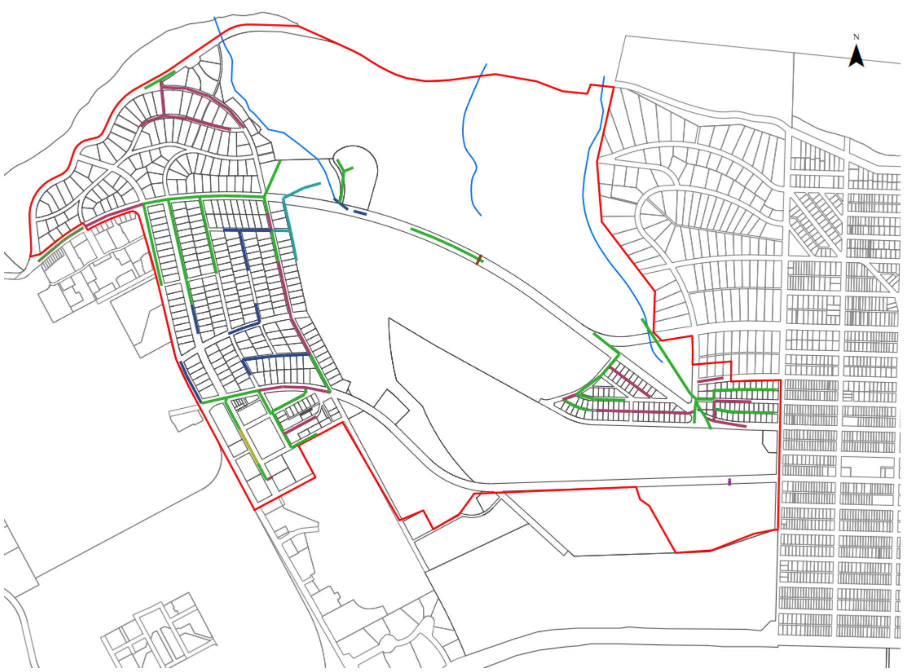

Figure 12: UEL storm sewer infrastructure colour coded based on type of material

Action Item #9: Develop Erosion and Sediment Control requirements

The UEL Works and Services Bylaw Schedule B Section 1.20 stipulates that "an Erosion and Sediment Control (ESC) plan that has the objective of preventing deleterious substances from entering the storm system during construction must be submitted to and approved by the UEL in advance of any works". While the requirement of the ESC plan developed by a Qualified ESC Professional is a good practice, the W&S Bylaw does not provide any criteria on what is required to be included in the ESC plan, such as water quality objectives, monitoring criteria, and enforcement, as it is done in other municipalities in the Lower Mainland.

It is recommended that the UEL establishes the ESC plan requirements that are in line with the British Columbia erosion and sediment control best management practices. Establishing the ESC Plan requirements would help UEL achieve **Goals 2, 3,** and **4.** Private property new development is required to have a Storm Water Management Plan submitted by a Qualified Professional, for discharge from the property. That plan should also include an ESC Plan, with the elements noted below, for construction activity on the site. An ESC bylaw, or an amendment to an existing bylaw, will ensure that the UEL drainage system is adequately protected during construction or development of public and private properties.

A typical ESC Plan shall include, but not be limited to, the following:

- A phased construction schedule that limits the extent of tree and vegetation removal and soil disturbance to the immediate areas of site construction.
- Details showing site access and measures in place to address soil tracking.
- Plans to control and treat TSS and pH in runoff water from the construction site.
- Plans to prevent clogging of any nearby rainfall capture facilities (e.g. rain gardens) and their underlying soils.
- Protection of any identified rainwater infiltration areas to prevent disturbance and compaction.
- Location(s) of discharge to the UEL's storm system, and the environment.
- A program to remove debris from UEL property.
- Storm sewer catch basin and drain inlet protection.
- Sampling and analysis to demonstrate compliance with the Bylaw.

The ESC requirements should work in tandem with the W&S Bylaw by specifying standards for meeting maximum discharge suspended under dry and wet weather conditions.

ESC Plans should outline provisions for implementing Erosion and Sediment Control BMPs such as:

For Erosion: Mulch, Polyethylene Sheeting, Check Dams, Straw Wattles, and Slope Texturing/Tracking.

For Sediment Control: Fencing, Stabilization of Construction Access (wheel wash), sediment barriers, filter socks/tubes/berms, stormwater treatment system.

Sample erosion and sediment control BMPs are shown in Figures 13, 14, and 15.

Cost

The estimated costs are associated with development of standards and ESC requirements, and UEL staff time requirement for Bylaw amendments, permit reviews and construction inspections. The estimated cost is $10,000 - $20,000 for consulting support for the initial development and bylaw amendments. UEL staff time will be required in the development of the bylaw, for permit review and construction inspection.

Figure 13: Catch Basin Donut (photo source BMP Supplies)

Figure 14: Silt Fence and Posts (photo source BMP Supplies)

Figure 15: Example of sediment-laden water storage tanks (photo source Stormtec)

Action Item #10: Controlling runoff from private properties

In order to limit the loading on the storm sewer system, the UEL historically required all new single family dwellings to limit the runoff from their site to 3 litres per second. As the average home is approximately 0.12 hectares in size, this requirement translates to a discharge limit of 25 litres per second per hectare. Fisheries and Oceans Canada, along with Metro Vancouver, recommend limiting runoff from individual properties to 4 litres per second per hectare in order to protect downstream receiving waters. The additional benefit of further limiting the discharge from individual properties is that it reduces the need to upgrade the UEL's stormwater system for capacity reasons.

The UEL's new W&S Bylaw is in accordance with the new runoff limits outline above. It is not clear if the UEL is applying these new limits to all new single-family dwelling developments in the UEL.

Various options available to developers for limiting the stormwater runoff from their site are described in Section 4.2 of this report and examples of each proposed BMP are provided in Appendix D. It should be noted that stormwater management on new development in Area B will need to consider the outcome of Action Item #7 above.

Cost

The only cost will be UEL staff time in communicating and enforcing the new requirements to developers.

Implementation Considerations

If the UEL is already applying the new allowable stormwater discharge limits from individual properties then the stormwater model will need to be updated accordingly, which could result in a reduction in required stormwater upgrades based solely on capacity. The sewer upgrades within this 10 year capital plan will not be affected as most of those are based on condition and/or sewer separation.

4.2 Stormwater Best Management Practices (BMPs)

This section provides information specific to six (6) stormwater BMPs (absorbent landscaping, rain gardens, infiltration swale, infiltration trench, pervious pavement, and green roofs) that may help homeowners meet the 6-months/24-hour storm event on-site retention (which is approximately 4.0 L/s per hectare of allowable runoff) as prescribed by Metro Vancouver's Source Control Guidelines. Appendix D provides conceptual drawings of each BMP along with rough size estimates, maintenance practices and requirements for a typical single-family residential lot at University Endowment Lands. The BMPs were chosen for evaluation based on design information available through Metro Vancouver's Stormwater Source Control Design Guidelines and previous AECOM experience. These six BMPs provide a range of options based on complexity of design and construction.

Absorbent Landscaping

Natural landscape surfaces have an inherent ability to soak up, store, and slowly release rainfall. Depending on the soil type and location, the ability of the natural landscape to perform the retention and filtration of rain water may differ. Percolation testing for the Block F development in Area D yielded a percolation rate of 8.8 minutes / 25mm drop in water level. However, further area specific soil infiltration tests can be done to determine the natural infiltration rate, which may change the design requirements for stormwater BMPs. Absorbent landscaping can consist of natural forest land, existing trees, and undisturbed soil. It is recommended to conserve as much of the natural environment as possible in order to have areas that inherently act as natural rainwater filtration and attenuation features. The capacity of the absorbent landscaping is designed to infiltrate the rainfall that falls on it and may infiltrate runoff from limited upstream impervious area. The ratio of impervious area to absorbent landscape area is designed to be maximum 2:1. As a BMP, absorbent landscape can include the disconnection of rooftop leaders from the storm sewer and directing the rainfall from all impervious areas onto the absorbent landscape.

Infiltration Rain Garden

Rain gardens are an extension of an absorbent landscape solution. However, the rock trench and overflow outlet features allows the rain garden to reduce the footprint area required to capture desired rainfall amount. The maximum design ratio of impervious area to rain garden footprint within a single family lot is 50:1 and for a local roadway is 30:1. In addition to the bioretention and filtration functions, rain gardens are also aesthetically pleasing. The surface vegetation must reflect the soil moisture conditions but mostly consists of shrubs and grasses. Rain gardens are beneficial for volume reduction as well as water treatment. The soil layer and vegetation serve as natural filtration devices and the deeper rock layer adds a temporary storage layer due to the rock void space (approximately 35% of rock volume).

Pervious Pavement

Pervious paving is a surface layer which allows rainfall to percolate into the under layer where the rainfall is stored and either filters into the subgrade or discharged via a sub drain. The pervious pavement may consist of porous asphalt or concrete with greater void space for percolation; concrete grid pavers that support the load and large void space with pervious material; or pavers with gapped joins that allow water to pass between the pavers. Pervious paving is not suitable for extensive treatment of stormwater due to the absence of deep soil and vegetated layer. The maximum design ratio of impervious area to pervious pavement footprint is 2:1.

Infiltration Swale

An infiltration swale system is a combination of an absorbent landscaping with a deeper rock trench. The grassed swale is designed to collect the surface runoff from adjacent impervious areas and retain the flow behind a weir. With a design of a rock trench below the grass layer, the infiltration swale allows the water to infiltrate slowly into the soil. This combination allows for stormwater volume reduction, flow attenuation, as well as some treatment as the water percolates through the soil layer. Similar to the rain garden, the maximum design ratio of impervious area to swale footprint is 50:1 for single family lots. However, the footprint of a swale tends to be larger than a rain garden due to a minimum side slope of 3:1. The side slope allows for easier maintenance of the grassed swale.

Infiltration Trench

An infiltration trench provides an opportunity for runoff from impermeable surfaces to soak away into the ground. Most commonly, infiltration trenches are used for management of roof runoff. For water that comes off other surfaces, especially vehicle accessible surfaces, pre-treatment to the infiltration trench is required as it does not provide any water quality treatment options. A typical pre-treatment to an infiltration trench is composed of a rain garden. Installation of infiltration trenches in soils with infiltration rates as low as 0.06mm/hr is possible with a use of an overflow feature, however, installation of infiltration trenches in poor soil conditions is ill advised. Infiltration trenches also require more maintenance and have a poor performance history across the Lower Mainland, B.C. While the infiltration trenches remain a viable BMP, implementation of these features at UEL is not recommended.

Green Roof

Green roof allows for support of living vegetation, which allows for natural attenuation of stormwater runoff and water treatment. An impermeable membrane protects the building from damage due to water and vegetation. The thickness of the soil layer may vary based on the design and rainfall capture targets. Green roofs that support grassed vegetation require a soil layer of 300mm. For a green roof that supports trees a soil layer greater than 300mm thickness is required. Green roofs are suitable for many industrial, commercial, and institutional buildings that have extensive and relatively flat roofs. Rooftops with slopes greater than 20 degree angles may require additional engineering considerations. Green roofs have benefits beyond stormwater management such as insulation, reduced heat island effect and protection of rooftop membrane from external damage. The additional benefits of green roofs are not considered in the evaluation of this BMP in this report.

5. Stage 4 – "How do we stay on target?"

Stage 4 provides guidelines for monitoring and tracking water quality, quantity, and instream habitat through the lens of the UEL Watershed Health Monitoring and Adaptive Management Framework. The proposed framework is a condensed version of the Metro Vancouver's Monitoring and Adaptive Management Framework (MAMF; Metro Vancouver, 2014) document and consists of recommendations that are most applicable to the UEL.

5.1 Metro Vancouver's Monitoring Adaptive Management Framework

The MAMF distinguishes three types of watershed systems - lower gradient, higher gradient, and piped Systems. Lower gradient systems are defined as natural watercourses, ditches, and canals with gradient less than one percent (<1%). Higher gradient systems are defined as natural watercourses, ditches, and canals with gradient more than one percent (>1%). The piped systems consist of predominantly buried storm sewer infrastructure. Depending on the system type, MAMF prescribes monitoring programs specific for each type (Figure 16). The UEL has a mix of piped system, lower gradient system and higher gradient system.

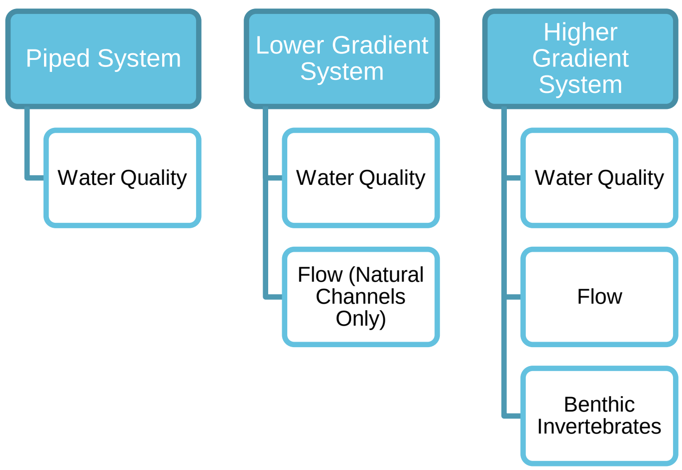

Figure 16: Monitoring programs based on system type (Adapted from Metro Vancouver MAMF, 2014)

5.1.1 AECOM Water Quality Sampling 2015

AECOM conducted a water quality sampling program for the purposes of establishing baseline conditions in the UEL watersheds. The sampling program identified system types and conducted sampling and analysis in four (4) locations. Water quality sampling locations are presented in Figure 17 and system type at each sampling location is described in Table 5. The rationale for choosing each location is also provided in Table 5.

Table 5: 2015 Watercourse Sampling Locations and Rationale

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

Station ID	Location	System Type	Parameters	Rationale
UEL-004	Upper Salish Creek	Low Gradient	Water Quality	Characterizes the impacts from the golf course.

Flow (i.e. quantity) data was not collected during the sampling period in 2015. However, Metro Vancouver recommends that, as a minimum, one year of continuous flow data is collected for high gradient systems. Urbanized watersheds with increased impervious areas have a direct effect on the flows in watercourses such as increased peak flows, lower baseflows, and increased frequency of high flow events (flashier streams).

The water quality sampling program provided the baseline conditions of the watershed's health in the UEL. The following recommendations have stemmed from the study:

- Consideration of alternative benthic invertebrate sampling and reporting protocols at sites with low water levels. Under the current B-IBI sampling protocols the benthic invertebrate sampling was not possible at sampling site UEL-002 due to low water levels.
- Conduct benthic invertebrate sampling every 3-5 years to track long term trends.
- Add a new sampling location downstream of UEL-004 and upstream of UEL-003 sites to gain a more discrete understanding of water quality concerns within the UEL watershed, such as the point source for elevated occurrences of fecal coliforms and E. coli upstream of the UEL-003 sampling location.

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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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

August 2017

AECOM

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5.2 Watershed Health Monitoring

The primary objectives of the watershed health monitoring framework for the UEL are to monitor and protect watershed health, to assess the effectiveness of the ISMP's implementation strategies and to determine if any changes need to be made to these strategies.

5.2.1 Objectives

The goal of the UEL Watershed Health Monitoring is to establish a repeatable process for tracking changes occurring within the watershed. The MAMF (Metro Vancouver, 2014) recommended that a combination of water quality, flow monitoring, and benthic invertebrate sampling are used for monitoring a watershed's heath.

5.2.2 Monitoring Parameters

Water Quality

Water quality in higher gradient systems in general tends to be more amiable to salmonids and macro invertebrate populations due to more stable water temperatures, higher levels of dissolved oxygen and neutral levels of pH. However, increased imperviousness in an urban setting has the potential to introduce metals, oils, and grease from runoff. It is recommended that water quality is monitored and reported for all system types within the UEL. The MAMF (Metro Vancouver, 2014) has suggested the following water quality parameters for monitoring:

- Dissolved Oxygen
- Temperature
- Turbidity
- pH
- Conductivity
- Nitrate (as nitrogen)
- E. Coli
- Fecal coliforms
- Total Iron
- Total Copper
- Total Lead
- Total Zinc
- Total Cadmium

The best practice for monitoring water quality is to have two sampling periods annually for municipalities in Metro Vancouver. The first sampling period should be during the wet season (November-December) and the second should be during the dry season (July-August). Five (5) samples should be taken during each sampling period on a weekly basis.

All surface water samples can be taken from the watercourses as grab samples, collected mid-stream. *In situ* data can be obtained for dissolved oxygen (DO), temperature, pH, conductivity, and turbidity parameters using a YSI Pro Plus type probe and LaMotte turbidity meter.

Flow

The UEL ISMP study area contains higher and lower gradient systems. Flow monitoring is recommended for all higher gradient systems. The Metro Vancouver's MAMF recommends at least one (1) year of continuous flow data collection. Flow monitoring methodology should be consistent with the Manual of British Columbia Hydrometric Standards. Design and implementation of flow monitoring must be done by a qualified professional to ensure high quality of flow data. For high quality analysis, it is recommended to collect precipitation data for the area. The University Of British Columbia's Department of Geography collects rainfall data at UBC's Climatology Station. If this data is not available or is incomplete, then Metro Vancouver's VA01 Kitsilano High School station may be used.

Table 6: Proposed hydrological indicators for flow monitoring

Hydrological Indicator	Definition
T_{Qmean}	Proportion of the year during which daily flow exceeds the annual average discharge
Low Pulse Count (Counts)	Number of times each calendar year that daily flow drops below 0.5 times the mean annual discharge
Low Pulse Duration (Days)	Average duration of low flow pulses during the calendar year
Summer Baseflow (m^3/s)	Average of daily discharges during July through September with seven-day antecedent rainfall less than 1mm
Winter Baseflow (m^3/s)	Average of daily discharge during November through March with seven-day antecedent rainfall less than 1mm
High Pulse Count (Counts)	Number of times each water year that daily flow increases above twice the mean annual discharge
High Pulse Duration (Days)	Average duration of high flow pulses during water year

Benthic Invertebrates

The diversity and number of benthic invertebrate communities reflect site specific environmental conditions. The variability in the presence of these communities can be attributed to a number of environmental stress factors such as poor water quality, sedimentation, rapid changes in flow regime, erosion, siltation, and loss of food sources within the riparian habitat. The complete absence of macroinvertebrates indicate degraded water quality and instream habitat.

The *Benthic Index of Biological Integrity (B-IBI)* has been adopted by Metro Vancouver and remains a recommended methodology for assessment of instream health. *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) taxa are sensitive to environmental stress and therefore are commonly prescribed for use as indicators of watershed health. Samples are collected using a surber sampler with 250 µm mesh with substrate cleaning lasting for 3 minutes for each placement. Each placement samples an area of 0.09 m^2 and each sample is a composite sample from 3 riffle surber placements. Each of the composite samples is filtered through a 250 µm screen and the sampler thoroughly washed. Washed samples are transferred to pre labeled plastic sample containers and preserved with 80% ethanol. The scoring system overview that is used for the benthic invertebrate analysis is 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)

The 2015 AECOM Water Quality Sampling Report recommended alternatives for B-IBI protocols for some or all of the previous sample locations because sampling site UEL-002 had too low water levels for use of the surber sampler (specific methodology B-IBI sampling procedures) and samples were not able to be collected in this watercourse. 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.

Spanish Bank Streamkeepers conduct bug counts each summer with a Pacific Streamkeepers Federation volunteer. This is a great event to increase public engagement with stormwater quality, which should be encouraged. However, a benthic invertebrate sampling and analysis should still be conducted by a Qualified Environmental Professional to ensure that all quality assurance and quality control procedures are followed.

Riparian Area Regulation Assessment

It is important to include erosion and slope stability assessments as part of the continuous monitoring program within the UEL watercourses. The Riparian Area Regulation Assessment allows the UEL to determine the applicable Streamside Protection and Enhancement Area (SPEA) width for the watercourses. The Detailed Assessment requires evaluation of stream width, reach banks, potential vegetation type, channel type and assessment measures to protect the integrity of the SPEA. The measures to protect the SPEA integrity that may be considered include assessment and treatment of danger trees, windthrow, slope stability, tree protection during construction, encroachment, and sediment and erosion control. Developing appropriate measures to address slope stability will require consultation with a geotechnical engineer. The Detailed Riparian Area Regulation Assessment would provide the UEL with a repeatable process for evaluating slope stability and riparian area integrity and should be considered during the next UEL ISMP iteration.

5.2.3 Sampling and Monitoring Locations

The AECOM Water Quality and Benthic Sampling report identified sampling locations that were used to determine the baseline conditions (Figure 17). It is recommended that these sampling locations should remain for consistent water quality monitoring in the future. Flow monitoring and benthic invertebrate sampling is proposed at three (3) locations within UEL, which are presented in Figure 18.

A Block F sampling site will be monitored by the Block F developer for 2 years after construction. The monitoring will be limited to ensuring that the Block F's BMPs are functioning as required. The cost of monitoring at that site will be offset by the developer but the monitoring will not be as comprehensive as the recommended water quality and flow methodologies identified in Section 5.2.2.

5.2.4 Data Quality Assurance and Quality Control (QA/QC)

Standardized field forms and Chain of Custody forms are QA/QC best practices that apply to all field, laboratory and benthos monitoring programs.

Field Monitoring and Sampling QA/QC

It is recommended that water quality monitoring, sampling, analysis and reporting is done by a Qualified Professional (QP) such as a qualified aquatic biologist or environmental professional. All water samples must be collected using industry standard sampling protocols (refer to the MAMF for guidance). Appropriate measures must be taken to reduce potential for sample contamination. Field sampling best practices must be followed at all times, such as wearing disposable nitrile gloves when sampling and use of bottles and preservatives supplied by the analytical laboratory. All samples must be collected with mouth of sample bottles facing upstream with sampler standing downstream of the sample bottle. The sampling methodology should ensure that no upstream disturbance occurs within the watercourse prior to sampling. All field sampling and measurement equipment should be maintained in good condition and all instruments must be calibrated prior to use. For additional QA/QC best practices consult the MAMF (Metro Vancouver, 2014).

Laboratory Analysis QA/QC

The laboratory conducting the water quality analysis of the sample must provide documentation to support that quality checks were made and that quality control results indicate that the analysis meets the quality standards. For additional QA/QC best practices consult the MAMF (Metro Vancouver, 2014).

Benthic Invertebrate Monitoring and Sampling QA/QC

It is recommended that the Benthic Invertebrate analysis be done by taxonomic experts certified in freshwater taxonomy. It is recommended that 25% of the samples are spot checked and a reference collection is created for third party verification. Sample re-sort may also be recommended to evaluate sorting efficiency. For additional QA/QC best practices consult the MAMF (Metro Vancouver, 2014).

5.2.5 Watershed Health Monitoring Cost Estimates

Adaptive Management Framework Monitoring cost estimates are provided for municipalities in Section 10 of the Metro Vancouver's Monitoring and Adaptive Management Framework document. The higher gradient systems have a higher cost for monitoring due to requirements to assess water quality, flow, and benthic invertebrates. Each individual monitoring program consists of labour (including field sampling), laboratory analysis, and data analysis costs. The total monitoring and sampling costs are presented in Table 7. The estimated costs are the total for a 5 year monitoring and sampling period and include:

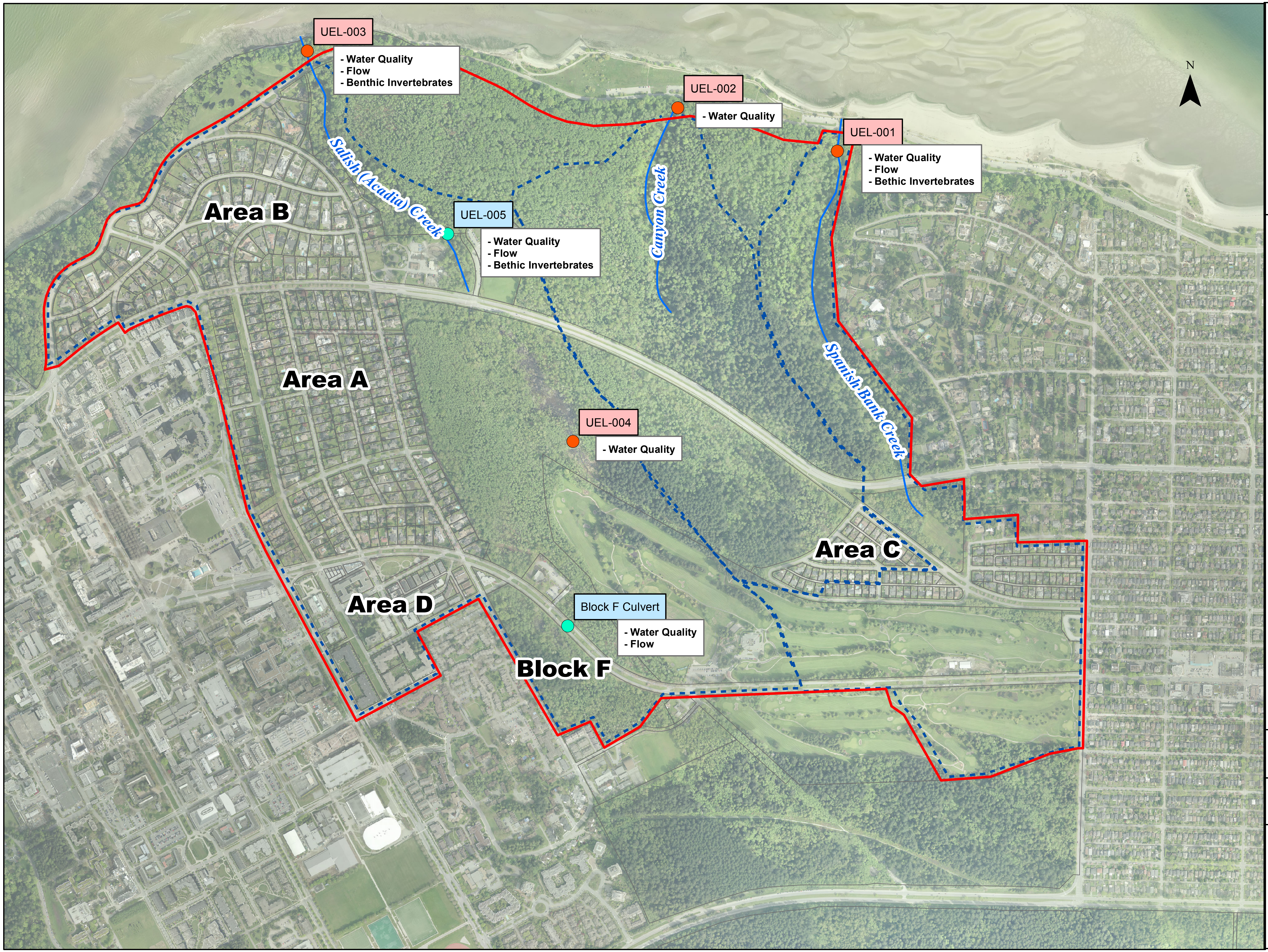
- Water quality sample collection every five years during two periods of the year (dry and wet seasons) with five samples collected over 30 days.
- Hydrometric monitoring for a single year, which includes gauge installation, discharge rating, data download and data processing.
- Benthic invertebrate sampling every 5 years.

Table 7: Total Monitoring Cost Estimates by Site for a 5 Year Period

Location	Water Quality			Benthic Invertebrates			Hydrometrics			Total
	Labour	Lab	Data Analysis	Labour	Lab	Data Analysis	Labour	Lab	Data Analysis	
UEL-001	$ 4,000	$1,500	$3,500	$1,250	$1,220	$1,500	$8,000	$4,200	$6,000	$31,170
UEL-002	$ 4,000	$1,500	$3,500							$9,000
UEL-003	$ 4,000	$1,500	$3,500	$1,250	$1,220	$1,500	$8,000	$4,200	$6,000	$31,170
UEL-004	$ 4,000	$1,500	$3,500							$9,000
Works Yard	$ 4,000	$1,500	$3,500	$1,250	$1,220	$1,500	$8,000	$4,200	$6,000	$31,170
Block F	$ 4,000	$1,500	$3,500	-	-	-	$8,000	$4,200	$6,000	$27,200
									Total	**$ 138,710**

To offset some of the labour cost for monitoring and sampling it is recommended to partner with the Pacific Streamkeepers Federation and the Pacific Spirit Park Society who already conduct some instream benthic invertebrate and water quality studies. However, the UEL needs to ensure that the partner organizations are following sampling and monitoring methodologies consistent with the Metro Vancouver MAMF document and provide a record of data QA/QC checks. Other cost-saving recommendations include:

- Adopt the same monitoring and reporting forms across all sampling locations.
- Share laboratory analysis costs with other municipalities within Metro Vancouver that adopt ISMPs and the Adaptive Management Framework.
- Purchase sampling equipment in bulk or cost share with other municipalities within Metro Vancouver.



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

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Project No.	Date
60222155	August 2017

Proposed UEL Watershed Health Monitoring Locations

Figure 18

5.3 Adaptive Management

The adaptive management principles allow the UEL to determine if the ISMP and its associated action items are achieving the desired benefits (i.e. maintain or improve watershed health) or whether changes are required (e.g. need to further control run-off volumes). Therefore an assessment approach is required that will allow the UEL to determine, in a simplified manner, if the conditions in the watercourses are good or if there is a concern. The MAMF includes evaluation criteria for the water quality, flow, and benthic invertebrate indicators that are proposed for the UEL watershed health monitoring.

5.3.1 Assessment of Watershed Health Monitoring Results

Water Quality Results

The water quality monitoring results can be evaluated against the classification table proposed by Metro Vancouver's MAMF (Table 8). This provides a straight forward method to identify if further adaptive management practices are required to address the water quality concerns.

Table 8: Classification of Water Quality Results, adapted from Table 4 of the MAMF (Metro Vancouver, 2014)

	Good Level	Satisfactory Level	Needs Attention Level
General Parameter			
Dissolved Oxygen (mg/L)	≥ 11	6.5 to < 11	< 6.5
pH	6.5 to 9.0	6.0 to < 6.5 or > 9.0 to 9.5	< 6 or > 9.5
Water Temperature (° C)			
Low flow summer	< 16	16 to 18	>18
Wet Weather	7 to 12	5 to <7 or >12 to 14	< 5 or > 14
Conductivity (µS/cm)	< 50	50 to 200	> 200
Turbidity (NTU)	≤ 5	> 5 to 25	> 25
Nutrients			
Nitrate as Nitrogen (mg/L)	≤ 2	2 to 5	> 5
Microbial Parameters			
E.coli (freshwater) (CFU/100ml)	Geomean ≤ 77	Geomean between 78 - 385	Geomean > 385
Fecal coliform (CFU/100ml)	Geomean ≤ 200	Geomean between 2201 - 1,000	Geomean > 1,000
Metals (Total Metals) (µg/L)			
Iron	< 800	800 to 5,000	> 5,000
Cadmium	< 0.06	0.06 to 0.34	> 0.34
Copper	< 3	3 to 11	> 11
Lead	< 5	5 to 30	> 30
Zinc	< 6	6 to 40	> 40

Flow Monitoring Results

Similarly to the water quality results, the MAMF provides a methodology for assessing the hydrologic monitoring results. For proper assessment of the hydrologic monitoring results, it is necessary to establish the pre-development baseline conditions. In the developed areas of the UEL, establishing pre-development baseline conditions is not viable and, therefore, trending hydrologic monitoring results will allow the UEL to rate watershed conditions as improving or degrading.

Table 9: Hydrologic response to land development or disturbance, adopted from Table 4 of the MAMF

Hydrological Indicator	Expected Response to Land Development or Disturbance
T_{Qmean}	Decrease
Low Pulse Count (Counts)	Increase
Low Pulse Duration (Days)	Decrease
Summer Baseflow (m^3/s)	Usually Decrease
Winter Baseflow (m^3/s)	Decrease
High Pulse Count (Counts)	Increase
High Pulse Duration (Days)	Decrease

Benthic Invertebrate Sampling Results

Assessing benthic invertebrate sampling results requires understanding the changes in the total taxa richness, total abundance of all taxa, and evaluation of the overall composition of benthic invertebrate communities. The B-IBI score and ranking can be used to determine the level of habitat degradation and the results can be used to establish trends. In general, the following trends are expected as a response to disturbance and pollution:

- Increase in pollution-tolerant species within the benthic invertebrate community.
- Decrease in pollution intolerant EPT taxa.

5.3.2 Adaptive Management Practices

Adaptive Management Practices (AMPs) are responses to degradation of the watershed. Table 8 outlines how water quality results can be used to evaluate the health of the watershed. If the monitoring program identifies that the watershed's health requires attention ("Need Attention Level") then a number of measures (known as adaptive management practices) can be taken to improve the health of the watershed. Appendix E provides a list of adaptive management practices that can be implemented in response to negative changes in the watershed. A more detailed description of some of the AMPs is provided below.

Source Control Measures

Source Control measures reduce the volume of stormwater flow through attenuation of runoff from impervious surfaces. In turn, a reduction in stormwater runoff may also reduce the negative impacts on water quality, watercourse morphology, and biological health. Stormwater source control measures are also known as Best Management Practices (BMPs). As part of the Stage 3 UEL ISMP implementation plan, AECOM evaluated six stormwater BMPs:

- Absorbent Landscaping
- Rain Garden
- Infiltration Swale
- Infiltration Trench
- Pervious Pavement
- Green Roof

Other BMPs that are recommended as source control measures in the Metro Vancouver AMF Guideline are:

- Disconnection of roof leaders and downspouts;
- Rainwater harvesting; and
- Tree retention and re-establishment.

Education and Public Outreach

Education and public outreach regarding stormwater issues can encourage the local residents to take ownership and responsibility for stormwater management. Implementation of signage in areas of concern, outreach to homeowners, developers, and industry are some of the examples of effort that may be required to increase awareness of stormwater issues and change the habits that may be detrimental to a watershed's health. Currently, the Spanish Bank Streamkeepers, in partnership with the Pacific Streamkeepers Federation and Pacific Spirit Park Society, play an integral role in stormwater education.

Cross Connection Control

As the sewer system in Area B of the UEL is planned to be separated it is important to help ensure that the private side separation strategy is well established and is in coordination with the mainline sewer separation. This means that as the new sewer is built, the private properties are being connected to the right sewer line (sanitary vs. storm). For areas where sewers are already separated, investigations may be conducted to determine if there are cross connection issues. For example, if a sanitary sewer flow increases significantly after a rain event then it is possible that storm runoff is entering the sanitary sewer via a wrongful connection.

Runoff Detention, Retention, and Treatment Facilities

Detention and retention facilities are typically designed to limit the runoff volume, frequency and duration in order to maintain predevelopment flow conditions. The runoff treatment facilities are designed to remove pollutants that may impact downstream habitat. Typical runoff treatment methods may include, but are not limited to, biofiltration, oil/water or oil/grit separation, bioretention, and media filtration. The Block F development at the UEL aims to maintain the functionality of the existing wetland in conjunction with an oil-grit separator and swales to treat and retain flow from the increased total impervious area of the site.

Riparian Habitat Restoration

Stream riparian areas (landscaped area on other side of the stream) serve an important ecological function. They provide nutrients for terrestrial and aquatic life, filter pollutants, maintain lower water temperatures, are a source of large woody debris for instream habitat and provide a barrier to protect the stream from humans and animals (e.g. off-leash dogs). The Riparian Area Regulation requires protection and improvement of this habitat by protecting existing riparian setbacks, removal of invasive species within the riparian areas, and development of public education and outreach programs.

Mitigation of Construction Impacts

Land development and redevelopment construction activities can impact water quality and instream habitat. Soil erosion, generation of suspended sediment, increased runoff volume and the potential presence of contaminants are some of the impacts of construction activities. The recommended development of Erosion and Sediment Control requirements in Stage 3 is aimed to equip the UEL with more tools for mitigating runoff impacts from construction sites.

5.3.3 Summary of Recommendations

In summary, we recommend that the UEL implement an adaptive management plan for its ISMP. The key components of this plan are:

- Water quality and B-IBI sampling at the same four (4) locations where previous sampling was conducted (see Figure 17).
- Consider alternative benthic sampling methodology for sampling locations where B-IBI methodology was not possible (i.e. UEL-002).
- Conduct additional flow, water quality and/or benthic invertebrate sampling at two additional locations as shown in Figure 18.
- Assess the results of monitoring with the list of Adaptive Management Practices in the MAMF document recommended for specific impacts of development or land disturbance (the list of recommended AMPs is attached in Appendix E).
- An annual review of the monitoring data and ISMP implementation strategy to determine if the ISMP and its action items need modifying and whether additional adaptive management practices are warranted.

5.3.4 References

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Appendix A
Stage 1 Report

University Endowment Lands

Integrated Stormwater Management Plan
Stage 1 Report

Prepared by:

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Project Number:

60222155

Date:

October 14, 2016

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October 14th, 2016

Jonn Braman
Manager
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5495 Chancellor Boulevard
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Dear Jonn:

Project No: 60222155
Regarding: Integrated Stormwater Management Plan Phase 1

Please find attached our report for Phase 1 of the UEL ISMP. Please let me know when you are available to discuss this report.

Sincerely,
AECOM Canada Ltd.

Graham Walker
Project Manager
Graham.walker2@aecom.com

Encl:

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Version #	By	Date	Description
1	Taylor Briggs	May 3, 2016	Phase 1 Report
2	Semyon Chaymann	May 31, 2016	Phase 1 Report – addressed comments from meeting on May 16th, 2016
3	Semyon Chaymann	Sept. 28, 2016	Phase 1 Report – Review and amendments

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Executive Summary

Background and Context

An Integrated Stormwater Management Plan (ISMP) is an over-arching, long-term strategy that focuses on the protection and enhancement of a watershed's health. ISMPs combine concepts of urban planning, stormwater management and environmental management to facilitate sustainable development within a watershed.

The University Endowment Lands ("the UEL") retained AECOM to develop the UEL ISMP ("the ISMP") in line with the Metro Vancouver Integrated Liquid Waste and Resource Management Plan (ILWRMP) and the Environmental Management Act. Development of the ISMP will occur in four stages. This report summarises Stage 1 of the ISMP.

Stage 1: What do We Have?

Study Area

- The population and impervious area in the study area are likely to increase, with the development of Block F and as redevelopment occurs in Area D

Legislative Context

- The study area falls within the jurisdiction of Provincial (British Columbia) level of government that enforces legislative requirements relevant to the ISMP.
- The most significant regulatory items are the BC Environmental Management Act, and the Metro Vancouver Integrated Liquid Waste and Resource Management Plan, which are the drivers for developing the ISMPs in the region.
- It will be important to monitor changes in legislation relating to environmental management, water, and flood management to ensure that the ISMP remains compliant.
- The UEL Works and Services Bylaw was approved and implemented in 2016. The ISMP will specify the minimum standards for engineering design, including stormwater management and project execution in municipal infrastructure.
- The UEL currently lacks an Erosion and Sedimentation Control Bylaw to ensure that the engineered and natural drainage system is adequately protected during construction; and a Tree Protection Bylaw to regulate the cutting, removal and damage of trees on private property.

Land Use Planning

- The University Hill community consists of primarily single family homes in Areas A, B, and C. Area D consists of a mix of low and high-rise apartments, townhouses, mixed-use, and commercial development.
- A significant development is planned on the Block F property southeast of the existing Area D development. Other than the Block F property, the UEL Community has been built out. It is expected that there may be further densification of some properties within Area D when they are eventually redeveloped.
- Pacific Spirit Park, which contains a number of environmentally sensitive areas, is within the study area.

Hydrology

- The developed portion of the study area is made up of eight distinct catchments, most of which drain north towards English Bay through various creeks and ravines. A small portion of Block F drains south to Cut Throat Creek and is addressed through Musqueam Integrated Stormwater Management Plan.
- Climate change may cause more frequent and extreme storm or longer periods of drought than have historically occurred.

Existing Drainage System

- Within developed areas, the drainage system consists mainly of streets with curbs, gutters, catch basins and gravity storm sewers. Within the Pacific Spirit Park and University Golf course the system consists mainly of a network of ditches, creeks and culverts. A small section of the UEL (north of Chancellor Boulevard) is served by a combined sewer system, which is being separated as the sewers are replaced.
- All properties within the UEL that have been developed in the last 10 years have been required to limit discharge during a 5 year storm to a rate of 8 l/s.
- Hydraulic modelling of the existing drainage system was completed. Recommendations addressing drainage deficiencies are summarized in Table 6.4.
- The existing capital plan addresses some, but not all, of the deficiencies found during the hydraulic analysis.
- The storm sewer system is regularly inspected with CCTV, and was last inspected in 2012-2013. Sewers in poor condition have been slated for repair/replacement within the UEL 10 Year Capital Plan (2012-2021).

Hydrogeology and Soils

- Most of the study area is directly underlain by low permeability till which limits the ability of infiltration as a method of reducing storm water runoff.
- Groundwater flow in the Upper Aquifer discharges from the cliff faces along Spanish Banks resulting in mass wasting and erosion. Increasing infiltration is generally not recommended in the vicinity of these cliffs.
- Existing wells show the aquifer ground water table is located at approximately 50-95 m. below the surface depending on location; however, there is conflicting information from nearby shallow water wells showing ground water depth as high as 3.8m below surface. Also seasonal surface ponding will occur at some locations.

Environment

- Sampling in UEL creeks was completed 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).
- Both fecal coliform and E. coli levels exceeded regional guidelines at the Spanish Bank Creek and Salish Creek sampling locations during the wet sampling period. Exceedances for the two bacteriological parameters during the dry period only occurred in Salish Creek. The point sources for these contaminations should be determined.
- 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. Urban areas can have high metal concentrations primarily during wet season sampling due to roadway runoff.
- Benthic macro invertebrate scoring provided an overall rating of very poor stream condition for both sampling locations, at Spanish Bank Creek and Salish Creek.
- 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.
- Coho Salmon, Chum Salmon, and Cutthroat Trout have been observed in Spanish Bank Creek; and Coho Salmon has been observed in Salish Creek. It should be assumed that these fish species are also present in Canyon Creek.
- The majority of Spanish Bank, Canyon and Salish Creeks, north of Chancellor Boulevard, have retained their 30 metre riparian setback, but there are some areas where this is reduced to 15 metres or less.

Next Steps and Priorities

- Identify a vision and determine the goals for the UEL Integrated Stormwater Management Plan by hosting a Visioning Workshop with key stakeholders.
- As determined from the results of Stage 1 report, UEL could get a head start in the effort to create a more robust ISMP by following up on the key recommendations.
    - The review of current legislative context identified the need for Erosion and Sediment Control Bylaw to ensure that adequate protection of municipal drainage system is applied during any construction.
    - Implement a Tree Management Bylaw to regulate the cutting, removal, and damage of trees on private property. This bylaw would complement the Provincial and Federal regulations for the protection of riparian features and conditions that area crucial in maintaining long-term watercourse health.
    - Address cliff erosion issues along NW Marine Drive. Implementation of BMPs should be carefully evaluated along the cliff edge as increased infiltration could cause erosion due to increased pore water pressure.
    - Include roadway runoff in the water quality monitoring program. Especially in urbanized areas, where high concentration of metals is present.
    - Investigate cross connections for locations where households discharge into the environment. Noted issues include presence of washing machine detergent in the nearby watercourses.

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Appendices

1. Introduction

1.1 Overview

The 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. Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRM) requires 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 (ISMP) 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 University Endowment Lands ("the UEL") retained AECOM to develop the University Endowment Lands ISMP ("the ISMP") in line with the requirements of the Metro Vancouver LWRMP and the Environmental Management Act. The ISMP relates to the UEL area that drains north into the Burrard Inlet.

1.2 Goals and Objectives

The primary, over-arching goals of the ISMP are as follows:

- Alleviate existing and/or potential drainage, erosion, and flooding concerns
- Protect and/or restore stream health including riparian and aquatic habitat
- Remediate existing and/or potential water quality issues

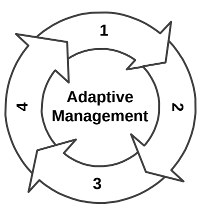
The ISMP focus is on the integration of stormwater management and land use planning. An ISMP is an integral component of a local government's land development and growth management strategy because upstream activities including land use change have downstream consequences including flood and environmental risks.

1.3 Approach

Development of the ISMP will occur in four stages, as outlined in Table 1.1, and was based on the approach outlined in Chapter 9: Developing and Implementing an ISMP in Stormwater Planning: A Guidebook for British Columbia.

Table 1.1 Summary of ISMP Approach

Stage	Question Answered	Description of tasks	Relevant ISMP Sections
1	What do we have?	Review background information and summarize existing conditions	- Study Area - Regulatory Context - Land Use - Hydrology - Stormwater System - Hydrogeology and Soils - Environment - Hydraulic Modelling and Assessment
2	What do we want?	Establish the vision for future development	- Vision and Goals
3	How do we put this into action?	Development of an implementation plan, funding and enforcement strategies	- Implementation Plan
4	How do we stay on target?	Development of a monitoring and assessment program	- Adaptive Management Plan



The ISMP contains long-term goals and objectives that have a planning horizon of up to 30 years. Predicting changes in factors such as the economy, technology, policy, land-use and public opinion over the long term horizon is challenging.

Subsequently, an Adaptive Management approach is proposed, in which the ISMP is periodically updated to ensure that it remains relevant and applicable. The adaptive process is cyclical - the last stage in the cycle focuses on monitoring, and will generate new information that should be reviewed in the first stage of the next cycle.

This report reflects the first stage of the ISMP, outlining the existing conditions and highlighting the gaps in regulation, land use planning, and infrastructure.

2. Study Area

2.1 Overview

The UEL consist 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 or 77%, is forested with the remaining 280 Ha, or 23%, 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 and streams which the stormwater infrastructure discharges to. Figure 2.1 provides an overview of the ISMP study area.

University Hill is divided into four areas:

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

The Village is the UEL's centre for commercial activity located in Area D. This area includes a high density, mixed commercial and residential use development (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 University Hill areas are shown in Figure 2.2.

2.2 Population

The population of the UEL is estimated at 4,000 residents, and 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 with increased 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 2,275. The total projected population of the UEL is approximately 6,600.

2.3 Topography

The developed portion of the study area is divided into eight main catchments, all of which discharge to English Bay via various creeks and ravines. The elevation varies from a high of approximately 100 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. The topography of the study area is shown in Figure 2.3.

2.4 Existing and Proposed Infrastructure

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 Blvd., University Boulevard, and Wesbrook Mall. The major roads are shown in Figure 2.4.

The UEL Capital Plan outlines the planned capital improvements for the next five years, including sewer separation, storm sewer improvements, and ravine projects.

The proposed development of Block F includes new municipal water, sewer, parks, and transportation infrastructure. The proposed development consists of a 22 acre parcel of land bounded by Acadia Rd, University Boulevard, Toronto Road, and Ortona Rd. The parcel is currently zoned for multi-family residential townhouse development but if proposed rezoning is approved it may include a community center and some commercial occupancy. The development of Block F will require various improvements to the existing infrastructure as well as new infrastructure.

Translink has analyzed rapid transit options to replace or supplement the existing bus system. A rapid transit line would be built through the UEL, linking the City of Vancouver and UBC. However, the timing and route of this project is currently undetermined.

2.5 Summary

The key points relating to population, topography and infrastructure issues relevant to the ISMP are as follows:

- The population and impervious area in the study area is likely to increase, with the development of Block F and redevelopment in Area D

BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

Study Area

Lots (UEL)

Watercourses

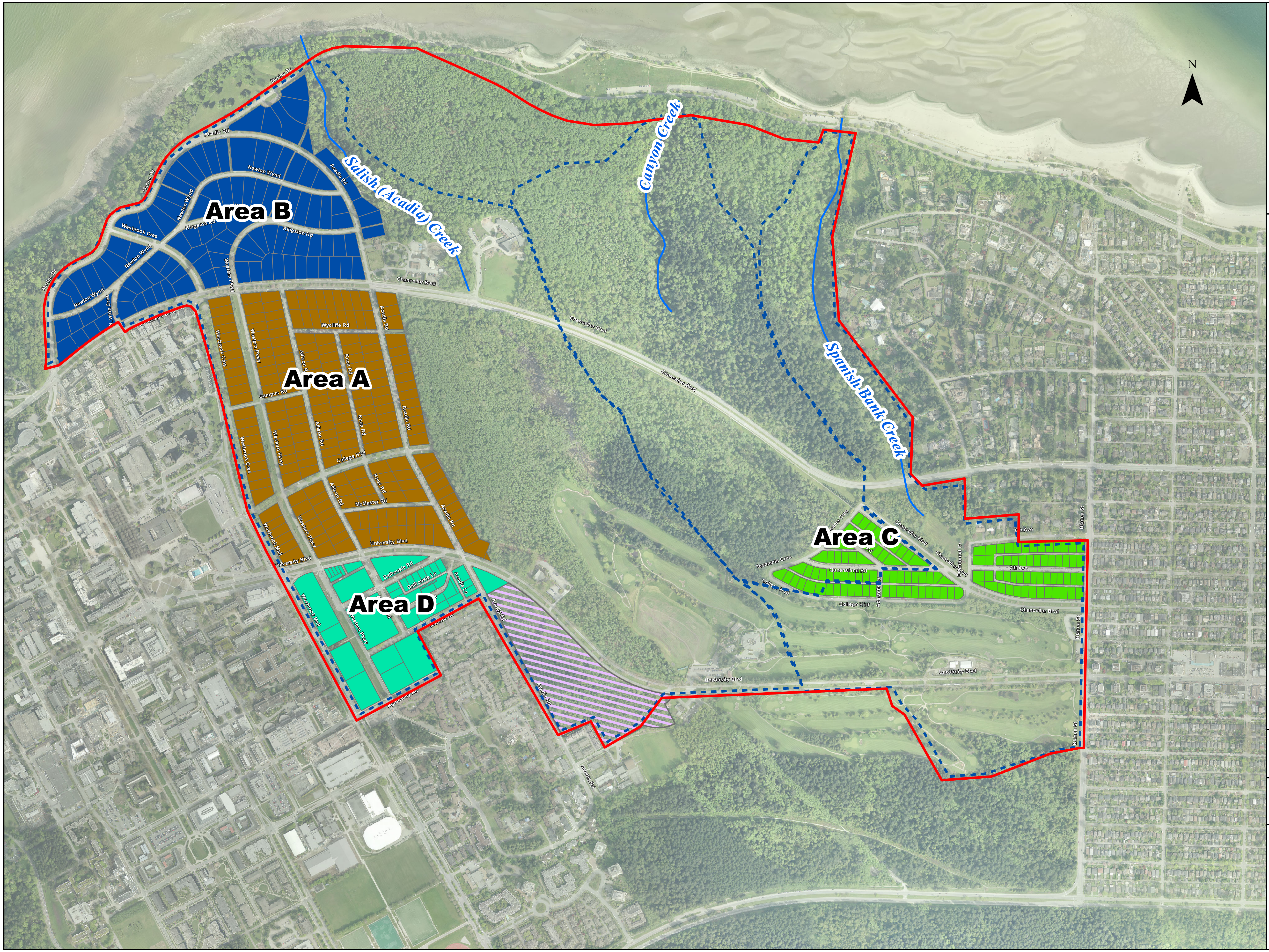
AECOM

Meters
0 100 200 400

Project No.	Date
60222155	October 2016

Study Area

Figure 2.1



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Study Area
- Watershed Boundary
- Watercourses

Areas

- Area A
- Area B
- Area C
- Area D
- Block F

AECOM

Meters
0 100 200 400

Project No.	Date
60222155	October 2016

University Hill Areas

Figure 2.2

BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Study Area
- Contours
- Watercourses
- Lots (UEL)

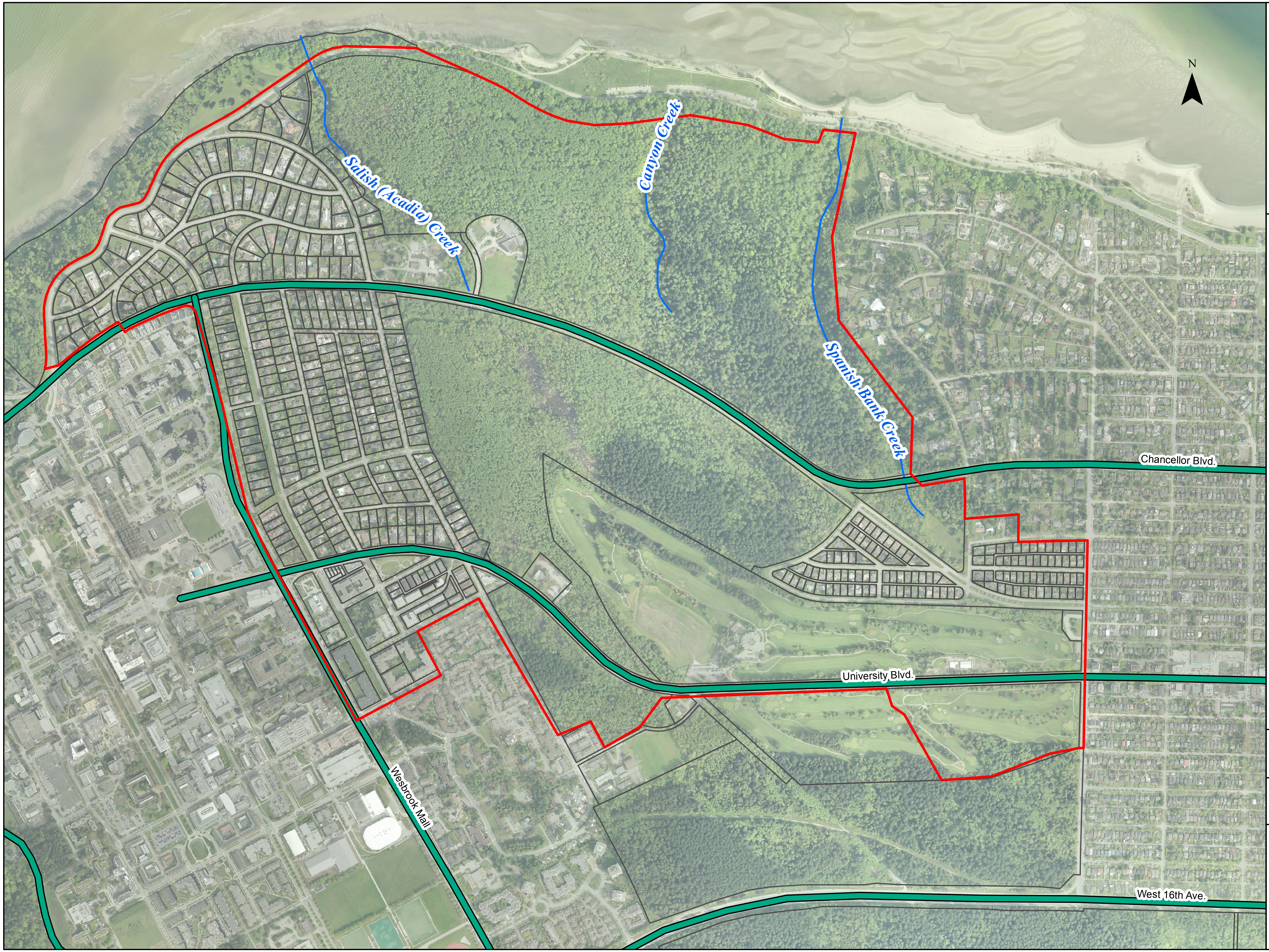
AECOM

Meters
0 100 200 400

Project No.	Date
60222155	October 2016

Topography

Figure 2.3



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Study Area
- Major Roads
- Watercourses
- Lots (UEL)

AECOM

Meters: 0, 100, 200, 400

Project No.	Date
60222155	October 2016

Major Roads

Figure 2.4

3. Regulatory Context

3.1 Overview

As an unincorporated area, the UEL does not have an elected municipal council. Instead, the provincial government is the governing body, and is administered through the Ministry of Community, Sport and Cultural Development under the University Endowment Land Act. This legislation enables the Minister to, among other things:

- levy property taxes;
- enact bylaws;
- appoint a person to administer the University Endowment Lands.

The Minister of Community, Sport and Cultural Development appoints a Manager who is responsible for the day-to-day administration of the UEL. Decisions made by the UEL Administration and staff are guided by the Official Community Plan, and the Land Use, Building and Community Administration Bylaw

The study area falls within the jurisdiction of three levels of government, from federal down to regional, and all three levels enforce legislation with which the ISMP will need to comply. 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.

This section summarises the regulatory drivers, legal requirements, and other planning, engineering or environmental guidelines relevant to the ISMP.

3.2 Regulatory Drivers

The UEL is developing and implementing this ISMP under Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (MV ILWRM) as a member body of the Greater Vancouver Sewerage & Drainage District (GVS&DD).

Table 3.1 summarizes the context of the ISMP in relation to Metro Vancouver's ILWRM and BC Environmental Management Act.

Table 3.1 Context of UEL ISMP

Government Body	Instrument	Key Points
BC Ministry of Environment	Environmental Management Act	- Protects human health and the quality of water, land and air in British Columbia - Allows municipalities to develop community-specific solutions for wastewater management under LWMPs - Authorizes and regulates LWMPs
Metro Vancouver	Metro Vancouver Integrated Liquid Waste and Resource Management Plan	- Identifies liquid waste management goals and actions for wastewater infrastructure operated by Metro Vancouver - Sets specific actions for GVS&DD members regarding their management of stormwater runoff - Prescribes that GVS&DD members submit an Integrated Stormwater Management Plan for drainage areas within their jurisdiction - Goal 3, Strategy 3.4.7: "Municipalities will... Develop and implement integrated stormwater management plans at the watershed scale that integrate with land use to manage rainwater runoff"

Government Body	Instrument	Key Points
UEL	University Endowment Lands Integrated Stormwater Management Plan	- A comprehensive, ecosystem-based approach to long-term rainwater management in line with the requirements of the Metro Vancouver ILWRM - Provide direction for future development plans by balancing land use planning; stormwater engineering; flood and erosion protection; and environmental protection

3.3 Legislative Requirements

The ISMP study area falls within the jurisdiction of three levels of government: Federal, Provincial (BC), and Regional (Metro Vancouver). All three levels of government enforce legislative requirements relevant to the ISMP, and the ISMP outcomes will need to comply with these requirements.

Table 3.2 summarizes the key purpose and requirements of legislation relevant to the ISMP.

Table 3.2 Legislative requirements of ISMP

Regulation / Policy	Key Points
Federal (Canada)	
Fisheries Act	- Protects riparian features and conditions that are crucial in maintaining long-term watercourse health
Provincial (British Columbia)	
Environmental Management Act 2004	- See Table 3.1
Fish Protection Act 1997	- Provides legislative authority for water managers to consider impacts on fish and fish habitat before approving new licenses, amendments to licenses or issuing approvals for work in or near streams - Focuses on four major objectives: ensuring sufficient water for fish; protecting and restoring fish habitat; improved riparian protection and enhancement; and stronger local government powers in environmental planning
Riparian Areas Regulation 2004	- Protects riparian features and conditions that are crucial in maintaining long-term watercourse health - Requires local governments to protect riparian areas against developments that border along streams, lakes, and wetlands
Sensitive Streams Designation and Licensing Regulation	- Protects water flows in streams significant to fisheries by designating them as “Sensitive Streams”, which triggers a higher level of protection from development and other stressors
Water Sustainability Act 2015	- Principal law for managing the diversion and use of provincial water resources - Specifies activities that may be conducted within a stream or a stream channel, as well as regulating dam safety and ground water protection - The Water Sustainability Act was put into force in early 2016 repealing the Water Act 1996.

Regulation / Policy	Key Points
Regional (Metro Vancouver)	
Regional Growth Strategy Bylaw	- “A Bylaw to adopt a Regional Growth Strategy for the Greater Vancouver Regional District (Metro Vancouver)” - Enforces the application of the MV Regional Growth Strategy by members
Sewer Use Bylaw 299	- “A bylaw respecting the direct or indirect discharge of waste into any sewers and drains connected to a Sewage Facility operated by the District” - Restricts the discharge of anything but stormwater, uncontaminated water or water from the provision of municipal services such as street flushing and fire extinguishing activities into stormwater sewers
Local (UEL)	
UEL Official Community Plan	- A broad statement of objectives and policies to guide decisions on planning and land use management. - Derived from a consensus-based process to provide a framework for administrating the collective decision-making of the community from service provision to development applications and zoning regulations. - Provides policies for Green Space and Tree Management - Provides policies for densification and commercial development - Provides policies for stormwater management
Land Use, Building and Community Administration Bylaw	- A bylaw that regulates land use and building within the University Endowment Lands - Regulates utility service connections - Regulates site coverage
UEL Works and Services Bylaw	- Implemented in 2016 this bylaw provides a standardized set of guidelines for design and construction of municipal infrastructure within the UEL - Contains policies relating to stormwater runoff control

3.4 Related Policies, Strategies and Guidelines

The outcomes of the ISMP will also be influenced by non-legislative strategies, plans and engineering standards issued by the provincial and regional decision-making bodies. The non-legislative documents that are likely to influence the outcomes of the ISMP are summarized in Table 3.3.

Several land use plans also apply to the study area and the impact of these plans are discussed in Section 4.

Table 3.3 Summary of relevant non-legislative documents

Policy / Plan	Key Points
Provincial (British Columbia)	
Stormwater Guidebook	- Provides a watercourse-level, site-specific approach to stormwater management in British Columbia
Regional (Metro Vancouver)	
Regional Growth Strategy (RGS)	- Establishes land use designations and policies to support growth and enhance economic prosperity whilst maintaining the environmental qualities that contribute to the livability and sustainability of the Vancouver region. - A core goal of the RGS is to protect the environment and respond to climate change impacts. This is supported by a number of strategies which include protecting conservation and recreation lands (Strategy 3.1) and protecting and enhancing natural features and their connectivity (Strategy 3.2). To support these objectives, municipalities are requested to consider integrated stormwater management when developing municipal plans
Integrated Liquid Waste and Resource Management Plan	- See Table 3.1
Local (UEL)	
UEL 2012-2021 Capital Plan	- Identifies a number of infrastructure upgrades as well as the sewer separation strategy.

3.5 Summary

The key points relating to the regulatory context of the study area are summarized as follows:

- The study area falls within the jurisdiction of Provincial (British Columbia) level of government that enforces legislative requirements relevant to the ISMP.
- The most significant regulatory items are the BC Environmental Management Act, and the Metro Vancouver Integrated Liquid Waste and Resource Management Plan, which are the drivers for developing the ISMPs in the region.
- It will be important to monitor changes in legislation relating to environmental management, water, and flood management to ensure that the ISMP remains compliant.
- The UEL Works and Services Bylaw, which was recently implemented in 2016 specifies the minimum standards for the design and construction of municipal infrastructure.
- The UEL currently lacks an Erosion and Sedimentation Control Bylaw to ensure that adequate protection of the municipal drainage system is taken during any construction; and a Tree Protection Bylaw to regulate the cutting, removal and damage of trees on private property.

4. Land Use

4.1 Overview

Land use planning for the study area is guided by strategic plans, policies and objectives which have been developed at the regional and local administrative levels. This section describes the existing land use, zoning classes, and plans that are in place for the study area and surrounding lands.

4.2 Existing Land Use

Areas A, B, and C consists solely of single-family housing and together contain 441 lots all of which have been developed. Further sub-division of existing lots is not permitted, nor are new developments encroaching on Pacific Spirit Regional Park land. All other land uses are restricted in these areas.

Area D consists of a mix of low and high-rise apartments, townhouses, mixed-use, and commercial development.

University Golf Course is situated along University Drive between Areas C and D is approximately 60 hectares.

4.3 Land Use Planning

The ISMP study area falls within the planning jurisdiction of Metro Vancouver, the UEL, which is administered by the provincial Ministry of Community, Sport and Cultural Development and the provincial Ministry of Transportation and Infrastructure (MoTI). Metro Vancouver is responsible for land-use planning on a regional scale, with the UEL responsible for local planning and the MoTI manages the Major Road Network and serves as the subdivision approving officer.

4.3.1 Regional

Regional planning for the study area is guided by Metro Vancouver, which sets long-range goals and objectives for managing land use across the region. Metro Vancouver members are required to produce Regional Context Statements to establish how their plans and policies align with regional goals. The regional planning documents that will impact the outcomes of the ISMP are listed in Table 4.1.

Table 4.1 Summary of Regional Planning Documents

Plan	Purpose and Description	Key Points for ISMP
Regional Growth Strategy 2040	- “Looks out to 2040 and provides a framework on how to accommodate the over 1 million people and 600,000 new jobs that are expected to come to Metro Vancouver in the next 30 years” - Identifies 5 goals for the region, and strategies to meet those goals - Specifies role of member municipalities/ electoral areas in achieving roles	- Growth to be focused to Urban Centres - Existing industrial and agricultural areas to be generally protected from land use change - Existing conservation and recreation areas are to be generally maintained, and should be buffered from adjacent activities
Metro Vancouver’s Regional Parks Plan (2011)	- Identifies goals for the management and improvement of regional parks, and strategies to meet those goals	- Pacific Spirit Park is located within the ISMP study area

4.3.2 Local

The ISMP will need to align with the goals of the land use plans enacted by the UEL. The plans may also be used as an instrument for implementing recommendations stemming from the ISMP. Table 4.2 summarises the local land use plans that relate to the ISMP study area, and the likely impact of those plans on the ISMP.

Table 4.2 Summary of Local Planning Documents

Plan	Scope and Purpose	Key Points
Official Community Plan	- The Official Community Plan (OCP) is a statement of objectives and policies that guide local planning decisions - It is the principal land use document for the UEL	- A broad statement of objectives and policies to guide decisions on planning and land use management.
Regional Context Statement	- Identifies how the UEL fits into the Metro Vancouver regional growth strategy	- Outlines the UEL’s policies to align with the regional priorities for protecting green zones, building complete communities, achieving a compact metropolitan area, and increasing transportation choices

A significant development is planned for a parcel referred to as “Block F”. “Block F” is a 21.4 acre property adjacent to the existing Area D development. The proposed development is planned to consist of residential and commercial mixed-use development as well as not less than 3.0 acres of public park space.

Aside from Block F, the University Hill area is fully built-out. The University Golf course is restricted for development for more than 75 years. Further densification is possible in Area D when some of the existing multi-family buildings are eventually redeveloped.

4.4 Park and Natural Areas

The location of parks and natural areas within the study area are shown in Figure 4.1. Pacific Spirit Park, which is partially within the study area, is mostly a natural forest but also includes walking, cycling, equestrian trails, and public beaches. The UEL municipal stormwater system discharges to watercourses within Pacific Spirit Park. Pacific Spirit Park contains a number of environmentally sensitive areas, a few of which are within the study area.

4.5 Summary

The key points relating to the land use of the study area are summarized as follows:

- The University Hill community consists of primarily single family homes in Areas A, B, and C. Area D consists of a mix of low and high-rise apartments, townhouses, mixed-use, and commercial development.
- A significant development is planned on the Block F property southeast of the existing Area D development. Other than the Block F property, the University Hill Community has been built out. It is expected that there may be further densification of some properties within Area D when they are eventually redeveloped.
- Pacific Spirit Park, which contains a number of environmentally sensitive areas, is within the study area.

BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Watercourses
- Parks
- Study Area
- Lots (UEL)

AECOM

Meters
0 100 200 400

Project No.	Date
60222155	October 2016

Parks

Figure 4.1

5. Hydrology

5.1 Overview

This section describes the hydrological characteristics that influence the study area. Understanding the relationship between hydrologic aspects such as rainfall intensity and duration is an important component of integrated stormwater management planning.

5.2 Climate

The study area is located within the Lower Mainland ecoregion that surrounds Metro Vancouver. The region is bounded by the Coast and Cascade Mountains to the north and east, and the Pacific Ocean to the west. The climate of the study area is typical of the inter-coastal Pacific-Northwest, with wet winters with heavy rainfall often lasting into the spring, and mild summers. The UEL rarely experiences significant snowfalls.

The Vancouver International Airport is the closest Environment Canada weather station to the study area. Average temperature and rainfall recorded at this station between 1981 and 2010 are summarized in Figure 5.1 below. The average annual precipitation is 1189 mm, with the highest average precipitation in November and lowest in July. The daily average temperature varies between 18°C in July and 3.6°C in December.

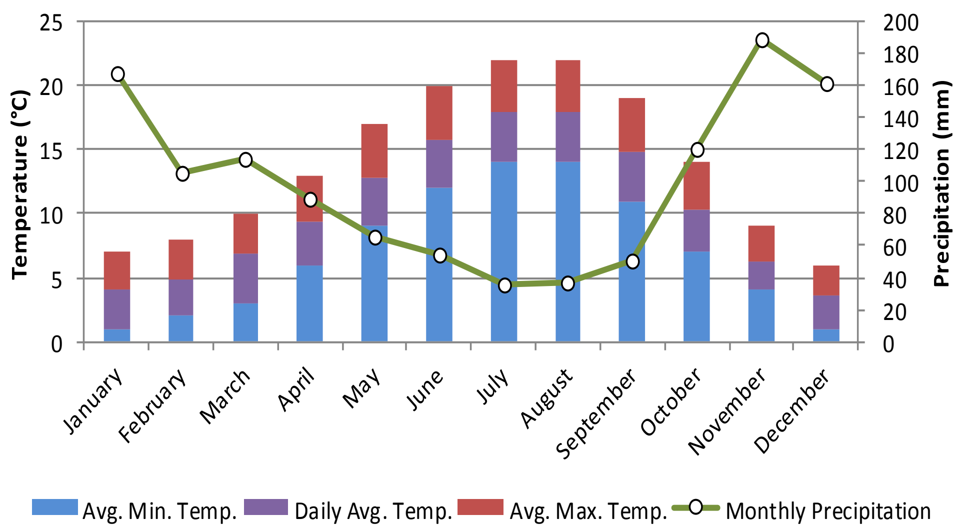


Figure 5.1 Climate of the Study Area

The UEL also references the rainfall curves developed by the City of Vancouver for use in stormwater system design and planning.

5.3 Catchments and Impervious Area

The study area is divided into eight main catchments, all of which have a unique outfall and drain northwards to English Bay via various creeks and ravines. As part of the UEL *Master Drainage Plan* completed by Urban Systems in 2007, the impervious areas were estimated using aerial photographs and construction drawings of recent homes. A range of total impervious areas was calculated, ranging from 40% to 60% for newer homes with an average of 46%. For older homes the values ranged from 29% to 44% with the average being 38%. It was estimated that as many as 40% of the homes in the UEL were not yet connected to the storm system and either discharge to on-site rock pits, the sanitary sewer, or the combined sewer. The UEL requires that property owners modify roof leaders are connected to the storm sewer system when the property undergoes significant redeveloped.

5.4 Climate Change

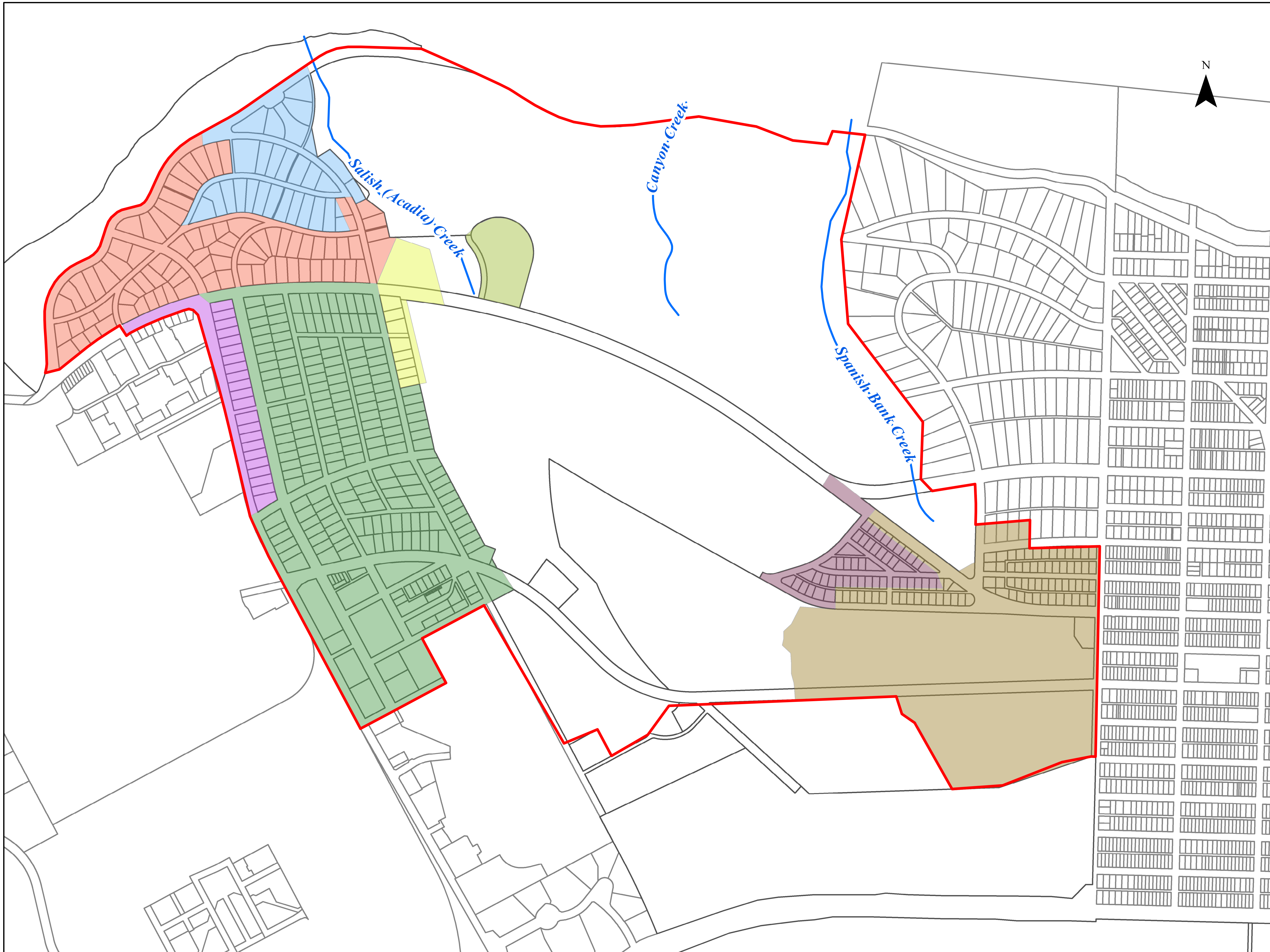
Climate change is likely to have an effect on the regional weather patterns, possibly causing more frequent and extreme storm events or longer periods of drought than have historically occurred. Due to the topography of the UEL, sea level rise is not expected to have a significant effect on the community, but may affect the downstream ends of the creeks and stormwater outfalls.

The City of Vancouver is currently updating their rainfall curves in consideration of climate change and the UEL may want to review these updated curves for its own stormwater planning.

5.5 Summary

The key points relating to the hydrology of the study area are summarized as follows:

- The developed portion of the study area is made up of eight distinct catchments, all of which drain north towards English bay through various creeks and ravines.
- Climate change may cause more frequent and extreme storm or longer periods of drought than have historically occurred.



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

Study Area

Watercourses

Catchments

1
2
3
4
5
6
7
8

AECOM

Meters
0 100 200 400

Project No. 60222155

Date October 2016

Drainage Catchments

Figure 5.2

6. Stormwater System

6.1 Overview

The study area generally drains south to north through a network of roadside ditches, sewers, creeks, and ravines before discharging to English Bay. A small portion of the UEL south of Block F and University Boulevard drains south into Cut Throat and Musqueam Creeks before discharging into the Fraser River. The UEL manages a stormwater drainage system consisting of approximately 14 km of dedicated storm sewer, 4 km of combined sanitary and storm sewer, and 1 km of open drainage channels. The UEL drainage system discharges into either the Metro Vancouver sewer or natural drainage channels in Pacific Spirit Park.

Many private properties have implemented on-site stormwater BMP's to reduce the rate of stormwater flow leaving their site to meet UEL stormwater requirements. Pacific Spirit Park contains a number of open channels and wetlands. There are a number of stormwater BMP's (wetland, raingardens, swales, OGS units etc.) planned for the development at Block F. Within the existing urban developed area there are not any existing stormwater BMP's within the public realm (e.g. detention ponds or rain gardens) but the new Works and Services Bylaw makes a number of requirements with respect to managing stormwater run-off and minimum soil depths.

The study area has eight catchments, each with its own outfall. The catchments are defined by the ground topography as well as the direction of flow in the storm sewers and combined sewers. The catchments are shown in Figure 5.2.

University Golf Course has a series of culverts, drainage lines, and open ditches that primarily discharge into the Salish Creek and Spanish Bank Creek. A portion of the golf course drains south to Cut Throat and Musqueam Creeks. A more detailed illustration of the University Golf Course drainage is attached in Appendix B.

6.2 Existing Drainage System

A review of the existing municipal stormwater drainage system upstream of the discharge points was performed to develop an understanding of the composition of the network, including size, material, conduit type and age, and identify opportunities for improvements. The review was performed using GIS information obtained from the UEL.

6.2.1 Sewers

The drainage system consists predominantly of gravity sewers up to the outfalls at the creeks. The 16 km of gravity sewer make up approximately 95% of the drainage system by length.

Table 6.1 summarizes the existing stormwater sewers according to size. For the purpose of this study all stormwater sewers greater than or equal to 525 mm in diameter were assumed to be trunk sewers.

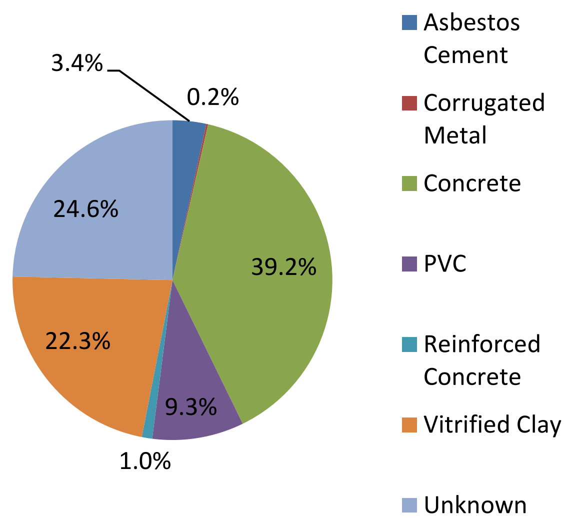
Table 6.1 Summary of Stormwater Sewer Sizes

Classification	Total Length (m)
Trunk (≥525mm)	1,198
Minor (≤525mm)	12,710
Total	13,908

Table 6.2 summarizes the construction material of the stormwater sewer network within the study area. The data shows that the most common pipe material is concrete, followed by vitrified clay; however, a significant amount (25%) of the pipe material is unknown. The storm sewers materials are shown graphically in Figure 6.2 Existing Storm Sewer Materials.

Table 6.2 Summary of Stormwater Sewer Materials

Material	Length (m)
Asbestos Cement	472
Corrugated Metal	27
Concrete	5,448
PVC	1,288
Reinforced Concrete	146
Vitrified Clay	3,099
Unknown	3,427
Total	13,908



The GIS data from the City also showed that the drainage network also includes a large number of manholes and other devices. The quantity of these other drainage features is summarized in Table 6.3.

Table 6.3 Other Stormwater Features in Network

Asset Type	Quantity
Manholes	169
Property Connections	181
Catch Basins	435

6.2.2 Creeks and Ditches

There are 3 major creeks within the study area: Spanish Bank Creek, Salish Creek (also known as Acadia Creek), and Canyon Creek (listed from west to east). Water Quality and Benthic Sampling was performed on each of these creeks as part of this study. The sampling is discussed in Section 8.

6.3 Existing Drainage Issues

Any reported drainage issues typically occur within the open channels due to the build-up of debris, sometimes due to resident beavers within Pacific Spirit Park.

6.3.1 Combined Sewer System

The UEL has approximately 4 km of combined sewers in operation, all of which are located in Area A. The combined sewers direct stormwater into the Metro Vancouver wastewater collection system. There is an existing plan to separate all combined sewers. Separation of a significant portion of these combined sewers is planned within the UEL's current 10 year Capital Plan (2012-2021).

6.3.2 Water Quality

Water quality issues were identified during water quality sampling in the creeks that was completed as a part of this study. This issue is discussed further in Section 8.

6.4 Hydraulic Modelling and Analysis

6.4.1 Approach

The UEL has previously had hydraulic modelling of the stormwater drainage system completed as a part of previous assignments. AECOM analyzed the existing sanitary, storm, and combined sewer computer models which were originally developed by Urban Systems. As part of previous modelling projects for UEL, AECOM performed a number of checks of the accuracy of the model, including rainfall volumes, runoff mass balance, confirmation of catchment and impervious areas, sanitary flow and I&I volumes. The adjustments made to the models are summarized below:

- The modelled 5 year 30 minute storm event was adjusted for a total rainfall depth of 9.4 mm from 9.0 mm to match the 2007 Urban Systems report and Environment Canada's Atmospheric Service design storm.
- UBC sanitary flows were added to the model to match the existing system configuration and Urban Systems report.
- It was also noted that the modeled I&I volumes appeared to be a conservative estimation, but were not changed in the model.

With the adjustments noted above, the provided model was verified to be consistent with the following reports completed by Urban Systems:

- University Endowment Lands Master Drainage Plan 2007 Update, February 22, 2007
- UEL Sanitary and Storm Systems Model Generation and Capacity Analysis, December 10, 2010
- UEL Block F Development – Impact to Sanitary and Storm Infrastructure, December 8, 2010

The model was simulated using a 5-year 30-minute design storm condition to identify hydraulic constraints in the sewer network. Storm sewers running more than 100% full (Qpeak/Qfull > 1.0) were recommended for upgrade.

6.4.2 Findings

The results of the hydraulic analysis are shown in Table 6.4. The sewers referenced in Table 6.4 are show in in Figure 6.3.

All of the combined sewers in the drainage network are located in Area A. Sewer separation is currently planned to create separate sanitary and drainage networks in place of all remaining combined sewers.

Table 6.4 Hydraulic Modelling Results

Project Reference	Description	Recommendation
CMB-01	56 m of 250 mm combined sewer on Acadia Rd. between Chancellor Blvd. and Kingston Rd.	Sewer separation is planned for this area. If all drainage connections are removed from the combined sewer, no upgrades will be required to service sanitary flows. Sewer separation planned for CMB-01 to CMB05 in 2018.
CMB-02	115 m of 250 mm combined sewer on Acadia Rd. between Kingston Rd. and NW Marine Dr.	
CMB-03	91 m of 250 mm combined sewer on Acadia Rd. between Kingston Rd. and NW Marine Dr.	
CMB-04	91 m of 250 mm combined sewer on Acadia Rd. between Kingston Rd. and NW Marine Dr.	
CMB-05	91 m of 300 mm combined sewer on Acadia Rd. between Kingston Rd. and NW Marine Dr.	
CMB-06	91 m of 375 mm combined sewer on Acadia Rd. between Kingston Rd. and NW Marine Dr.	
CMB-07	91 m of 375 mm combined sewer on Acadia Rd. between Kingston Rd. and NW Marine Dr.	
STM-01	42 m 250 mm dia. culvert underneath University Blvd.	Upgrade is a requirement of the proposed Block F development.
STM-02	91 m of 200 mm storm sewer on Acadia Rd. between Newton Wynd and NW Marine Dr.	Upgrade to 375 mm dia. Planned for 2018.
STM-03	91 m of 200 mm storm sewer on Acadia Rd. between Newton Wynd and NW Marine Dr.	Upgrade to 375 mm dia. Planned for 2018.
STM-04	91 m of 250 mm storm sewer on Acadia Rd. between Newton Wynd and NW Marine Dr.	Upgrade to 450 mm dia.
STM-05	91 m of 375 mm storm sewer on Acadia Rd. between Newton Wynd and NW Marine Dr.	Upgrade to 525 mm dia.
STM-06	30 m of 200 mm storm sewer between Acadia Rd. and NW Marine Dr.	Upgrade to 525 mm dia.
STM-07	65 m of 375 mm storm sewer on NW Marine Dr., east of Acadia	Upgrade to 525 mm dia.
STM-08	192 m of 375 mm storm sewer on NW Marine Dr., east of Acadia	Upgrade to 525 mm dia.
STM-09	95 m of 600 mm storm sewer on University Blvd., west of Acadia Rd.	Upgrade to 675 mm dia.
STM-10	166 m of 450 mm storm sewer on Acadia Rd., north of University Blvd.	Upgrade to 525 mm dia.
STM-11	151 m of 450 mm storm sewer on Acadia. Rd., north of McMaster Rd.	Upgrade to 600mm dia.
STM-12	154 m of 450 mm storm sewer on Acadia Rd., north of College Highroad	Upgrade to 600mm dia.

Project Reference	Description	Recommendation
STM-13	68 m of 450 mm storm sewer on Acadia Rd., between Wycliffe Road and College Highroad	Upgrade to 600mm dia.
STM-14	120 m of 450 mm storm sewer on Acadia Rd., south of Wycliffe Rd.	Upgrade to 600mm dia.
STM-15	68 m of 450 mm storm sewer on Acadia Rd., north of Wycliffe Road	Upgrade to 600mm dia.

6.5 Scheduled Capital Works

UEL's 2012-2021 Capital Plan was updated in 2015. This plan outlines the scheduled capital improvement projects for UEL's municipal infrastructure. Table 6.5 outlines the stormwater capital projects identified within the 10-year Capital Plan.

Table 6.5 10-Year Capital Plan Stormwater Projects

Project Reference Number	Description
2015-02	Construction of stormwater/sanitary sewer separation on Wesbrook Cres, north of Chancellor Blvd.
2016-02	Construction of storm sewer replacement on Wesbrook Cres. South of Chancellor Blvd.
2016-01	Construction of new storm sewer on Alison Rd between Campus Rd. and College Highroad, and on Western Parkway between College Highroad and University Blvd.
2017-02	Design and construction of storm sewer replacements on lane north of College Highroad
2018-01	Construction of sanitary/stormwater separation on Acadia Rd. north of Chancellor Blvd.
2018-02	Design and construction (reline) of storm sewer on Drummond Dr. and College Highroad
2021-01	Construction of Water, Sewer and Road replacement on Newton Wynd between Acadia Rd. and Kingston Rd.
TBC-02	Construction of storm sewer replacement on lane north of Wycliffe Rd.

6.6 Best Management Practises

Best Management Practices (BMPs), sometimes known as low impact development strategies, are tools that can be implemented to manage stormwater in order to protect natural resources such as watercourses and wetland areas. The objective of BMPs is to mimic the natural hydrologic regime within a development to provide a more sustainable way of managing stormwater. The objective is often accomplished through one or more of the following processes:

- Reducing imperviousness
- Conserving natural resources and ecosystems
- Maintaining natural drainage courses
- Reducing the use of and reliance on conventional pipe systems
- Minimizing clearing and grading of land for development (cluster housing)
- Maintaining pre-development time of concentration by strategically routing flows to maintain travel time or through the installation of detention facilities
- Infiltrating run-off into the ground

- Implementing effective public education programs to encourage property owners to use pollution prevention measures; and, maintain the on-lot hydrologically functional landscape management practises

BMPs can be utilized to aid in peak flow attenuation, volume reduction, and water quality protection. BMPs are not only beneficial for stormwater management and the environment, but they can also improve the aesthetic appeal of urban developments and contribute to a positive community sentiment.

Historically, the UEL has restricted run-off from all new development to a maximum rate of 25 l/s per hectare for a five (5) year storm. As a result, most newly developed properties limit the amount of imperviousness, have disconnected roof leaders and/or provide on-site stormwater storage. The proposed new development at Block F and all future development subject to the Works and Services Bylaw will need to meet the following criteria outlined below.

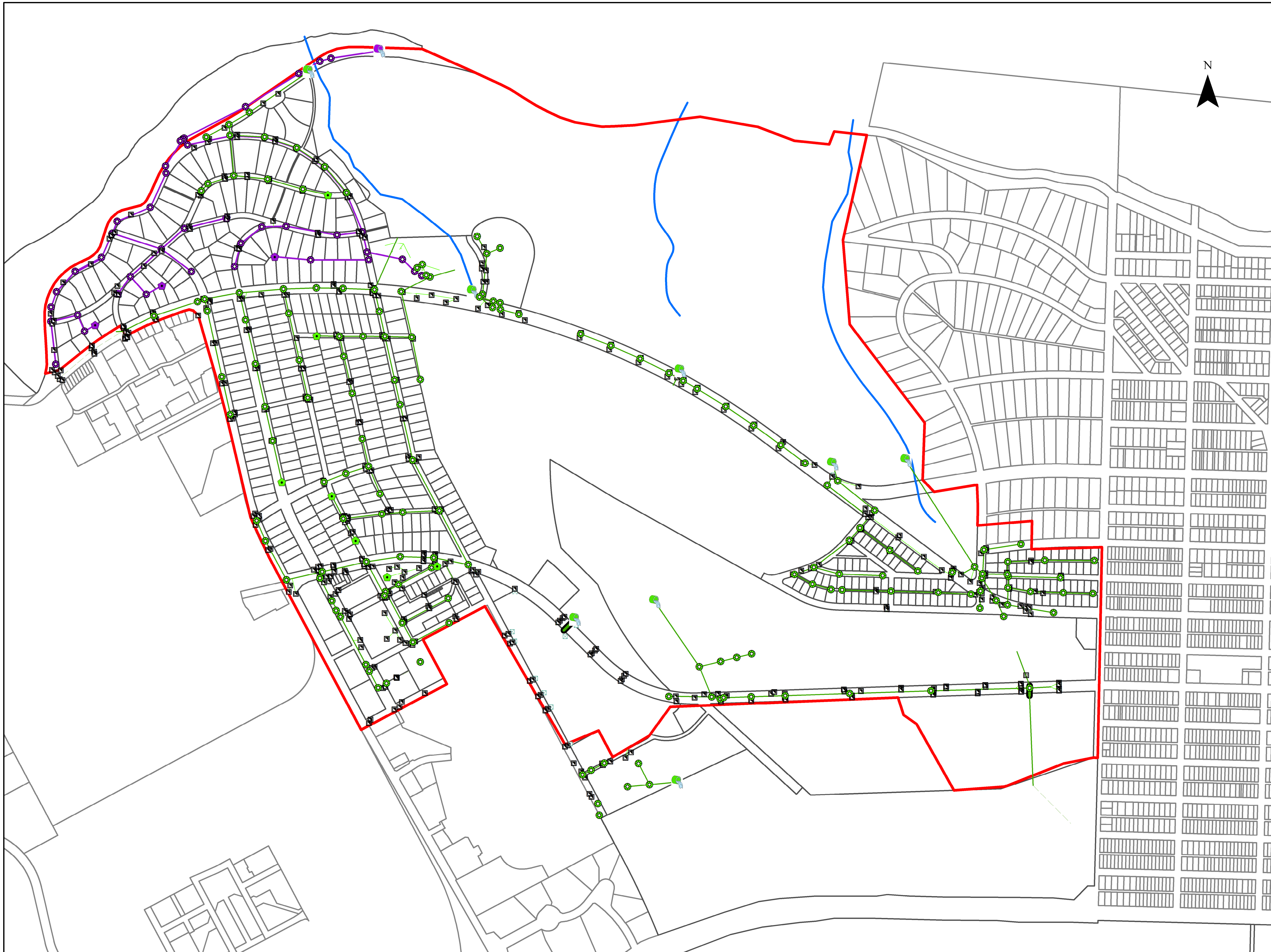
Stormwater runoff rates, volume and quality requirements are as follows:

- Reduce post-development flow (volume, shape and peak instantaneous rates) to pre-development levels for the 6-month, 24 hour and the 5-year, 24 hour precipitation events.
- Retain the 6-month, 24 hour post-development volume from impervious areas on-site and infiltrate into ground where it will not cause instability of steep slopes. If infiltration is not possible, the rate of discharge from the “flow reduction BMPs” will be equal to the calculated release rate of an infiltration system.
- Collect and treat the volume of the 24-hour precipitation event equaling 90% of the total rainfall from impervious areas with vehicular traffic with suitable BMPs.

6.7 Summary

The key points relating to the stormwater system of the study area are summarized as follows:

- The study area generally drains from south to north through a network consisting of predominantly gravity sewers and discharge to one of three creeks and eventually to English Bay
- Hydraulic modelling of the existing drainage system was completed. Recommendations addressing drainage deficiencies are summarized in Table 6.4.
- The existing 10 Year capital plan (2012-2021) addresses some, but not all, of the deficiencies found during the hydraulic analysis.



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Storm Outfall
- Storm Cleanout
- Storm Manhole
- Junction Box
- Catch Basin
- Culvert Headwall
- Abandoned Main
- Storm Sewer
- Culvert
- Catchbasin Lead
- Combined Cleanout
- Combined Manhole
- Combined Outfall
- Combined Sewer
- Study Area
- Watercourses

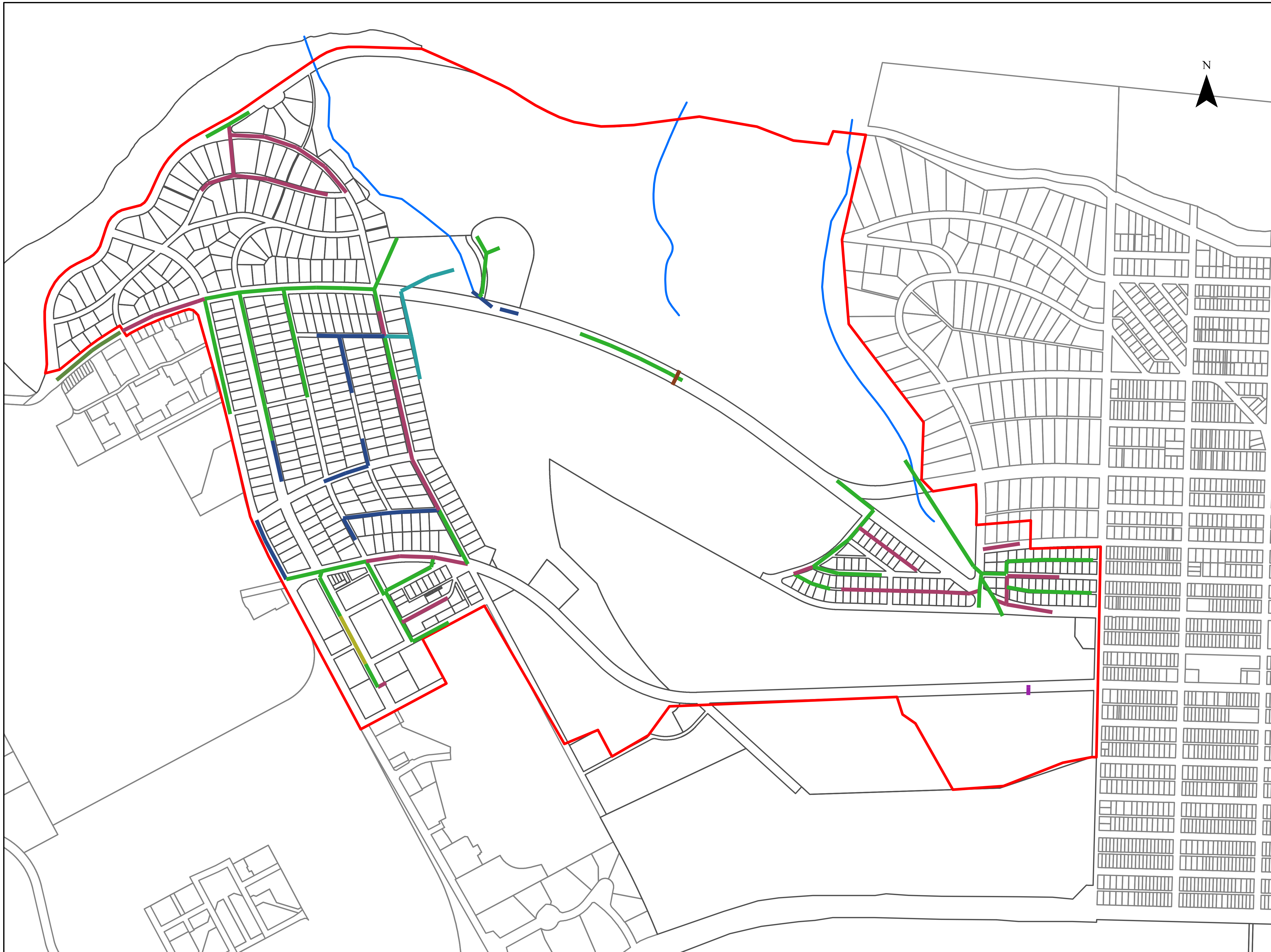
AECOM

Meters
0 100 200 400

Project No.	Date
60222155	October 2016

Existing Stormwater and Combined Sewer Infrastructure

Figure 6.1



BRITISH COLUMBIA

University Endowment Lands

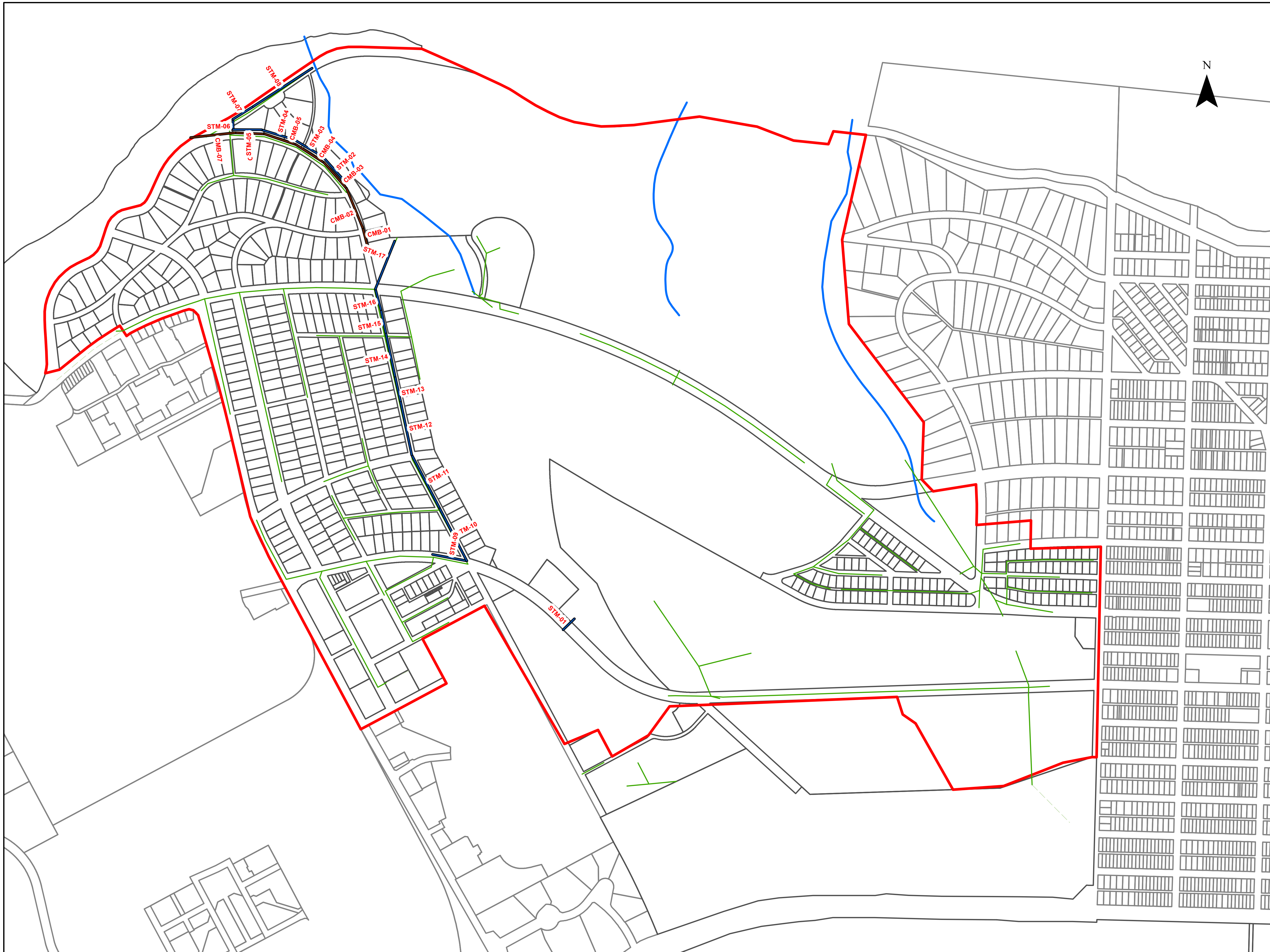
Integrated Stormwater Management Plan

AECOM

Project No.	Date
60222155	October 2016

Existing Storm Sewers Material

Figure 6.2



BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

Legend

- Storm Service
- Culvert
- Abandoned Main
- Storm Sewer
- Catchbasin Lead
- Combined Sewer
- Study Area
- Watercourses

Recommended Projects

- Combined
- Storm

AECOM

Meters
0 100 200 400

Project No.	Date
60222155	October 2016

Hydraulic Analysis Recommendations

Figure 6.3

7. Hydrogeology and Soils

7.1 Overview

This section summarizes the hydrogeological and geotechnical features of the UEL study area based on the review of previous reports, aerial photos, contour mapping, and Ministry of Environment (MOE) water Atlas.

7.2 Bedrock

Bedrock, which is blanketed by thick layers of till and sediments, is approximately 100m from the surface. Bedrock in the study area likely consists of tertiary sedimentary rocks including sandstone, siltstone, shale, and conglomerate.

7.3 Surficial Geology and Soils

Surficial soils are a key component of the hydrologic cycle. They form the interface between rainfall infiltration and runoff. Soil is not a homogeneous material. It is composed of various mineral and organic components that may or may not be distributed and organized into vertical and horizontal patterns. The soil components and their distribution is a function of parent geological materials, topography, climate, biology, and geologic history. An understanding of surficial soils is important to developing knowledge of the study area and its operation under a range of conditions. A review of surficial soils was undertaken to establish an understanding of the potential engineering opportunities and constraints relating to drainage and possible infiltration as it relates to stormwater BMPs.

The surficial geology units in this area have been mapped by the Geological Survey of Canada (Reference: Surficial Geology GSC Map 1486A Surficial Geology, New Westminster, BC). The main surficial soil units that occur in the study area are described below.

7.3.1 Capilano Sediments (Ca)

There is a pocket of Capilano sediments (Ca) along Spanish Bank Creek and branching westward. This layer consists of raised marine beach, spit, bar and lag veneer, poorly sorted sand and gravel up to 10 m thick mantling older sediments and containing fossil marine shell casts.

7.3.2 Capilano Sediments (Cb)

There is a pocket of Capilano sediments at the upstream end of Spanish Bank Creek running through the middle of Area C and the eastern portion of the golf course. This layer consists of raised beach medium to coarse sand 1 to 5 m thick.

7.3.3 Vashon Drift and Capilano Sediments (VCb)

The majority of the study area and nearly all of the developed area in University Hill is mapped as Vashon Drift and Capilano Sediments; including lodgement and minor flow till, lenses and interbeds of sub stratified glaciofluvial sand to gravel, and lenses and interbeds of glaciolacustrine laminated stony silt up to 25 m thick. This dense till unit has low permeability and infiltration through this unit will be very slow.

7.3.4 Pre-Vashon Deposits (PV)

Towards the north end of the study area and including a small portion of the most northern properties in University Hill are underlain with pre-Vashon deposits. This layer also lies beneath the Vashon Drift and Capilano Sediment layers. This layer consist of pre-Vashon Quadra sand fluvial channel fill and floodplain deposits including cross-bedded sand containing minor silt and gravel lenses and interbeds. The lowest layer of the Quadra Sand unit consists of interbeds of sand and laminated silt which acts as an aquitard. This unit overlies another sand unit that extends from below sea level in some locations.

7.4 Stormwater Infiltration

Soil infiltration rates are generally expected to be low based on the surficial geological mapping that indicates the presence of Vashon glacial till underlying the study area. There are pocket areas with sandy fill where higher percolation rates could be expected; however, these pockets are underlain by dense till with low percolation rates. Percolation testing for the Block F development, where surficial soils generally consisted of sandy materials, yielded a percolation rate of 8.8 minutes / 25mm drop in water level.

In the context of the ISMP this means that greater runoff can be expected compared to regions with more permeable soils. Where there is low permeability of the soils, implementation of infiltration based volume reduction type best management practises may be more difficult. It is recommended to conduct percolation tests in advance of designing infiltration facilities. If infiltration is low, then other techniques for volume reduction may need to be investigated such as the implementation of surficial vegetated facilities (i.e. rain gardens) that use evapotranspiration.

7.5 Aquifers and Wells

Water that seeps through the till cap, typically percolates down through the Upper Sand unit until it reaches the Sand Silt unit, which acts as an aquitard. The perched water bearing sand unit located above the aquitard is referred to as the Upper Aquifer. The water that seeps through the aquitard flows down into the lower sand unit, which when saturated, forms the Lower Aquifer.

The Upper Aquifer is classified as low demand, moderate productivity, and moderate vulnerability. No data was available for the Lower Aquifer.

The BC Water Resources Atlas shows there are five existing wells in the study area. Well data for each well is summarized in Table 7.1. The well data shows the groundwater table to be 48 - 87 metres below the surface. Nearby shallow wells on University Blvd., west of Wesbrook Mall show the ground water elevation to be just 4 metres below the surface. This groundwater elevation is well above those reported elsewhere.

Table 7.1 Well Data

Well Number	Location	Use	Well Depth (m.)	Water Depth (m.)	Yield (GPM)
18016	Allison Rd., north of Chancellor Blvd.	Unknown	105	89	25
17995	Acadia Rd., north of Chancellor Blvd.	Observation	104	84	-
17996	Acadia Rd., south of Chancellor Blvd.	Unknown	91	48	-
56790	Dalhousie Rd., west of Western Pky.	Regent College	34	25	100
17970	College Highroad, west of Tasmania Cres.	Observation	79	68	-

7.6 Groundwater Flow and Slope Stability

Groundwater flow generally follows the topography of the low permeability layers towards the cliffs. Seepage from the Upper Aquifer results in piping at the cliff face resulting in mass wasting and erosion. Increased subsurface infiltration will likely result in increased discharge and erosion at the cliff faces. Discharge from the Lower Aquifer passes mostly through beach deposits and does not significantly impact cliff erosion. Increased infiltration into the Upper Aquifer near the cliff face is generally not recommended as a method of reducing stormwater runoff. As part of their Integrated Stormwater Management Plan, the University of British Columbia has contracted Golder Associates to estimate erosion along the NW Marine Dr. The study produced a series of maps along the UBC cliffs that show erosion and accumulation between 2010 and 2015. Based on this assessment UBC is implementing a best management practice of mandating 300 metre “No Infiltration” buffer along the cliff face of the UBC property. The UEL may consider coordination with UBC on efforts in protection of slope stability along the North West Marine Drive.

7.7 Contaminated Sites

There are no known contaminated sites within the University Endowments Lands.

7.8 Summary

The key points relating the hydrogeology and soil characteristics of the study area are summarized as follows:

- Most of the study area is directly underlain by low permeability till which limits the ability to count on infiltration as a method of reducing storm water runoff.
- Groundwater flow in the Upper Aquifer discharges from the cliff faces resulting in mass wasting and erosion. Increasing infiltration is generally not recommended north of Chancellor Blvd.
- Existing wells show the aquifer ground water table is located at approximately 48 - 87 metres below the surface depending on location; however, there is conflicting information from nearby shallow water wells showing ground water depth as high as 3.8 m below surface. There will also be seasonal surface ponding at some locations.

8. Environment

8.1 Overview

The study area is located in the Eastern Variant of the Very Dry Maritime Subzone of the Coastal Western Hemlock Biogeoclimatic Ecosystem Classification Zone. This climate is characterized by warm, dry summers and moist, mild winters with little snowfall.

According to the Pacific Spirit Park Society, the following species of trees can be found within Pacific Spirit Park: Cedar, Hemlock, Douglas Fir, Sitka Spruce, Vine Maple, Red Alder and Bitter Cherry. Other plant varieties found in the park include salal, salmonberry, blackberry, elderberry, ferns, mosses, lichens and mushrooms. Birds and small animals that have been found in Pacific Spirit Park include owls, bald eagles, chickadees, warblers, wrens, kinglets, woodpeckers, sea birds, Douglas Squirrels, voles, mice, coyotes, skunks and raccoons, salamanders, newts, Garter Snakes, toads and tree frogs.

As part of this ISMP, AECOM performed benthic macroinvertebrate and water quality studies for the UEL over the course of one sampling year which included sampling in both the wet and dry seasons. 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.

8.2 Stream Conditions

A site visit was conducted for the three creeks (Spanish Bank Creek, Canyon Creek, and Salish Creek) located within the study area of the UEL. The lower reaches of the three creeks were examined to determine if they could support fish passage.

The Spanish Bank Creek has the best streambed condition of the three streams and can be attributed to the daylighting of the stream in 1999 and the rehabilitation in the spring of 2014. The creek has an 800 mm diameter wood culvert with water flowing at a depth of 200 mm which runs under Northwest Marine Drive. The stream is narrow with sufficient depth to allow fish passage upstream. There was limited debris in the stream. The lower reaches of this creek are at a gentle grade. The Ministry of Environment Habitat Wizard Streams Report states that Chum Salmon, Coho Salmon, and Cutthroat Trout have been observed in the stream.

Salish Creek has a concrete culvert that crosses under Northwest Marine Drive. This is the only culvert that has baffles installed to assist the upstream passage of fish. The stream has sufficient flow for fish passage; however, the streambed is very wide in sections which limit the water depth. Debris is present throughout the lower courses of the stream. The wide streambed and significant amounts of debris is expected to present a problem for fish passage. The Spanish Bank Streamkeepers have reported observation of Coho Salmon attempting to swim up Salish Creek.

Canyon Creek has a concrete culvert that crosses under Northwest Marine Drive. The stream flow was lower than 100 mm in the culvert and would present problems for fish passage. The stream has significant number of trees and other debris that severely block portions of the stream. The low flow and debris would make fish passage through the lower reaches of this stream very difficult. No reports of fish could be located for this stream. It should be assumed that this creek may contain the same fish species as both Salish Creek and Spanish Bank Creek.

The riparian setbacks for each of the three creeks were examined using GIS. Figure 8.1 shows the riparian setbacks for each of the creeks. The riparian area of Salish Creek is encroached upon on the west side by single family homes and to a greater extent by the Public Works Yard. There is no encroachment on Canyon Creek. Spanish Bank Creek's riparian area is encroached upon by a trail at the north-west end of the creek and by single family homes on the east side. The contour map of the area notes that there are some steep grades (46% slope) in the middle to upper reaches of the streams.

The City of Vancouver have confirmed that based on the stormwater servicing information for the properties 1600-1900 BLKS of Drummond Dr. and 4800 BLKS of Belmont and Fannin, all properties have applied for new stormwater service connections and should have service to the property frontage. However, incomplete records suggest that over time some properties have developed discharge to ground systems that may runoff to the Spanish Bank Creek ravine.

A detailed assessment of the creeks would need to be undertaken to determine the extent of fish passage for the entire length of the watercourses, to assess riparian habitat integrity, and to assess stream erosion.

The Spanish Bank Streamkeepers volunteer group is actively involved in monitoring, assessing, and safeguarding the Spanish Bank Creek, Canyon Creek, and Salish Creek. The group receives support from the Pacific Streamkeepers Federation and members are encouraged to get Streamkeeper Certification, which provides training in watercourse monitoring and assessment. The Spanish Bank Streamkeepers have provided educational opportunities for the public, including school children programs and summer camps. The Streamkeepers have also taken on investigative work in assessing water quantity variability in the Salish Creek. Together with the UEL Operations staff, the Spanish Bank Streamkeepers have discovered that, during the dry summer months, Regent College is discharging groundwater directly into the UEL storm drains after it is utilized for the building cooling system. The flow discharges into the Salish Creek at the box culvert at Acadia Circle. The Streamkeepers are eager to determine the impact of the flow from the Regent College on the ecology in the Salish Creek, and have contacted the Pacific Streamkeepers Federation to provide further guidance on the next steps.

8.3 Water Quality

Benthic macroinvertebrate and water quality sampling was performed over the course of one sampling year. 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. The water quality assessment system, when considered along with the benthic invertebrate and hydrometric indicator information, gives a holistic assessment of stream health in watersheds at risk from urban land use and non-point source pollution.

High levels of mayflies, stoneflies, and caddisflies are indicative of a healthy stream. The majority of the benthic invertebrates collected during sampling were predominately blackflies, which are pollution tolerant, and an overall benthic invertebrate score of very poor was obtained at Spanish Bank Creek and Salish Creek.

Bacteriological analyses were based on Health Canada guidelines for recreational primary contact levels. E.coli guideline values were exceeded at Spanish Bank Creek and Salish Creek sampling locations. Both fecal coliform and E. coli levels exceeded guideline values at these two sites during the wet sampling period. Exceedances for the two bacteriological parameters during the dry period only occurred in Salish Creek. The point sources for these contaminations should be determined. Coliforms could be coming from either or both wildlife and sewage cross connections. Caffeine could be included in the sampling locations of concern. Measuring caffeine measurements in municipal water systems provides a good estimate of fecal contamination caused solely by humans.

The Monitoring and Adaptive Management Framework (MAMF) document produced by Metro Vancouver was used to identify key water quality parameters. The 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, with fecal coliform, E.coli, dissolved oxygen, conductivity, and total iron marked as ‘Needs Attention’ at one or more locations. The ‘Needs Attention’ priority indicator suggests that water quality is in non-attainment with Provincial Water Quality guidelines and it is recommended that supplemental water quality monitoring and/or adaptive management actions are taken. If concentrations of E.coli or fecal coliforms exceed guideline concentrations, the Health Authority should be contacted and informed of the findings. Sources of metals could be natural or anthropogenic. Typically, anthropogenic sources in urban water system are related to roadway runoff. A stormwater sampling program could be designed to aid in determining the source of the issue.

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. Areas with high metal concentrations primarily during wet season sampling have a higher indicated of metal concentrations from roadway runoff. High levels at sites in both the dry and wet season sampling periods indicate a high probability of elevated natural levels. 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. It is recommended to include 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.

The full Benthic Macroinvertebrate and Water Quality draft report is included in Appendix A. The 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.

8.4 Summary

Water quality and benthic macroinvertebrate sampling was completed in 2015. The follow are the key points and recommendations resulting from the report:

- Sampling of creek water was completed during the development of the Integrated Stormwater Management Plan (ISMP). The sampling program was completed according to the methodology outline in the Monitoring and Adaptive Management Framework for Stormwater (Metro Vancouver 2014).
- Coho Salmon, Chum Salmon, and Cutthroat Trout have been observed in Spanish Bank Creek; and Coho Salmon has been observed in Salish Creek. It should be assumed that these fish species are also present in Canyon Creek.
- Benthic macro invertebrate scoring provided an overall rating of very poor stream condition for both sampling locations, at Spanish Bank Creek and Salish Creek.
- 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.
- Bacteriological analyses were based on Health Canada guidelines for recreational primary contact levels. E.coli guideline values were exceeded at Spanish Bank Creek and Salish Creek 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 in Salish Creek. This may be a result of either or both wildlife and sanitary sewer cross connection. Caffeine sampling could be done in future water quality sampling to determine if there is fecal contamination from human waste.
- 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 all the water quality sampling locations. Urban areas with high metal concentrations primarily during wet season sampling have a higher indicated of metal concentrations from roadway runoff. 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.
- The Metro Vancouver Monitoring and Adaptive Management Framework 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.

BRITISH COLUMBIA

University Endowment Lands

Integrated Stormwater Management Plan

AECOM

Project No.	Date
60222155	October 2016

Riparian Setbacks

Figure 8.1

9. Next Steps

With the conclusion of this report, Stage 1 of the four stage ISMP approach is complete. This report provides a thorough review of background information and a summary of the existing conditions. In addition to providing the context for the study, this report also highlights opportunities for improvement of UEL stormwater system. When addressing the highlighted opportunities, UEL should prioritise efforts in the following areas.

- The review of current legislative context identified the need for Erosion and Sediment Control Bylaw to ensure that adequate protection of municipal drainage system is applied during any construction. The new Works and Services Bylaw requires that all construction shall be accompanied by an Erosion and Sediment Control plan.
- Implement a Tree Management Bylaw to regulate the cutting, removal, and damage of trees on private property. This bylaw would complement the Provincial and Federal regulations for the protection of riparian features and conditions that are crucial in maintaining long-term watercourse health.
- Address cliff erosion issues along NW Marine Drive. Implementation of BMPs should be carefully evaluated along the cliff edge as increased infiltration could cause erosion due to increased pore water pressure.
- Include roadway runoff in the water quality monitoring program. Especially in urbanized areas, where high concentration of metals is present.
- Investigate cross connections for locations where households discharge into the environment. Noted issues include presence of washing machine detergent in the nearby watercourses.

In terms of developing an Integrated Stormwater Management Plan, the next steps are:

- Establish the vision for future Development (Stage 2),
- Develop an implementation plan, funding, and enforcement strategies (Stage 3),
- Develop a monitoring and assessment program (Stage 4).

Appendix A

Water Quality & Benthic Sampling
Draft Report

Environment

University Endowment Lands

Water Quality & Benthic Sampling

Prepared by:

AECOM
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Burnaby, BC, Canada V5A 4R4 — 604 294 8597 fax
www.aecom.com

Project Number:

60222155

Date:

July 2016

Statement of Qualifications and Limitations

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- were prepared for the specific purposes described in the Report and the Agreement
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- as required by law
- for use by governmental reviewing agencies

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This Statement of Qualifications and Limitations is attached to and forms part of the Report.

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604 444 6400 tel
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July 11, 2016

Graham Walker, P.Eng.
3292 Production Way
Burnaby, BC
V5A 4R4

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
melissa.mukai@aecom.com

Distribution List

# of Hard Copies	PDF Required	Association / Company Name
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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

Report Prepared By:

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

Report Reviewed By:

Bruce S. Ford, MRM, R.P.Bio.
Senior Aquatic Biologist

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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.

N
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Metres

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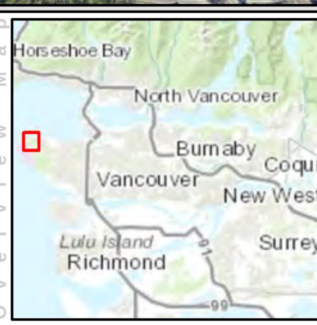
NAD 1983 UTM Zone 10N

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.

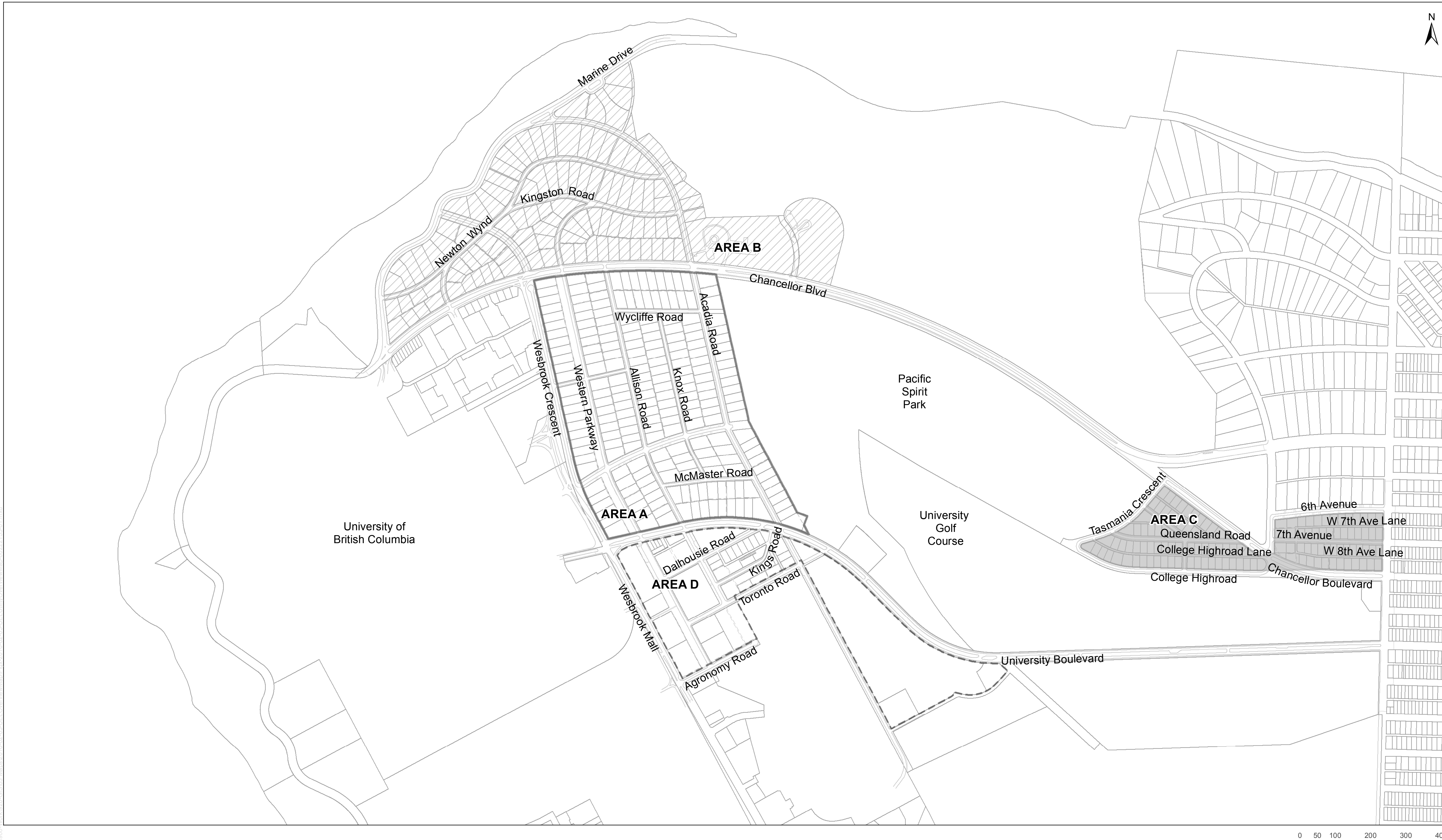
The study area is divided into seven main catchments (four University Hill development areas contained within these catchments), all of which discharge to English Bay via various creeks and ravines. The elevation varies from a high of approximately 90 m to a low of 10 m. The topography of the study area 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 ≤200/100 mL for geometric mean values and ≤400 E.coli/100 mL maximum. BC Water Quality guidelines for E. coli based on recreational primary contact levels are ≤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 $\leq$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

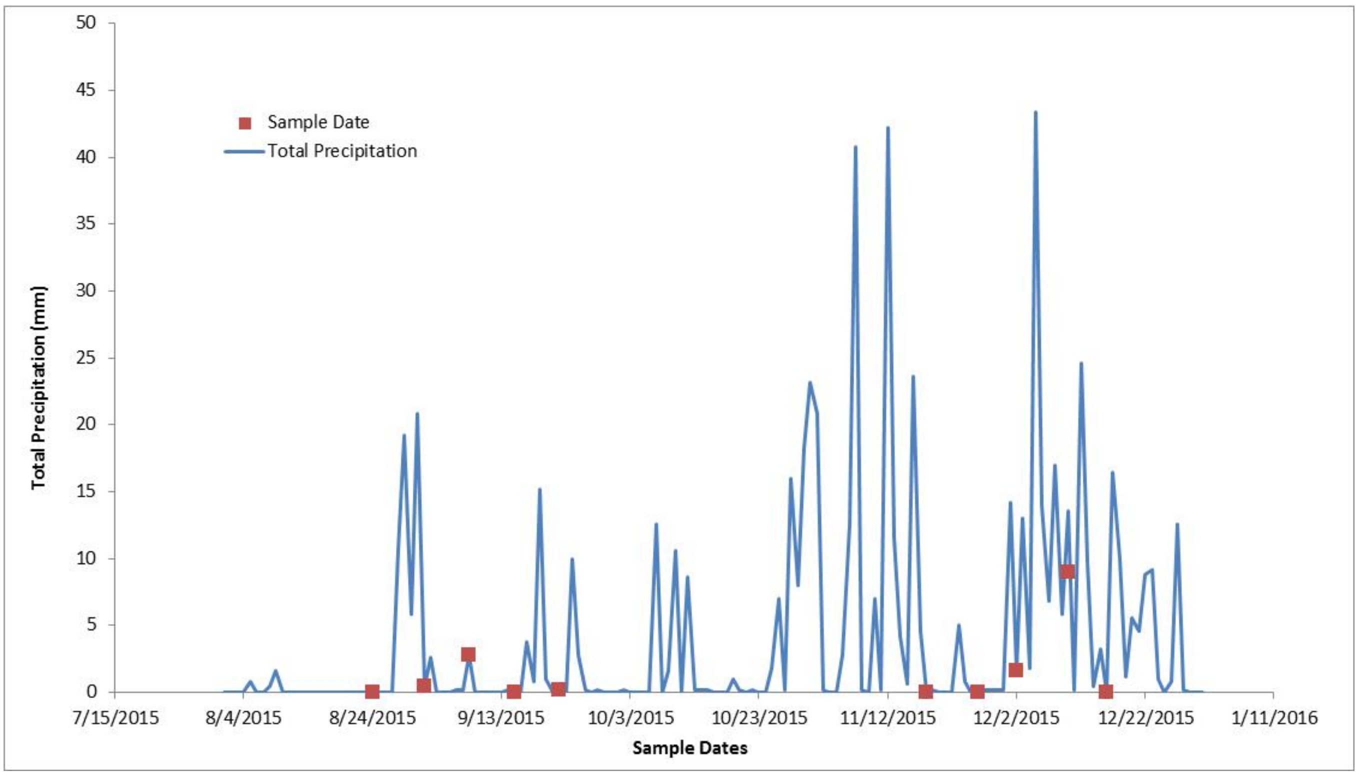
Parameter	Units	AMF Ranking System	UEL-001			UEL-002			UEL-003			UEL-004		
			Wet Mean	Dry Mean	AMF Rank	Wet Mean	Dry Mean	AMF Rank	Wet Mean	Dry Mean	AMF Rank	Wet Mean	Dry Mean	AMF Rank
Dissolved Oxygen (DO)	mg/L	11 = Good 6.5 to 11 = Satisfactory <6.5 = Need Attention	11.50	10.5	Good (wet), Satisfactory (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

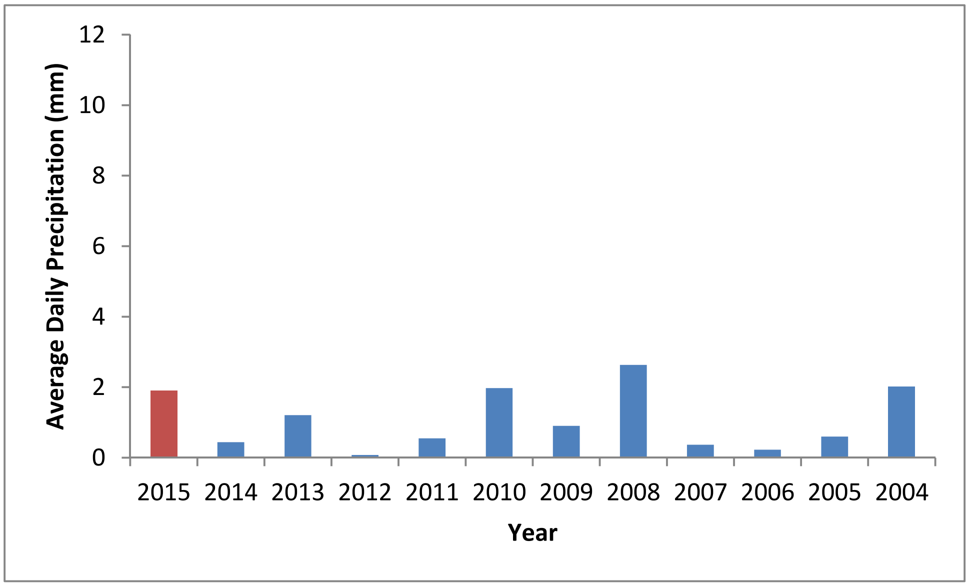


Figure 5. Regional Precipitation during Sampling in September, in Relation to Climate Normal near UEL

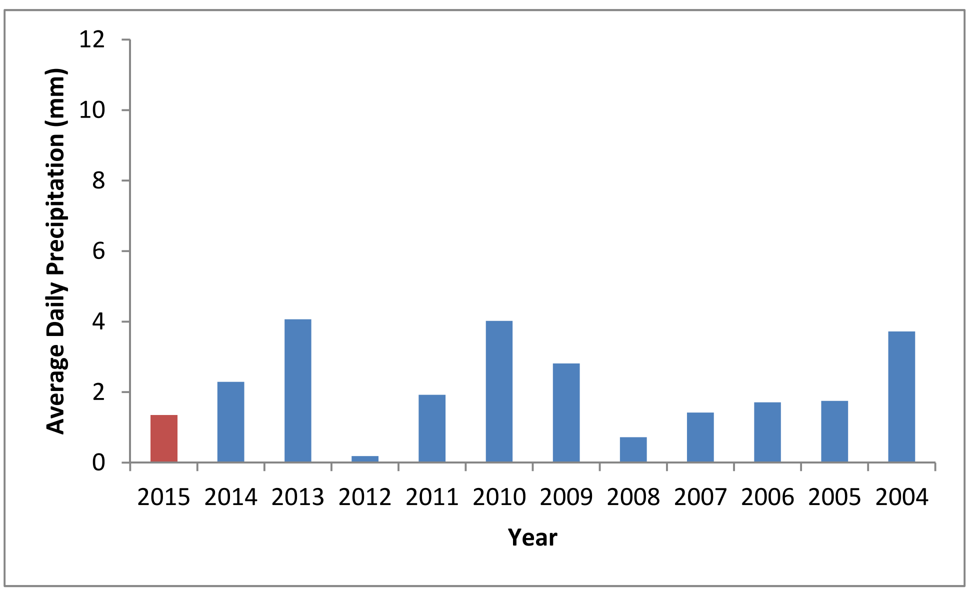


Figure 6. Regional Precipitation during Sampling in November, in Relation to Climate Normal near UEL

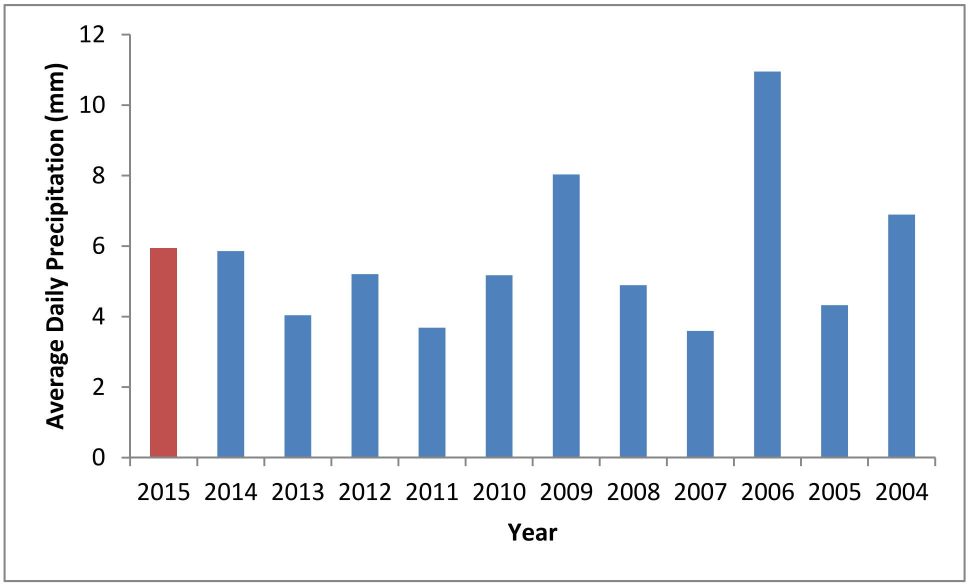
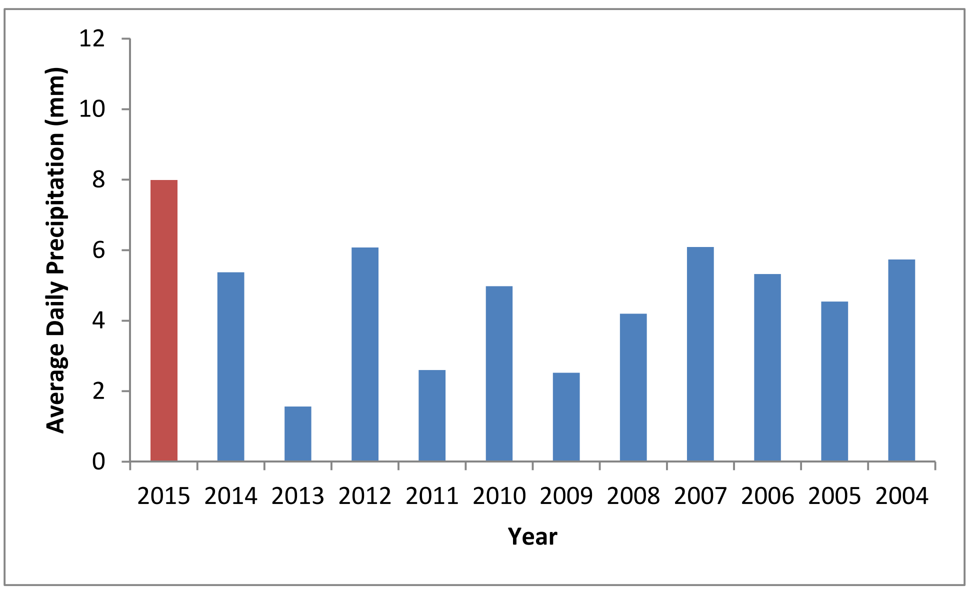


Figure 7. Regional Precipitation during Sampling in December, in Relation to Climate Normal near UEL



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

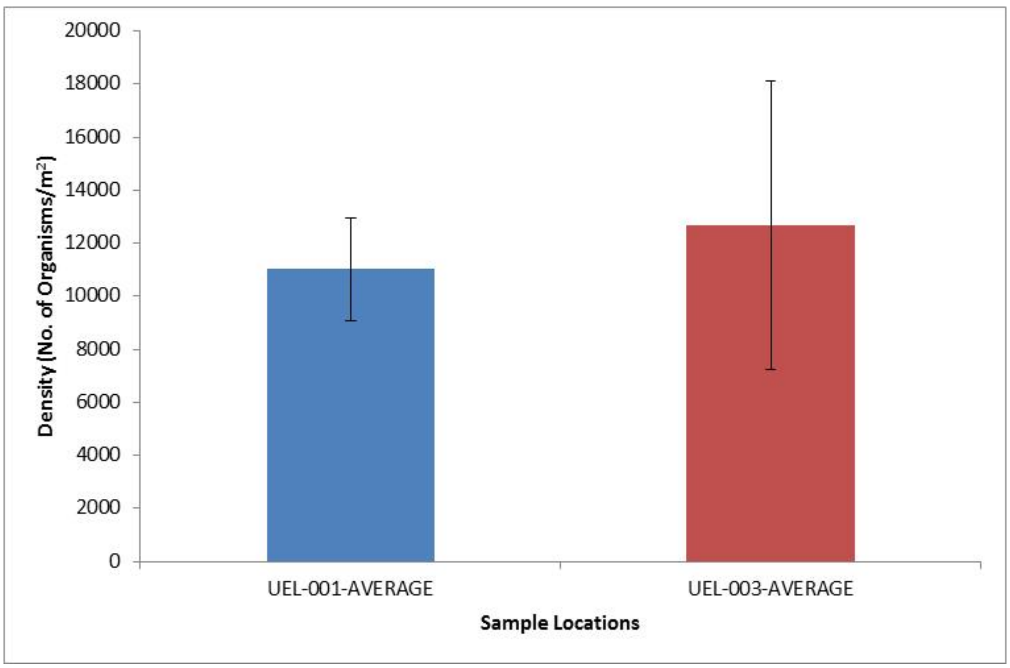


Figure 9. Species Richness of Benthic Invertebrates, UEL Project, August 2015

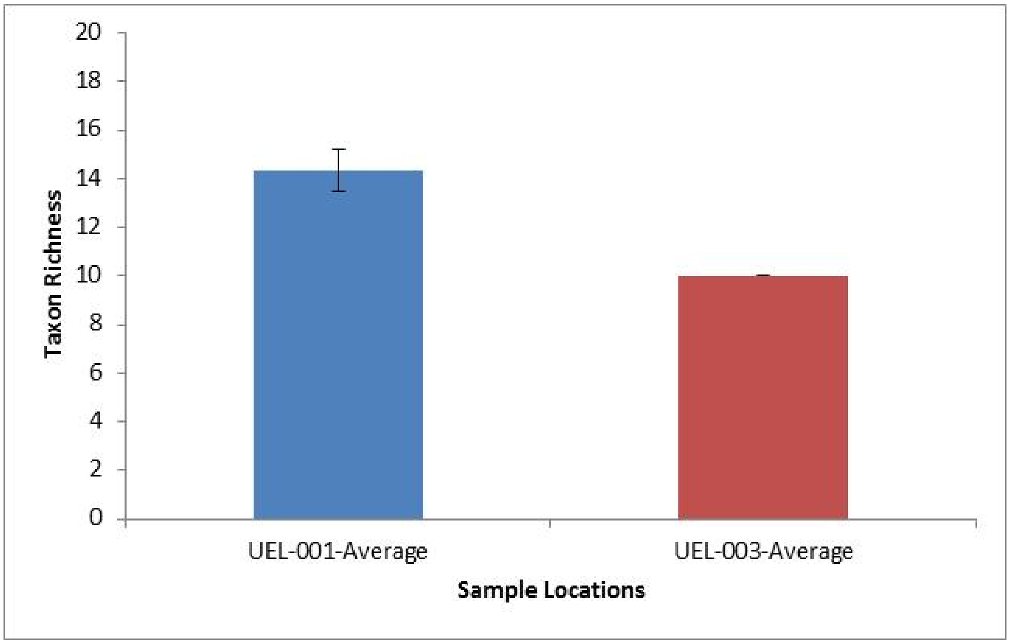


Table 12. Percentage Composition of Benthic Invertebrate Communities, UEL Project, August 2015

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

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Appendix A

Water Quality Data

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**			
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															BC 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-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 $10^{\{1.016(\log[hardness]) - 1.71\}}$ 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 $e^{\{0.8545[\ln(hardness)]-1.465\}}$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 $e^{\{1.273[\ln(hardness)]-4.705\}}$ 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 $e^{\{0.76[\ln(hardness)]+1.06\}}$ 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; $e^{(1.273\ 1n\ [hardness])-1.460)}$ 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 $10^{\{0.83(\log[hardness]) - 2.46\}}$ 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

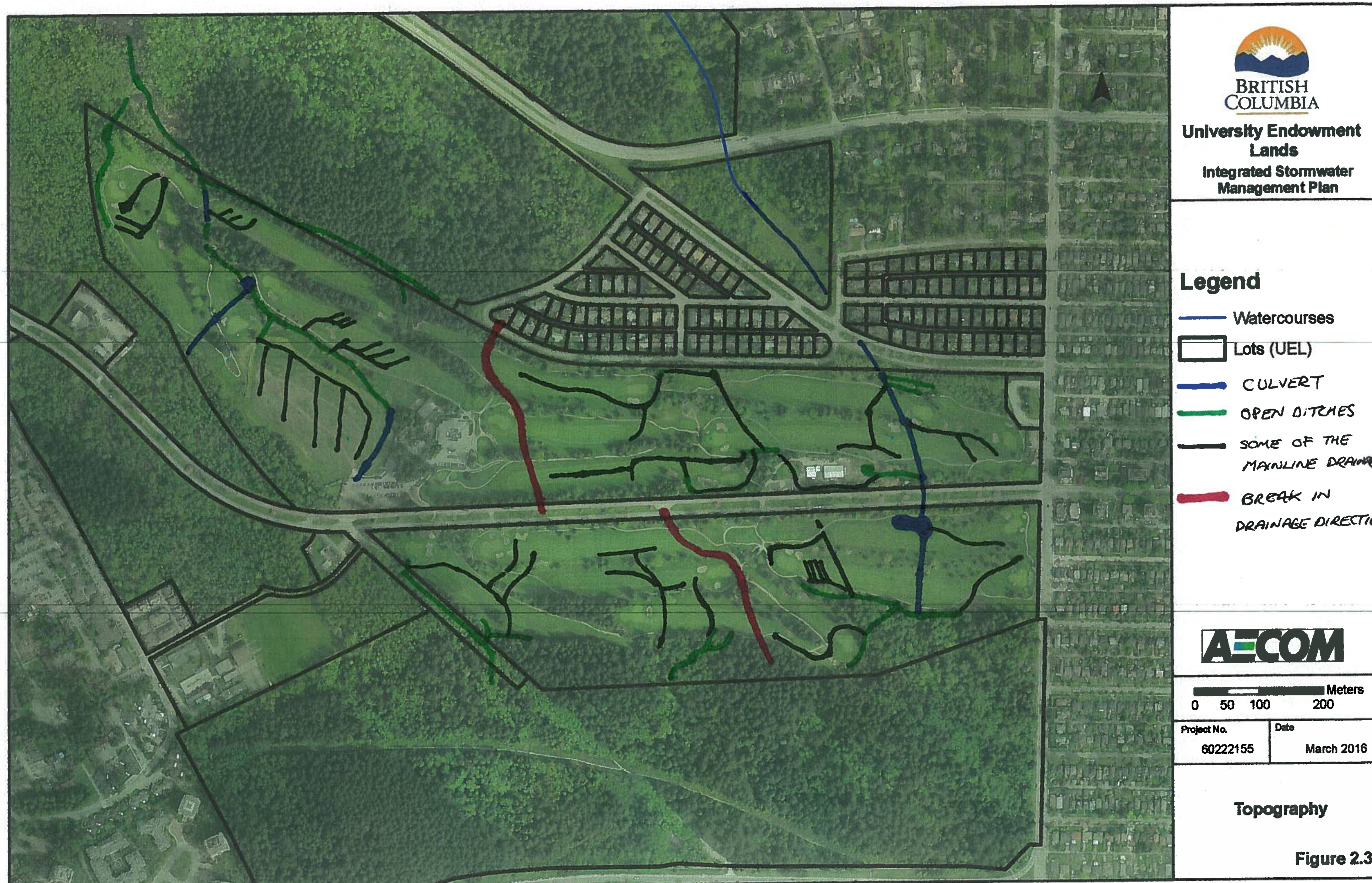
Photograph 1. ↑
UEL-001, Replicate 2 benthic invertebrate sampling,
August 24, 2015.

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.

Appendix B

University Golf Course Drainage Map



Topography

Figure 2.3

Appendix B

Visioning Workshop – Minutes of Meeting and Presentation Slides

University Endowment Lands

Integrated Stormwater Management Plan

June 24, 2016

BRITISH COLUMBIA AECOM

2

BRITISH COLUMBIA AECOM

Workshop Agenda

- Introductions and Workshop Agenda
- UEL Integrated Stormwater Management Plan (ISMP) Approach
- Review of Stage 1 Findings
- Drafting of the ISMP Vision and Objectives
- Next Steps

3

BRITISH COLUMBIA AECOM

ISMP Overview and Project Scope

- Alleviate existing and/or potential drainage, erosion, and flooding concerns
- Protect and/or restore stream health including riparian and aquatic habitat
- Remediate existing and/or potential water quality problems

4

BRITISH COLUMBIA AECOM

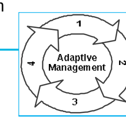
UEL ISMP Approach

Stage 1 "What do we have?"
- Review background information
- Summarize existing conditions

Stage 2 "What do we want?"
- Establish the vision for future development
- Visioning Workshop

Stage 3 "How do we put this into action?"
- Development of an Implementation Plan
- Funding Strategies
- Enforcement Strategies

Stage 4 "How do we stay on target?"
- Development of a monitoring and assessment program
- Adaptive Management Plan

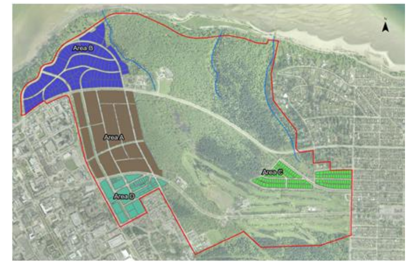


Stage 1 – “*What do you have?*”

Findings

6

Study Area

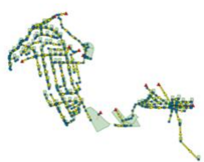


- Study area focuses on the developed portion of the UEL and the watercourses downstream
- Pacific Spirit Park contains environmentally sensitive areas.
- The University Hill community consists of primarily single family homes in Areas A, B, and C. Area D consists of a mix of low and high-rise apartments, townhouses, mixed-use, and commercial development
- The planned Block F development is to consist of residential and commercial mixed-use development. The development plan includes a stormwater detention pond to attenuate peak flows.

7

Information Gathering

Hydrologic Model



GIS

Aerial Photo

Utility Maps

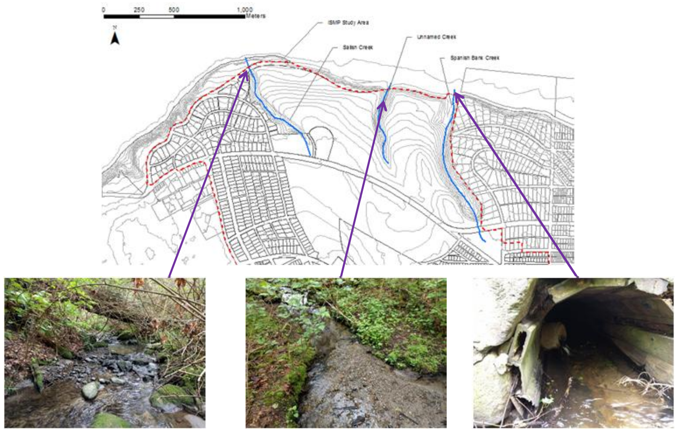
8

Stormwater Infrastructure - Summary

Stormwater Infrastructure Breakdown		Source
Storm Sewer Mains	13,908 m	GIS / Model
Ditches	866 m	Model
# of Watercourses	3	GIS
# of Culverts	2	GIS/Utility Maps
# of Property Connections	181	GIS
# of Manholes	169	GIS
# of Catch Basins	435	GIS

9

Natural Watercourses



10

Stormwater Infrastructure - Examples

Streams

Culverts

Ditches

Catch Basins

11

Regulatory Context

Applicable Statutes and Guidelines

Federal

- Fisheries Act

Provincial

- Fish Protection Act and Riparian Area Regulations
- Environmental Management Act
- Water Act

Regional

- Integrated Liquid Waste and Resource Management Plan

Local

- UEL Official Community Plan and Land Use, Building and Community Administration Bylaw
- UEL Works and Services Bylaw

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Summary of Topics Reviewed for ISMP

- Land Use
- Hydrology
- Stormwater System
- Hydraulic Modelling and Assessment
- Hydrogeology and Soils
- Local Environment
- Water Quality and Benthic Sampling
- Field Investigation

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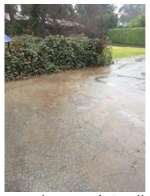
Stormwater Issues



- Erosion and Sedimentation Control
- Tree Protection
- Combined Sewer System
- Storm sewer capacity on Acadia Rd.
- Cliff erosion
- Street run-off and cross connections: metals and coliforms in watercourses

Your Observations

Have you noticed anything about UEL stormwater system that we have missed?

Stage 2 – "What do we want?"

Developing Vision and Objection for UEL ISMP

16

Visioning Exercise – Let's Get Your Input!

- What do you want the vision for UEL ISMP to look like?
- What goals do you want to set for UEL in terms of stormwater management?
- Group visioning exercise

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Questions to help with the visioning

- What do currently have that you like/works well?
- What do you currently have that you don't like?
- What have you seen elsewhere that you like?
- Are there opportunities that the UEL can leverage?
- Are there any barriers that will need to be overcome?

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Stage 1 - Findings

- Erosion and Sediment Control
- Tree Management
- Cliff erosion issues along NW Marine Drive
  - Infiltration may not be the Best Practice
- Water quality monitoring for roadway runoff
- Investigate cross-connections (poor water quality noted)

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Example ISMP Vision and Goals

UBC ISMP Objectives:

1. Protection of flooding and prevention of overland flooding across the cliffs
2. Ensure that the requirements of legislation area met
3. Protect the campus environmental values and minimize the impact of campus discharge on neighbouring watercourses
4. Improve the quality of the stormwater that leaves the campus
5. Incorporate the natural hydrological cycle into the stormwater system

City of Vancouver:
Citywide Integrated Stormwater Management Plan
or Integrated Rainwater Management Plan

- **To maintain clean water from watersheds to receiving environments**
- **To reduce potable water demand**
- **To connect people to urban and natural ecosystem functions**

Why rainwater management?

- **Greenest City Action Plan**
- **Supporting Nature's Ecosystem**
- **Preparing for climate change and severe weather**
- **Protecting Sensitive Waterbodies**
- **Reducing Combined Sewer Overflows**
- **Meeting Regulatory Requirements**
- **Honouring Vancouver's Rainfall Resource**

Be a solution to runoff pollution!

Keep it Clean!

Stormwater Smart

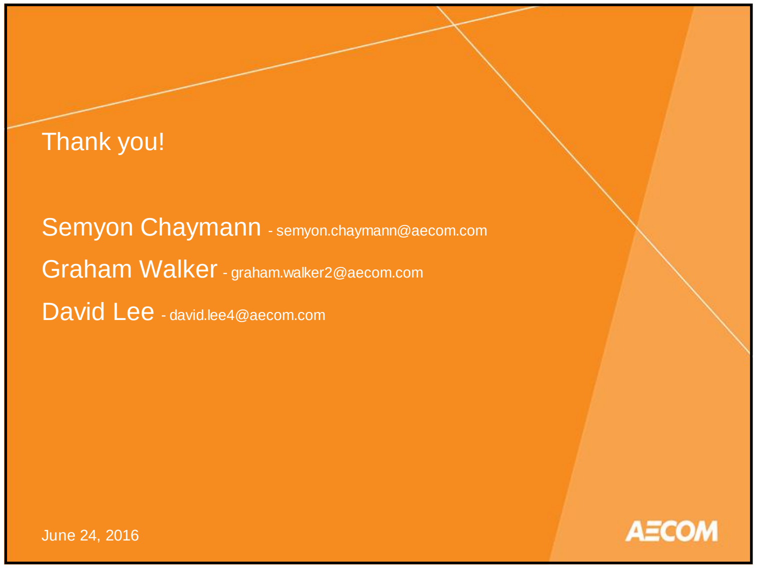
Only rain in our storm drain!

Sample Mission/Vision Statement:

"Provide a stormwater system that controls damage from storms, protects surface water quality, supports fish and wildlife habitat, and protects the environment"

Next Steps

- Workshop Summary
- Stage 3 – Implementation Plan
- Stage 4 – Adaptive Management Plan


Thank you!
Semyon Chaymann - semyon.chaymann@aecom.com
Graham Walker - graham.walker2@aecom.com
David Lee - david.lee4@aecom.com
June 24, 2016
AECOM

AECOM

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Minutes of Meeting

Date of Meeting	June 24th, 2016	Start Time	10:00am	Project Number	60222155 (412)

Project Name	University Endowment Lands Integrated Stormwater Management Plan
Location	UEL Administration Building
Regarding	Visioning Workshop for Integrated Stormwater Management Plan
Attendees	Jonn Braman (UEL), Sylvia Pendl (Metro Vancouver), Robyn Worcester (Metro Vancouver), Andrew Ling (City of Vancouver), David Lee (AECOM), Graham Walker (AECOM), Semyon Chaymann (AECOM)
Distribution	All Attendees
Minutes Prepared By	Semyon Chaymann

PLEASE NOTE: If this report does not agree with your records of the meeting, or if there are any omissions, please advise, otherwise we will assume the contents to be correct.

	Action
The objective of the meeting was to allow UEL, Metro Vancouver (Parks) and City of Vancouver to discuss the UEL's initial work on its Integrated Stormwater Management Plan. Pacific Spirit Regional Park is a significant component of the UEL for storm water management. Vancouver completed an ISMP for southern drainages that begin in the UEL.	
Semyon Chaymann (AECOM) provided introductory remarks regarding the UEL ISMP and presented the results of the Stage 1 of the project. The floor was open for discussion on the results of Stage 1 and participants were encouraged to add on to the findings of the summary report.	
The following are general comments from the discussion:	
• Andrew Ling was not provided a copy of Stage 1 report and appendices.	
▪ **AECOM to provide**	AECOM
• Flow monitoring in the streams was not completed as part of the ISMP study but stream flow information was acquired from the Spanish Bank Streamkeepers volunteer organization, which monitor the streams at UEL on an annual basis.	
• Jonn Braman noted that part of the runoff from Block F heads predominately north, but western portions feed southwards to Cutthroat Creek and requested that the southern drainage delineation be reviewed.	
▪ **AECOM to adjust drainage areas**	AECOM
• Jonn Braman noted that there is a ditch that runs parallel to the Hydro R.O.W., which collects runoff from houses along the eastern border of Area A in the Pacific Spirit Regional Park. The ditch is piped before it	

reaches Chancellor Drive. The daylighting location is shown on UEL Detailed Stormwater and Combined System Map No. 4. ▪ **AECOM to investigate the ditch and add it to the Figure 6.1 in Stage 1 Report**	AECOM
• Block F catchment is not delineated in Figure 5.2 of the report. Metro Vancouver wants to ensure that sufficient attention is given to the Block F stormwater management component. • Major roadways (Chancellor Blvd, University Blvd, and W 16th Avenue) in the UEL are under the MoTI management, include stormwater catchment.	
• Andrew Ling (City of Vancouver) will provide information regarding drainage from backyards of properties along the east side of Spanish Bank Creek	Andrew Ling (CoV)
After the discussion of the Stage 1 findings, the participants were invited to provide their input into the creation of the vision and goals for the UEL ISMP. The follow items were discussed as part of the development of vision and goals: *Engagement with the Local Community* - Education for Residents regarding stormwater best management practices - Utilize resources and studies conducted within the watershed - A library of local knowledge about the watercourses and parks - Pursue concepts of connected community and sharing of information - Engage Golf Course in stormwater planning, BMPs, and water conservation practices *Protect Water Quality* - Protect, Enhance, and Improve streams - Protect Park area - Implement stormwater BMPs where applicable - Understanding of water flow patterns through the Park - New Developments/Redevelopments o Increase in impermeable area o Infiltration is not always the best option *Protect Water Quantity;* - Maintain flows in watercourses - Investigate water flows to stormwater system from Regent College - Contribution to Salish Creek and maintaining fish habitat - Maintain current fish values and fish importance to the community *Protect Life and Property* - Erosion along NW Marine Dr. *Natural Environment* - Tree protection and management - New developments/ redevelopments o Keep older trees	

- Climate Change ○ Higher flows ○ Storm frequency *Develop by-laws* - Tree Protection - Erosion and Sediment Control In addition to the breakdown of goals/vision topics above, the participant provided comments as part of the general discussion: • It was noted that UBC Slope Stability Study and Geotechnical Report is available for area west of Area B ▪ **AECOM to consult with UBC on geotechnical studies**	AECOM
• What are the agreements for the discharge of stormwater into the park? ○ Metro Vancouver minimum requirements ▪ Improve runoff quality onsite using a Best Management Practice ▪ Reduce runoff quantity onsite: Capture and infiltrate 40% of the 2-year, 24 hour storm ▪ Department of Fisheries and Oceans stormwater guidelines are listed in the Metro Vancouver Source Control Guidelines as follows:	

Table 1-2: DFO Stormwater Guidelines

Objective	*Target*
Volume Reduction	Retain the 6-month/24-hour post-development volume from impervious areas on-site and infiltrate to ground. If infiltration is not possible, the rate-of-discharge from volume reduction Best Management Practices (BMPs) will be equal to the calculated release rate of an infiltration system.
Water Quality	Collect and treat the volume of the 24-hour precipitation event equalling 90% of the total rainfall from impervious areas with suitable BMPs.
Detention or Rate Control	Reduce post-development flows (volume, shape and peak instantaneous rates) to pre-development levels for the 6-month/24-hour, 2-year/24-hour, and 5 year/24-hour precipitation events.
Notes: Flood conveyance events are not addressed in the DFO guidelines, but are stipulated by municipalities.	

Source: Greater Vancouver Sewerage & Drainage District, Stormwater Source Control Design Guidelines 2012

- It was observed that tree loss due to development or redevelopment could increase flows in streams due to increased impermeability
- The UEL Official Community Plan is in place but is dated
- AECOM need to verify stormwater attenuation requirements for Block F. Metro Vancouver requires up to 3 to 5 year events to be considered in the planning
  - Block F stormwater runoff rates, volume, and quality requirements are as follows:
    - Reduce post-development flow (volume, shape and peak instantaneous rates) to pre-development levels for the 6-month, 24 hour and the 5-year, 24 hour precipitation events.
    - Retain the 6-month, 24 hour post-development volume from impervious areas on-site and infiltrate into ground where it will not cause instability of steep slopes. If

infiltration is not possible, the rate of discharge from the "flow reduction BMPs" will be equal to the calculated release rate of an infiltration system. ▪ Collect and treat the volume of the 24-hour precipitation event equaling 90% of the total rainfall from impervious areas with vehicular traffic with suitable BMPs. • Jonn Braman noted that golf course has a water management plan which should be updated in July to comply with the drought management plans; currently no water reuse ▪ **AECOM to consult golf course as part of the ISMP** • Metro Vancouver members noted that Musqueam Aquatic Stewardship program may serve as a resource for potential educational programs or serve as an education resource • Reiteration of Metro Vancouver's mandate "to protect and connect" parks • Metro Vancouver Parks does not have a goal for fish spawning in Canyon Creek, presently there are no account of fish in this stream • Protecting life and property and maintain integrity of the cliffs should be part of the ISMP vision • Visioning for the ISMP should be complete after community consultation in the fall.	AECOM
Summary of Action Items • AECOM to provide Stage 1 summary report to Andrew Ling • AECOM to adjust drainage areas based on the updated information • AECOM to investigate a ditch line parallel to Hydro R.O.W. at Area A • AECOM to consult with UBC on geotechnical studies • AECOM to consult with University Golf Course as part of the ISMP • Andrew Ling (City of Vancouver) will provide information regarding drainage from backyards of properties along the east side of Spanish Bank Creek	
Next Steps: • Consultation with UBC and University Golf Course • Consultation with Community Advisory Council (CAC) • Visioning Workshop with Key Stakeholders – Streamkeepers, UBC, Golf Course, Metro Vancouver, and City of Vancouver (October/November) • Preparation of ISMP Implementation Plan • Preparation of ISMP Adaptive Management Plan	

Appendix C
ISMP Information Sheet

Integrated Stormwater Management Plan (ISMP)

An Integrated Stormwater Management Plan (ISMP) is an over-arching, long term strategy that focuses on protection and enhancement of a watershed's health. ISMPs combine concepts of urban planning, stormwater management, and environmental management to facilitate sustainable development within a watershed. An ISMP is an integral component of a local government's land development and growth management strategy because upstream activities including land use change have downstream consequences including flood and environmental risks. The primary goals of the ISMP are:

- Alleviate existing and/or potential drainage, erosion, and flooding concerns,
- Protect and/or restore stream health including riparian and aquatic habitat,
- Remediate existing and/or potential water quality issues.

The UEL is within the Greater Vancouver Sewerage & Drainage District (part of Metro Vancouver) and is developing an Integrated Stormwater Management Plan that is consistent with the requirements of Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRMP). The UEL consists of approximately 1200 hectares of land and is situated between the City of Vancouver and the University of British Columbia. The majority of the land (77%) is forested and the rest (23%) is developed for residential, commercial, institutional, and recreational land uses. The management of the rainfall that falls on the developed portion of the UEL community is the focus of this ISMP. The study area includes three watercourses - Spanish Bank Creek, Canyon Creek, and Salish Creek – that flow north into the Burrard Inlet. The area of the UEL that drains south to Fraser River is addressed through Musqueam Integrated Stormwater Management Plan.

The ISMP Development Process:
The UEL has retained AECOM Canada Inc. to develop the ISMP in line with the requirements of Metro Vancouver's ILWRMP and British Columbia's Environmental Management Act. Development of the ISMP will occur in four stages and was based on the approach outlined in Chapter 9: Developing and Implementing an ISMP in Stormwater Planning: A Guidebook for British Columbia.

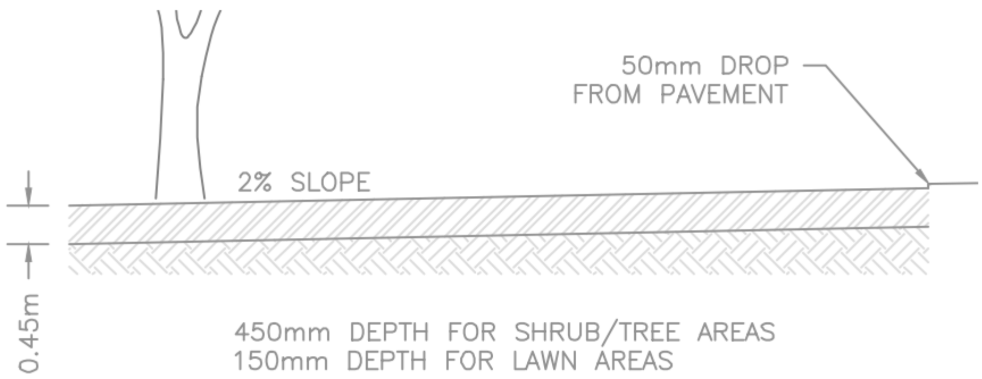
Stage 1 – What do we have? – Review background information and summarize existing conditions
(Review and summary of study area, regulatory context, land use, hydrology, stormwater system, hydrogeology and soils, environment, hydraulic modelling and assessment)
Stage 2 – What do we want? – Establish the vision, goals, and objectives for stormwater management
Stage 3 – How do we put this into action? – Develop an implementation plan, funding and enforcement strategies
Stage 4 – How do we stay on target? – Develop a monitoring and assessment program

Currently, AECOM is undertaking Stage 1 of the approach outlined above. The summary and review of background information is being put together to form a comprehensive report. As part of the information gathering exercise, initial contact regarding the project was made with Metro Vancouver Parks, City of Vancouver, Spanish Banks Streamkeepers, Pacific Spirit Park Society, University Golf Course, and the University of British Columbia to gain and document stormwater related information and concerns.

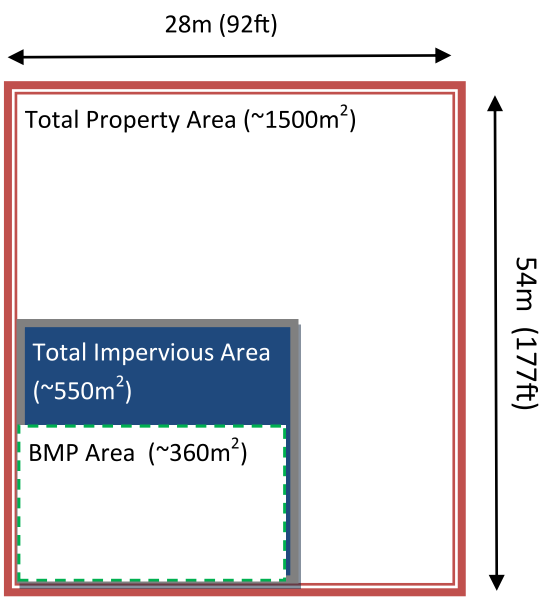
Next Steps?
As we move into the next phase of the project, we are asking the Community Advisory Council to weigh in. AECOM is invited to the October meeting to provide a presentation on the project, to answer any questions, and collect your feedback. There will be further opportunities for comment as the ISMP is developed.

Appendix D

ISMP Best Management Practices for Typical Single-Family Residential Lots at the UEL



Conceptual Cross Sectional Drawing of Absorbent Landscaping




Above: Example of absorbent landscaping
Photo Credit: GoogleEarth

General Notes:

1. Design on-site drainage from impervious areas to absorbent landscape areas (Max Ratio of Impervious Area to Pervious Area allowed is 2:1).
2. Ensure adequate depth of media for stormwater needs—150mm depth for lawns and 450mm for trees/shrubs
3. Ensure presence of organic content at 8% for lawns and 15% for tree and planting beds.

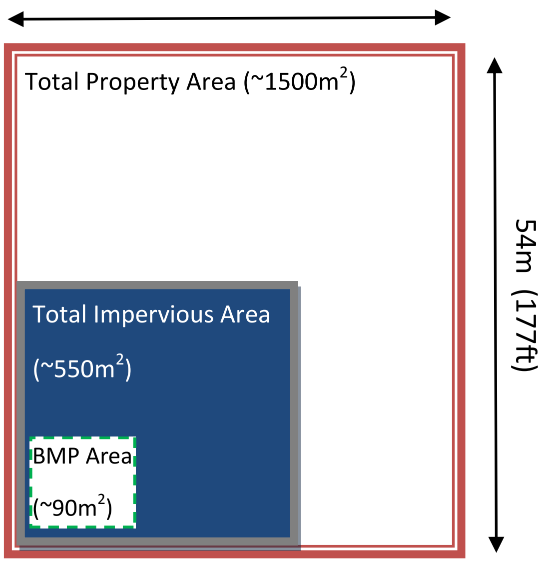
Maintenance:

1. Routine upkeep as part of regular yard maintenance.
2. Provide protection from sediment deposition onto the landscaped areas
3. Do not use fertilizers or pesticides of any kind.
4. Pruning and mulching are recommended on annual basis.

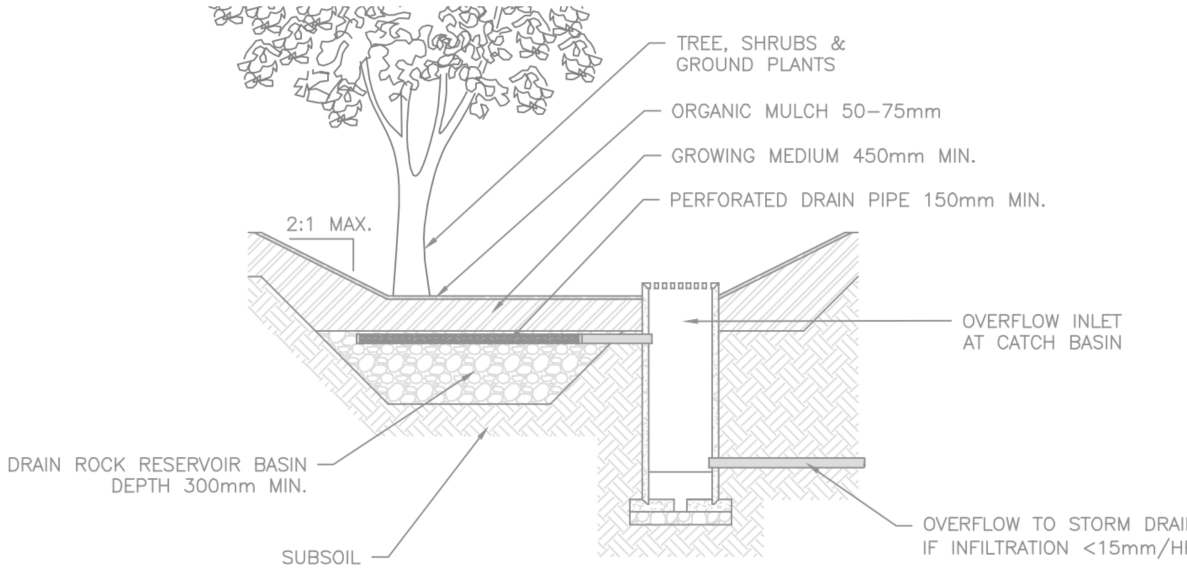
University Endowment Lands Integrated Stormwater Management Plan	Stormwater BMPs for a Typical Single-Family Residential Lot **Absorbent Landscape**	Project 6022155 Date March 2017	AECOM / BRITISH COLUMBIA

Above: Example of on-site stormwater rain garden

Photo Credit: designbuzz.com



(not to scale)



Conceptual Cross Sectional Drawing of Rain Garden

General Notes:

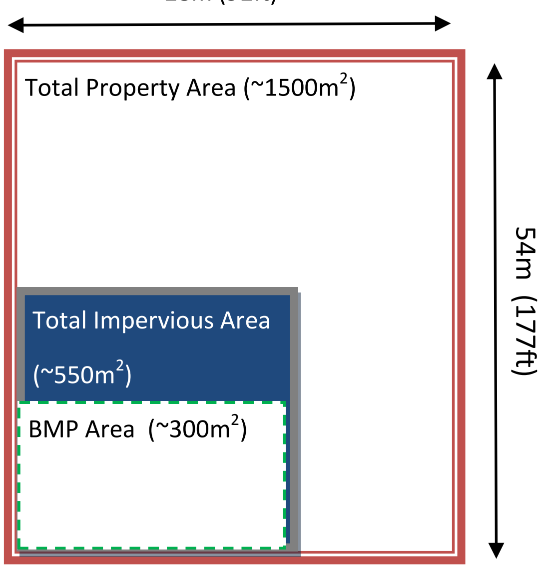
1. On-site stormwater rain gardens should be located 3 meters from the house and 12 meters from steep slope.
2. Design rain gardens to drain within 48 hours to reduce risk of standing water and mosquito breeding.
3. Max Ratio of Impervious Area to Pervious Area allowed is 50:1 for single-family residential lots

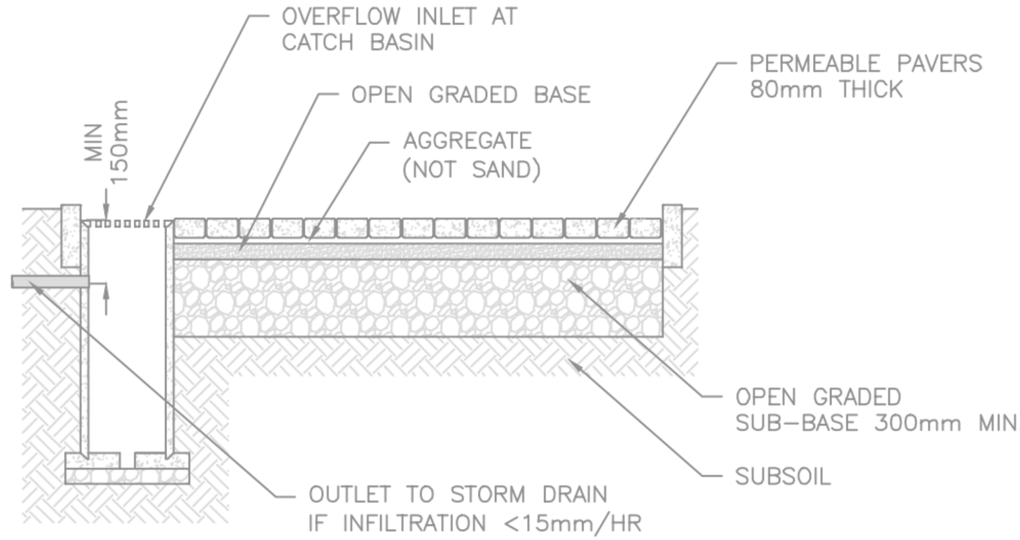
Maintenance:

1. Routine upkeep as part of regular yard maintenance.
2. Weeding and irrigation is essential until recommended rain garden plants have been established (use native and drought tolerant plants as prescribed in Schedule C of the Works and Services Bylaw).
3. Do not use fertilizers or pesticides of any kind.

University Endowment Lands Integrated Stormwater Management Plan	Stormwater BMPs for a Typical Single-Family Residential Lot **Rain Garden**	Project 6022155 Date March 2017	AECOM / BRITISH COLUMBIA

Above: Example of on-site pervious paving
Photo Credit: mnrhardscaping.ca





Conceptual Cross Sectional Drawing of Pervious Pavement

General Notes:

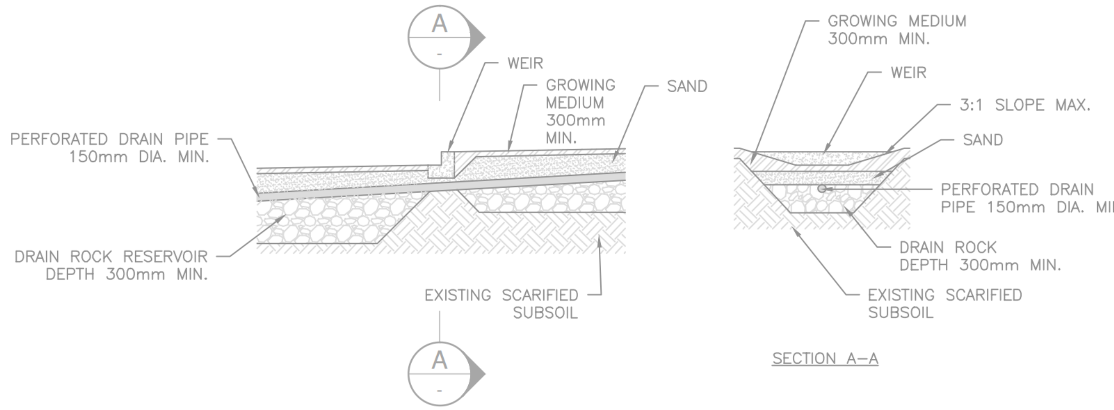
1. Direct on-site drainage from impervious areas to pervious pavement areas (Max Ratio of Impervious Area to Pervious Area allowed is 2:1).
2. Plant vegetation in between or around pavers.
3. Do not use pervious pavement BMP in areas with high sediment loads that can clog porous areas.

Maintenance:

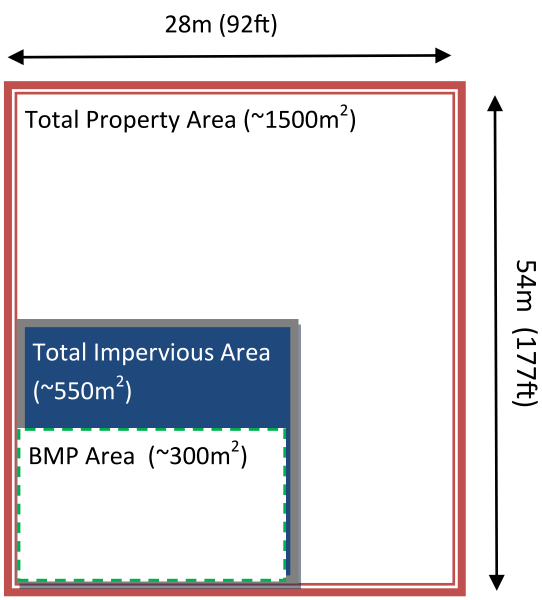
1. Keep impervious areas draining to pervious pavement free of sediment to prevent clogging.
2. Perform annual sweeping and vacuuming to maintain permeability.
3. Remove weeds and invasive plants from in-between pavers.

University Endowment Lands Integrated Stormwater Management Plan	Stormwater BMPs for a Typical Single-Family Residential Lot **Pervious Pavement**	Project 6022155 Date March 2017	AECOM / British Columbia

Above: Example of bioswale/ infiltration swale
Photo Credit: NRCS, US Department of Agriculture



Conceptual Cross Sectional Drawing of Infiltration Swale



General Notes:

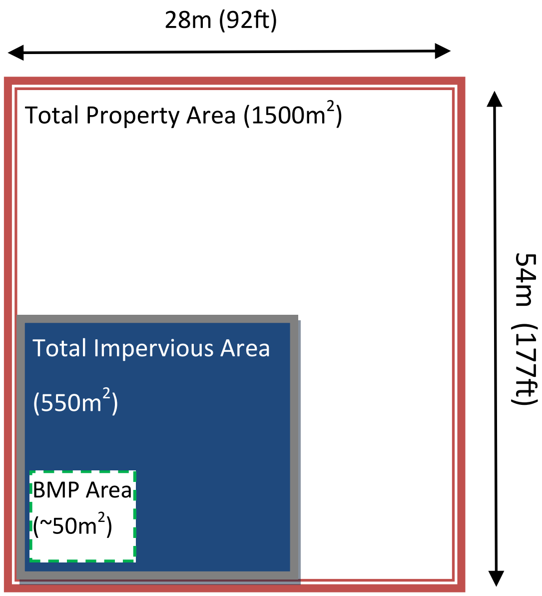
1. Slope swales at a minimum of 2% from beginning to end to convey water
2. Direct on-site drainage from impervious areas to pervious pavement areas (Max Ratio of Impervious Area to Pervious Area allowed varies between 20:1 and 50:1 depending on impervious surface type).
3. Plant native or drought tolerant vegetation.
4. Do no allow heavy machinery into the swale to prevent soil compaction

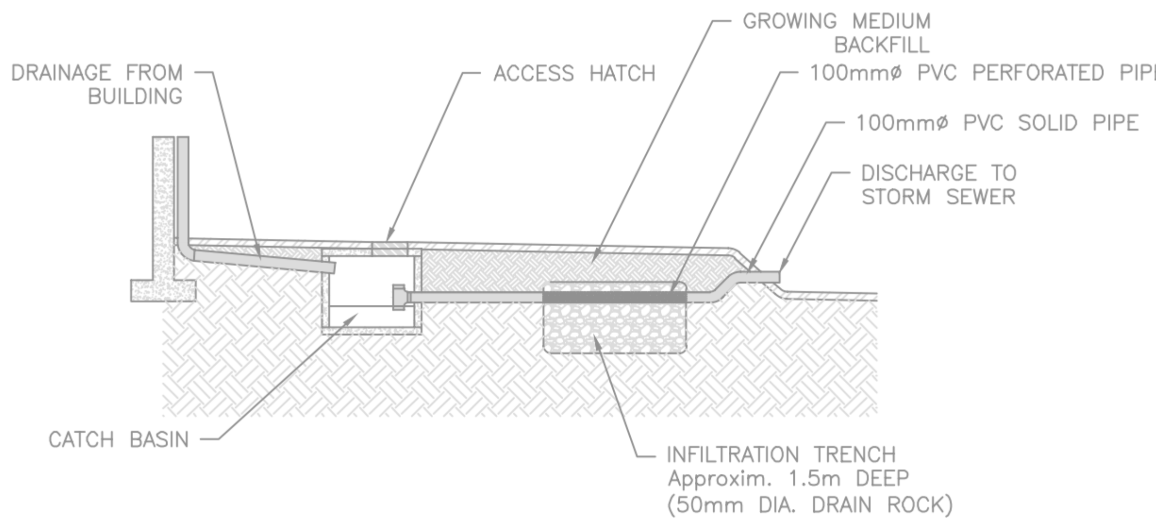
Maintenance:

1. Protect swale from erosion potential before the plants in the swale are well established.
2. Perform mowing in spring and fall (to 3 inches), weed control, vegetating bare areas, clearing debris and accumulated sediment.

University Endowment Lands Integrated Stormwater Management Plan	Stormwater BMPs for a Typical Single-Family Residential Lot **Infiltration Swale**	Project 6022155 Date March 2017	AECOM BRITISH COLUMBIA

Above: Example of an infiltration trench
Photo Credit: SuDs Wales, Sustainable Drainage Systems





Conceptual Cross Sectional Drawing of Infiltration Trench

General Notes:

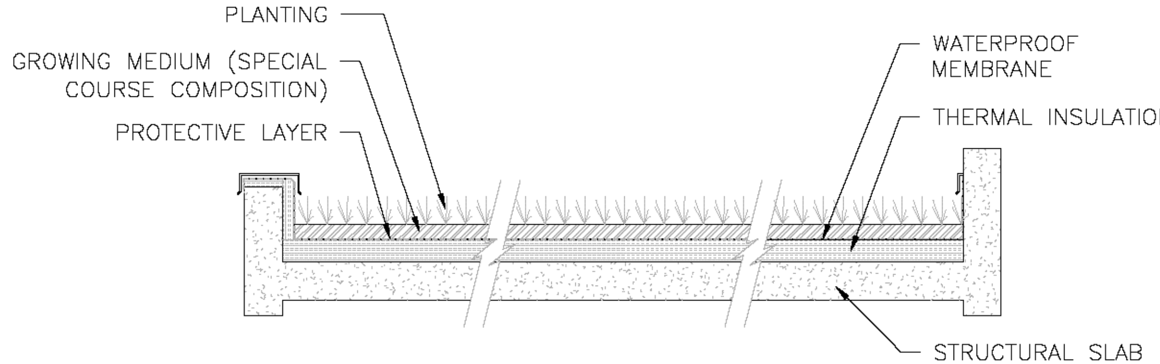
1. All infiltration structures must be professionally designed and constructed. There is a high risk of failure for improperly sited, designed, or maintained infiltration trench.
2. Maximum impervious/pervious surface area ratio is 50:1 for single-family lots
3. Do not build infiltration trench in area with high sediment input.
4. Design the infiltration trench to drain within 72 hours.

Maintenance:

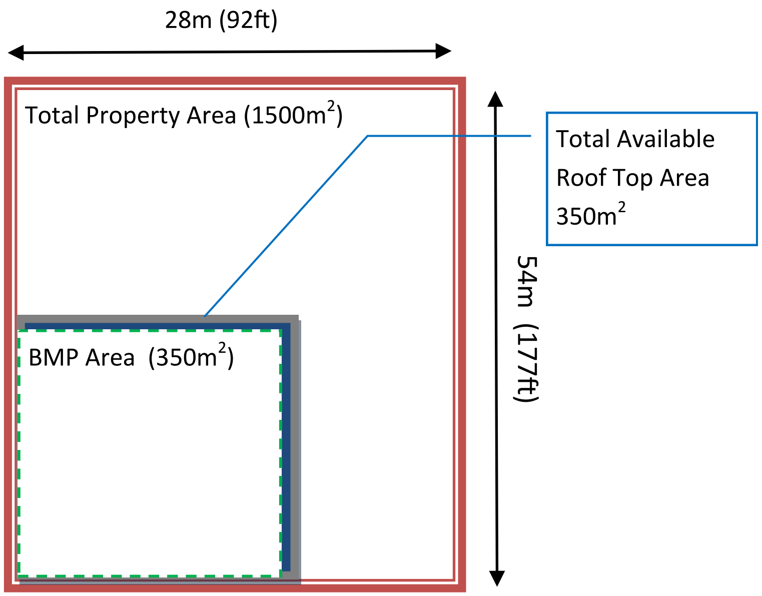
1. Specific inspection and maintenance schedule is required.
2. Inspect during and after a major precipitation event in the first year. Inspect twice per year in consequent years.
3. Remove garbage and plant debris on a regular basis.
4. If the infiltration structure appears clogged, consult a professional immediately for repair requirements.

University Endowment Lands Integrated Stormwater Management Plan	Stormwater BMPs for a Typical Single-Family Residential Lot **Infiltration Trench**	Project 6022155 Date March 2017	AECOM / BRITISH COLUMBIA

Above: Example of a green roof
Photo Credit: Vancouver Convention Centre



Conceptual Cross Sectional Drawing of Green Roof



General Notes:

1. Summer rainfall retention—70-90% ; Winter rainfall retention—25-40%
2. Identify and select growing medium/material and loading capacity to suit climate.
3. Rooftop slope should not exceed 20%

Maintenance:

1. Maintenance depends on the type of plants, growing medium and climate/ weather conditions.
2. Irrigate as required to establish the vegetation.
3. Perform regular inspections for damage, roots penetrating the waterproof membrane, debris, invasive species, and weeds

University Endowment Lands Integrated Stormwater Management Plan	Stormwater BMPs for a Typical Single-Family Residential Lot **Green Roof**	Project 6022155 Date March 2017	AECOM British Columbia

Appendix E

Adaptive Management Practices recommended for specific impacts
(Table 8 in Metro Vancouver Monitoring and Adaptive Management Framework
for Stormwater, 2014)

Table 8 - Adaptive Management Practices recommended for specific impacts

Indicator	AMP Trigger	Impact	Examples of Recommended AMPs
Dissolved Oxygen (DO)	Exceeds satisfactory or need attention thresholds	• potential impacts to resident fish, such as salmonids (intolerant to reduced DO) • potential alterations to benthos communities – loss of intolerant taxa	• enhancement of riparian areas to increase shading (reduce water temperatures and increase oxygen carrying capacity) • instream habitat to enhance aeration (e.g. riffles) • source controls (to reduce organic matter and associated consumption of oxygen)
Water Temperature	Exceeds satisfactory or need attention thresholds	• potential impacts to resident fish, such as salmonids (intolerant of elevated temperatures) • potential alterations to benthos communities – loss of intolerant taxa	• enhancement of riparian areas (plantings) to increase shading • retention or re-establishment of tree cover • reducing impervious surfaces • in-stream complexing to provide increased shading / cover
Turbidity	Exceeds satisfactory or need attention thresholds	• potential impacts to fish including smothering of eggs and direct impacts to fish gills; also potential impacts on fish behaviour and feeding • potential alterations to benthos communities (e.g., reduced feeding activity of filter feeders)	• inventory and assessment of erosion sites and implementation of remedial actions as applicable • operations and maintenance activities such as street cleaning and catch basin cleanout • establishment and enforcement of sediment / erosion bylaws / policies • education and outreach
Nutrients (e.g., Nitrates)	Exceeds satisfactory or need attention thresholds	• potential for increased algal growth within watercourse which could alter resident aquatic communities such as benthos • direct toxicity of nitrate to amphibians and aquatic life • potential indirect impacts to aquatic biota due to reduced dissolved oxygen levels	• identification of sources and implementation of appropriate source controls (e.g., cross connections, control of runoff from agricultural fields; application of fertilizers on fields during wet periods, septic field and yard maintenance education, etc.)
Metals	Exceeds satisfactory or need attention thresholds	• potential direct toxicological impacts to aquatic biota • potential accumulation of metals in sediments	• identification of sources and implementation of appropriate source controls (e.g., swales, infiltration galleries, disconnect downspouts, detention ponds/tanks, etc.) • educational programs
Microbiological Parameters	Exceeds satisfactory or need attention thresholds	• potential human health issues if water is used for recreation or irrigation • no direct impacts to aquatic biota, however high bacteria levels can be associated with loadings of organics and nutrients that can affect dissolved oxygen levels	• source controls, dog waste mgmt; control of agricultural and urban runoff • educational programs • cross connection ID

Metric	Simple Definition	Observed Change	Indicates	Effect	Related BMP
T_{Qmean}	Days per year that flows exceed the mean annual flow rate.	Lower than pre-development value, or decreasing trend	increased flashiness	• more frequent disturbance of benthic organisms • increased erosion and sediment deposition • increased pollutant loads	• source controls • runoff detention facilities • riparian buffer • wetland rehabilitation/construction • infiltration facilities
Low Pulse Count	Number of times per year the flow decreases below half of the mean annual flow rate	Higher than pre-development value, or increasing trend	more frequent interruption of seasonal low flows by small runoff events	• disruption of benthic organisms and salmonid alevins/fry • increased pollutant loads	• source controls • runoff detention facilities • riparian buffer • wetland rehabilitation/construction • rain gardens, infiltration facilities
Low Pulse Duration	Amount of time (days) that the flow is below half of the mean annual flow rate.	Lower than pre-development value, or decreasing trend	more frequent interruption of seasonal low flows by small runoff events	• disruption of benthic organisms and salmonid alevins/fry • increased pollutant loads	• source controls • runoff detention facilities • riparian buffer • wetland rehabilitation/construction
Summer Baseflow	Dry weather average flow rate during summer months.	Altered from pre-development value, increasing or decreasing trend	alteration of water table elevation due to groundwater pumping, surface water abstraction or diversion, drainage, or irrigation with imported water	• drying of stream channels, fish stranding, desiccation of biota • decreased flow available for water supply	• wetland rehabilitation/construction • soil augmentation • infiltration facilities • protection of groundwater recharge areas • limit groundwater pumping for foundation protection (require underground structures to be tanked)
Winter Baseflow	Dry weather average flow rate during winter months.	Lower than pre-development value, or decreasing trend	decreased shallow subsurface storage	• decreased pool habitat • decreased flow for available for water supply	• source controls • runoff detention facilities • riparian buffer • tree retention and re-establishment • wetland rehabilitation/construction • retention and re-establishment of trees
High Pulse Count	Number of times per year the flow rises above twice the mean annual flow rate	Higher than pre-development value, or increasing trend	more frequent runoff events	• more frequent disturbance of benthic organisms • increased erosion and sediment deposition • increased pollutant loads	• source controls • runoff detention facilities • riparian buffer • wetland rehabilitation/construction • retention and re-establishment of trees
High Pulse Duration	Amount of time (days) that the flow is above twice the mean annual flow rate.	Lower than pre-development value, or decreasing trend	faster rise and recession of stormflow	• more frequent disturbance of benthic organisms • increased erosion and sediment deposition • increased pollutant loads	• source controls • runoff detention facilities • riparian buffer • wetland rehabilitation/construction

Appendix F

Stage 3 and 4 Presentation to the UEL Community Advisory Council

University Endowment Lands

Integrated Stormwater Management Plan

Stage 3 & 4 Reports

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May 15, 2017

BRITISH COLUMBIA

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Agenda

1. Work completed to date
2. Stage 3 Report Summary
3. Stage 4 Report Summary
4. Discussion

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Work completed to date

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UEL ISMP Approach

Stage	Question Answered	Description of tasks	Relevant ISMP Sections
1	What do we have?	Review background information and summarize existing conditions	- Study Area - Regulatory Context - Land Use - Hydrology - Stormwater System - Hydrogeology and Soils - Environment - Hydraulic Modelling and Assessment
2	What do we want?	Establish the vision for future development	- Vision and Goals
3	How do we put this into action?	Development of an implementation plan, funding and enforcement strategies	- Implementation Plan
4	How do we stay on target?	Development of a monitoring and assessment program	- Adaptive Management Plan

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Stormwater Management Vision and Goals

"A stormwater management plan that protects the natural and built environment through enhancement of natural watercourses, and provides opportunities for collaboration and engagement with community and residents on stormwater issues"

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Stormwater Management Vision and Goals

Goal 1: The UEL community is engaged in stormwater management

Goal 2: Healthy streams and a natural environment are a part of the UEL

Goal 3: Stormwater infrastructure provides an adequate level of service, while protecting life and property

Goal 4: The UEL provides guidelines and a regulatory framework for stormwater management

Goal 5: Stormwater management at UEL adapts to change

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Comments from Stage 2 Report?

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Stage 3

Development of an Implementation Plan

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UEL ISMP Stage 3
Development of an Implementation Plan

10 Action Items were identified and are proposed for implementation to help the UEL meet the goals and the vision established in Stage 2

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Action Item #1:

Promote stormwater management awareness and engagement opportunities

- Promote Spanish Bank Streamkeepers
- Retain all stormwater reports and study results on record

In this issue:

- Snow Removal Policy
- Area A & B Parking
- Recycling
- UEL Waste Collection
- Boulevard Maintenance
- Sewer Work in Area A

Sewer Work – Area A

The UEL will be completing sewer work in Area A this winter and spring. Residents directly affected by work will be notified in advance. Sewer work will be followed by repaving, weather permitting. Please be patient with work crews and anticipate some traffic delays.

Water Billing – Next Cycle Ends December 31, 2016

Water bills will be sent out to residents and businesses of the UEL. Payments can be mailed or dropped off at the UEL Administration Office. We accept cheques by mail, or cash or cheque in person. Water payments should be made out to "University Endowment Lands" and should reference your **Address** and **Water Account ID** (located on the top right corner of your invoice).

Garbage and Green Bin

The UEL is responsible for garbage and green bin pick-up in the UEL. Waste pickup varies by neighbourhood. Schedules can be picked up from the box outside of the UEL office or accessed on our website.

UEL University Endowment Lands

Winter Newsletter - 2016

Christmas Tree Disposal

Wondering how to dispose of your Christmas tree following the holiday season? UEL residents can participate in the UBC Botanical Garden Christmas Tree Recycling Fundraiser for John Norquay Elementary School. Trees can be dropped off:

- Between **December 26, 2016** and **January 8, 2017**
- **9:30am – 4:30pm daily** at the **UBC Botanical Gardens**
- http://botanicalgarden.ubc.ca/events/event/tree-recycling/

Please visit their website for more information or call 604-822-3928. The suggested donation is $5.

For those unable to safely dispose of their trees, UEL will provide a tree pick up service for Areas A, B and C on **Wednesday, January 11, 2017**. Please ensure that all tinsel, lights, decorations and tree stands are removed.

- Areas A & B place tree at curb side no later than 7:30 AM
- Area C place tree in lane no later than 7:30 AM

Any questions regarding tree removal can be directed to the UEL Administration Office at 604-660-1808.

Snow Removal Policy

The UEL would like to remind its residents of their responsibility to clear the sidewalk fronting their home and/or business.

Parking Permits – Area A & B – New Decals!

Are you a resident of Area A or B? Was your parking decal acquired before August 2015 (the older decals can be identified as the white decals)? Then please come to the UEL office with proof of residence and your vehicle's registration to obtain a new RED (Area A) or BLUE (Area B) Parking Decal!

Residents of Areas A & B are reminded to park in their driveway. If that's not possible, residents are permitted to park on the road in front of their home, so long as their vehicle is registered with the UEL and has the appropriate decal. These decals do not permit vehicles to park in other areas of the UEL.

Parking Permits – Multi-Family Area

All 2015-2016 multi-family parking permits expired at the end of September 30, 2016. Please come to the UEL office with photo ID, proof of residency (Tenancy Agreement or a letter from the Property Manager confirming residency) and vehicle registration with the appropriate address and resident's name listed as the principal operator. **Vehicles without valid permits will be towed at the owner's expense and without notice.**

British Columbia | Ministry of Community, Sport and Cultural Development | University Endowment Lands Administration Office, 5495 Chancellor Boulevard, Vancouver BC V6T 1E2 | P: (604) 660-1808, F: (604) 660-1874, UEL@gov.bc.ca | www.universityendowmentlands.gov.bc.ca, The Office is open Monday – Friday 8:30 am – 4:30 pm

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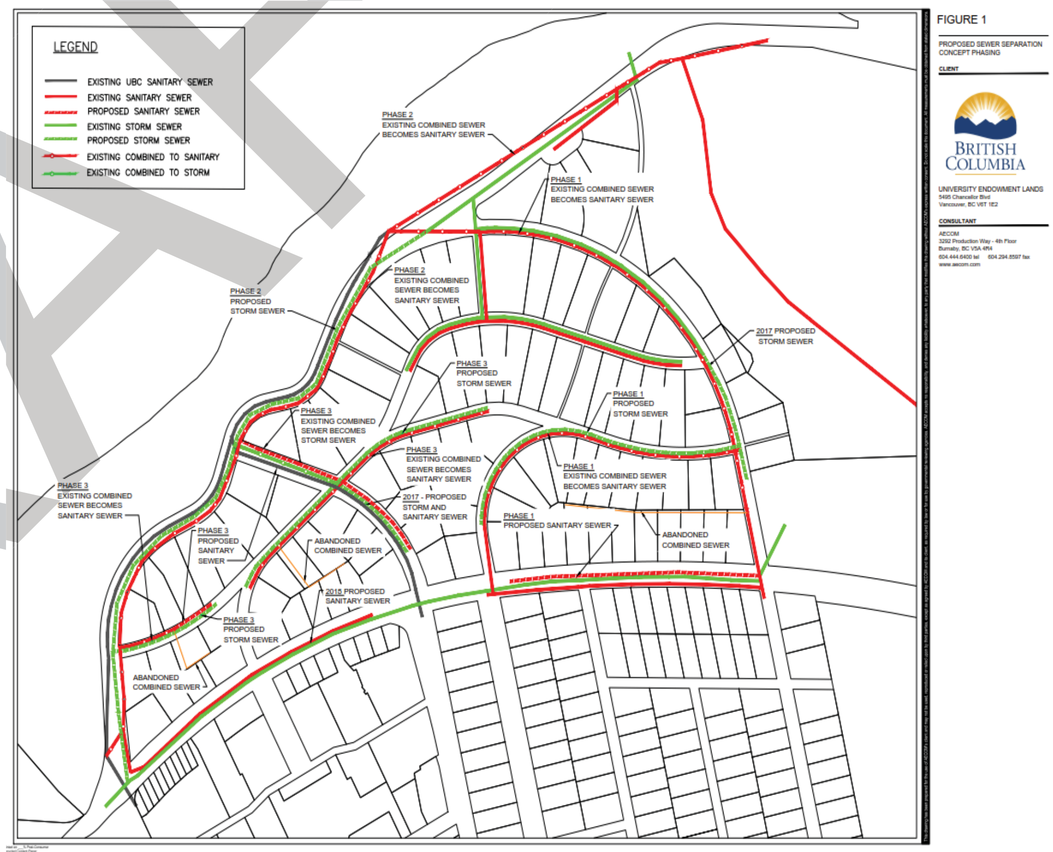
Action Item #2:

Continue to implement UEL's combined sewer separation strategy

- Currently in implementation phase of separating existing combined sewers in Area B
- Sewer separation helps reduce combined sewer overflows, sewage backups, and negative impact on baseflows in the Acadia Creek
- Opportunity to implement BMPs, such as rain gardens, to manage stormwater efficiently



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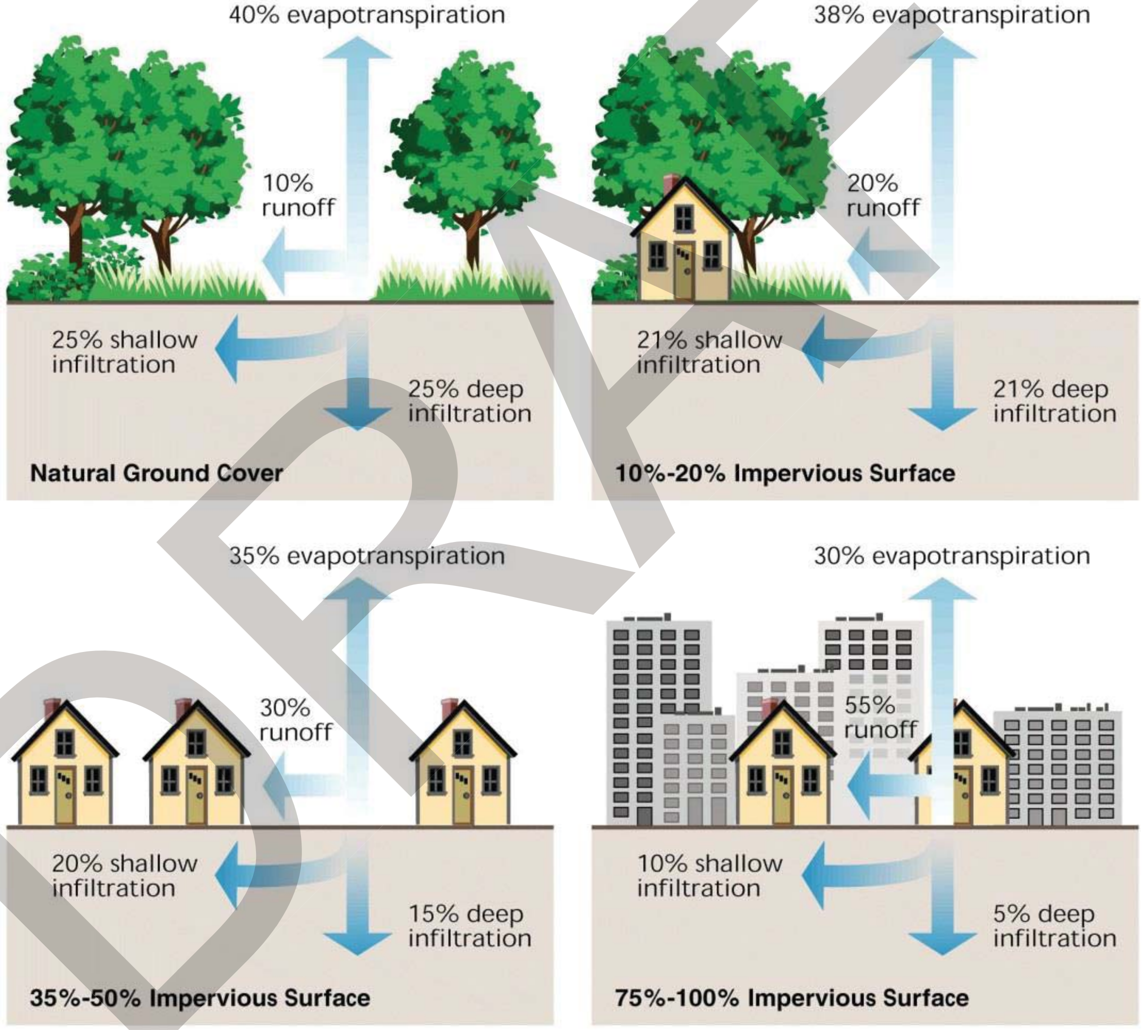
Action Item #3:

Manage the quantity of road runoff



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Action Item #3:

Manage the quantity of road runoff

- Reduce impact of increased impervious areas
  - Decrease stream erosion
  - Groundwater recharge
  - Increased stream baseflows

- Rain gardens provide a plausible solution

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Action Item #4:

Upgrade stormwater treatment at the UEL Works Yard

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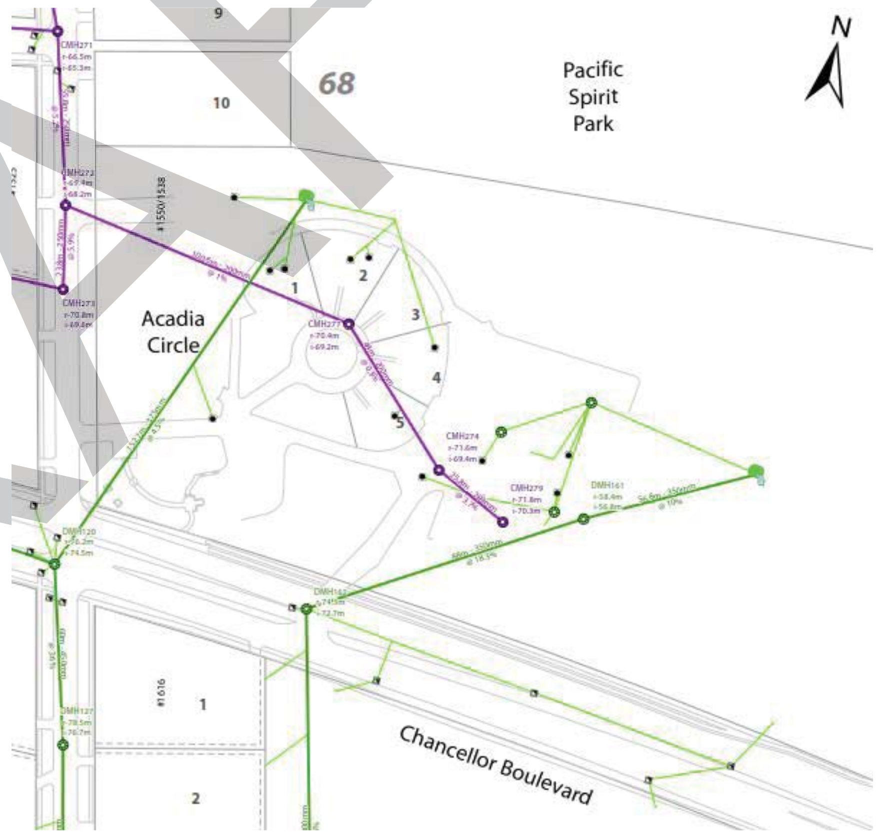
Action Item #4:

Upgrade stormwater treatment at the UEL Works Yard



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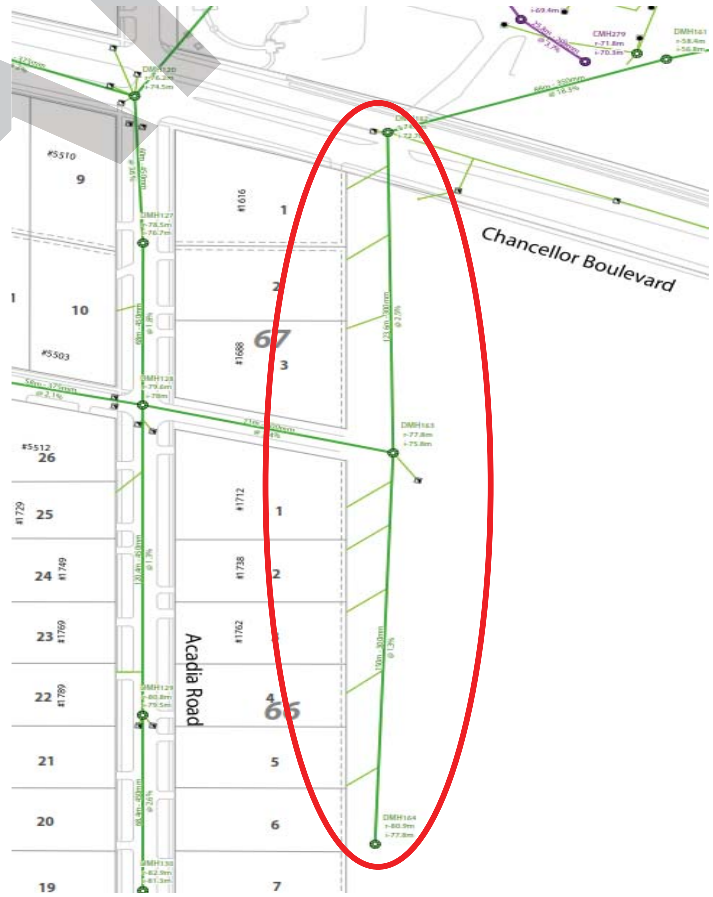
Action Item #5:

Identify stormwater infrastructure that are poorly located for maintenance. Develop plans for management or replacement.

(i.e. the 300mm diameter storm sewer in Pacific Spirit Park east of Acadia Road)



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Action Item #6:

Continue to upgrade system capacity and renew aging infrastructure in a proactive manner through the capital planning process

Project Reference Number	Description
2015-02	Construction of stormwater/sanitary sewer separation on Wesbrook Cres, north of Chancellor Blvd.
2016-02	Construction of storm sewer replacement on Wesbrook Cres. South of Chancellor Blvd.
2016-01	Construction of new storm sewer on Alison Rd between Campus Rd. and College Highroad, and on Western Parkway between College Highroad and University Blvd.
2017-02	Design and construction of storm sewer replacements on lane north of College Highroad
2018-01	Construction of sanitary/stormwater separation on Acadia Rd. north of Chancellor Blvd.
2018-02	Design and construction (reline) of storm sewer on Drummond Dr. and College Highroad
2021-01	Construction of Water, Sewer and Road replacement on Newton Wynd between Acadia Rd. and Kingston Rd.
TBC-02	Construction of storm sewer replacement on lane north of Wycliffe Rd.

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Action Item #7:

Develop mitigation measures to address slope stability in Area B

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Action Item #8:

Integrate stormwater asset maintenance with work order management using a GIS-centric system

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Action Item #9:

Develop Erosion and Sediment Control requirements

BULLETIN 2002-003-EV | March 1, 2017
EROSION AND SEDIMENT CONTROL LARGE LOT DEVELOPMENTS (1,000M² OR MORE) | (Revised)

EROSION AND SEDIMENT CONTROL (ESC) MONITORING CRITERIA

Applicable Bylaw	Sewer and Watercourse Bylaw No. 8093 (the Bylaw)
pH Requirements	Discharge water to have a pH of 6.0-9.0
Turbidity Requirements	Discharge water Total Suspended Solids (TSS) not to exceed 75mg/L.
Environmental Monitoring	Must be completed by a Qualified Person (QP). Acceptable designations include Applied Science Technologist (ASc.T), Environmental Professional in Training (EPt) or EP, BC Certified Erosion and Sediment Control Lead (CESCL) or equivalent, Engineer in Training (EIT), Professional Engineer (P. Eng), and Biologist in Training (BIT) or higher.
Monitoring Frequency	Dry Season (May-Sept): Bi-weekly Wet Season (Oct-Apr): Weekly Additional monitoring is required within 24 hours of a significant rainfall event (SRE) (>25 mm in 24 hrs). Additional monitoring is not required if the SREs are within 48 hours of each other. Discharge water sampling can cease once the Site is connected to the City sewer system or with written approval from Environmental Protection. Monitoring of best management practices should continue for the duration of the project. Monitoring frequency can be modified upon agreement in writing between the City Inspector and the Contractor or QP.
Sampling Parameters	Samples will be submitted for laboratory analysis of TSS if field testing results exceed the Trigger Value of 45 nephelometric turbidity units (NTU)** The Environmental Monitor may be permitted to submit a Site specific calibration curve to the City if analytical results are consistently below 75 mg/L. If the field measurements exceed 45 NTU or if the pH is less than 6.0 or greater than 9.0, the Contractor **must cease discharge** until appropriate remedial measures have been undertaken.
Report Submission	Templated report submitted within 48 hours of the monitoring event for Sites which are out of compliance. Templated report submitted within 7 days of the monitoring event for Sites which are in compliance. If laboratory analysis is required, the analytical results must be submitted within 7 calendar days. Reports are to be submitted to: environmentalprotection@vancouver.ca
Site Maintenance	No sediment-laden water from the work site shall be pumped out or otherwise discharged directly to a storm sewer system, water course, or other drainage system in such a manner as to bypass the sediment control system. Deficiencies identified by the Environmental Monitor are to be resolved as soon as practically possible.
Removal/Alterations of Treatment Works	No changes to the water treatment system are to be made without the City's Environmental Protection approval. A written request must be approved by Environmental Protection. A Site inspection may be required prior to approval.

DOC/2016/359505 | Page 2 of 3

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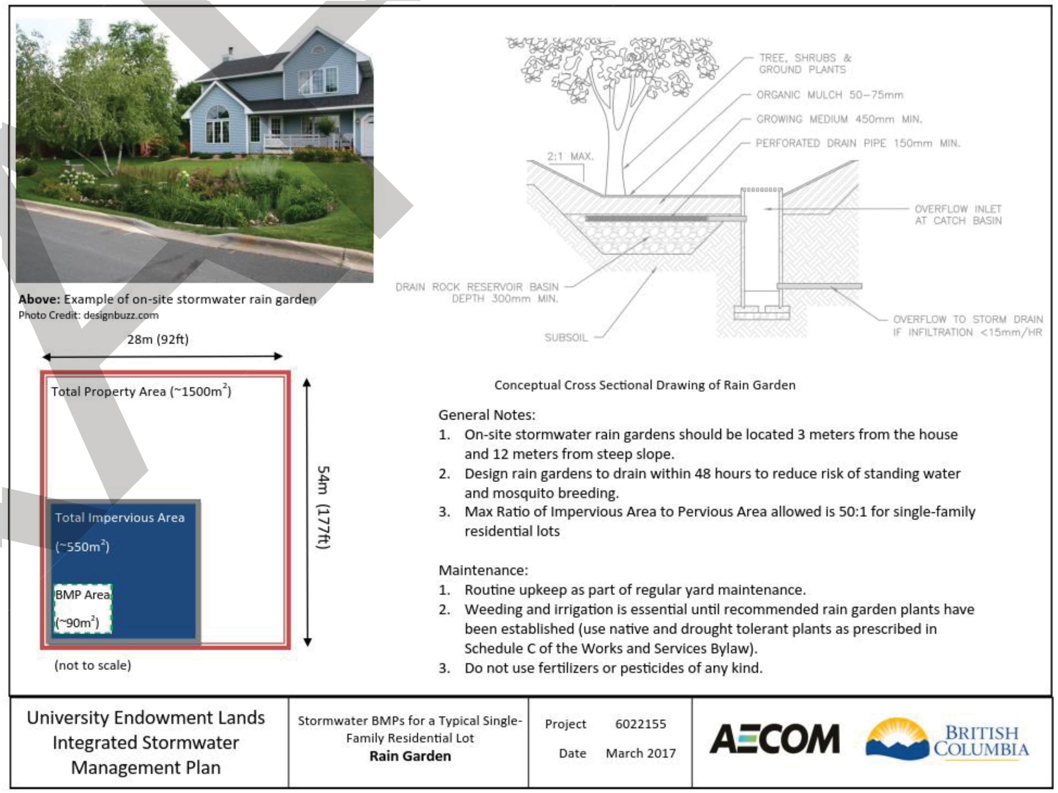
Action Item #10:

Control runoff from private properties

- Review and formalize stormwater discharge limits for developments
- Provide options for developers for limiting stormwater runoff



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Summary of Stage 3 Action Items

1. Promote stormwater management awareness and engagement opportunities
2. Continue to implement UEL's combined sewer separation strategy
3. Manage the quantity of road runoff
4. Treat stormwater runoff from the UEL Works Yard
5. Decommission, where possible, pipes that are poorly located for maintenance and replacement (i.e. the 300mm diameter storm sewer in Pacific Spirit Park east of Acadia Road)
6. Continue to upgrade system capacity and renew aging infrastructure in a proactive manner through the capital planning process
7. Establish areas of no infiltration at the UEL so as not to threaten slope stability
8. Integrate stormwater asset maintenance with work order management using a GIS-centric system
9. Develop Erosion and Sediment Control requirements
10. Control runoff from private properties

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Stage 4

Adaptive Management Plan

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Metro Vancouver's Monitoring and Adaptive Management Framework

Recommended Monitoring Programs

- Piped System
  - Water Quality
- Lower Gradient System
  - Water Quality
  - Flow (Natural Channels Only)
- Higher Gradient System
  - Water Quality
  - Flow
  - Benthic Invertebrates

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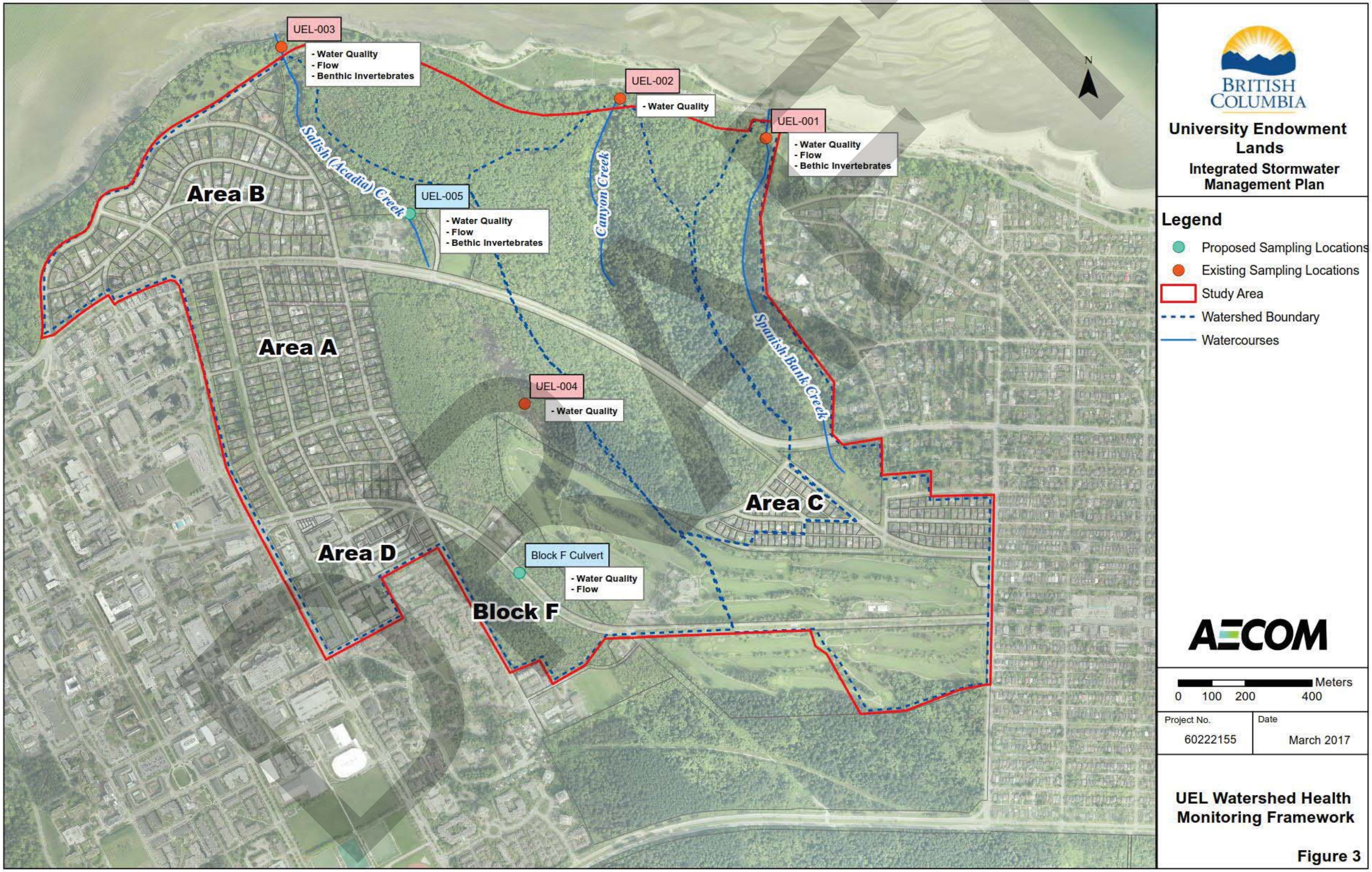
Monitoring Watershed Health



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Adaptive Management

Assessment of Watershed Health Monitoring Results

- Water Quality Results
- Flow Monitoring Results
- Benthic Invertebrate Sampling Results

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Adaptive Management

Assessment of Watershed Health Monitoring Results

For Example,

Water Quality Assessment Criteria (MAMF, 2014)

	Good Level	Satisfactory Level	Need Attention Level
General Parameter			
Dissolved Oxygen (mg/L)	≥ 11	6.5 to < 11	< 6.5
pH	6.5 to 9.0	6.0 to < 6.5 or > 9.0 to 9.5	< 6 or > 9.5
Water Temperature (° C)			
Low flow summer	< 16	16 to 18	>18
Wet Weather	7 to 12	5 to <7 or >12 to 14	< 5 or > 14
Conductivity (μS/cm)	< 50	50 to 200	> 200
Turbidity (NTU)	≤ 5	> 5 to 25	> 25
Nutrients			
Nitrate as Nitrogen (mg/L)	≤ 2	2 to 5	> 5
Microbial Parameters			
E.coli (freshwater) (CFU/100ml)	Geomean ≤ 77	Geomean between 78 - 385	Geomean > 385
Fecal coliform (CFU/100ml)	Geomean ≤ 200	Geomean between 2201 - 1,000	Geomean > 1,000
Metals (Total Metals) (μg/L)			
Iron	< 800	800 to 5,000	> 5,000
Cadmium	< 0.06	0.06 to 0.34	> 0.34
Copper	< 3	3 to 11	> 11
Lead	< 5	5 to 30	> 30
Zinc	< 6	6 to 40	> 40

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Adaptive Management Practices

- Source Control Measures
  - Absorbent Landscaping
  - Rain Gardens
  - Pervious Pavement, and etc.
- Education and Public Outreach
- Cross Connection Control
- Runoff Detention, Retention, and Treatment Facilities
- Riparian Habitat Restoration
- Mitigation of Construction Impacts

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Stage 4 Report In Summary

1. Monitor watershed health at strategic locations
2. Evaluate results of monitoring according to available criteria
3. Adapt to changes in watershed health through implementation of Adaptive Management Practices

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Thank You!

Discussion and Questions

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May 15, 2017

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About AECOM

AECOM is built to deliver a better world. We design, build, finance and operate infrastructure assets for governments, businesses and organizations in more than 150 countries. As a fully integrated firm, we connect knowledge and experience across our global network of experts to help clients solve their most complex challenges. From high-performance buildings and infrastructure, to resilient communities and environments, to stable and secure nations, our work is transformative, differentiated and vital. A Fortune 500 firm, AECOM companies have annual revenue of approximately US$18 billion. See how we deliver what others can only imagine at aecom.com and @AECOM.

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