CIVIL ENGINEERING

CAPSTONE DESIGN PROJECT

Report No.

CECDP – 2015/03

# DAYLIGHTING OF GUICHON CREEK

## by DOMS & Associates Ltd.

(Hurd, 2006)

Steven Dindo
Kyle Doyle
Daniel Hurd
Samuel Jones
Michael Sheffer

March 2015

Department of Civil Engineering
School of Construction and the Environment
British Columbia Institute of Technology
Burnaby, BC, Canada, V5G 3H2

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March 2015

March 15, 2015

Martin Bollo, B.A.Sc., M.Eng., P.Eng.
British Columbia Institute of Technology
3700 Willingdon Avenue
Burnaby, BC, Canada, V5G 3H2

Dear Martin:

**Submission of Civil 7090 Capstone Design Project:**
**Daylighting Guichon Creek**

DOMS & Associates Ltd. is pleased to submit our Capstone Design Project report, as per CIVL 7090 course requirements. This report outlines the work completed for our group's project, Daylighting Guichon Creek. This project was conducted to explore possible solutions to civil engineering problems that would arise from daylighting the creek through BCIT's campus. We believe this is a helpful step to continue moving this project forward, and are confident this report will be of use in future years.

The attached report draft is an original, team submission and was composed entirely by the DOMS & Associates Ltd. team. We would like to thank the Capstone Committee, BCIT Facilities and Campus Development, and Jennie Moore for their assistance during this project. Also, our project sponsor, Ken Ashley of BCIT Rivers Institute has provided invaluable expertise and guidance to our team during this project, for which we are extremely grateful.

We would like to thank you for your support during our time at BCIT, especially this semester, and for taking the considerable time to review this report. We would be happy to address any questions or concerns, and can be reached at doms.associates@gmail.com. We look forward to receiving your feedback, and seeing this project progress.

Sincerely,

DOMS & Associates Ltd.

Steven Dindo    Kyle Doyle    Daniel Hurd    Samuel Jones    Michael Sheffer

Enclosed: Daylighting of Guichon Creek Project Report

cc: Ken Ashley, BCIT Rivers Institute
Mike Newall, BCIT Facilities and Campus Development

# DISCLAIMER

The work represented in this Client Report is the result of a student project at the British Columbia Institute of Technology. Any analysis or solution presented in this report must be reviewed by a Professional Engineer before implementation. While the students' performance in the completion of this report may have been reviewed by a faculty advisor, such review and any advice obtained therefrom does not constitute professional certification of the work. This report is made available without any representation as to its use in any particular situation and on the strict understanding that each reader accepts full liability for the application of its contents.

# ACKNOWLEDGEMENTS

As a team we would like to thank everyone who has sacrificed their valuable time to assist our team during this project. Specifically the following:

Ken Ashley, BCIT Rivers Institute – for offering us guidance throughout this entire project, and providing his expertise into the design requirements for fish passage. We also want to thank Ken for hosting our bi-weekly progress meetings at BCIT Rivers Institute.

Jennie Moore, BCIT – for being a champion of this project and for introducing us to the idea of daylighting Guichon Creek.

Mike Newall, BCIT – for helping provide drawings, information on Campus Development plans, and answering his door whenever we knocked, literally.

Barry Chilibeck, NHC – for providing guidance and clarity through this ambiguous task.

BCIT Civil Engineering Capstone Committee, specifically: Martin Bollo, Colleen Chan, Renatta Wood, and Paul Thurston. Your confidence in our unorthodox project enabled to explore beyond our comfort zone. We are grateful for this. Thank you for your continued commitment to us as students, and enduring teaching us all for the last four years.

# EXECUTIVE SUMMARY

Rehabilitation of urban streams has captured the imagination of the general public. Where developers once sought to conquer the challenges of the environment, a new paradigm of low-impact development is gaining momentum in our society. This vision of harmonious growth has combined with efforts to undo past harms and restore a natural balance to urban ecosystems. Once a vibrant aquatic habitat, Guichon Creek has been buried below British Columbia Institute of Technology's Burnaby Campus for over 50 years. The following summarizes DOMS & Associates investigation into the possibility of daylighting Guichon Creek.

The aim of this BCIT Civil Engineering Capstone Project is to provide proposed alignment designs and to identify the civil related problems each alignment faces. This report is designed to offer guidance as the project moves forward, and provide direction for further work towards daylighting Guichon Creek.

Currently Guichon Creek is conveyed through a buried arch culvert for over 700 m, approximately half of its length on campus. This arrangement neglects the needs of fish and other wildlife by preventing continuous passage to the upper creak reaches. Migrating salmon and other aquatic species have been unable to access their historical spawning habitat further upstream along Guichon Creek. Salmon have been observed in the reaches downstream of the culverted sections, frustrated by the barriers to their natural migratory rhythms.

Recent policy shifts at various levels of government have promoted the benefits of daylighting urban steams. Examples of successful projects around the world demonstrate that daylighting can offer substantial economic, environmental, and societal benefits. These benefits align with BCIT Facilities and Campus Development's future plans for campus development and growth. As such, a desire to daylighting Guichon Creek has been voiced and a commitment made by the leadership of BCIT.

Many groups, both on and off campus, support Daylighting Guichon Creek. BCIT Facilities and Campus Development aims to mitigate flooding risks and to promote the creation of an aesthetic 'Blueway' for pedestrian traffic. The BCIT Rivers Institute hopes to restore fish migration and rebuild a thriving aquatic ecosystem. The City of Burnaby hopes to improve stormwater management throughout the municipality and this project could act as an example for future projects. Various faculties on campus also stand to benefit from educational opportunities from this project.

Two main factors were the focus of the project: a) all proposed designs needed to mitigate the risk of flooding on campus, while at the same time b) providing a naturalized channel that promotes fish migration and wildlife habitat. For guidance, we referenced numerous relevant publications, case histories where both major requirements have been successfully addressed, applicable fish habitat regulations, and utility configuration regulations.

DOMS research determined that the flows in Guichon Creek resulting from a 200-year storm event could reach rates as high as 40 cms. To safely convey this flow and create a naturalized fish passable stream, DOMS designed three conceptual alignments, creatively named Alignment #1, #2, and #3.

Alignment #1 was designed to divert a portion of Guichon Creek's full storm flow in a shallow culvert leading east from the sedimentation pond outside SE 16. The aim of this route was to limit the amount of infrastructure conflicts and utilize the space around building SE 1. Alignment #1 takes the longest path of the three routes to maximize the naturalization of the channel and promote fish passage. A construction estimate for on this route gave a total construction cost of $1,015,000.

Similar to the first route, Alignment #2 bypasses a portion of the flow from Guichon Creek. This route was focused on meeting BCIT's future vision by having a 'Blueway' running through campus. Alignment #2 travels straight through the middle of campus. This is a high-density area of infrastructure and therefore has a higher cost of construction; approximately $1,250,000.

Alignment #3 follows a similar path as the second route through the middle of campus. While maintaining the existing infrastructure, this route is capable of maintaining the full flows from Guichon Creek. The design of Alignment #3 focused on maintaining usability, as a living lab, while ensuring flooding will not be a risk. With a larger capacity and its path through high-density existing infrastructure, Alignment #3 had a total construction cost of $1,725,000.

All three alignments were analysed using a sustainability decision matrix. This matrix was generated to eliminate personal preferences and provide a quantitative evaluation of each option. Interested stakeholders were asked to provide a weighting of importance on 24 criteria. Alignments were graded on these criteria and a weighted score was determined. Alignment #1 was found to be the best option that provided a well-balanced solution for all design requirements of this project.

# TABLE OF CONTENTS

# LIST OF GRAPHICS

## Tables



## Figures

# DEFINITIONS & ABBREVIATIONS

BMPs – Best Management Practices

Blueway – A proposed pedestrian corridor for people to use to move around campus.

BCIT – British Columbia Institute of Technology

Catchment Area – An area within which all runoff is expected to join a single flow stream.

CMS – Cubic Meters per Second

Daylighting – The act of restoring buried watercourses to a more natural state.

Detention Pond – A pond intended to store and release runoff to attenuate peak flows.

Discharge – The rate of flow in a stream (in cubic meters per second, cms).

DOMS – DOMS & Associates Ltd.

Fish Window – The time period when work in and around the creek will have the least risk to fish and fish habitat.

DFO – Fisheries and Oceans Canada

Floodplain – The relatively flat area, adjacent to a stream that would be flooded during extreme storm events.

Hydrograph – A graph showing the discharge of water with respect to time, for a given point of a stream.

Imperviousness Ratio – The ratio of impervious surfaces to the total surface area within a drainage area.

Incised – Down-cutting of streambed, creating vertical stream banks.

Intermittent Stream – A stream with a defined channel that may run dry during certain periods of the year, usually late summer.

KWL – Kerr Wood Liedal

Lag Time – The time interval between rainfall and runoff.

Living Lab – An evolving, user-centred, accessible ecosystem integrated with the natural habitat.

LWD – Large Woody Debris – Woody obstructions to promote aquatic habitat.

Morphology – The shape of a river channel, and how it changes over time.

NHC – Northwest Hydraulic Consultants

Riparian zone / Riparian area – The interface between the creek and the land.

Riffle Zones – Shallow rapids where the water flows swiftly over completely or partially submerged obstructions to produce surface agitations without standing waves.

Salmonids – Any fishes of the salmonidae family, including salmon, trout, whitefish, and char.

Shovel Ready – A term used to describe construction projects that are close to being ready for construction to start.

Sinuosity – The curvature or bend of a river or stream.

Step Pool – A regular series of steps, similar to a staircase, in the bed of a stream.

Streambank – The sloped ground rising from the streambed.

Streambed – The bottom of a stream, below typical water level.

Stream Reach – A section of stream with mostly uniform properties.

SWMM – Storm Water Management Model

WBM – Water Balance Model

# 1.0 INTRODUCTION

Guichon Creek is a second-order fish-bearing tributary of Still Creek located in Burnaby, British Columbia. The catchment area for Guichon Creek measures over 370 hectares, constituting more than 5% of the Brunette Watershed. Guichon Creek's catchment area is bounded to the west by Boundary Road and extends south past Kingsway Avenue (see Appendix A: Burnaby Watershed Map). More than half of the catchment area is concentrated before Guichon Creek flows north across Deer Lake Parkway onto the British Columbia Institute of Technology (BCIT) Burnaby campus. The creek continues through a revitalized riparian zone before it is conveyed underground through a corrugated steel culvert for over 700 m, eventually discharging on the north side of Canada Way. From there it passes under Highway 1 to its confluence with Still Creek, before flowing into Burnaby Lake, the Brunette River, and eventually the Fraser River as shown in blue below in Figure 1: Waterways of Burnaby.

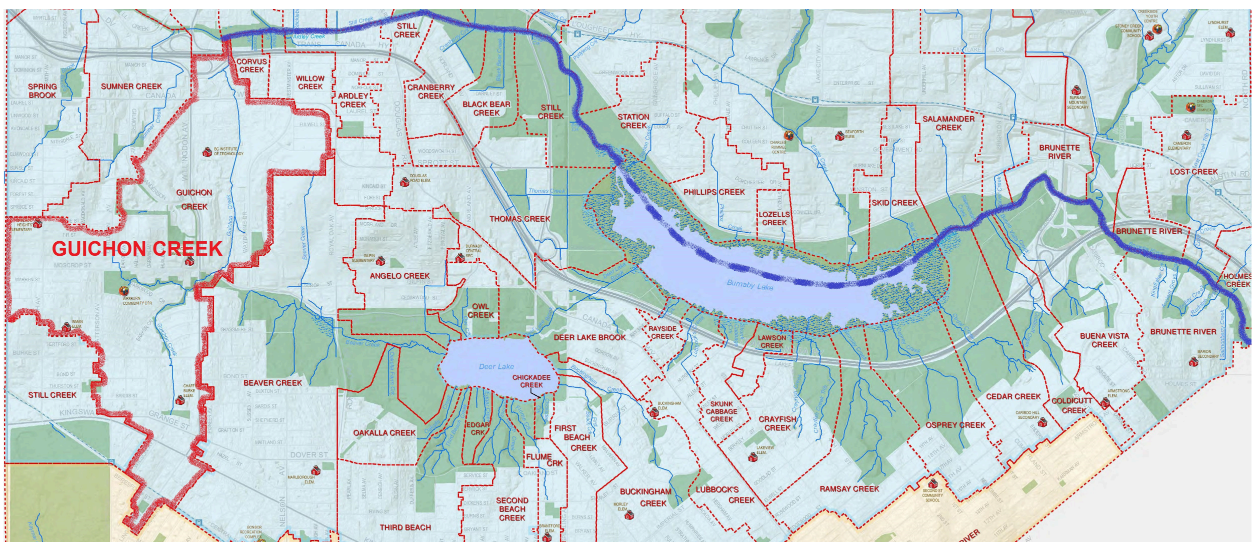



**FIGURE 1: WATERWAYS OF BURNABY** CITY OF BURNABY, 2014

In the recent past, public opinion on the value of restoring streams and creating aesthetic water features in urban environments has evolved. It is now understood that salmonids rarely migrate long distances in enclosed stream reaches. Culverts provide insufficient flow conditions, inadequate lighting, and excessive water velocities, all of which restrict upstream migration. Recent efforts to restore Guichon Creek by the BCIT Rivers Institute, the City of Burnaby, and BCIT students have enabled trout and other wildlife to reoccupy the area upstream of the underground culvert.

Local watershed restoration efforts, including the daylighting of Still Creek and the upgrades of the Highway 1 - Willingdon interchange have resulted in spawning salmon returning as far upstream as Canada Way. Bringing spawning salmon back to Guichon Creek is a significant incentive to daylight the culverted section under BCIT and restore the natural habitat.

In 2004, BCIT President Tony Knowles committed to daylighting Guichon Creek. Since then, preliminary studies have been conducted on the water quality of Guichon Creek, but to date little progress has been achieved on daylighting. In September 2014 the commitment to daylight Guichon Creek was reiterated by current President Kathy Kinloch with the endorsement of the Lieutenant Governor of BC, Judith Guichon.

With this renewed commitment in mind, DOMS & Associates Ltd. (DOMS) have prepared this report to outline the civil engineering requirements and challenges presented by this project. This will help provide solutions that will allow the client, BCIT Facilities and Campus Development, to further their goal of daylighting Guichon Creek. Three potential daylighting options have been identified and evaluated under key criteria. Various stakeholders have been polled to develop a fair and balanced decision matrix that reflects the opinions of all parties involved.

DOMS used this decision matrix to determine the best route option for BCIT to investigate further. Recommendations for future works and potential student projects have been made to allow BCIT to take advantage of the resourceful student population and to provide future students with direction when considering future Industry and/or Capstone Projects.

## 2.0 BACKGROUND

Our team's first exposure to this project came during a presentation from Jennie Moore, acting Associate Dean of Building Design and Construction Technology, to our CIVL 7089 class regarding campus sustainability. Jennie Moore appealed for a group to assist the institution in advancing the daylighting of Guichon Creek, as little progress has occurred since the idea was first raised over a decade ago. Jennie Moore expounded the value of daylighting Guichon Creek to BCIT, and the potential for a student project to be used as a starting point for future campus improvement.

### 2.1 Project History

In the 1930's, Guichon Creek was a thriving open waterway, home to many species of fish including salmon and cutthroat trout. Although development north of Kingsway had begun, Guichon Creek was still an unaltered stream from the area around present day Moscrop Secondary School as it ran towards Burnaby Lake. As Burnaby began urban development in the early 1960's, the fish-bearing Guichon Creek was either channelized or buried in culverts below the new infrastructure to mitigate flooding, erosion, and other inconveniences.

As Burnaby continued to urbanize Guichon Creek was buried below the expanding BCIT campus. The upper portion of the creek remained open but became ecologically isolated from the lower reach due to the impassable barrier created by the buried culvert. More recent projects have been conducted to restore the south end of Guichon Creek, specifically habitat restoration for trout, salmon, and other amphibian species.

### 2.2 Long Term Campus Development Plan

BCIT Facilities and Campus Development are currently formulating a long-term Campus Development Plan. This plan will "serve as a road-map for future facility renewal and development to implement Institute education and research priorities" (BCIT, 2015). The Campus Development Plan is being developed through the following five stages shown in Figure 2 below.

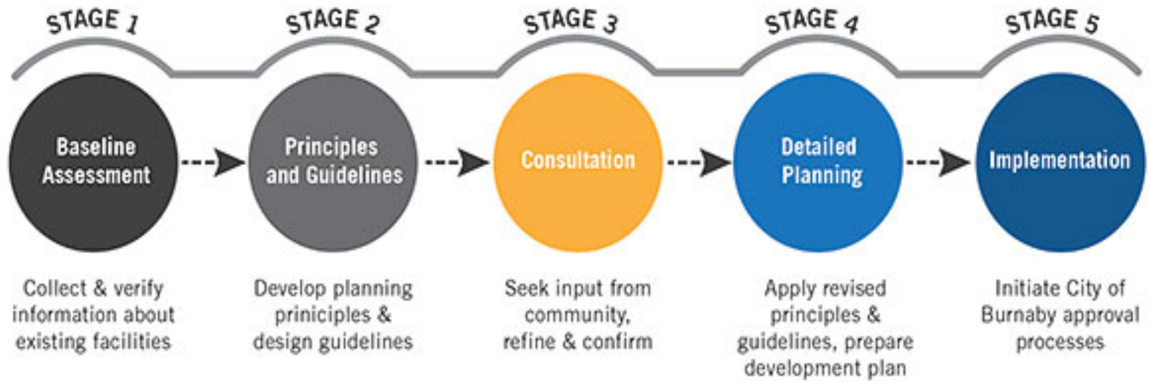



**FIGURE 2: CAMPUS DEVELOPMENT PLAN STAGES** **BCIT CAMPUS PLAN, 2015**

The primary objectives of the Campus Development Plan include:

- Providing a vision for the campus that offers richer experiences for students, faculty and staff.
- Developing new academic facilities that prioritise educational programs.
- Establishing a more compact, pedestrian oriented, sustainable urban design for the campus.
- Defining and designing an integrated network of open spaces and natural habitats.

Daylighting Guichon Creek provides BCIT with an opportunity to satisfy all these objectives while also establishing a reputation for world-class sustainable campus design. DOMS has considered these objectives in the design of Guichon Creek.

# 3.0 PROJECT TEAM ORGANIZATION

The DOMS & Associates Ltd. team is a well-balanced design team with vast civil engineering experience. We created our team to offer expertise in engineering areas specific to this project. Our team is proficient in the fields of geotechnical analysis, hydrology, construction management, and utility layout design.

## 3.1 Project Organizational Chart

This project was completed with sponsorship and assistance from the following groups and people: BCIT Facilities and Campus Development, Jennie Moore, BCIT Rivers Institute, and BCIT Civil Engineering Faculty. The following figure shows a project organizational chart of the parties involved.

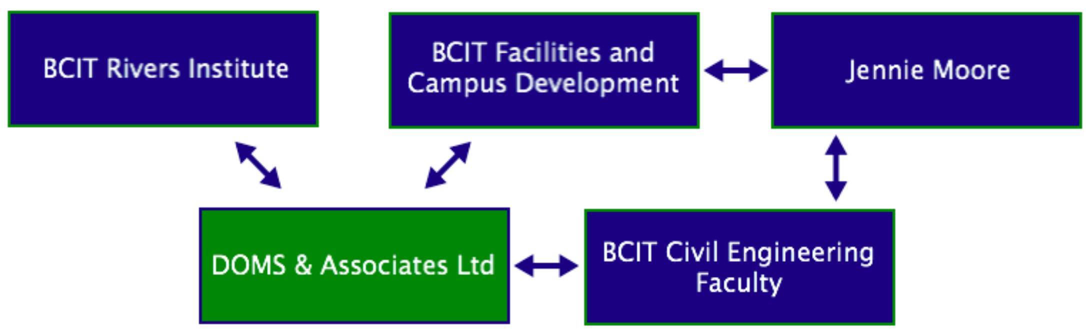



FIGURE 3: PROJECT ORGANIZATIONAL CHART DOMS, 2015

Official sponsorship and invaluable guidance has been provided by Ken Ashley, B.Sc., M.A.Sc., M.Sc., Ph.D. of BCIT Rivers Institute. Consultations with Barry Chilibeck, P.Eng., of NHC, and Dave Murray, P.Eng., of KWL provided insight and mentorship throughout the project. Regular meetings were also scheduled between DOMS and other members of the project organizational chart.

## 3.1 Team Member Roles

Due to the unique nature of this project, most sections called for a collaborative group effort. The following outlines specific roles taken by individual DOMS & Associates Ltd. team members during this project.

Steven Dindo - Utility layouts using AutoCAD and Civil3D.
Kyle Doyle - Hydrological analysis, report preparation and project management.
Daniel Hurd – Route analysis, AutoCAD design, and ecological considerations.
Sam Jones - Geotechnical analysis, conceptual design, and report preparation.
Michael Sheffer - Construction management, scheduling and cost estimates.

# 4.0 SITE DESCRIPTION

Guichon Creek's flow from the southern half of the catchment area is conveyed under Deer Lake Parkway onto the Burnaby campus through a large corrugated steel culvert. The tab labelled 'Campus Map' can be pulled out for reference. Once on campus, Guichon Creek has two distinct sections; one visible above ground and one buried below the campus. The above ground section initially runs through a large riparian zone, then parallel to the BCIT playing field before it slows in a ponding area near SE16 where sediment is able to settle out. Just west of the intersection of Ford Avenue and Roper Avenue the creek spills over a concrete weir before entering a 2 m by 3 m corrugated steel arch-culvert. Of the approximately 1.5 km section of Guichon Creek that passes through the BCIT campus, nearly half of its length is buried in this underground culvert.

## 4.1 Daylighted Constructed Wetland Section

Guichon Creek enters the BCIT campus through a 2 m diameter corrugated steel culvert, shown in Figure 4 below, which runs under Deer Lake Parkway.

**FIGURE 4: DEER LAKE PARKWAY CULVERT** **DOMS, 2015**

The culvert empties into a manmade, step-pool section that was constructed in 2010 as part of the joint restoration project by Blue+Green Design Studio, Northwest Hydraulics, and Raincoast Applied Ecology. This restored area is shown in Figure 5 below.

**Figure 5: Restored Section of Guichon Creek** **DOMS, 2015**

For the first 700 m that Guichon Creek runs through BCIT, flow is conveyed in a constructed aboveground channel. Running north from the campus boundary, the creek first flows parallel to Kyle Road. In this section, the streambed has incised up to half of a meter into its vegetated banks, which rise 4 m above the water level. The edge of Kyle Road is offset approximately 8 m from the top of these steep banks.

Before the creek enters the culverted section, it ponds behind a concrete weir outside building SE16. This ponded section of the creek was built for flow calming, sedimentation control, and to create a waterfowl habitat. The pond area is dredged of accumulated sediments every three to four years. This upper section is maintained by various BCIT faculties such as the Wildlife and Recreation program who monitor erosion of sediments at the south end of the creek.

### 4.2 Culverted Section

The exact route of the culvert is not accurately known due to poor documentation during construction over 50 years ago. The underground culvert passes below two buildings and appears to run immediately adjacent to several others. Investigative work is currently being conducted by Mar-Tech Industries to produce an accurate layout of the storm sewer network on campus. The estimated path of the culverted section of Guichon Creek is shown below in Figure 6: Guichon Creek Culverted Section.


**FIGURE 6: GUICHON CREEK CULVERTED SECTION** **DOMS, 2015**

Due to the inaccuracy of available as-built drawings, to complete this project, DOMS has used engineering judgment based on the best information available.

The proposed project site is currently an important access route for BCIT service vehicles, and staff parking spaces. Consideration has been given to ensure all proposed designs minimize disruption for these services. This will be discussed further in the Transportation Management section of this project report.

# 5.0 PROJECT VISION

The motivation to daylight Guichon Creek is twofold. Firstly, recent flooding has occurred on campus, highlighting the importance of upgrading infrastructure to meet increasing storm capacity demands. Secondly, a growing understanding of the benefits that stream restoration can provide BCIT; an opportunity to beautify its campus, while increasing its educational facilities. The goal to daylight Guichon Creek has been reiterated by the Lieutenant Governor of British Columbia, past BCIT presidents, and is supported by the current BCIT president, staff, students and Facilities' Campus Development Plan. The route options and impediments to development highlighted in this report will allow Campus Planning to make a more informed decision moving forward with this valuable project.

## 5.1 Project Importance

The rapid development of the BCIT campus neglected Guichon Creek. In its current form, the creek is unrecognizable from its original natural state. Being buried below campus and not sustaining aquatic life, a culverted Guichon Creek is unable to offer its full potential.

Rapid climate change has affected both storm intensities, and the frequency of severe storm events. In order to safely accommodate these increased flows, BCIT will need to be proactive in its campus design. As proven by the 2007 flooding of several buildings on campus, the existing infrastructure is insufficient, and needs to be upgraded. Daylighting Guichon Creek offers an opportunity to improve the current infrastructure, while also gaining the associated benefits.

## 5.2 Benefits of Daylighting

A daylighted creek provides numerous benefits to the surrounding area that a culverted one does not. The daylighting of Guichon Creek would benefit BCIT students, staff, local community, and aquatic life in the following ways:

- Replacing an aging culvert with an open drainage system that is easier to monitor and maintain.
- Improving the water quality by exposing the creek to air and natural light.
- Exposing the creek flow to soils and natural vegetation, which improve the water's ability to neutralize contaminants, pollutants, and other runoffs.
- Enhancing fish passage and other aquatic life.
- Re-establishing a riparian zone around the creek, which promotes natural flora, fauna, and wildlife habitat.

- Creating an urban 'Blueway'; a dedicated corridor for pedestrian traffic to move through campus.
- Developing a living lab for BCIT students to conduct experiments, and offering opportunity for students to learn about caring for a fish-bearing stream.
- Potentially increasing property values and improving local businesses by creating a new green amenity.

# 6.0 RELEVANT PUBLICATIONS

Daylighting previously buried streams is a relatively new concept, reflecting a reversal from past efforts to maximize potential development areas. While researching methodology, regulations and similar projects, DOMS has compiled a short summary of several relevant publications and case studies that would be useful for anyone considering undertaking a daylighting project. These publications have been cited throughout this report.

## 6.1 Daylighting and Restoring Streams in Rural Community City Centers

The US National Parks Service (NPS) published a collection of case studies in a 2002 document titled, 'Daylighting and Restoring Streams in Rural Community City Centers: Case Studies' (Hoobyar, 2002). Observations from five projects throughout the United States were compiled and recommendations were made for future daylighting projects. Although the report covers rural communities, most projects occurred in areas with similar density to BCIT.

A key factor is the importance of involving the public early in the planning stages. By involving the public early, opposition to the project can be mitigated, resulting in smoother permitting and fewer project delays. Partnerships with other groups that will support the project are recommended to increase the support for the project. These can include local conservatory, educational or commerce associations.

Development of a comprehensive public education plan can also help to solicit support for projects. One example in the report is a children's book that was distributed to local schools. The benefits of daylighting were then spread throughout the region via inquisitive children and subsequently their parents.

The economic benefits of each project varied depending on the region and a multitude of other factors. Construction costs however, were found to be related to the depth of investigation conducted prior to ground breaking. The report emphasized the importance of thorough planning prior to construction. This included ensuring all regulatory bodies were aware and satisfied with any work to be conducted in the stream, as well as complete investigation of any conflicts.

## 6.2 Daylighting of Thain Creek

The Daylighting Thain Creek project involved removing over 200 m of 2 m diameter wooden culvert in North Vancouver, making it the largest completed daylighting project in British Columbia to date. The culvert was replaced with an open channel, and one short culvert, allowing the area to become fish friendly and enhancing the riparian zone wildlife habitat (KWL, 2000).

The need to upgrade Thain Creek came from an aging culvert that partially collapsed in 1997. Design challenges included working within a narrow right-of-way, protecting downstream fish habitat, and mitigating an increased chance of flooding. After public consultation, a daylighting design that had improved flood protection, as well as improved spawning zones for salmonids, was approved.

The total cost for the project, which was completed in June 2000, was $1.4 million. Specific project components included the use of a fish-friendly concrete box culvert, a new road crossing for the stream, weirs, ripple pools, and bioengineered slopes. The project was deemed a success by designers Kerr Wood Leidal Associates Ltd in spring 2000 when steelhead fry were seen in the newly constructed open channel.

## 6.3 Still Creek Study

Presented to the City of Vancouver Community Services Planning Department in March 2002, the Still Creek Rehabilitation and Enhancement Study offers a comprehensive overview of the historical background, challenges, and future plans related to Still Creek. The study was conducted to investigate the effects of the growing Grandview Boundary Industrial Area (GBIA) on Still Creek. Stakeholders interested in the study include staff from Vancouver City Planning, local businesses and landowners, Vancouver Board of Parks and Recreation, BCIT Rivers Institute and many more (Lees + Associates et al, 2002).

In conclusion, the study offered a ten-year as well as a ten to fifty-year action plan for Still Creek. To avoid conflict, any proposed work on Guichon Creek should ensure consideration is given to these existing plans.

## 6.4 Riparian Buffers

A publication from North Carolina State University elaborates on the benefits of riparian buffer zones. The moderately technical document is targeted towards nitrogen rich run off from agricultural areas, but is relevant to any restoration project (Gilliam et al, 1997).

Buffers help to improve the health of streams by reducing the temperature of the water, increasing the food available and by intercepting contaminants. This report details how each of these processes occur. Emphasis is placed on ensuring a minimum width is achieved when designing riparian buffers.

### 6.5 Strawberry Creek – Data Collection Study

A study was conducted to determine the feasibility of daylighting Strawberry Creek in Berkeley, California. The location to be daylighted covers approximately nine city blocks near the University of California Berkeley campus. The study compares various levels of daylighting and evaluates them using a simplified decision matrix (Wolfe Mason Associates, 1999).

This report explains the benefits and consequences of a range of options, from repairing the box culvert in the ground to a fully restored, naturalized channel. After identifying the impediments to each design, the report provides a 'logical framework' to enable the process of daylighting to continue.

Economic development and aesthetic improvement are the key factors evaluated by this report, as the stream does not have a strong aquatic wildlife population.

# 7.0 APPLICABLE CODES AND REGULATIONS

The proposed alignments each conform to all applicable codes and regulations. These regulations include those related to fish habitat areas and utility configuration design. All applicable regulations followed are summarized in this section.

## 7.1 Fish Habitat Regulations

The regulations that protect fish habitat are established by municipal, provincial, and federal legislation. Guichon Creek falls under the administration of applicable municipal bylaws, including the City of Burnaby's *Streamside Protection and Enhancement Area, Green Zones*, and the City of Vancouver's *Brunette Basin Watershed Plan*. The provincial and federal regulations consist of the *Fish Protection Act*, *Water Act*, and *Fisheries Act*. The following table provides a brief description of the various legislations in place to protect the Guichon Creek habitat.

**TABLE 1: GUICHON CREEK HABITAT REGULATION** **(DOMS, 2015)**

| Regulation | Description |
|---|---|
| **Streamside Protection and Enhancement Areas Bylaw (CoB)** | To protect streamside protection and enhancement areas from residential, commercial and industrial development so that the areas can provide natural features, functions and conditions that support fish life processes. (City of Burnaby, 2015) |
| **Fish Protection Act** | Provides legislative authority for water managers to consider impacts on fish and fish habitat before issuing approval for work in or near streams. (Province of BC, 2015) |
| **Water Act** | Provides for approval of all short term use, storage and diversion of water, as well as alterations and work in and about a stream. (GVRD, 2001) |
| **Environmental Management Act** | Provides for environmental assessments, protection orders, environmental emergency measures and enforcement with an outline of the duties and powers of the Minister. (BC Laws, 2003) |
| **Water Protection Act** | Confirms Crown ownership of surface and groundwater and prohibits large-scale diversion or removal between watersheds or outside of BC. (GVRD, 2001) |

| | |
|---|---|
| **Land Development Guidelines for Protection of Aquatic Habitat** | To protect fish populations and their habitat from the damaging effects of land development activities. Includes: preservation of Pacific salmon populations, a federally-managed resource (DFO), and steelhead, trout, char and other freshwater species, which are managed by the provincial Ministry of Environment, Lands and Parks (MOELP, 1993).) |
| **Federal Fisheries Act** | Conservation and protection of fish habitat essential to sustaining freshwater and marine fish species, produced by Fisheries and Oceans Canada (Government of Canada, 1985). |
| **Federal Navigable Water Protection Act** | Prohibits the discharge of deleterious substances and activities that result in harmful alteration, disruption or destruction of fish habitat, and ensures uninterrupted year round passage for salmonids. (GVRD, 2001) |

These guidelines and legislations were combined into the *Brunette Basin Watershed Plan*, which outlines the habitat requirements for Guichon Creek. Within these guidelines are required permits related to in-stream work under the *Water Act* regulations.

## 7.2 Utility Configuration Regulations

The regulations for utility configuration design are established by municipal legislation. The applicable municipal bylaws for this project are found within the City of Burnaby's design criteria manual. Due to complications in obtaining this document, the City of Surrey's design criteria manual was chosen for utility conflict resolution. The following table provides a brief description for utility right-of-way design.

**TABLE 2: GENERAL UTILITY REGULATION** **(DOMS, 2015)**

| Regulation | Description |
|---|---|
| **Utility Right-of-Way Widths** | Provides minimum widths of right-of-ways for a single service, for two services within the same trench, or for two or more services adjacent to one another but in separate trenches. (City of Surrey, 2004) |
| **Utility Separation: Sanitary or Strom Sewer vs. Water Mains** | Provides minimum horizontal and vertical distances between utilities according to requirements of the Regional Health Board and AWWA Standards. (Design Criteria Manual: City of Surrey) |
| **Utility Separation: Storm Sewers vs. Sanitary Sewers** | Provides conditions for installing of storm and sanitary sewers in common trenches. (City of Surrey, 2004) |

The above codes are typically considered for design purposes. As most of the proposed route options are subject to significant utility conflict, recommendations for their relocation or removal must be provided before construction starts. All recommendations however, must follow the regulations stated above.

# 8.0 FISH PASSAGE REQUIREMENTS

Fish habitat requirements were based on the species found during a fish survey conducted by the Ecological Restoration program at BCIT in accordance with the Department of Fisheries and Oceans (DFO). This survey determined the fish species present in Still Creek Watershed, which are listed in the Resident Species section. These species swimming abilities and migration schedule drove the fish passage culvert design requirements for this project.

## 8.1 Resident Species

The variety of fish species plays a large role in determining the habitat conditions and constraints on the creek design. The fish mark-recapture surveys that have been conducted in Guichon Creek have established three species: cutthroat trout, crayfish, threespine stickleback (Baker & Perkin, 2013).

A more comprehensive survey, conducted on the entire Still Creek watershed, established the following species: (Province of BC, 2015)

- Brassy Minnow - Hybognathus hankinsoni
- Brown Bullhead - Ameiurus nebulosus
- Carp - Cyprinus carpio
- Chum Salmon - Oncorhynchus keta
- Coastal Cutthroat Trout - O. clarki clarki
- Coho Salmon - Oncorhynchus kisutch
- Cutthroat Trout (General) - Oncorhynchus clarki
- Fathead Minnow - Pimephales promelas
- Goldfish - Carassius auratus auratus
- Black Crappie - Pomoxis nigromaculatu
- Crayfish - Astaciodea (sp.)
- Northern Pikeminnow (Squawfish) - P. oregonensis
- Peamouth Chub - Mylocheilus caurinus
- Prickly Sculpin - Cottus asper
- Pumpkinseed - Lepomis gibbosus
- Rainbow Trout - Oncorhynchus mykiss
- Redside Shiner - Richardsonius balteatus
- Sculpins (General)
- Sockeye Salmon - Oncorhynchus nerka
- Threespine Stickleback - Gasterosteus aculeatus

The swimming and jumping capabilities of these species and their habitat requirements such as minimum water depth and maximum velocity provided insight into design requirements.

## 8.2 Fish Swimming Abilities

The swimming capabilities of salmonids have been used to determine the design parameters for culverts, step-pools, and other creek sections. The swimming and jumping capabilities of the primary salmonids residing in Guichon Creek were based on Table 3: Swimming Capabilities of Select Salmonids, shown below.

**TABLE 3: SWIMMING CAPABILITIES OF SELECT SALMONIDS** **SLANEY & ZALDOKAS, 1997**

| Species and Life Stage | | Max. Swimming Speed (m/s) | | | Max. Jump Height (m) |
|---|---|---|---|---|---|
| | | Sustained | Prolonged | Burst | |
| **Coho / Chinook** | Adults | 2.7 | 3.2 | 6.6 | 2.4 |
| | Juveniles (120 mm) | | 0.6 | | 0.5 |
| | Juveniles (50 mm) | | 0.4 | | 0.3 |
| **Sockeye** | Adults | 1 | 3.1 | 6.3 | 2.1 |
| | Juveniles (130 mm) | 0.5 | 0.7 | | |
| | Juveniles (50 mm) | 0.2 | 0.4 | 0.6 | |
| **Chum / Pink** | Adults | 1 | 2.3 | 4.6 | 1.5 |
| **Steelhead** | Adults | 1.4 | 4.2 | 8.1 | 3.4 |
| **Cutthroat / Rainbow** | Adults | 0.9 | 1.8 | 4.3 | 1.5 |
| | Juveniles (125 mm) | 0.4 | 0.7 | 1.1 | 0.6 |
| | Juveniles (50 mm) | 0.1 | 0.3 | 0.4 | 0.3 |
| **Arctic Grayling** | Adults | 0.8 | 2.1 | 4.3 | 1 |
| **Whitefish** | Adults | 0.4 | 1.3 | 2.7 | 1 |

The swimming and jumping capabilities of salmonids provided us with parameters for certain design features in the creek alignment and profile. The swimming speeds determine the distance that salmonids can overcome obstacles such as culverts and low-flowing riffle zones. The jumping height determines salmonids ability to jump over weirs and other obstacles, such as large woody debris. The habitat conditions that salmonids best operate in are described below in Table 4: Required Water Depths and Velocities.

**TABLE 4: REQUIRED WATER DEPTHS AND VELOCITIES** **SLANEY & ZALDOKAS, 1997**

| Species | Min. Depth (m) | Velocity (m/s) | Substrate Size (mm) |
|---|---|---|---|
| **Fall Chinook Salmon** | 0.24 | 0.30 - 0.91 | 13 - 102 |
| **Spring Chinook** | 0.24 | 0.30 - 0.91 | 13 - 102 |
| **Summer Chinook** | 0.3 | 0.32 - 1.09 | 13 - 102 |
| **Chum Salmon** | 0.18 | 0.46 - 1.01 | 13 - 102 |
| **Coho Salmon** | 0.18 | 0.30 - 0.91 | 13 - 102 |
| **Pink Salmon** | 0.15 | 0.21 - 1.01 | 13 - 102 |
| **Sockeye Salmon** | 0.15 | 0.21 - 1.07 | 13 - 102 |
| **Kokanee** | 0.06 | 0.15 - 0.91 | 13 - 102 |
| **Steelhead** | 0.24 | 0.40 - 0.91 | 6 - 102 |
| **Rainbow Trout** | 0.18 | 0.48 - 0.91 | 6 - 52 |
| **Cutthroat Trout** | 0.06 | 0.11 - 0.71 | 6 - 102 |

The parameters described above are sued to determine channel geometries, creek alignment and profile, and riparian features (not described in this report). The minimum swimming depths and velocities provided above were used to design the creek cross-sections along with the creek profile slope; this is further described in the Hydrological Assessment section.

As with all design calculations, it is essential to draw FBD's to ensure all relevant forces are included. Refer to Figure 7: Example Fish Body Diagram for reference.

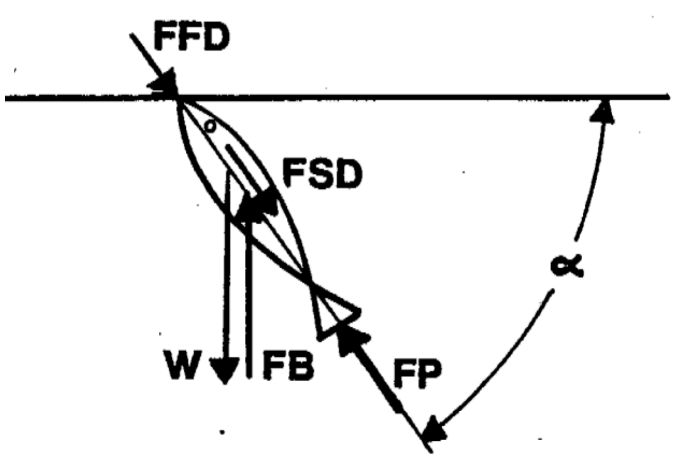


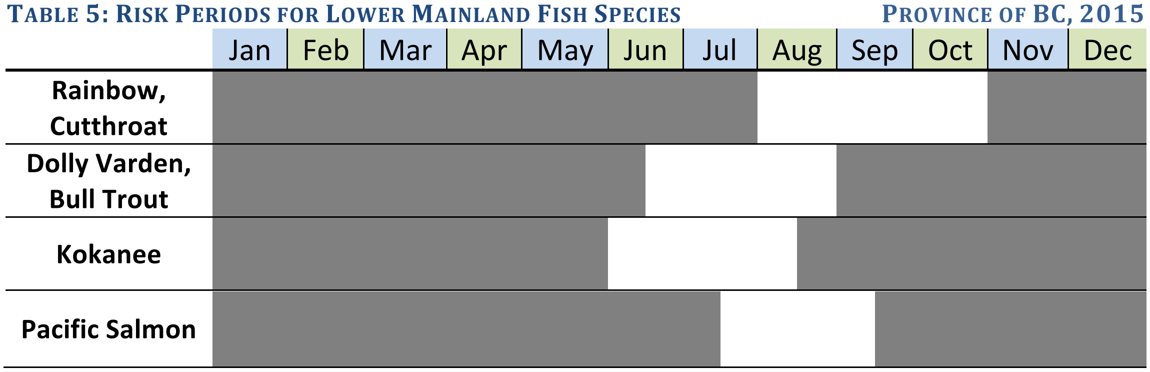

**FIGURE 7: EXAMPLE FISH BODY DIAGRAM** **US DEPT. OF ENERGY, 1986**

By setting up the problem before attempting to solve it, one is able ensure part marks are awarded.

## 8.3 Migration Schedule

The migration schedule of fish plays a significant role in the construction schedule. To ensure minimum disruption to the fish and their habitat, the Ministry of the Environment requires construction work to be completed during the fish window. The windows of lowest risk to fish are shown below in Table 5 for select species that are known to inhabit local creeks and rivers. The periods of lowest risk are shown as unshaded. Careful planning will be necessary to ensure construction aligns with the fish window in Guichon Creek.

**TABLE 5: RISK PERIODS FOR LOWER MAINLAND FISH SPECIES** — **PROVINCE OF BC, 2015**




As shown in Table 5, fish (specifically salmon) typically migrate from late October to August. For design considerations, the runoff during these periods introduces a challenge in the creek design. Depending the species of fish, there are different requirements of water depths and velocities. Using the flow data during these periods, the creek must be designed to ensure fish passage.

# 9.0 CULVERT DESIGN CONSIDERATIONS

To facilitate fish migration, it is imperative to create fish-passable culverts. Culverting eliminates natural meandering, riffles, and gravel bars, which causes increased velocities, increased silt migration, and reduced creek depths. Culvert designs must mitigate the impediments to migration to ensure upstream fish passage can occur in the widest variety of flow conditions.

The culvert beginning at Canada Way is currently blocking fish from the upper reach of Guichon Creek, which could be a productive salmon habitat due to its channel size, speeds and other factors. It may not be practical to daylight Guichon Creek in some sections, such as beneath Canada Way, so alternative fish passage solutions need to be implemented. The methodology used to determine the best fish passable culverted system for each case is discussed below.

## 9.1 Culvert Design

During the design phase of there are important considerations for culverts and their capability for fish passage. 'Culvert Siting' is the consideration of the length of culvert versus the deviation from normal upstream/downstream course. A long slowly deviating culvert may become just as much of a fish barrier as a short, highly deviating culvert and therefore must be assessed thoroughly. A large deviation can cause increased turbulence, silt transport and scouring. A deviation of 30 degrees past original stream direction is the maximum acceptable range.

The decision to install either a hydraulically engineered culvert or a 'no-slope' culvert should be based on project requirements and site conditions. Hydraulically engineered culverts are more difficult to design but provide more certainty that the requirements for capacity and fish passage can be met. No-slope designs are typically larger than hydraulic culverts, require no special design expertise or additional survey information and can lower engineering costs. The design can be applied as long as velocities are sufficiently low to allow a bed to deposit in the culvert, this will allow most species of fish to pass with ease. A final check against flow requirements stated in Section 8 above should be done before a final design is approved.

### 9.2 Culvert Types

The type of culvert to use in a fish passable stream is determined by available flow and cost constraints. Appendix B outlines the types of culverts available and the applications for each culvert. The open bottom box culverts have considerable advantages because they allow the native earth to remain in place. This type of culvert complements the no-slope design and can be engineered to protect from scour since the bedding is designed to stay in place. Alternatively, a trough box culvert can help to maintain minimum stream depths in low-flow situations, but is more prone to deposition related issues.

### 9.3 Culvert Bed Design

The ideal culvert bed design will match the upstream width, slope, and composition of soil; however, it is rare that this can be achieved. Discontinuity in these features will result in a change in sediment transport characteristics, which can cause the fines in the artificial bedding to scour.

A thorough investigation of upstream native size and gradation of streambed should be used as a starting place for bed designs. It should be noted that culverts generally have a more chaotic flow as compared to natural stream flows. Naturally occurring streambed sediments are distributed in the "S" curve as seen below in Figure 8: Natural Streambed Sediment Distribution.

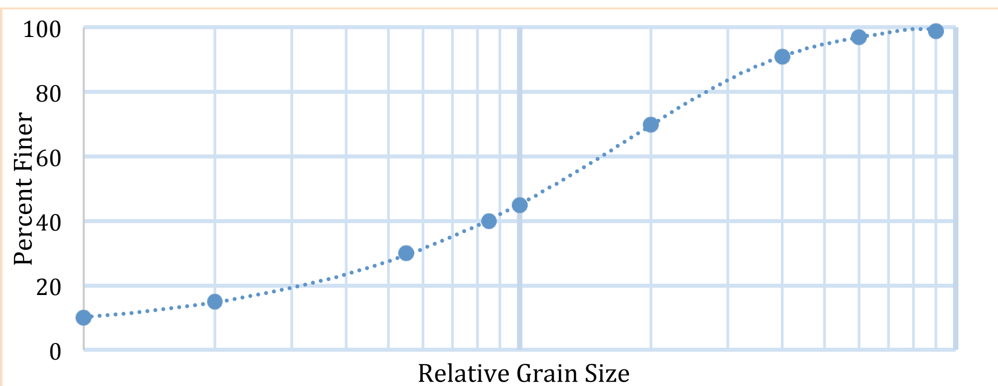



FIGURE 8: NATURAL STREAMBED SEDIMENT DISTRIBUTION BATES, 2003

If a bed material must be constructed, it is best to try to replicate the same distribution seen above Typical ratios are: D84/D100 = 0.4; D84/D50 = 2.5; D84/D16 = 8.0. In practice it is possible to determine D100 by examining the natural channel and measuring the large, stable, moss-covered boulders.

# 10.0 ECOLOGICAL CONSIDERATIONS

BCIT Rivers Institute is a leader in sustainable restoration of aquatic ecosystems and environmental educational programs such as the Ecological Restoration Degree Program. Above and beyond the fish regulations discussed previously, daylighting Guichon Creek brings up many other ecological concerns. To address these, this project has been designed with the following ecological principles in mind.

The daylighting design for Guichon Creek must:

- Enhance the current biological diversity of the BCIT campus by restoring native species growth.
- Encourage mixed vegetation growth throughout the daylighted zone.
- Minimize disturbance of environmentally sensitive habitat areas and other habitat requirements.
- Ensure eroded material doesn't create turbidity, leading to fish gills becoming irritated.
- Promote a network of corridors between habitat areas to facilitate species dispersal and movement. Species movement, both flora and fauna, must be considered.
- Improve water quality within Guichon Creek.
- Minimize erosion and sedimentation along the entire riparian zone.
- Ensure that post-storm runoff after construction does not exceed current flows pre-construction by minimizing impervious surface areas.
- Utilize vegetation and ground cover to provide moisture retention in the soil.
- Advocate fish passage through the campus.
- Have little impact on the stream temperature, ensuring it stays in a fish-friendly range.

By following these considerations, daylighting Guichon Creek will enhance the local ecological environment, improve fish passage, and provide an improved learning environment for BCIT.

## 10.1 Water Quality

One of the most important ecological considerations is to ensure the quality of the water in Guichon Creek is suitable for the reintroduction of native species. Environmental Engineering Technology student, Heather White, recently completed a study titled "Sediment Analysis for Heavy Metal and Metalloids and Preliminary Ecological Risk Assessment to Facilitate the Rehabilitation of Guichon Creek on the BCIT Burnaby Campus". The focus of her study was to conduct a preliminary ecological risk assessment for 30 heavy metals and metalloids, and determine the creek's suitability for spawning salmon and trout, reintroduction of native fauna and flora, and other wildlife habitat.

After taking a total of 13 samples at approximately 70 m intervals along the creek, Heather White analyzed the creek water using US EPA Method 6020A. A resulting Risk Quotient (calculated as Estimated Environmental Concentration / Threshold Risk Values) was calculated for the following metals: Chromium, Copper, Iron, Manganese, Nickel, Lead, and Zinc. Of those tested, only Manganese (1.2) had a Risk Quotient value over 1.0.

Based these results, Heather White reported that it is "not expected that restoration efforts in Guichon Creek on the BCIT campus will be hampered due to heavy metal concentrations" (White, 2015). To ensure this continues to be the case, any alterations to the current infrastructure must preserve or better the current water quality.

## 11.0 BEST MANAGEMENT PRACTICES

Best Management Practices (BMPs) are methods, techniques, or actions determined to be the most effective in achieving a project specific objective. Regarding daylighting Guichon Creek, many BMPs are applicable for different aspects of the project. The Province of British Columbia has published an Urban Stormwater Management project BMPs document that outlines over 50 different BMPs that should be followed to ensure successful construction of urban stormwater infrastructure.

For the purpose of this project BMPs can be categorized into three sections, relating to the protection of:

- Life, property, and existing infrastructure
- Wildlife habitat, and the riparian zone
- Water quality, and aquatic species life

Specific BMPs relating to daylighting Guichon Creek relate to ensuring the proposed designs meet Campus Development's future plans, protect against flooding, and make use of wildlife and aquatic friendly design components. These components include such things as grass swales, infiltration galleries, and parking lot detention basins to improve water quality, and protect aquatic species life. The use of constructed wetlands, as well as a diverse selection of plant life will help provide an ecologically sustainable riparian zone that promotes wildlife habitat.

Where conflicts exist between BMPs, the hierarchy to follow is: 1) flow volume reduction, 2) water quality, and then 3) runoff control. (Chilibeck & Sterling, 2014)

## 12.0 HYDROLOGICAL ASSESSMENT

As development in Burnaby continuously increases, the rate of flow in Guichon Creek follows. Recent flooding, such as in 2007, has shown that extreme storm events can exceed current infrastructure capacities and cause significant damage and disruptions on campus. The safety of the public and protection of property are the top priorities for daylighting Guichon Creek, therefore high flow capacities will govern design. Two of the proposed routes utilise a diversion to limit the maximum flow, allowing a simplified design. The third option was designed to convey the full flows of extreme storm events. Effort was made to incorporate urban stormwater BMPs priority of volume reduction by designing typical infiltration swales to install alongside the proposed alignments.

### 12.1 Guichon Creek Catchment Area

The catchment area for Guichon Creek covers over 350 hectares. Ground cover consists of mostly dense urban residential, with intermittent green space. Development has increased the impervious ground cover, causing increased flows. Imagery obtained from Vintage Air Photos (Vintage Air Photos of BC, 2015) compared to a current Google Map image illustrates the change caused by a half-century of growth (see Figure 9).

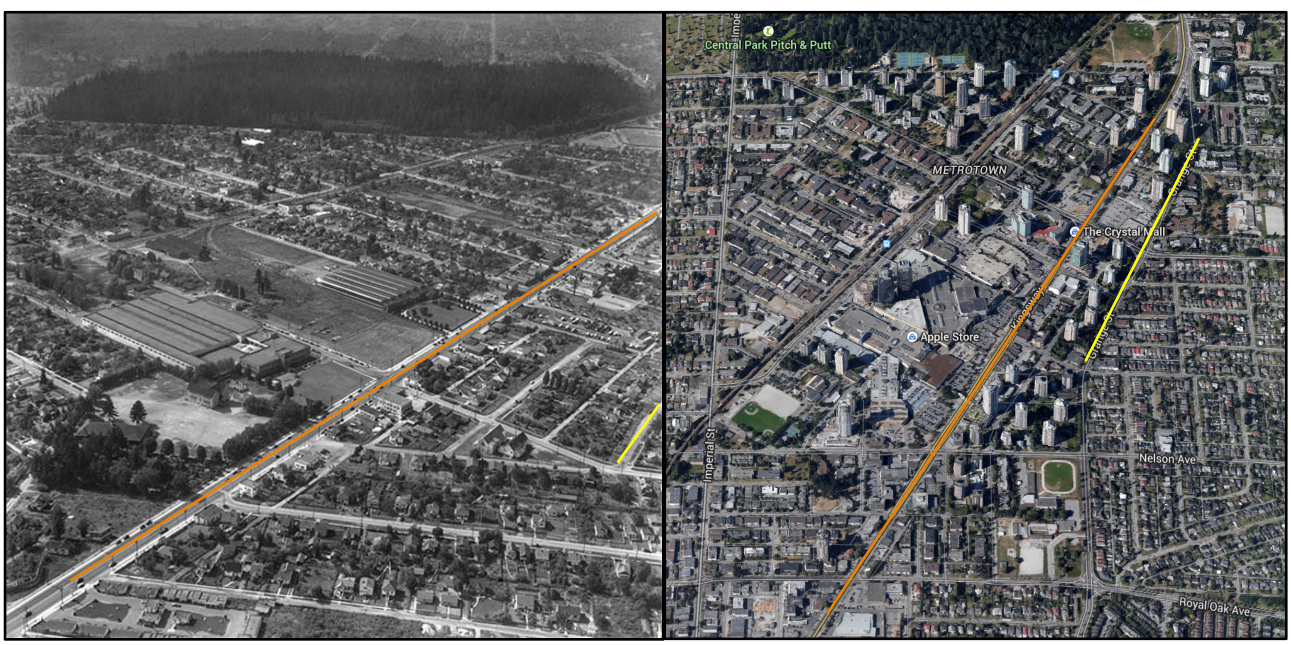



**FIGURE 9: URBANIZATION OF BURNABY** **VINTAGE AIR PHOTOS OF BC, 2015**

Kingsway Ave and Grange Street are highlighted in both pictures to provide a reference point for comparison.

Reduced residential lot size and increased commercial area has altered the run-off characteristics of the area. Reduced infiltration area results in more intense flows that concentrate more rapidly as demonstrated by the typical hydrograph comparing pre and post-development flows in Figure 10: Pre and Post Development Hydrographs.

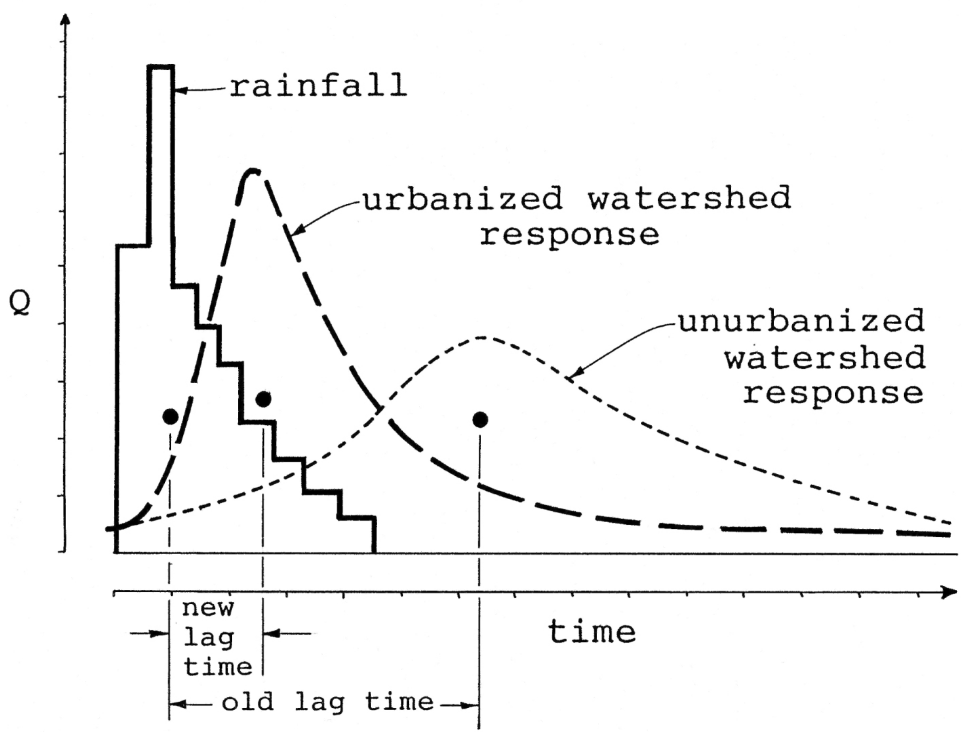



**FIGURE 10: PRE AND POST DEVELOPMENT HYDROGRAPHS** **ROGERS, ND**

These more intense flows erode streambeds and are more likely to exceed capacities of aging stormwater infrastructure. BCIT has no control over further development in the Guichon Creek watershed and should assume densification will continue. Historical flood events may reoccur and should be considered when planning capacities of any daylighting project going forward.

## 12.2 Historical Flows

No hydrological studies of significant term have been conducted on Guichon Creek. A report by Northwest Hydraulic Consultants on an upstream rehabilitation project determined high flow estimates by scaling data from Still Creek by the ratio watershed areas as seen in Table 6 below.

**TABLE 6: EXTREME FLOWS ESTIMATES IN GUICHON CREEK** BLEZY, 2012

| Location | Watershed Area ($km^2$) | Flood Frequency 10-Year ($m^3/s$) | 25-Year ($m^3/s$) | 100-Year ($m^3/s$) | 200-Year ($m^3/s$) |
|---|---|---|---|---|---|
| **Still Creek at Gilmore Mouth** | 11.4 | 50.1 | 64.9 | 86.7 | 97.6 |
| **Guichon Creek Upstream of BCIT** | 1.9 | 14.3 | 18.5 | 24.7 | 27.8 |
| **Guichon Creek Downstream of BCIT** | 3.2 | 20.6 | 26.7 | 35.6 | 40.1 |

For the purpose of this report 200-year flows were assumed to be 40 cms. This value corresponds with the downstream estimates provided by NHC's report. We feel this to be a conservative estimate that will ensure the safety of the BCIT campus during an extreme storm event.

### *12.2.1 Observations*

Over the course of two days in January 2015, DOMS observed a heavy rain event and subsequent flows in Guichon Creek. Precipitation data collected from BC Hydro's meteorological station at Coquitlam Dam Forebay indicated a 48 hr rainfall of 90.3 mm and a peak 12 hr rainfall of 67.7 mm. During this period the max 1 hr rainfall was 8.5 mm. (USGS, 2015).

These depths correspond to 1-year return periods for a 1 hr storm and a 2-year return period for a 12 hr storm according to rainfall data from the Hydrological Division of the National Department of Agriculture in the United States (US Department of Commerce, 1961). During this common event noticeable ponding on the footpath between Guichon Creek and the BCIT playing field was observed. Infiltration areas near the creek were fully saturated and ponding.

### *12.2.2 Historical Flooding*

Significant flooding occurred on the BCIT campus during a storm event in 2007. Damage occurred in several building and several classes were cancelled. News reports state a total of 13.8 mm of precipitation was recorded in Coquitlam over three hours on September 18, 2007 (Canada Classic Edition, 2007). According to discussions with various campus staff it is thought that several factors combined to facilitate flooding. Initially the trash rack that prevents large debris from entering the culvert was blanketed in leafy debris. Anecdotes suggest a hail event preceded the peak rainfall, solidifying the debris blocking the culvert and preventing flows from entering the culvert (The Province, 2007). Water was then conveyed north along Roper Avenue as seen in Figure 11: 2007 Flooding Along Roper Avenue.

**FIGURE 11: 2007 FLOODING ALONG ROPER AVENUE** **MAGEL & DAUM, 2009**

All designs proposed by DOMS are capable of accommodating 200-year flows to ensure that BCIT is protected from flood events in the future. Whether this is through a high-flow bypass design, or a full flow conveyance depends on the alignment.

### 12.3 Diversion Design

One of the three alignments was designed to convey full 200-year storm flows, while the other two are designed to provide an aesthetic daylighted creek while diverting large flows to be conveyed within the existing storm sewer. For the two partial-flow alignments a diversion structure was designed to allow low flows to be routed into the daylighted section. During high flow periods the majority of the water bypasses the daylighted section of the creek to prevent excessive scouring and to limit the damage to the aquatic habitats.

To achieve this high-flow bypass design while still permitting lower flows to enter the daylighted section, a box culvert was treated as a flume and set lower than the existing weir in the sedimentation pond near SE16. An excel spreadsheet was created using the weir equation:

$$Q = \frac{2}{3} * Cd * L * \sqrt{2g} * h^{\frac{3}{2}}$$

When solved for a broad crested weir results in:

$$Q = 1.6 * Cd * h * L$$

And for a flume:

$$Q = 1.65 * Cd * h * L$$

Where:

Q = flow
Cd = coefficient of discharge
h = height of water
g = gravity
L = Length of weir/flume

The existing weir has a length of 11 m while the proposed box culvert is 2 m wide. By adjusting the relative depths of the flume to the existing weir a ratio of flow during the 200-year flow was found to be 4:1, or 32 cms to 8 cms entering the weir and flume respectively.

This configuration also allowed for all flows below 0.55 cms to be conveyed through the flume and subsequently the daylighted section of creek. This rate of flow was found to provide sufficient depths and velocities for fish migration through all reaches of the proposed alignments.

### 12.4 Channel Design

Route options were designed with flood mitigation as a primary concern. In order to ensure capacities were sufficient, every variance in the channel was assessed using Manning's Equation:

$$Q = VA = \frac{1}{n} * R^{\frac{2}{3}} * s^{\frac{1}{2}}$$

Where:

Q = flow
V = velocity
A = area
n = Manning's number
R = hydraulic radius
s = slope

All proposed routes were checked using Manning's equation and are capable of conveying the design flows. For the two partial flow alignments the flume structure was found to limit flows to a maximum of 10cms whereas the rest of the alignment is capable of conveying more than 20cms.

Alignment #3 was designed to accommodate full 200-year flows. Bank full depths determined using Manning's Equation can be seen in Appendix C, D and E for routes #1, #2 and #3 respectively.

### 12.5 Infiltration Swales

The term infiltration swale can be used interchangeably with infiltration basin, swale or buffer zone. All of these comprise of a combination of small detention areas, resistant vegetation, and highly permeable soils that allow infiltration and filtration. As runoff enters the swale from the paved/parking lot areas, it will be slowed and remain in the channel which will naturally filter out toxins through infiltration.

Infiltration swales provide an effective barrier to prevent toxic runoff from parking lots and other urbanized structures from entering streams. It is generally agreed that infiltration of stormwater through healthy soils is one of the most effective processes to improve water quality and remove urban pollutants (Greater Vancouver Sewerage and Drainage District, 2012).

### *12.5.1 Design*

DOMS has provided an infiltration swale design based on standards from the "Greater Vancouver Sewerage & Drainage Districts: Stormwater Source Control Design Guidelines – Infiltration Swales" for a 2-year 24-hour rain event. In addition, the 2-year storm has been chosen to ensure the space required for our infiltration basin will align with the campus development plan and be economically feasible. A percent capture of 50% has been chosen since storms in excess of the design storm will simply spill over into Guichon creek. A typical layout of the infiltration swale is shown below in Figure 12.

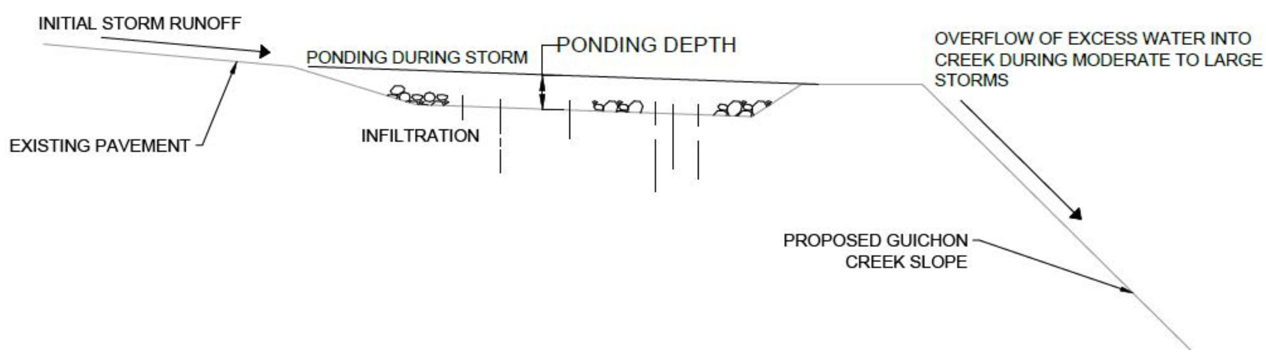



**FIGURE 12: BASIC RAIN GARDEN DESIGN** **(DOMS, 2015)**

Figure 12, above, shows a general swale design to filter out toxins that can deteriorate water quality. Runoff from the pavement will enter the swale as sheet flow, it will then be slowed and infiltrate through the permeable soils into the water table or Guichon creek. Excess flow will be spilt into the creek. (Ferguson, 1998)

Assumptions made were based on both the consultants' knowledge and the guidelines described in "Greater Vancouver Sewerage & Drainage Districts: Stormwater Source Control Design Guidelines – Infiltration Swales" (Government of BC, 2015).

The following are the assumptions DOMS has used to during design:

- Design storm will be assumed to be a 2-year 24-hour rain depth for the Vancouver area using a 50% capture.
- All locations will be designed with trapezoidal cross-sections with a swale bottom width between 600 mm and 2400 mm.
- The swale bottom is designated as the "base area" for infiltrating in the swale and slopes will not be considered.
- Flow to the swale will be assumed to be sheet flow.
- Pavement edge adjacent to the swale will utilize wheel stops and provide a 50mm drop at the edge to reduce build-up of sediment on road surfaces.
- A side slope of 3:1 (horizontal : vertical) will be assumed.
- Swales will have a maximum longitudinal slope of 2%.
- Drain rock reservoirs will have a maximum drawdown time of 4 days to allow for aerobic conditions to optimize water quality treating.
- Surface ponding will have a maximum drawdown time of 2 days.
- Treatment soil (growing medium) depth will be 450 mm where possible and will not be less than 150 mm or 100 mm minimum if overlaying a minimum of 100mm of washed sand.
- Treatment soils will be assumed to be Sand Loam with a saturated hydraulic conductivity of 26 mm/hr.
- Subsurface soils will be assumed to be Silty clay Loam with a saturated hydraulic conductivity of 1.5 mm/hr.
- Drain rock will have a porosity of 0.4.
- The maximum Impervious/Pervious (I/P) ratio is 20 for a parking lot with >1 car/day/parking space to determine the required swale base area. All impervious areas of BCIT will be assumed to have these criteria.
- Stormwater conveyance in channels can be modeled using Manning's Formula.
- Rational Method applies for areas less than 20 Ha.

Sizing of infiltration swales depends on the site requirements, designer's preference and design criteria. Some approaches to design include continuous simulation modeling in WBM or SWMM, water balance done through spreadsheet calculations and a simplified design that is outlined in the "Greater Vancouver Sewerage & Drainage Districts Infiltration Swale

Systems". DOMS has decided that at the current project stage it is best to provide a more simplified design method.

The simplified method provides an idea of space requirements and associated costs. The design should be re-evaluated and finalized with a detailed modeling following hydrological studies and choosing the appropriate route. The simplified method procedure has been completed as follows:

- Determine the total pavement area (Impervious).
- Determine the 2-year 24-hour rain depth for specified area.
- Determine the required base area of the swale using the maximum I/P ratio (the simplified method does not account for infiltration through the sloped sides).
- Check that designed swale base is greater than the required.
- Determine drain rock depth.
- Check that swales are adequate for stormwater conveyance using Rational Method for peak flows and Manning's Formula for channelized flows.
- Repeat for each effective area.

The design for the critical area in Alignment #1 has been hand calculated and a typical cross section has been produced, shown in Appendix F. The remaining areas have been checked for adequacy in Excel (also in Appendix F). For each route there will be one typical cross section for ease of constructability.

Alignment #1 will require the removal of the most catch basins where the sub-catchment areas collect and thus will lead to the greatest swale requirement for all routes. It is safe to assume that the infiltration area required for each route will never exceed the typical cross section produced for Alignment #1.

#### *12.5.2 Advantages, Disadvantages and Maintenance*

Infiltration basins are a crucial part of maintaining water quality in an urbanized environment. In addition, they can provide a reduction of peak flows, ground water recharge and promotion of local vegetation.

In contrast, there are several drawbacks that a designer must be aware of during development. Rain gardens have potential to fail from sediments clogging the infiltration area, as can be seen along the west side of Kyle Road. Regular inspections and maintenance are necessary to ensure an adequately functioning system (Government of BC, 2015).

### *12.5.3 Recommendations for Further Stormwater Management Improvement*

Strategies must be developed in order to effectively and efficiently implement storm water source controls. Beyond the creation of infiltration swales, DOMS suggests BCIT consider the following in all future construction:

- Use required landscape areas efficiently – convert berms into permeable islands or courtyards
- Infiltrate flow into tree wells – This recommendation is summarized below in section 12.5.4: Infiltration Tree Basins
- Fortify organic matter content and depths of landscape soils – this will allow greater water storage potential within the landscape
- Incorporate pervious pavements – can be used in pedestrian areas, walkways, certain parking lots.

### *12.5.4 Infiltration Tree Basins*

In small sub-catchment areas where it is not feasible to incorporate an infiltration swale, an infiltration tree basin should be considered. Tree basins require less maintenance and provide effective pollutant removal from runoff (Low Impact Development, 2015) These systems can be sized in a similar process as the infiltration swales and should be explored in further studies. DOMS envisions the infiltration tree basin as detailed below in Figure 13: Infiltration Tree Basins

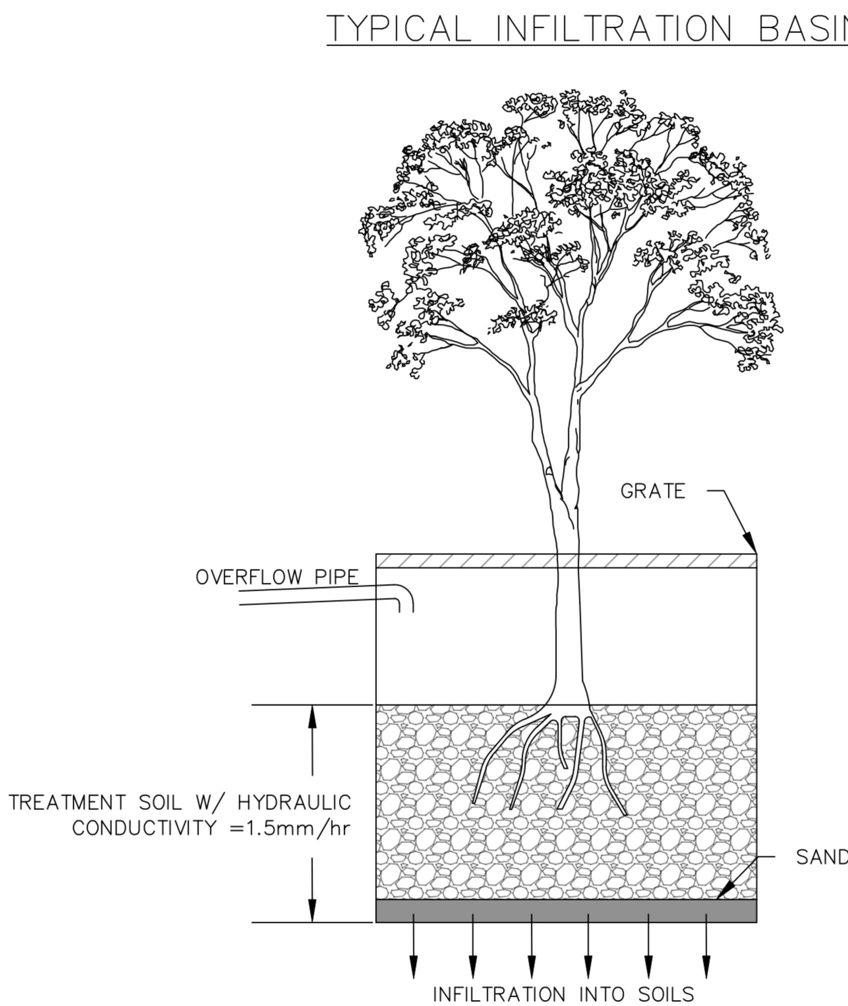



**Figure 13: Infiltration Tree Basins** **DOMS, 2015**

## 13.0 GEOTECHNICAL CONSIDERATIONS

According to the Geological Survey of Canada's Surficial Geology Maps 1486a (published 1979) and 1484 (1980) much of Burnaby, including the BCIT campus, is situated on Vashon drift and Capilano deposits. Labeled VC (Green) in Figure 14: Surficial Geology of Burnaby, such areas are commonly composed of materials such as lodgement and minor flow tills.

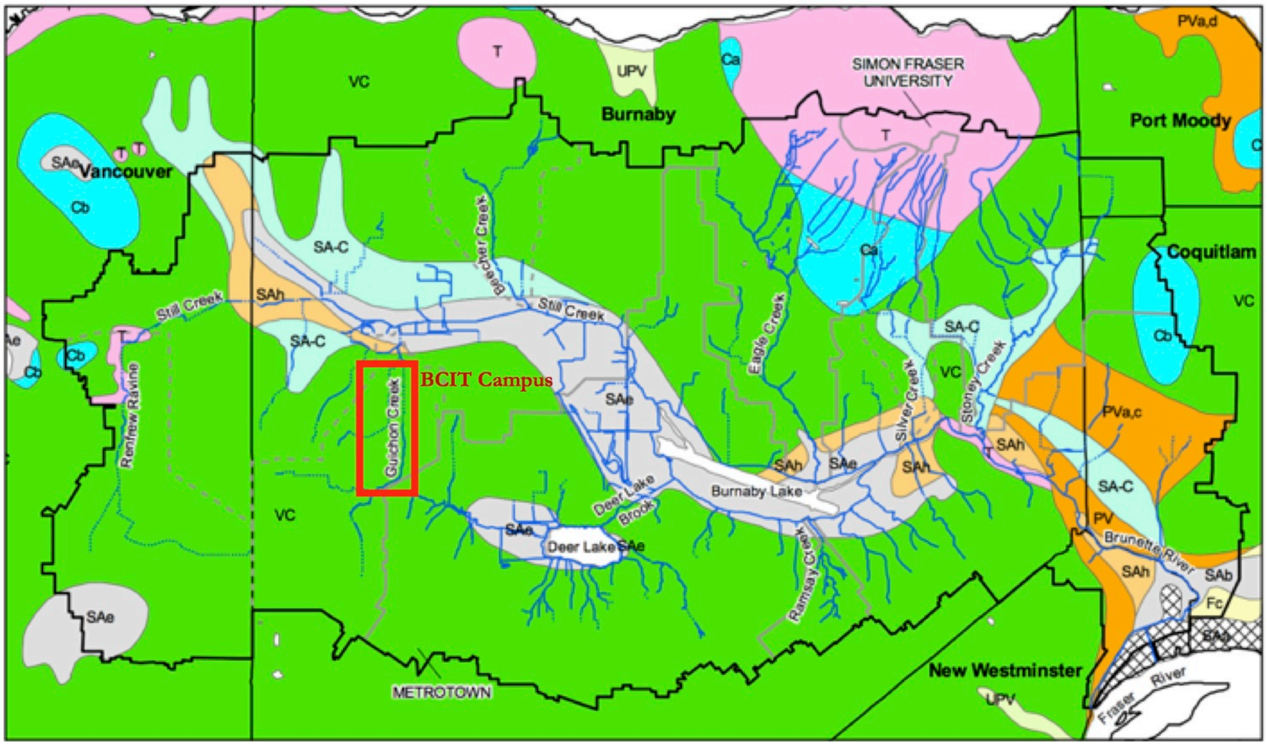



**FIGURE 14: SURFICIAL GEOLOGY OF BURNABY** **GVRD 2001**

Typical native subsurface conditions consist of bedrock at more than 10 m below surface, overlain by glaciomarine and marine stony to stoneless silts, and clay loam with minor sand and silt.

### 13.1 Site Ground Assessment

The most recent ground assessment at BCIT was conducted by On-Track Drilling, under the direction of Centennial Geotechnical Engineers. Testing was conducted using a truck-mounted auger drill on August 26, 2014. A total of twelve boreholes were drilled along Goard Way between Willingdon Avenue and Carey Avenue. The approximate locations of these test holes are shown below in Figure 15: Goard Way Test Borehole Locations.

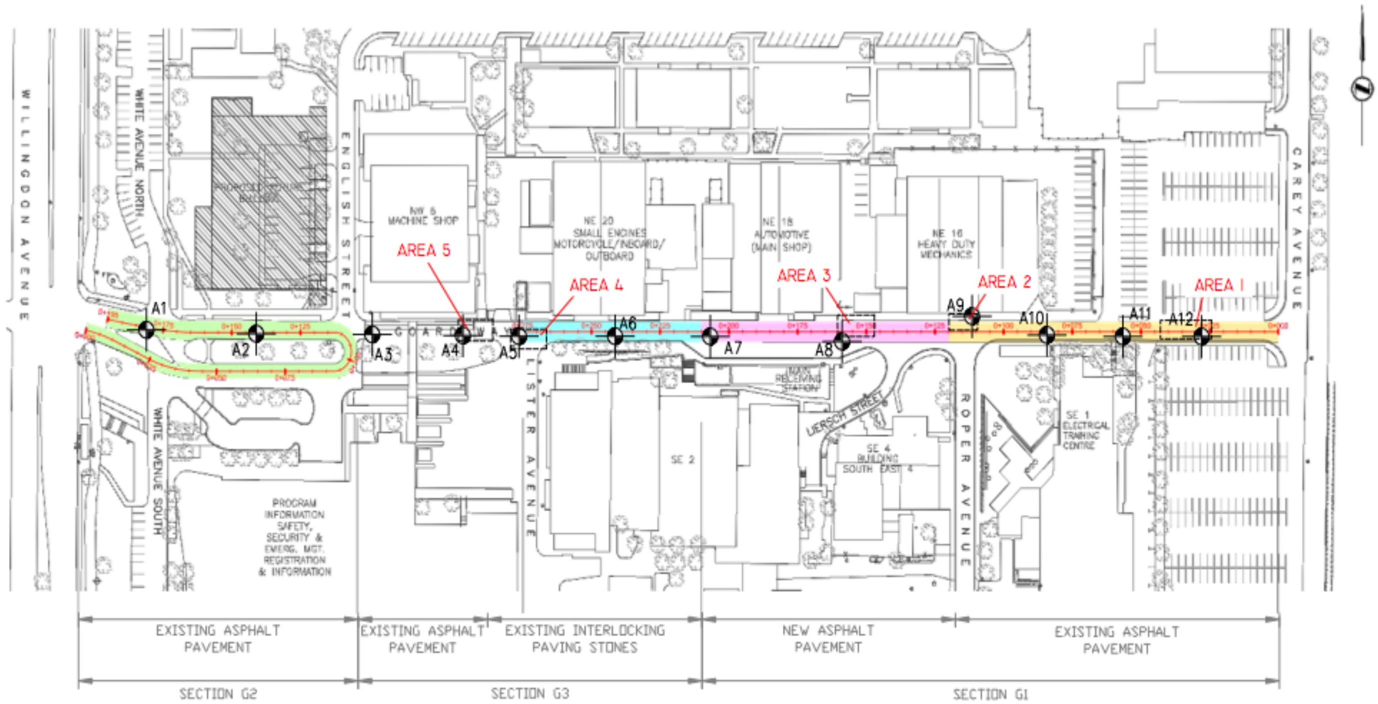



**FIGURE 15: BOREHOLE LOCATIONS ALONG GOARD WAY** **CENTENNIAL GEOTECHNICAL ENGINEERS, 2014**

Based on these drill hole logs, Centennial Geotechnical Engineers Ltd. Provided BCIT with a summary of the subsurface conditions below Goard Way, which are shown in Appendix G. Due to the proximity of the geotechnical investigation, the recentness of the Centennial report, and our limited time and budget, DOMS extrapolated subsurface conditions to gain a general idea of the materials close to our project site.

Based on the general trend along Goard Way, as well as a visual inspection conducted on Friday December 5, 2014 while Hexcel Construction were replacing utilities at the east end of Goard way, we developed a general subsurface stratigraphy along Goard Way, as shown in Appendix H.

The above-mentioned subsurface stratigraphy gives a general idea of geotechnical conditions around campus, but geotechnical conditions should be confirmed before use for design purposes.

## 13.2 Slope Stability Analysis

Given the trends in soil data and site observations discussed above, we decided to check the slope stability of our design we constructed a typical 1:1 slope in SlopeW, and analyzed stability with various parameters. This is shown below in Figure 16: Geotechnical Design of a Typical Cross Section.

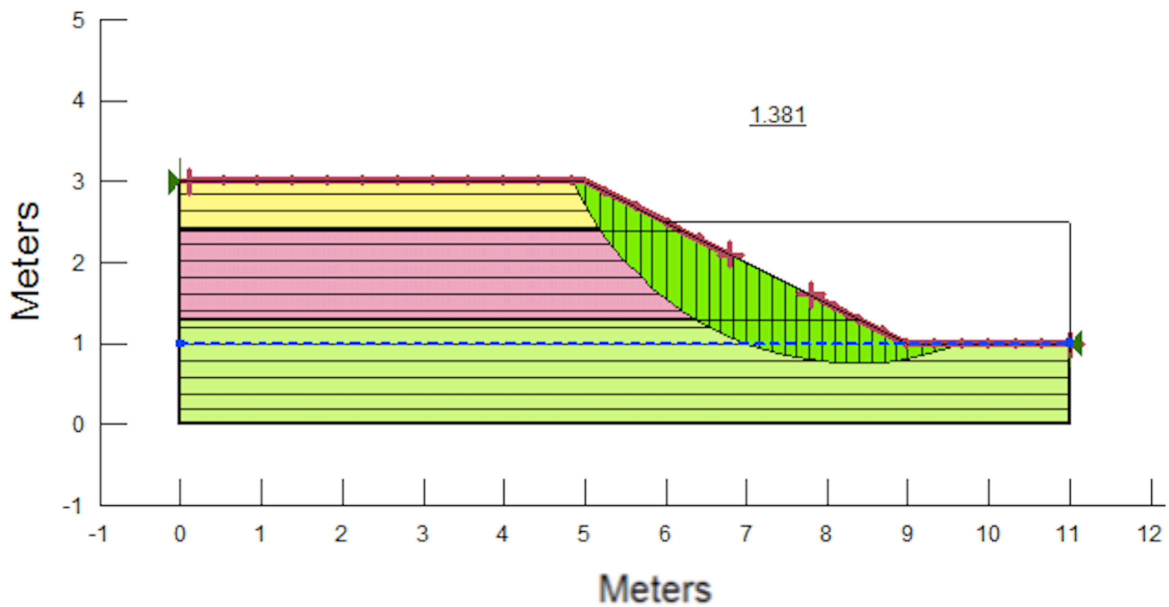



**FIGURE 16: GEOTECHNICAL DESIGN OF A TYPICAL CROSS SECTION** **DOMS, 2015**

The drawing above has layer depths and material properties we deemed to be most representative of the soils found near our project site. These layer properties are shown in the table below.

**TABLE 7: MATERIAL PROPERTIES** **DOMS, 2015**

| Material | Colour | Depth | Unit Weight | Phi' |
|---|---|---|---|---|
| Fill | Yellow | 0.6 m | 19.2 kN/m$^3$ | 28$^o$ |
| Clay | Pink | 1.1 m | 19 kN/m$^3$ | 30$^o$ |
| Sand | Green | 1.3 m | 17 kN/m$^3$ | 28$^o$ |

After analyzing the design in SlopeW, and adjusting parameters to be most conservative, we determined an adequate governing Factor of Safety of 1.381, as shown above.

To improve the Factor of Safety, DOMS has the following suggestions:

- In wider areas, or whenever possible, decrease the steepness of the slope.
- Streambanks should be planted with plant species that improve the stability of the slope.
- Large machinery should be kept back from top of bank.
- All backfill material should be approved by the Geotechnical Engineer, and tested for compacted after placement.

Given the brief slope stability analysis discussed above, we believe the project site is suitable for this project. A further geotechnical analysis is required before proceeding with detailed design.

## 14.0 TRANSPORTATION CONCERNS

According to BCIT's own sustainability charrette, BCIT is described as a commuter campus, meaning that most students live off campus and commute daily. Traffic reduction strategies such as mandatory U-Passes, bicycling clubs and carpool groups are currently being implemented. Despite these efforts many students and staff still rely on personal vehicles to travel to and from BCIT. This makes transportation planning an essential consideration for any construction project on campus.

### 14.1 Parking

All of the recommended creek alignments will impact existing campus thoroughfares and parking infrastructure. A detailed plan will be necessary to minimize inconveniences imposed on staff, students and visitors of BCIT during construction and once completed.

Although parking capacity will be reduced, conversations with Mike Newall from BCIT Campus Planning indicate that current capacity exceeds City of Burnaby requirements by approximately 1000 parking stall. City of Burnaby bylaw 800.4.10 regarding off-street parking requires that 1 parking stall is provided for every staff member or for every 10 students (City of Burnaby, 2015)

BCIT reported a 17,981 full-time students and 2,391 staff in 2014 (BCIT, 2014) A BCIT campus parking lot survey by AECOM reports 4,556 spaces on the Burnaby campus (See Appendix I).

According to the City of Burnaby's off-street parking bylaw an **excess of 356 parking stalls** exist on BCIT's Burnaby campus. Over the past 4 years, DOMS & Associates have observed that the parking lots at the south end of the campus are typically unused. According to AECOM's survey, these lots have a combined 656 parking stalls.

### 14.2 Traffic

A 2013 study jointly conducted by CH2MHILL and BCIT Campus Development quantified traffic at campus access points. This provides a sense of traffic rates during peak periods. The study produced existing and projected traffic volumes, however due to the draft nature of the report, only the existing totals are available for this report. Appendix J shows the ingress and egress traffic values for peak morning and afternoon times:

During construction access points will be affected and detours established to maintain traffic flow. Based on the location of proposed alignments, the north-eastern section of campus is of primary concern. The traffic report indicates that Carey Avenue is one of the three primary choices for accessing the BCIT campus.

# 15.0 EVALUATION CRITERIA

DOMS & Associates developed a 'Sustainability Matrix for Option Evaluation' to help. This was motivated by the desire to have a qualitative way to evaluate each route, and compare the pros and cons of each design. Matrix criteria were designed to evaluate each option based on the three aspects of sustainability: economic, social, and environmental. The weightings for the sustainability matrix were developed using input from all members of the project organizational chart shown in Section 3.2.

After developing the matrix questions, project stakeholders were asked to evaluate the matrix and weigh the importance of each criterion. After discussing the responses, and averaging the stakeholders' weightings, we produced our Sustainability Matrix for Option Evaluation, able to be viewed by pulling out the tab labelled 'Sustainability Matrix'.

Applying the above sustainability matrix, and scoring each design with respect to the weighting above allowed us to evaluate the routes, and give final results and recommendations. The filled out Sustainability Matrix is available in Appendix K.

# 16.0 ALIGNMENT #1 – Around SE 1

Alignment #1 diverts a portion of Guichon Creek's flow through a shallow culvert from the east side of the sedimentation pond. A high-flow bypass is designed to direct approximately 75% of the flow into the existing stormwater system. The proposed route, as shown in Appendix C was chosen to minimize conflicts with existing utilities and buildings. Dimensions and slope were designed to accommodate the 200-year storm flows while providing adequate depths and velocities for salmonid migration.

## 16.1 Conceptual Layout

The conceptual layout of Alignment #1 was designed to minimize conflicts with utilities, roadways and building. A pull out tab labelled Alignment #1 allows the reader to follow the route visually. The layout travels north through the campus in a sinusoidal manner and then around the east side of SE 1. This avoids many utility conflicts near Goard Way and Roper Avenue in particular a recent significant BC Hydro upgrade. The alignment drops further east to avoid the new electrical substation that is being constructed on the northeast corner of SE 1.

The creek veers northwest after SE 1 and heads towards Guichon Alley (alleyway between NE 8 and NE 6). Through Guichon Alley, the creek is restricted to a straight alignment due to the proximity of building foundations. The proposed route then meanders north until it passes under Canada Way.  A new culvert is suggested under Canada Way to provide for better fish passage. The alignment for the Canada Way outlet is the same for Alignment #1 and #2 and is shown on separate drawings.

The sinuosity of Alignment #1 was determined based on the average conditions of natural channels. The channel sinuosity was determined based on a meander length of 8 times the bankfull width and a radius of curvature of 2.3 times the bankfull width (REFERENCE FHRP). With an average bankfull width of 10 m, the design meander length was 80 m and the radius of curvature was 23 m.

Two locations along the alignment were designed for low flow ponding areas. The first section on the northeast corner of SE 1 is designed with a 20 m bankfull width and 0.5% slope.  The second ponding area, located south of NE 6, is designed to tie-in to future wetland. These ponding areas and wetland will help to mitigate the severity of low-flow conditions, and provide habitat for resident species.

## 16.2 Route Specific Constraints

The majority of constraints Alignment #1 encounters are related to avoiding utility conflicts. By diverting the creek away from the major utility right-of-way beneath Roper Avenue conflicts have been minimized, reducing the cost of this alignment. Due to the inaccurate nature of currently available utility information approximations have been made where necessary.

There are approximately 20 occurrences where there is interference with either an existing storm pipe, lead, or catch basin. These items are not seen as considerable issues as the majority of the catch basins and leads are to be removed and replaced by infiltration galleries. There are ten other minor conflicts with existing gas, sanitary, and water network to make 30 total conflicts.

A description and visual representation of each conflict can be seen in the attached excel spreadsheet found in Appendix L. While this provides an approximate location for existing utilities, any future work should be preceded by thorough utility investigation.

## 16.3 Budget and Cost

The construction estimate can be used throughout the conceptual planning and design phases to evaluate the projects budget and feasibility. The cost estimate provides unit costs derived from the 2006 version of *RSMeans: Metric Construction Cost Data* (RS Means, 2006) combined with the judgement, experience and knowledge of the DOMS team. The cost estimate for Alignment #1 has been completed using the following simplifying assumptions:

- Utilities removed and installed are assumed to have a diameter of 300 mm
- Utilities are assumed to be up to 2 m deep
- Backfill of new utility trenches can utilize 50% of the material removed from utility excavation
- Catch basins and manholes are one size with a face area of 8 $m^2$
- New re-routed utilities have the same length as what was removed
- Creek bedding fill will be 200 mm in depth throughout the creeks base area
- Allotment of 40 $m^3$ for large rip rap materials
- Shoring in utility excavation is only required for a quarter of the total utility works

- Shoring in creek excavation is only required for areas with side slopes exceeding 1:1
- Swales will be of typical cross section and will run along 600 m of one side of the creek
- Side banks of creek and swales will be covered in sodding
- Large coniferous trees for shade will be planted every 20 m
- Creek footprint does not conflict with the arch culvert.

With these assumptions the cost estimate for Alignment #1 falls under APEG Class D cost estimates. The final construction estimate for Alignment #1 is **$1,015,000**. For a complete cost allocation breakdown of Alignment #1 please see Appendix M.

## 16.4 Constructability

Alignment #1 is the easiest of the three alignments to build. The least amount of excavation is required in this option even though it creates the longest watercourse. Utility conflicts are limited and mostly involve storm sewers and catch basins. This reduces utility service shutdowns throughout campus during construction. Alignment #1 requires less shoring because of its naturalized sections with low-grade slopes and only short lengths of culvert. Furthermore, there are no conflicts with the existing arch culvert so the entire creek can be constructed without the need to temporarily divert Guichon Creek.

## 16.5 Hydrologic Capacity

Alignment #1 relies on a diversion structure to limit the flows that are able to enter the daylighted creek section. The concrete box culvert that diverts flows from the ponding area has been designed to limit flows to 8 cms. This is approximately 20% of the flows generated by a 200-year storm event.

The naturalized sections of the creek are capable of much more than 8 cms. The region of limiting flow is the ponding area, with a maximum capacity of 28 cms. This does not take into account hydraulic backflow conditions, but provides a confident factor of safety for flooding considerations.

## 16.6 Fish Passage & Channel Naturalization

Alignment #1 is the longest proposed design and allows the most space for channel naturalization. The proposed route for Alignment #1 was designed to promote salmonid migration, and create the best possible natural habitat for fish and wildlife.

The advantages of a longer stream length and greater area as proposed by Alignment #1 include:

- More space for more meandering and sinuosity of the creek
- Greater space for pooling areas, and shading areas
- The ability to tie-in to proposed wetlands such as by NE 8
- A more fish-friendly slope throughout the proposed alignment.

Of all three proposed designs, Alignment #1 has the shortest amount of culverted section of creek. This encourages fish migration, and allows the creek to remain more accessible for students using the living lab.

One concern that arises with all alignments is the limited flows during summer months. Alignment #1 is designed to help minimize periods when the creek runs dry by tying-in to proposed wetlands, and creating ponding areas that maintain a more consistent flow.

## 16.8 Adherence to Campus Development Plan

The framework for the long-term campus development plan provides guidance for future work despite not being complete. In order to ensure that proposed work is feasible it must take into consideration adherence to the campus plan. The desire to create a campus 'Blueway', planned development, the future parking demands, and traffic requirements of the campus were considered.

### *16.8.1 Parking Alterations*

This design attempts to minimize utility conflict. To achieve this, the proposed corridor must veer east, and occupy sections of Lot P7, Lot B, and Lot A (these lots can be seen in Appendix I). The total number of parking spaces subject to removal for this alignment is 277.

Removal of parking spots from P7 may not be desirable for BCIT Campus Development as this is a designated staff parking lot during weekdays. Of the 277 stalls eliminated, 60 are from P7. Even with the 277 parking spaces to be removed, there is still an excess of 79 parking spaces on campus.

Decreasing the number of spots in some of these areas might force students to park in the gravel lots along the periphery of the campus. This may be considered a drawback from a student's perspective in terms of classroom proximity.

#### *16.9.2 Campus Blueway*

This route does not fully satisfy the campus Blueway goal because it circumvents the utility conflicts that exist at the intersection of Roper Avenue and Goard Way. Consideration is given to this shortcoming in the decision matrix.

### 16.9 Education / Community Impact / Accessibility

All proposed alignments offer an opportunity to educate the local community about daylighting, stream rehabilitation, fish migration, and wildlife habitat conservation. For BCIT students, daylighting Guichon Creek offers an opportunity for on-campus learning, a living lab space, and a place to conduct a wide variety of lab experiments. For Civil Engineering students, the process of daylighting Guichon Creek offers the added incentive of being an on campus construction project.

Of the three proposed routes, Alignment #1 is the most shovel-ready, and could provide the most immediate impact to BCIT and the local community. Moving forward as soon as possible would help create public awareness, and highlight the benefits of daylighting Guichon Creek.

## 17.0 ALIGNMENT #2 – Shallow Channel Along Roper Avenue

Alignment #2 also diverts a portion of Guichon Creek's flow through a shallow culvert from the east side of the sedimentation pond. The same high-flow bypass designed for Alignment #1 will direct approximately 75% of the flow into the existing stormwater system. The proposed route, as shown in Appendix D, was chosen to satisfy the 'Blueway' vision of BCIT's Facilities and Campus Development. Dimensions and slope were designed to accommodate the 200-year storm flows while providing adequate depths and velocities for salmonid migration.

### 17.1 Conceptual Layout

The conceptual layout of Alignment #2 was designed to fulfill the future of vision for Guichon Creek by passing through the middle of campus and in front of the library's future atrium. . A pull out tab labelled Alignment #2 allows the reader to follow the route visually. The creek travels a relatively straight path through campus.

The layout of the creek focused on providing an aesthetic appeal while trying avoiding utility and building conflicts. Alignment #2 begins after diverting through a culvert and meandering north along the west side of Roper Avenue. The creek narrows into another culvert approximately 50 m long outside the SE 10 Broadcast Center, to provide the necessary vehicle access to this area. Once the creek reaches SE 6 it is narrow as it passes between SE 1 and SE 4 before it is culverted again under Goard Way. The alignment then meets the same path as Alignment #1 and meanders towards Canada Way.

The channel sinuosity for Alignment #2 was designed under the same criteria as Alignment #1 and had the same meander length of 80 m and radius of curvature of 23 m. There are two proposed ponding areas, the first north of SE 1 and the second south of NE 6.

### 17.2 Route Specific Constraints

Alignment #2 is designed to match the vision of a campus 'Blueway' while attempting to minimize utility conflicts. This route runs into major existing utilities beneath Roper Avenue and the north end of campus. There are 13 occurrences of interference with the existing storm drainage system. There are approximately 28 other utilities conflicts with electric, gas, telecommunication, sanitary and water systems. This makes a total of 41 utility conflicts for this alignment. Determining utility conflicts requires further investigation to resolve uncertainties.

A description and visual representation of each conflict can be seen in the attached excel spreadsheet in Appendix N. Future work should be preceded by thorough utility investigation.

### 17.3 Budget and Cost

The construction estimate can be used throughout the conceptual planning and design phases to evaluate the projects budget and feasibility. The estimate provides unit costs derived from the 2006 version of *RSMeans: Metric Construction Cost Data* combined with the judgement, experience and knowledge of the DOMS team. The cost estimate for Alignment #2 has been completed using the following assumptions:

- Utilities removed and installed are assumed to have a diameter of 300 mm
- Utilities are assumed to be up to 2 m deep
- Backfill of new utility trenches can utilize 50% of the material removed from utility excavation
- Catch basins and manholes are one size with a face area of 8 $m^2$
- New re-routed utilities have the same length as what was removed
- Creek bedding fill will be 200 mm in depth throughout the creeks base area
- Allotment of 40 $m^3$ for large rip rap materials
- Shoring in utility excavation is only required for a quarter of the total
- Shoring in creek excavation is only required for areas with side slopes exceeding 1:1
- Swales will be of typical cross section and will run along 600 m of one side of the creek
- Side banks of creek and swales will be covered in sodding
- Large coniferous trees for shade will be planted every 20 m
- Creek footprint does not conflict with the arch culvert.

With these assumptions the cost estimate for Alignment #2 falls under APEG Class D cost estimates. The final construction estimate for Alignment #1 is **$1,250,000**. For a complete cost allocation breakdown of Alignment #2 please see Appendix M.

### 17.4 Constructability

Alignment #2 runs along Roper Avenue and through a central area of campus where electrical, sanitary, and water lines are present. This will result in major service shut-downs because of the increased conflicts with utilities. Similar to the first option, there is no removal of the existing arch culvert, eliminating the need to temporarily divert Guichon Creek. The shallow excavations involved in this route reduce construction costs. This alignment is considered to have moderate constructability compared to the other options.

## 17.5 Hydrologic Capacity

Alignment #2 relies on a diversion structure to limit the flows that are able to enter the daylighted creek section. The concrete box culvert that diverts flows from the ponding area has been designed to limit flows to 8 cms. This is approximately 20% of the flows generated by a 200-year storm event.

The naturalized sections of the creek are capable of much more than 8 cms. The region of limiting flow is the ponding area, with a maximum capacity of 29 cms. This does not take into account hydraulic backflow conditions, but provides a confident factor of safety for flooding considerations.

## 17.6 Fish Passage & Channel Naturalization

The proposed route provides adequate flow properties for fish migration. This is achieved through a naturalized channel where possible, and fish friendly slopes throughout the route. Where culverts are required, the design ensures velocities are minimized and provides for depths that promote upstream fish passage. This route is constrained by the desire to pass through the developed campus core, and some stepping was required to create fish passable sections where slopes exceeded recommended fish standards.

Wildlife and fauna will benefit from this route, although this route creates less naturalized area than Alignment #1. This route improves immeasurably upon the current underground culvert.

## 17.8 Adherence to Campus Development Plan

The framework for the long-term campus development plan provides guidance for future work despite not being complete. In order to ensure that proposed work is feasible it must take into consideration adherence to the campus plan. For this project the desire to create a campus 'Blueway' and the future parking and traffic requirement of the campus was considered.

#### *17.8.1 Parking Alterations*

The second proposed alignment is more consistent with how BCIT Facilities and Campus Development's vision for the daylighted creek. Conversations with Facilities staff have indicated that parking lots V3, P12, and P5 are slated for removal to accommodate future projects. The total number of spaces that would be affected by Alignment #2 is 159 stalls. This is lower than the proposed 277 stalls affected by Alignment #1.

#### *17.8.2 Temporary Traffic Control*

Alignment #2 runs down Roper Avenue, road closure will be required in to facilitate construction effectively. Primary access points affected by Alignment #2 include Ford Street off of Wayburne Drive, and Carey Avenue off of Canada Way..

Proper traffic control devices are to be used in accordance with the government of British Columbia's temporary Traffic Control Manual; it must also be understood that it may not be possible to meet minimum standards in unique conditions or emergency situations.

#### *17.8.3 Campus Blueway*

This route satisfies the planned development of a campus Blueway along Roper Avenue. BCIT hopes to use this to improve the aesthetics of the school, as well as to create a living lab and healthy ecosystem.

### 17.9 Education / Community Impact / Accessibility

Alignment #2 provides a more accessible space due to its proposed location on campus. Running the daylighted creek more directly down the centre of campus would allow the area to be more accessible, and more easily tied into a pedestrian 'Blueway'. This in turn will promote more interaction for students and be ideal for a living lab.

## 18.0 ALIGNMENT #3 – Replace Existing Culvert

Alignment #3 provides the solution for a full flowing creek. This route, as detailed in Appendix E, involves the complete removal of the existing storm water pipe and replacing it with an open channel capable of managing 200-year storm flows and salmonid migration. A pull out tab labelled Alignment #3 shows the plan view of this proposed route.

### 18.1 Conceptual Layout

The layout for Alignment #3 travels along a similar path as Alignment #2. The difference between the two alignments is that Alignment #3 is designed to fully convey 200-year storm events. Alignment #3 travels through the middle of campus while maintaining salmonid migration and acting as a full replacement of the existing 2 m by 3 m storm pipe.

Similar to Alignment #2, the layout of the creek focused on providing an aesthetic appeal and minimizing interference with surrounding infrastructure. Alignment #3 begins at SE 16 where it will replace the existing weir with a series of step-pools. The alignment continues to meander north along the west side of Roper Avenue. The creek narrows into a culvert approximately 50m long outside the SE 10 Broadcast Center; vehicle access to this area is required. Once the creek reaches SE6 it is narrow as it passes between SE 1 and SE 4 before it is culverted again under Goard Way. The alignment then meets the same path as Alignment #1 and #2 and meanders towards Canada Way.

The sinuosity for Alignment #3 was designed using a bankfull width of 15 m. This defined a channel meander length of 120 m and a radius of curvature of 35 m. Similarly to Alignments #1 and #2 there were two ponding areas. The first being just north of SE 1 and the second ties into the same future wetland south of NE 6.

### 18.2 Route Specific Constraints

The proposed design for Alignment #3 focused on full flow capability and therefore does not attempt to minimize utility conflict. This route conflicts with major existing utilities beneath Roper Avenue and Goard Way. Like Alignment #2, this design attempts to satisfy the vision of BCIT Facilities and Campus Development with a pedestrian ‘Blueway’.

This alignment has considerable impact on existing utility networks. There are 21 occurrences where there is interference with the existing storm drainage system.

The water distribution system has the second most with 11. There were approximately 20 other utilities conflicts with electric, gas, telecommunication, and sanitary systems. This makes a total of 52 conflicts. Determination of conflicts is challenging due to the complexity of the underground network. A further investigation is required in order to resolve some of these uncertainties.

A description and visual representation of each conflict can be seen in the attached excel spreadsheet in Appendix O. It should be noted there is a considerable degree of uncertainty with regard to depth in all cross sections. While this provides an approximate location for existing utilities, any future work should be preceded by thorough utility investigation.

### 18.3 Budget and Cost

The construction estimate can be used throughout the conceptual planning and design phases to evaluate the projects budget and feasibility. The cost estimate provides unit costs derived from the 2006 version of *RSMeans: Metric Construction Cost Data* combined with the judgement, experience and knowledge of the DOMS team. The cost estimate for Alignment #3 has been completed using the following assumptions:

- Utilities removed and installed are assumed to have a diameter of 300 mm
- Utilities are assumed to be up to 2 m deep
- Backfill of new utility trenches and removed arch culvert trenches can utilize 80% of the material removed from utility excavation
- Catch basins and manholes are one size with a face area of $8m^2$
- New re-routed utilities have the same length as what was removed
- Creek bedding fill will be 400 mm in depth throughout the creeks base area
- Allotment of 500 $m^3$ for large rip rap materials to slow large flows and protect bed from scour
- Shoring in utility excavation is only required for a quarter of the total
- Shoring in creek excavation is only required for areas with side slopes exceeding 1:1
- Swales will be of typical cross section and will run along 600 m of one side of the creek
- Side banks of creek and swales will be covered in sodding
- Large coniferous trees for shade will be planted every 20 m
- Arch culvert is assumed to be 2400 mm diameter
- Arch culvert will be removed entirely in all areas with overhead access.

With these assumptions the cost estimate for Alignment #3 falls in the APEG Class D classification. The final construction estimate for Alignment #1 is **$1,725,000**. For a complete cost allocation breakdown of Alignment #3 please see Appendix M.

### 18.4 Constructability

Alignment #3 is the most difficult of the three proposed options in terms of constructability. In addition to running through the central area of campus where electrical, sanitary, and water lines are located, it will require removal of the existing arch culvert and thus need a temporary diversion of Guichon creek. Alignment #3 also requires significantly more excavation due to the larger cross-sectional area and the void created by the removal of the arch culvert.

### 18.5 Hydrologic Capacity

This route was chosen as a replacement for the existing arch-culvert that is buried on campus. Whereas the other routes focus on constructability, Alignment #3 is designed to safely convey 200-year storm events through the BCIT campus. The design was checked using Manning's Equation to ensure that 40 cms flows would be contained within the banks of this design. Full flow depths along the route can be seen in Appendix E.

### 18.6 Fish Passage & Channel Naturalization

The greatest fish passage challenge for Alignment 3 relates to it conveying higher flows than the other two designs. During high flow time periods, from October until March, the daylighted Alignment 3 will carry the entire flow, which would not generate ideal conditions for fish migration.

Alignment 3 is also the least naturalized of the three proposed designs. In order to handle the extreme storm event flows, the channel was designed with high and steep streambank slopes. Alignment 3 was designed to follow a similar path to the existing culvert, meaning it had to fit between buildings, so was unable to meander as much as Alignment 1.

### 18.8 Adherence to Campus Development Plan

Although still incomplete, the framework for the long-term campus development plan provides guidance for future work. To ensure proposed work is feasible it must take into consideration future plans for the campus. For this project the desire to create a campus 'Blueway', future parking plans, and campus traffic requirements were considered.

#### *18.8.1 Parking Alterations*

Alignment #3 is similar to the second alignment as it follows a more central route through campus. This leads to similar implications for parking alterations, including removal of parking lots V3, P12, and P5. These lots, as previously mentioned, are not part of the long-term campus plan. Removing these lots would make the total number of stalls removed 159, which is still well within the allowable limit of 356.

#### *18.8.2 Temporary Traffic Control*

The traffic control procedures follow that of Alignment #2 as there is little deviance in corridor alignment. A detour to adjacent streets will be provided and a site-specific procedure is recommended. All traffic control devices and zones are to be specified prior to construction.

The same primary access points will be affected; Ford Street off of Wayburne Drive, and Carey Avenue from Canada Way. Proper traffic control devices are to be used in accordance with the government of British Columbia's temporary Traffic Control Manual.

#### *18.8.3 Campus Blueway*

This route accomplishes the vision set forth by BCIT Facilities and Campus Development to create a pedestrian friendly route down Roper Avenue.

## 18.9 Education / Community Impact / Assessment

As Alignment #3 is designed to convey the extreme storm flows, its streambanks are much deeper than the other two alignments. As a result, accessibility to the creek is more difficult in this alignment design. This was considered when scoring the alignments in the decision matrix.

At the same time, Alignment #3 may offer the living lab aspects that the other alignments do not. These advantages include being able to observe and measure the full stream flow during extreme storm events. Without knowing more about the purpose and design for the living lab it is hard to apply a tangible score to this advantage.

# 19.0 RESULTS

Following a thorough evaluation of the economic, social, and environmental impacts of each route, DOMS has tabulated the values generated from the sustainability matrix. The matrix shows that Alignment #1 is the most favourable, with a score of 61 out of a possible 71 points.

Some of the major factors contributing to Alignment #1 scoring highly in the sustainability matrix are low initial investment, ease of constructability, and high degree of channel naturalization. Constructability is a very important part of a feasibility assessment and the route designed for Alignment #1 scored well in subcategories such as utility conflicts, utility interruptions and excavation volume.

Alignment #2 scored 58 points on the decision matrix. One significant reason it scored lower than Alignment #1 was because of the increased number of utility conflicts. This caused a higher cost estimate for Alignment #2, as well as a reduced area for natural design, such as meandering sinuosity and ponding areas. DOMS believes that from both a cost and naturalization standpoint, Alignment #2 is an inferior design to Alignment #1.

Alignment #3 received 56 of a possible 71 points on the sustainability decision matrix. Mostly, this low score represented the difficulties associated with designing a deep passageway, which could convey the full storm flow of Guichon Creek, through the centre of campus. The higher flow required a more costly solution due to increased excavation volumes and greater utility conflicts. From a stream restoration and naturalization point of view, this design was unable to provide a stream that had as many desirable features as Alignment #1. This route may be preferable for BCIT due to the fact it eliminates the need to eventually replace the existing arch culvert.

In DOMS' opinion, Alignment #1 is the most feasible way to successfully align the economic and flooding concerns with campus beautification, all while maintaining a robust fish habitat in a naturalized, daylighted creek. This additional space gives the ability to further naturalize the channel. This design provides the highest percentage daylighted, a fish friendly riparian environment, and the capability of incorporating biological diversity.

# 20.0 RECOMMENDATIONS & CONCLUSION

The purpose of this report was to broaden the understanding of daylighting Guichon Creek. While DOMS was able to illuminate many challenges to this project, there is much work to be completed. BCIT would be well served to utilize its student body to minimize the cost of further studies where possible. This will also create excellent real-world learning opportunities while generating further awareness of daylighting Guichon Creek.

## 20.1 Education and Public Awareness

To allow this project to continue moving forward, further effort is required. There must be both increased education on the benefits of daylighting, and improved public awareness about the Guichon Creek project. While describing this project to both fellow students and local residents, DOMS frequently encountered people who were unaware of the concept of daylighting, or that Guichon Creek existed on campus. Educating both the student population at BCIT as well as the general public will help gather momentum for this vision to become a reality. We are hopeful that this project will further the discussion about daylighting, and lead to a revitalization of Guichon Creek and the BCIT campus.

## 20.2 Flow Measurements and Data Collection (Continued Studies)

To assist further work, there are some useful projects that could be started immediately. We believe the following would have either been valuable to us during this project, or will soon be useful as daylighting Guichon Creek continues.

- Flow measurements in Guichon Creek, specifically during peak flow periods. This would allow more accurate design parameters to be developed.
- Studies along Goard Way to determine the pedestrian and vehicular usage of the road. This will help to understand the impacts and requirements of a pedestrian Blueway through the center of campus.
- Installation of a rainfall / weather collection system on campus.

## 20.3 Future Work

DOMS has provided the client with a project definition report. The preliminary stage of the project omits many design aspects that can be undertaken by future students. Moving forwards, DOMS suggests the following detailed designs to be addressed:

- *Infiltration Design*: this consists of determining what toxic runoff is present on campus, which soils and plants are best suited for the removal of these toxins, and show how effective the system is at providing healthy return water to Guichon Creek.
- *Culvert Design*: A more detailed hydraulic analysis of the box culverts is required to confirm adequacy. Fish passage, traffic loading, and applicable culvert types should be considered.
- *Bridge and Overpass Design*: At locations of roadway crossings, culverts can be replaced with bridge crossings to replace culverts, maintain a continuous creek and facilitate traffic efficiently. A detailed design can be provided for several types of overpasses.
- *Geotechnical Investigation and Design*: A thorough investigation of native campus soils should be completed. This includes soils testing, slope stability analysis, design of mechanically stabilized walls, and shoring designs while working in close proximity of buildings.
- *Hydrological Monitoring and Analysis*: A detailed seasonal flow reference document and a detailed hydrological model following utility locating throughout BCIT campus.
- *Utility Relocations and Modeling*: Following a route confirmation and utility locating a detailed relocation plan of sanitary, storm, water, and electrical mains is required.
- *Parking Structure Design*: A detailed design for a parking structure can be completed to consolidate parking and increase green space on the campus.
- *Road Realignments*: Following a route confirmation, road realignments will be required and can be detailed accordingly.

The planned daylighting of Guichon Creek provides opportunities for a wide array of disciplines, both within Civil Engineering and other related faculties such as Ecological Restoration, Geomatics, and Architecture departments.

Further detailed studies should be conducted to fill in the gaps in available data. Public awareness programs should be implemented soon to begin building support for the daylighting of Guichon Creek. We believe this project is a worthwhile undertaking for BCIT that will establish the school as a leader in sustainable campus development.

# 21.0 REFERENCES