

# **Restoring Hydrological Connectivity in the Guichon Creek Watershed through Wetland Creation**

**by**

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## EXECUTIVE SUMMARY

Urbanization of areas alters the natural hydrology of the land through the creation of impervious surfaces, removal of vegetation, and construction of storm sewer systems. These alterations impact physical processes and the biological communities of our waterways through the introduction of pollutants, creation of uncharacteristic hydrological regimes, and habitat loss and fragmentation. Integration of natural areas in our built environments will mitigate some of these effects and reduce the degradation of streams in urbanized watersheds.

Guichon Creek flows through an urbanized environment, which includes the British Columbia Institute of Technology (BCIT) Burnaby campus. A tributary flows into Guichon Creek at the south end of campus and the majority of its flow is from a stormwater sewer which receives runoff from the residential area east of campus. The tributary is approximately 150 metres and runs between a community garden and a small gravel parking lot before entering Guichon Creek.

This project proposes restoration of a 2,000 m<sup>2</sup> parcel of land between Guichon Creek and the tributary. Restoration activities involve removal of an existing parking lot, management of invasive hybrid Japanese knotweed (*Fallopia x bohemica*) and Himalayan blackberry (*Rubus armeniacus*), creation of an off channel wetland, and addition of natural in-stream structures to the tributary. Wetlands provide important hydrological and ecological functions that will contribute to the restoration efforts on Guichon Creek. This wetland will improve hydrological functions of the Guichon Creek floodplain through increased groundwater infiltration, creation of a storage area, and pollutant filtration. Improving these functions is also an important component of making stream ecosystems more resilient to climate change. The wetland will also provide ecological benefits such as improved water quality and creation of amphibian habitat. This project focuses on the creation of habitat for northern red-legged frog (*Rana aurora*) and the Pacific chorus frog (*Psuedacris regilla*).

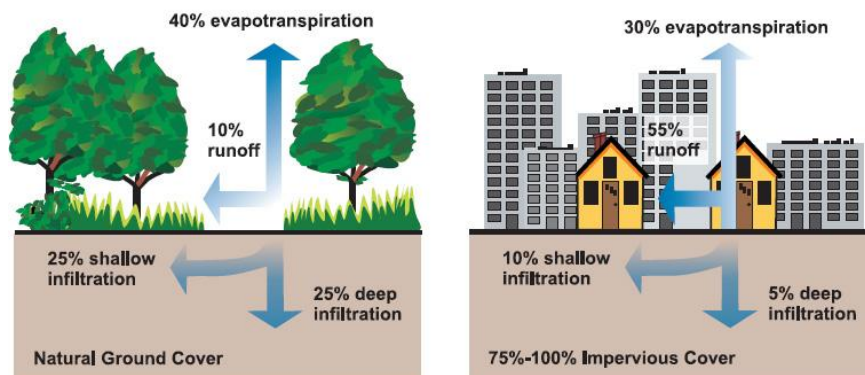
Another important component of restoration in an urban environment is creating a connection between people and the environment. Restoration of this space provides opportunities for public involvement and environmental education and awareness. This creates a forum to discuss the effects of urbanization on streams and show people where the runoff from their neighbourhood ends up. Forming that connection between people and their environment is an important step to creating interest and involvement in environmental issues.



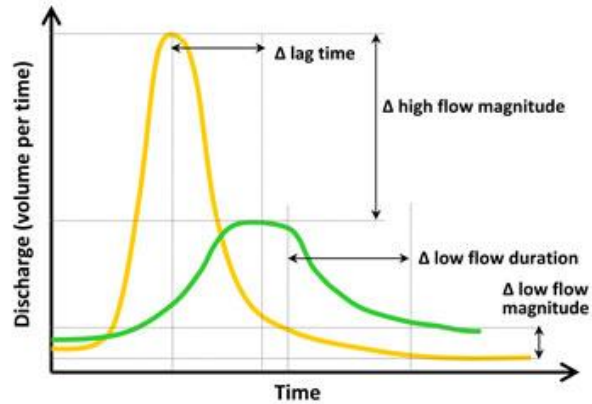
## 1.0 INTRODUCTION

Urbanization of watersheds has many detrimental effects to our aquatic ecosystems. Hydrology of streams and rivers is altered as vegetated areas are replaced with impervious surfaces and natural overland flow processes are replaced with a system of catch basins and storm sewers. These alterations result in point and non-point source pollution, channel erosion, increased runoff volume and rates, and higher potential of flooding (Walsh et al., 2005). Wildlife within the aquatic ecosystem is also affected by these changes through habitat loss, degradation, and fragmentation (Mitsch & Gosselink, 2015).

Impervious areas create an increase in the amount of runoff and a decrease in the amount of infiltration (Figure 1-1, 1-2). Subsequently, receiving water bodies in urban areas are subject to higher flow rates and higher volume of runoff than undeveloped areas. If the receiving streams are not capable of handling these hydrological changes, this can result in flooding, bank erosion, and degradation of in-stream habitat. Decreased infiltration also reduces groundwater recharge and reduces the amount of baseflow in streams.



**Figure 1-1:** The effects of impervious cover on watershed hydrology (USEPA, 2003)



**Figure 1-2:** Theoretical hydrographs of a rural stream (green) and urban stream (yellow) after a storm event (USEPA, 2016)

Research by the Center for Urban Water Resources Management showed the factors that determined the ecological health of an urbanized stream, in order of importance were (1) changes in the hydrology, (2) degradation of the riparian corridor, (3) changes to in stream habitat, and (4) changes in water quality (Stephens & Dumont, 2011).

Restoration in an urban setting can be a difficult task due to existing infrastructure and lack of space. However, many initiatives exist in the Lower Mainland, from large federal projects such as the Fraser River Action Plan to smaller municipal projects like the Still Creek Enhancement. One of these smaller rivers is Guichon Creek which runs through an urbanized area, including the British Columbia Institute of Technology (BCIT) campus in Burnaby, British Columbia. This tributary to Still Creek was once a salmon bearing stream prior to the logging and development of the area surrounding it (Global News, 2015). Guichon Creek has been the subject of restoration efforts for over 30 years and has shown that restoration of streams in an urban environment is possible. Addressing the issue of the altered hydrological processes and restoring hydrological connectivity will help restore stream health. It is important to continue these restoration efforts since Guichon Creek has become a flagship project and a forum for promoting environmental education and sustainable development.

This project will restore part of the riparian area of Guichon Creek through the removal of impervious surfaces, management of invasive species, and creation of an off-channel wetland. Enhancing aquatic ecosystem resilience can be achieved through measures such as restoring riparian corridors, habitat heterogeneity, and restoring hydrological connectivity (Wagner et al., 2008). Wetlands provide these important ecological and hydrological functions through increasing

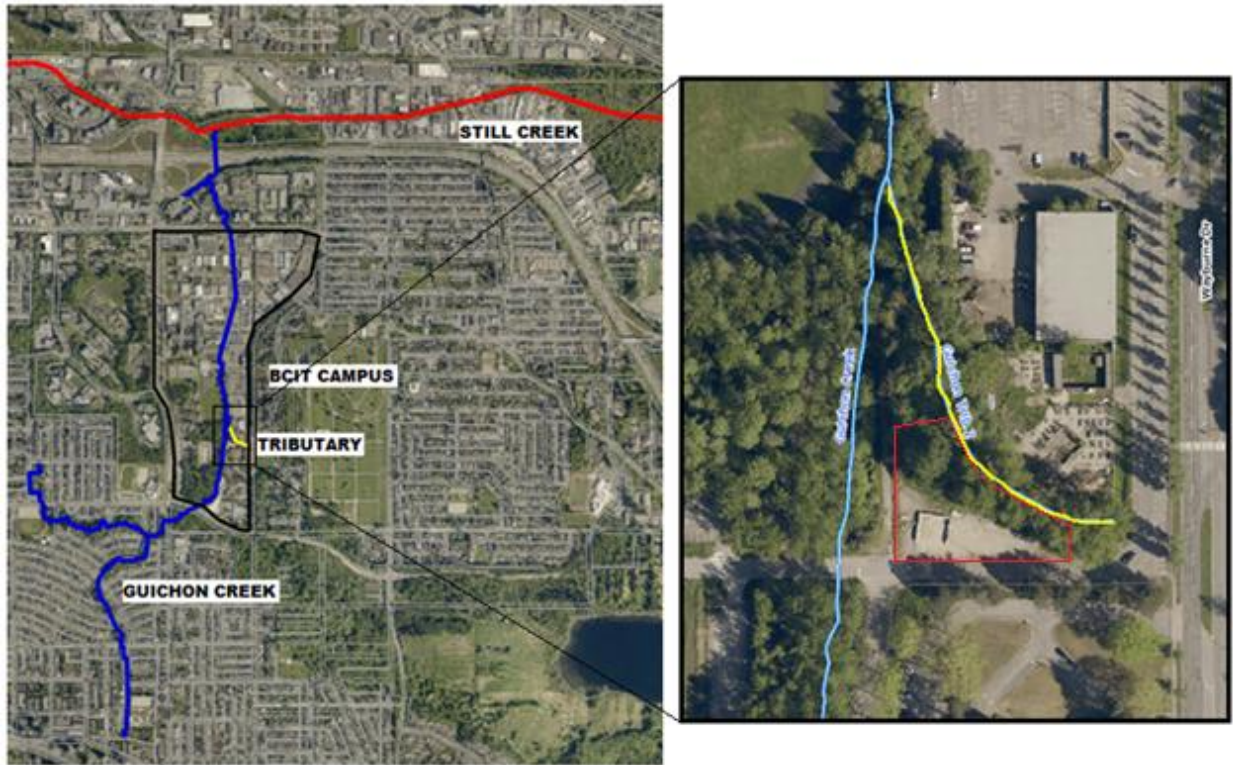
groundwater recharge, filtering out contaminants, reducing flooding, and increasing biodiversity (Mitsch & Gosselink, 2015).

This project will also provide an opportunity for public involvement and environmental education. An important aspect of implementing restoration projects in an urban environment is considering the interactions between people and their surrounding landscape. Improving public awareness of reasons behind the restoration project can be an effective way of getting people to care about, and take responsibility for, their surrounding environment (Herringshaw et al., 2010).

## **2.0 BACKGROUND**

### **2.1 Site Location**

Guichon Creek is one of the larger tributaries in the Still Creek watershed. Guichon Creek flows north through the BCIT campus before flowing into Still Creek just north of the Trans-Canada Highway. The southern portion of Guichon Creek has been the subject of restoration efforts from the Rivers Institute, BCIT, and the City of Burnaby since the 1970's. The northern section of Guichon Creek still remains underground for approximately 700 metres, until the northern side of Canada Way. This project will focus on restoration of a site adjacent to Guichon Creek located on the BCIT campus (Figure 2-1).



**Figure 2-1:** Location of the restoration site (red outline), Guichon Creek (blue), tributary (yellow), and Still Creek (red) in Burnaby, British Columbia

The tributary enters the campus through a storm culvert underneath Wayburne Drive at the southeast side of campus (Figure 2-2). This stormwater outfall receives runoff from the residential neighbourhood to the east and has a catchment area of approximately 10.5 hectares, based on aerial imagery and storm sewer data from the City of Burnaby. It flows for 150 metres through a small channel before entering Guichon Creek.

The project site outlined is approximately 2,000 m<sup>2</sup>. The triangular parcel of land between the tributary and Carey Avenue is a decommissioned parking lot, approximately 700 m<sup>2</sup>, which is currently used to store construction materials and concrete blocks (Figure 2-3). This is an ideal site for restoration since it will turn an unused parking lot into a wetland, which will remove impervious area, expand the riparian area of Guichon Creek, improve the water quality of the runoff, and create a storage and infiltration area. There is also an opportunity to create habitat for wildlife, such as amphibians.





**Figure 2-2:** Guichon Creek tributary at stormwater culvert, facing west, Burnaby, British Columbia.



**Figure 2-3:** Decommissioned parking lot on restoration site, facing southeast from northwest corner, Burnaby, British Columbia

## 2.2 Historical Conditions

BCIT campus is located on the territory of Musqueam, Tsleil-Waututh, and Squamish Nations (BCIT, n.d.). Prior to European settlement, the area in the Brunette River watershed was used by the First Nations as a hunting area. Post settlement, the Phillip-Hoyt Lumber Company constructed a dam on Guichon Creek in 1912 and used the Creek for transporting logs to the sawmill, which was located on what is now the BCIT campus. The forests were then cleared for a second time in the 1940's (Birmingham & Wood Architects, 2013).

The BCIT campus was opened in 1963, with a few buildings on the north side of campus. The campus continued to expand south with the addition of a few more buildings and the athletics field, which was constructed in 1967, and then expanded and upgraded several times from the 70's to the 90's (Birmingham & Wood Architects, 2013).

Guichon creek has gone through various stages of rehabilitation from when it was a straightened channel in the 1950's (Figure 2-4).



**Figure 2-4:** Historical photos of Guichon Creek (BCIT Archives)

## **2.3 Current Conditions**

The current conditions were determined through collection of field data and review of past studies conducted by BCIT staff, students, and consultants.

### **2.3.1 Hydrology**

The tributary begins at a storm sewer outfall that receives runoff from the residential area to the east. The drainage area is estimated to be 10.5 hectares based on aerial imagery and City of

Burnaby storm sewer system data. Since a large portion of this area consists of impervious surfaces, the large amount of stormwater runoff can cause high flows during storm events. The BCIT campus experienced flooding in September 2007 and January 2010, which resulted in damage to some of the buildings on campus (Rohatgi, 2016). A real-time water level monitoring system was installed in Guichon Creek in 2015, in part to help monitor water levels and potential flooding.

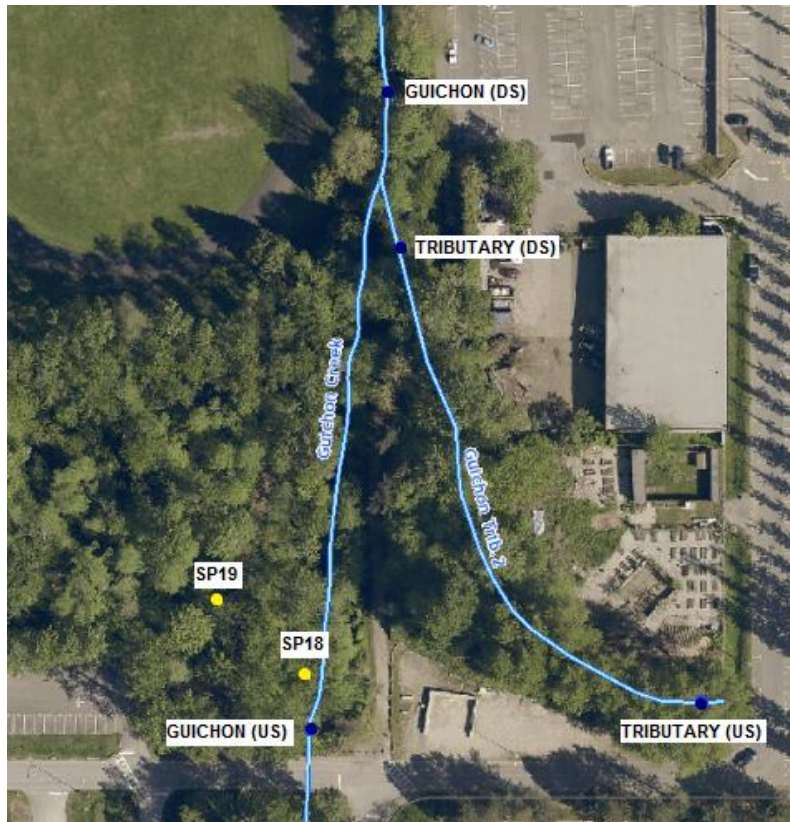
A stormwater management review of BCIT campus contained PCSWMM modelling results for flows in Guichon Creek during 2-year, 10-year and 100-year storm events for 1-hour, 6-hour, 12-hour, and 24-hour durations. The results showed that the pipes experienced surcharges in the culverted section that run through campus for the 10-year and 100-year storm events with the 12-hour and 24-hour durations (Stantec, 2016). This reiterates the need for additional stormwater management structures to be installed on campus.

Two soil pits were dug by students in the RENR 1130 class in the area just west of Guichon Creek in November 2016 (Figure 2-5). The water table was approximately 70 cm below the ground level and mottles and gleying were observed in the lower horizons of the soil, suggesting the soil experiences fluctuating saturated conditions (Biebighauser, 2011). Due to project timing, additional soil pits were not able to be completed on site to find the water table during the seasonally low period. Full soil descriptions can be found in Appendix A.

### **2.3.2 Water Quality**

Water quality was measured at four different sites within Guichon Creek and the tributary (Figure 2-5). The YSI Professional Plus water quality meter was used to measure temperature, pH, dissolved oxygen (DO), conductivity and salinity. Sampling events occurred on sunny days when it had not rained or snowed in a few days, but there was snow on the ground. Water quality results are shown in Table 2-1.





**Figure 2-5:** Soil pits (yellow) and water quality sampling (blue) locations

**Table 2-1:** Water quality sampling results at the tributary and Guichon Creek sites

Site	Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Conductivity (µs/cm)	pH	Salinity (ppt)
<i><b>January 31, 2017</b></i>						
Tributary (US)	6.6	84.6	10.3	429.1	6.9	0.3
Tributary (DS)	6.1	85.8	10.6	461.7	6.9	0.4
Guichon (US)	6.1	85.8	10.6	461.7	6.9	0.4
Guichon (DS)	5.0	102.3	13.1	267.6	7.1	0.2
<i><b>February 14, 2017</b></i>						
Tributary (US)	6.1	92.4	11.5	403.6	6.9	0.3
Tributary (DS)	6.2	89.8	11.1	438.3	6.8	0.3
Guichon (US)	6.2	89.8	11.1	438.3	6.8	0.3
Guichon (DS)	6.3	101.8	12.5	737.0	6.9	0.6



In both sampling instances, the upstream tributary, downstream tributary, and upstream Guichon Creek sites have fairly similar values for the tested parameters. The downstream tributary had higher dissolved oxygen, possibly due to the higher velocity and turbulence leading to more oxygen being dissolved into the water. Conductivity and salinity were lower than the other three sample sites the first sampling event and higher the second sampling event. This suggests that impacts to the water quality in this area may be more strongly linked to the land use in the area between the upstream and downstream sampling locations in Guichon, rather than the inputs from the tributary. However, more testing would be required to confirm this.

Additional water quality sampling was performed at the tributary culvert to acquire additional data for amphibian habitat suitability. The additional sampling days took place during and after a few days of light rainfall after all snow had melted.

**Table 2-2:** Water quality sampling results at tributary culvert

Date	Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Conductivity (µs/cm)	pH	Salinity (ppt)
1-31-17	6.6	84.6	10.30	429.1	6.85	0.33
2-14-17	6.1	92.4	11.46	403.6	6.86	0.31
3-13-17	6.9	83.9	10.21	238.5	6.92	0.18
3-15-17	7.1	81.0	9.75	286.1	7.00	0.20

Higher salinity and conductivity can likely be attributed to road salt since there was snow on the ground during the January and February sampling events, but not the March sampling events.

### 2.3.3 Soils

The Forest and Natural Areas Management (FNAM) program at BCIT has provided soils data for the area around the tributary and the proposed wetland site. Soil pits were dug by the RENR 1130 class (Appendix A) and additional soil tests on the material in the parking lot and the surrounding area were done by Pacific Soil Analysis Inc (Table 2-3). Full lab methods and results can be found in Appendix B.

**Table 2-3:** On-site soil characteristics and recommended values. Red indicates the values are below the standards and orange shows values that are marginally above the recommended values.

Attribute	Recommended Value <sup>1</sup>	Parking Lot	South of Tributary
Gravel	0 – 10%	29.5	22.4
Sand	30 – 70%	64.3	63.7
Clay + silt	< 60%	32	23.9
Organic Matter	5 – 20%	3.7	12.4
pH	4.5 – 7.0	5.8	6.3
Conductivity	< 3.0 mΩ /cm at 25°C	1.32	0.52
C/N ratio	< 40	19.7	22.5
Nitrogen	0.2% – 0.6%	0.11	0.32
Phosphorus	20 – 250 ppm	32	59
Potassium	50 – 1000 ppm	60	200

<sup>1</sup>BC Society of Landscape Architects and BC Landscape and Nursery Association (2012). British Columbia Landscape Standards.

As the soil results show, the site has low organic matter and available nitrogen, which are important for growth of plants and nutrient cycling.

### 2.3.4 Native Vegetation

During the soil classification activity carried out by the RENR 1130 class, general vegetation cover was recorded. The canopy cover in the area is dominantly deciduous and consists of black cottonwood (*Populus trichocarpa*), red alder (*Alnus rubra*), and big leaf maple (*Acer macrophyllum*). Understory consists of salmonberry (*Rubus spectabilis*), sword fern (*Polystichum munitum*), thimbleberry (*Rubus parviflorus*), hardhack (*Spirea douglasii*), and large-leaved avens (*Geum macrophyllum*).

Some of the trees are located directly on the bank of the tributary and will be left in place for the project (Figure 2-6).

### 2.3.5 Invasive Vegetation

There are a significant number of invasive species present along the tributary, with Himalayan blackberry (*Rubus armeniacus*) and hybrid Japanese knotweed (*Fallopia x bohemica*) being the most dominant (Figure 2-6).

Knotweed is present along the area between the parking lot and the tributary. Knotweed grows rapidly, outcompeting other vegetation and quickly forming a monoculture (ISC, 2014b). The roots of the plant also lack true root hairs, which can make stream banks covered in knotweed more

susceptible to erosion (ISC, 2014b). The plant can spread by seed and underground rhizomes that can grow 2 metres deep and 20 metres laterally. Fragments of roots and stems can also regenerate into new plants (ISC, 2014b). These characteristics make removal and management of knotweed incredibly difficult.

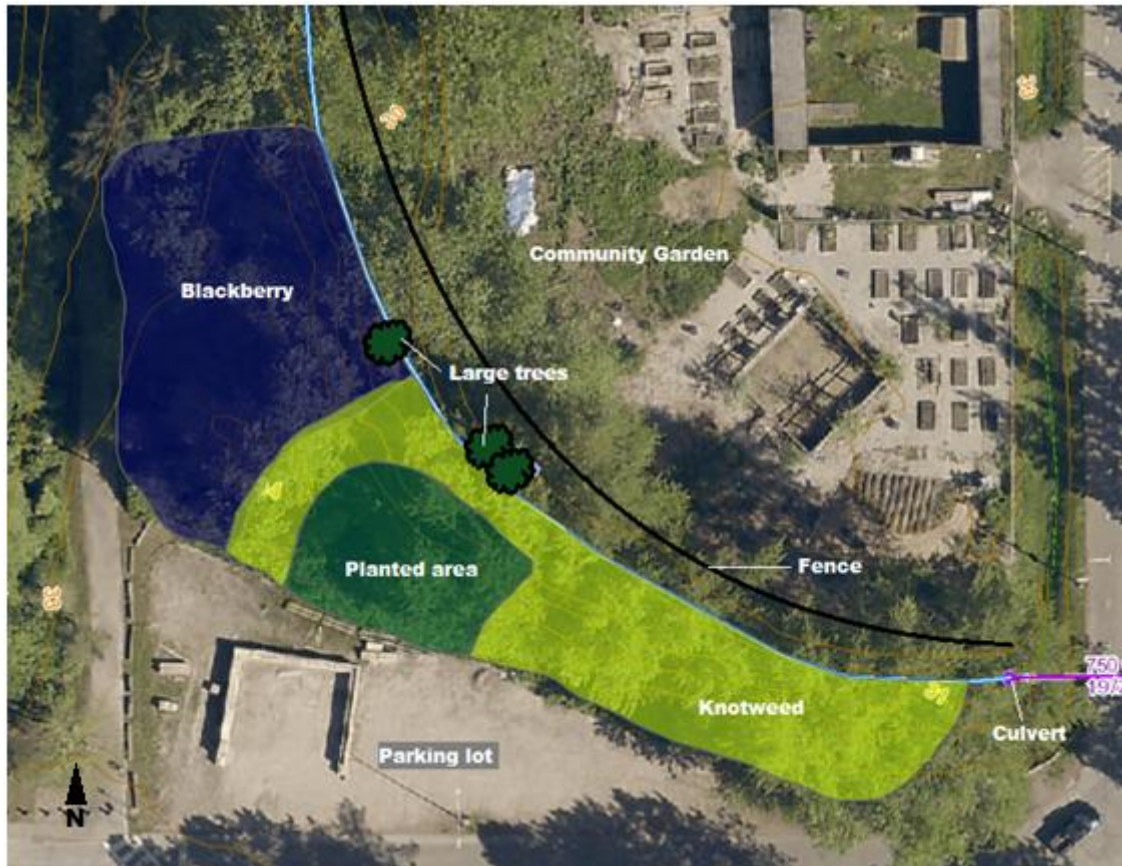
A study conducted by Vanderklein et al. (2014) showed that knotweed can impact the hydrology of a stream, specifically baseflow. The study showed noticeable differences in stream baseflow before and after knotweed was removed from the riparian zone.

Trials have been conducted by BCIT and the Invasive Species Council of Metro Vancouver (ISCMV) on the BCIT campus to test various knotweed management strategies. Three active 10-m x 4-m test plots were established on campus in May 2014 with three different 1-m x 1-m assessment areas in each. The initial treatments on the plots consisted of:

- (1) stem injection with 5cc of 480g/L glyphosate and foliar spray of 96g/L glyphosate (20% in water) on stems that were too small to be injected,
- (2) foliar spray with 96g/L glyphosate (20% in water), and
- (3) manual removal of shoots and root crowns.

Caldicott (2016) found that stem injection and foliar spray were the most effective methods of knotweed control. No new shoots were observed after two years of treatment. With manual removal methods, new shoots were still present, however manual treatment generally requires more than two years, so it is too soon to determine whether this method will be effective.

Himalayan blackberry was also present surrounding the proposed wetland. The most dominant patch is located downstream of the wetland. It is currently being managed by manual removal every 2 weeks (Caldicott, pers. comm., March 5, 2017). The knotweed patch is approximately 600 m<sup>2</sup> and the blackberry patch was approximately 500 m<sup>2</sup> (Figure 2-6, 2-7).



**Figure 2-6:** Site layout and vegetation polygons of restoration site in Burnaby, BC



**Figure 2-7:** Knotweed patch at southeast corner of restoration site in Burnaby, BC.

### 2.3.6 Wildlife

#### *Fish*

Cutthroat trout (*Oncorhynchus clarkii*) and chum salmon (*Oncorhynchus keta*) have been released into Guichon Creek as part of the Guichon Creek restoration initiatives. Due to an observed fish barrier where Guichon Creek flows enters the culverted section on campus, the chum salmon cannot return this far up stream without human intervention.

#### *Amphibians*

Amphibian species that have been observed around Burnaby Lake, approximately three kilometres west of the BCIT campus are listed below (Triton Environmental Consultants, 2014).

- Northern red-legged frog (*Rana aurora*) – Blue listed
- Bullfrog (*Lithobates catesbeianus*) – Non-native
- Green Frog (*Lithobates clamitans*) – Non-native
- Long Toed Salamander (*Ambystoma macrodactylum*)
- Northwestern Salamander (*Ambystoma gracile*)
- Western Toad (*Anaxyrus boreas*)

Northern red-legged frogs, Pacific chorus frogs, and bullfrogs are also present in Deer Lake, approximately two kilometres away (Mitchell & MacTavish, 2012). Amphibians usually stay within 500 metres of their breeding site, but may use land two to three kilometres away (Cox and Cullington, 2009). The northern red-legged frog can travel up to five kilometres away from their breeding site. Therefore there is a possibility for these amphibians to occur on the site.

This project will focus on the creation of aquatic and terrestrial habitat for the northern red-legged frog and the Pacific chorus frog. Aquatic habitat is used for breeding and larval development and terrestrial is used during the adult, non-breeding seasons.

The northern red-legged frog is a blue listed species provincially and has been designated as a species of special concern under the Canadian *Species at Risk Act*. It has been susceptible to urbanization, habitat loss, and predation by the invasive bullfrog (COSEWIC, 2015). The northern red-legged frog is found from British Columbia to California generally at elevations less than 500 metres (COSEWIC, 2015). Breeding occurs in permanent or temporary water bodies that are at least 30 cm deep, have low velocity, receive partial sunlight, and have emergent vegetation.



Breeding season begins in early spring or late winter and is generally complete by March. The larval period lasts 11-14 weeks and most tadpoles transform from early July to early August (COSEWIC, 2015).

Preferred terrestrial foraging habitat is usually located in moist forests near wetlands or streams. They are commonly found in second growth forests with complex understory structure that include sword ferns and large woody debris (COSEWIC, 2015). The distance travelled to suitable terrestrial habitat by foraging adults is highly variable, however movements are minimal once they arrive (COSEWIC, 2015).

Major threats to this species include landscape fragmentation and predation by invasive bullfrogs.

The Pacific tree frog is a common species of British Columbia (Matsuda & Klinkenberg, 2017). It breeds in shallow, often ephemeral bodies of water. Terrestrially, they are found in a large range of areas from fields to forests, sometimes far from water (Matsuda & Klinkenberg, 2017). North red-legged frogs seem to be more sensitive to habitat features, so a wetland designed to attract them will likely also attract the Pacific tree frog.

### ***Small mammals***

Bat surveys were also conducted on BCIT campus on Guichon Creek in 2014 by the South Coast Bat Action Team. A bat detector was installed on a tree on Guichon Creek and little brown bats (*Myotis lucifugu*) and silver-haired bats (*Lasionycteris noctivagans*) were detected (Rutherford, pers. comm., March 2017).

### **2.3.7 Restoration Initiatives**

The tributary was daylighted a few years ago as part of a series of enhancements on Guichon Creek (northwest hydraulics consultants, 2004). Guichon Creek has been the focus of restoration efforts by The Rivers Institute, BCIT, and the City of Burnaby. The Rivers Institute was founded in 2009 and has been working to transform Guichon Creek back into a salmonid bearing stream. Most recently, 15,000 juvenile chum salmon were released into Guichon Creek in the spring of 2016 (Baker, 2016). In the fall of 2016, three chum salmon managed to swim through the culverted section of Guichon and make it to the BCIT campus. Cutthroat trout have also released in Guichon Creek, and there is a small resident population.

BCIT and the City of Burnaby have signed a memorandum of understanding to protect and restore Guichon Creek. The forested area to the south of the site will remain protected. They have also made a commitment to daylight the northern portion of the stream, which was again reaffirmed by the BCIT President in 2014 (Campbell, 2014).

## **2.4 Site Stressors**

### ***Urban development***

Urbanization has introduced a suite of anthropogenic stressors on the project site. The roads, parking lots, and buildings in the watershed create impervious areas that alter the natural hydrology by increasing the amount of runoff, decreasing runoff to travel time, and decreasing the amount of infiltration. Urban runoff can contain a variety of pollutants such as suspended soils, nutrients (nitrogen and phosphorus), metals (copper, lead, zinc), and hydrocarbons (USEPA, 2015). Urbanization also leads to habitat fragmentation, which limits the movement of species throughout the watershed.

### ***Invasive Species***

Patches of Himalayan blackberry and hybrid Japanese knotweed are present in many areas along Guichon Creek, including the tributary and the proposed wetland site. These two species are very efficient in creating a monoculture and outcompeting the native vegetation. They are known to be difficult to remove and will likely require a constant effort to keep under control.

### ***Climate Change***

Based on projections from Metro Vancouver, by 2050, there will be noticeable changes in our climate. This includes increased temperatures, drier summers, more precipitation in the other seasons, and more intense extreme events (Metro Vancouver, 2016). In terms of the Guichon Creek system, this means lower baseflow in summer, increased flows from September to June, and increased potential for flooding.

## **3.0 GOALS AND OBJECTIVES**

The main goal of this project is to improve the hydrological functions of this section of the floodplain of Guichon Creek while creating wildlife habitat, with a focus on pond breeding amphibians. Restoration methods will aim to address the effects of urbanization of the area as well

as the long-term effects of climate change on the watershed. The secondary goal of this project is to create opportunities for environmental stewardship and education.

These goals will be achieved through the construction of a wetland in the parking lot area. This will remove an impervious surface and replace it with an area of ecological value. It will help restore a more natural hydrological process by increasing the amount of infiltration, providing filtration, and increasing water storage. It will also create a pool that can be used as breeding habitat for amphibians. The creation of the wetland will also serve as a learning tool and opportunities for public stewardship events. Since there is already an outdoor trail that passes the proposed wetland site, there is an opportunity to add interpretive signage.

## **4.0 RESTORATION TREATMENTS**

The restoration treatments for this site include removing the parking lot, managing the invasive species in the area and creating an off-channel wetland.

### **4.1 Site Preparation**

Before the wetland is constructed, the knotweed patch south of the tributary and the Himalayan blackberry patch to southwest side of the tributary will need to be removed. The invasive species removal area is roughly the space between the tributary and the parking lot, which is approximately 1100 m<sup>2</sup>, with 600 m<sup>2</sup> of blackberry and 500 m<sup>2</sup> of knotweed. After construction, the area will need to be managed to prevent re-establishment. The parking lot will also have to be removed and the underlying substrate will have to be decompacted and amended so that vegetation can grow.

#### **4.1.1 Knotweed Removal**

The removal and management of knotweed can be very difficult since even small fragments of the plant are capable of regenerating. The root systems also have large energy reserves (Davenport, 2006). The two general categories of knotweed management techniques are manual removal and chemical treatment. Manual removal includes methods such as hand pulling, mowing, covering, and goat browsing. Chemical treatment involves the use herbicide, most commonly glyphosate in the Lower Mainland.

Multiple options for knotweed removal on site have been identified, with and without the use of herbicides. Both methods have benefits and drawbacks that have been presented below. Ultimately,



it will depend on the preferences of BCIT and the City of Burnaby, budget, and timeline requirements.

Manual removal of knotweed has been shown to be effective if treatment is repeated twice per month over the growing season (May to August) for upwards of five years, according to the Invasive Species Council of British Columbia (2014b). Initially, the knotweed will send up even more shoots due to the stress on the plant, but continual removal will eventually exhaust the energy reserves in the root system. However, some studies also show that using only mechanical removal methods may not be effective (Clements et al., 2016, Payne & Hoxley, 2012, Soll, 2004). The knotweed trials on campus have collected data for only 2 years, so it is not possible to say whether it is effective yet. Manual removal is time consuming, requires significant time, and requires an area where the removed knotweed can dry or be disposed of safely.

Another manual method of knotweed removal is the use of goats. Goats have been used to effectively eradicate invasive species in BC since they are able to eat all above ground biomass. This is important for knotweed removal since it is able to regenerate with small fragments. There is limited data on the long-term feasibility of using goats to manage knotweed. Anecdotal evidence suggests they are effective in reducing above ground biomass in the short-term (Clements, 2016). However, since the patch is approximately 500 m<sup>2</sup>, it could be used as a trial plot for the effectiveness of knotweed removal using goats.

The chemical method uses herbicides, with glyphosate being the most commonly used one in the Vancouver area. The most common methods of applying glyphosate to knotweed are through foliar spray, stem injection, and cut and wick, which refers to cutting down the knotweed and applying glyphosate to the stem. Glyphosate can be used in selective application to noxious weeds up to 1 metre away from the high water mark (Integrated Pest Management Act, 2004). From the 1-metre line to the water edge, manual removal is the only allowed treatment option.

There have been many studies on the effects of glyphosate and glyphosate containing herbicides. In water, glyphosate dissipates quickly, with a half-life that varies from a few days to several weeks (CCME, 2012). There are multiple studies that show the potentially damaging effects of low glyphosate in concentrations in water to fish and amphibians (CCME, 2012). There is some controversy surrounding the use of herbicide based on conflicting results on aquatic toxicity. However, many studies also strongly suggest glyphosate adsorbs readily to soil, making it immobile and significantly decreasing bioavailability (Shushkova et al., 2009, Sørensen et al., 2006, USEPA,

1993). From there, microbes in the soil break down the glyphosate into AMPA, which also strongly adsorbs to soils, then to carbon dioxide (USEPA, 1993).

Based on the lack of conclusive data on the aquatic toxicity, foliar spray was not considered an option for this site in case of accidental overspray. This will prevent any chance of drift into Guichon Creek. However, using the cut and wick technique would virtually eliminate the chances of it directly entering the water, without first binding to soil particles. Based on a study in Washington State that tested various dilution ratios of glyphosate, it was found that using a 20% glyphosate solution for the cut and wick technique was sufficient for reducing the knotweed population enough that planted native plants were able to grow and compete (Davenport, 2006). This method would still have to be repeated twice a year, once at the start of the growing season (May), and once before it dies back in September. Even for large patches of 1,000 stems or more, with use of the stem injection method, after the first or second year, the knotweed had been suppressed enough that the area was able to be replanted (Apostol & Sinclair, 2006). Since herbicide use is not allowed within 1 metre of the water, manual removal methods will have to be used from the 1-metre mark to the water edge.

#### **4.1.2 Himalayan Blackberry Removal**

Manual removal of Himalayan blackberry has been shown to be an effective method of removal (ISC, 2014a). Removal should occur when the plant is flowering (spring) to increase chances of success. Blackberry can be removed by using hand tools or power tools, such as loppers, weed eaters, or clippers. The root crowns can then be dug up and removed. After two years of manual removal, native species can be replanted densely to attempt to outcompete the blackberry. Monitoring and removal of the blackberry will continue to ensure it doesn't grow above the planted vegetation.

It has been shown that the berries provide food for some animals. This ecological function will be replaced by the planting of native berry producing species, which include salmonberry and elderberry.

#### **4.1.3 Parking Lot Removal**

The gravel parking lot is approximately 700 m<sup>2</sup> and will be removed before wetland construction can begin. The layer of soil underneath will be decompacted down one metre and amended with 0.3 metres of top soil before planting. Healthy soil is important in a wetland restoration project because

it provides biological and physical requirements for plant growth and also plays a role in determining site hydrology.

The addition of soil amender can increase the survival rate of plants by up to 20% (Apostol & Sinclair, 2006). Adding a layer of top soil on top of the substrate will increase nutrients, percent organic matter, and allow the soil to retain more water. Tilling the soil amender into the top layer will allow improved integration into the existing soil on site. To cover the wetland area and the parking lot area with 0.3 metres (12 inches) of soil will require approximately 600 m<sup>3</sup> of soil.

## **4.2 Site Design**

The design will aim to meet the following goals:

- (1) improve hydrological function,
- (2) create suitable aquatic and terrestrial habitat for northern red-legged frogs and Pacific chorus frogs,
- (3) create a riparian buffer, and
- (4) create stewardship opportunities.

The created wetland will improve hydrological connectivity by increasing retention time and increasing infiltration rates. The surrounding riparian zone will act as a buffer to slow and filter campus run off before it enters the wetland. The combined effects of both will help reduce peak flows, improve water quality and decrease the amount of runoff entering Guichon Creek.

The wetland will also be an area that can be used by wildlife, most likely amphibians. Studies have shown that amphibians often use stormwater ponds, especially in areas where riparian corridors are present (Hamer et al., 2011; Holzer, 2014; Le Viol et al., 2012). Since studies have shown that there are amphibians present at Burnaby Lake, which is connected by a relatively intact riparian corridor, it is a reasonable expectation that they will inhabit the wetland. Since amphibians are sensitive to pollutants in the water, design measures will be implemented to minimize the impact.

### **4.2.1 Site Layout and Structures**

The size of the wetland was based on the amount of space available, since it is constrained by the footpath to the west, the road to the south, and the community garden to the northeast. Available area surrounding the wetland will be planted and act as a riparian buffer. The wetland will be a partially lined off-channel wetland and the location and general shape of the tributary will be

maintained, with the addition of a natural outlet structure. The wetland and riparian footprint will be approximately 1200 m<sup>2</sup> in size, with the deepest area at 1 metre and a storage capacity of 600 m<sup>3</sup> when completely full. With the water just filling the wetland area (400 m<sup>2</sup>), the deepest point would be 0.6 metres and hold approximately 150 m<sup>3</sup>. Storage volume for collecting stormwater runoff should be 40 m<sup>3</sup> to 100 m<sup>3</sup> for each hectare of impervious area (Wagner et al., 2008). Based on aerial imagery, there is approximately 7 hectares of impervious area in the catchment area, making the wetland a sufficient size.

The upland buffer area will be approximately 800 m<sup>2</sup> and surround the riparian area (Figures 4-1, 4-2).



**Figure 4-1:** Layout of restoration site in Burnaby, BC



**Figure 4-2:** Three dimensional rendering of wetland layout with a water depth of 0.3 metres

#### Outlet

The downstream section of the tributary will have a natural in-stream structure that will allow for continuous flow, while also raising the water level upstream (Figure 4-3). This type of structure has been implemented in other successful restoration projects where biologists have mimicked beaver dams (Podolak et al., 2016). This will provide a more natural water control structure that raises water levels, increases groundwater recharge, and dissipates flow energy. It will also cause the water to pool behind it and spill over the berm and into the wetland. The top of the structure will be constructed at 1 metre, so that it can also act as a spillway in very high flows and prevent flooding of the surrounding areas. Rocks and boulders will be added to the base of the dam to increase ponding upstream.





**Figure 4-3:** Natural flow control structure made to mimic the functions of a beaver dam (Pollock et al., 2012)

Wooden stakes will be pounded into the tributary, approximately 0.5 metres apart, with 1 metre above the bottom of the stream. Brush from trees that will be removed from the excavation site can be used to form the dam.

### Wetland

A section of the wetland will also be lined since water inputs may be limited during the drier summer months. Due to the lack of groundwater data over multiple seasons and the fact Vancouver will experience drier summers due to climate change, it is a safer design to use a liner to ensure there is water in the wetland. Three types of liners were considered for this project, compacted clay liner, high density polyethylene liner, and a geosynthetic clay liner. A high density polyethylene liner was not chosen because if the groundwater levels rise higher than the bottom of the liner, water can pool underneath the liner and push it upwards. Compacted clay was not considered since there is no clay on site and purchasing clay can be very costly (Biebighauser, 2011). The site would also have to be excavated deeper to accommodate the thickness of the compacted clay layer, adding to fill disposal costs. Geosynthetic clay liner was chosen as the most appropriate for this site. It consists of a layer of bentonite clay between two geotextile layers. When the liner is exposed to water, the bentonite swells and forms a hydraulic seal. No geotextile padding is required, and due to the properties of the bentonite clay, it is capable of self sealing small punctures.

Once the liner is installed, an additional 0.3 metres of top soil will be placed on the bottom of the pool area to maintain an average depth 0.4 metres. The bottom of the wetland should be made uneven to increase variation in microtopography. When the wetland reaches depths over 0.4 m, water will infiltrate into the surrounding substrate. The lined area of wetland will have a water surface area of 400 m<sup>2</sup>, and hold approximately 150 m<sup>3</sup> when full.

The use of a liner is a conservative design measure based on the lack of groundwater data. If additional soil pits or groundwater wells show that the groundwater table is suitable for a groundwater wetland, a liner may not be necessary. At least a year of groundwater monitoring would be necessary to ensure the wetland would be inundated from February to September to at least 30 cm and dry up during the winter.

### Berm

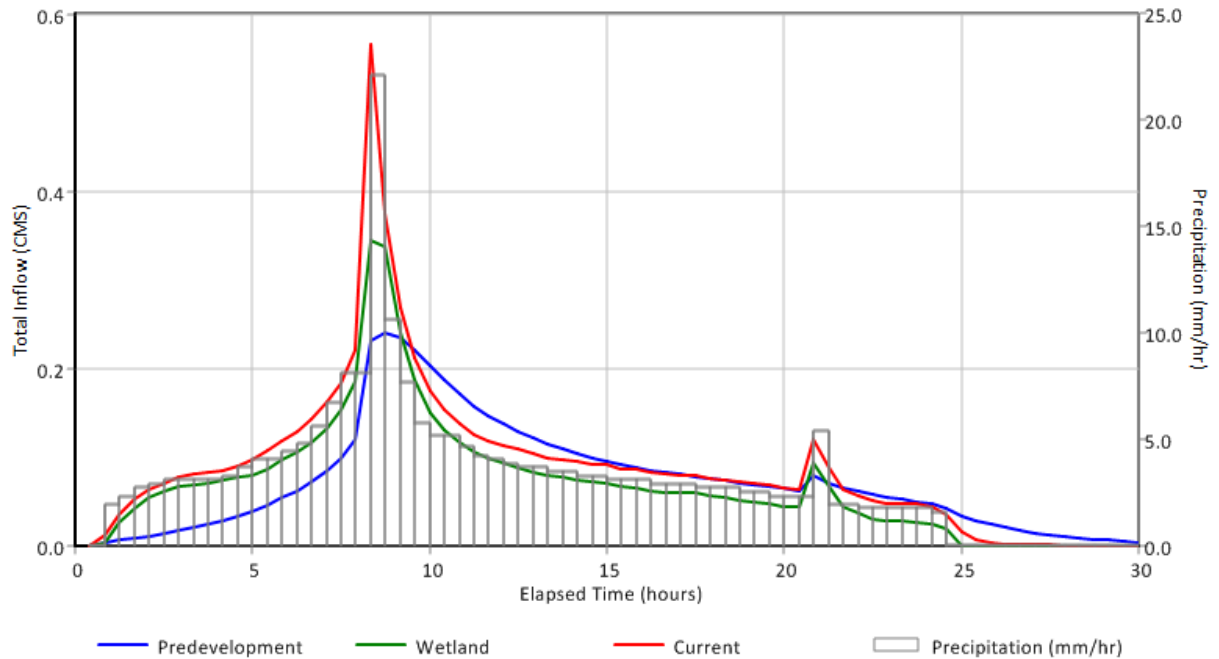
The berm will be 0.6 metres above the elevation of the bottom of the tributary and wetland. The slope on tributary side will left kept intact since it doesn't show signs of instability and there are trees growing right on the bank in some areas. The wetland side of the berm will have a gentler slope of 8:1.

## **4.2.2 Hydrology**

Hydrological modeling was conducted using the program EPASWMM, which is a stormwater management tool. This program can simulate rainfall-runoff scenarios based on the user's parameter inputs. It calculates catchment runoff based on catchment parameters such as percent impervious area, slope, and surface roughness. For this project, the three catchment models that were used are

- (1) current conditions,
- (2) predevelopment conditions (lower % impervious area), and
- (3) conditions with a wetland installed.

The rainfall data used in the model was taken from the BCIT Stormwater Management Report. Since the wetland occupies a small area relative to the catchment area, a 10-year storm with 24-hour duration was used for modelling (Figure 4-5). Catchment modelling parameters are available in Appendix D.



**Figure 4-4:** EPASWMM hydrograph comparison for three land use scenarios in a 10-year storm 24-hour storm event

Due to the nature of the outlet structure and the fact the wetland is only partially covered by a liner, the wetland modelling scenario is a very rough estimate.

The wetland is designed to be an ephemeral wetland, so it will be dry for a short duration of time during the summer. Inputs into the tributary are predominately surface runoff, material under the parking lot consists of course, and depth of the water table under the parking lot is unknown. To ensure the wetland will hold water, part of the area will be lined with a geosynthetic clay to create a water storage area that can also be used by amphibians. However, the area is designed to dry up at the end of summer or beginning of fall. This will help prevent mosquitoes and bullfrogs from becoming an issue.

Based on climate data from the Burnaby South weather station, data was obtained from the Farmwest evapotranspiration calculator. Evapotranspiration rates show that there is enough of moisture deficit to dry up the 0.4 metres of water in the wetland once the vegetation becomes established.



**Table 4-1:** Estimated evapotranspiration rates from May 1, 2016 to October 1, 2016 for Burnaby South, based on grass vegetation community (Farmwest, 2017)

Parameter	Total	Daily Average
Evapotranspiration (mm)	484	3.2
Effective Precipitation (mm)	87	0.6
Moisture Deficit (mm)	397	2.6
Total Precipitation (mm)	239	1.6
Historical Average Moisture Deficit (mm)	414	2.7

### 4.2.3 Water Quality

Based on first flush behaviour, a relatively large portion of the pollutants in runoff enters the water during the initial period of the storm event. First flush has been shown to affect smaller catchments with a large percent impervious area, which makes this relevant to this catchment (Shamseldin, 2011). Two measures have been added to the design to remove contaminants. The outlet will slow down flows and cause particles to settle out of suspension. The berm in the wetland also will create a separate wetland area that will receive water only when flows are high enough. This system will also remove the wetland from a direct line of flow, which will minimize high flow events from disturbing potential wildlife habitat.

### 4.2.4 Planting Plan

Based on the native vegetation found in the area and the Wetlands of British Columbia (WREC) guidebook, the closest wetland classes are middle bench and low bench flood classes. The Cottonwood - Red alder – Salmonberry Site Association (Fm50) is a medium bench site found along river system floodplains (MacKenzie & Moran, 2004). For the wetter areas of the wetland, the Red alder – Salmonberry – Horsetail site classification (FI51) will be used as reference for vegetation communities. See Appendix C for the full site descriptions from WREC.

Any native vegetation onsite will be preserved as best as possible. Trees that are growing along the bank of the tributary will be left in place. Three different planting areas for this project are wetland, riparian and upland associated plants. The riparian plants will be planted on the berm and also on the upland parts of the site. Planting will extend beyond the wetland site to cover the areas where the parking lot and invasive vegetation have been removed. A combination of potted nursery plant, live stakes, plugs and native seed mix will be used on site depending on elevation (Table 4-3).

**Table 4-2: Planting Plan**

<b>Location</b>	<b>Species</b>
Wetland	Baltic rush ( <i>Juncus balticus</i> )
	Sitka sedge ( <i>Carex stichensis</i> )
Riparian (also planted upland)	Pacific Willow ( <i>Salix lucida</i> )
	Red-Osier Dogwood ( <i>Cornus sericea</i> )
	Black Twinberry ( <i>Lonicera involucrata</i> )
	Salmonberry ( <i>Rubus spectabilis</i> )
	Red elderberry ( <i>Sambucus racemosa</i> )
Upland	Salmonberry ( <i>Rubus spectabilis</i> )
	Red elderberry ( <i>Sambucus racemosa</i> )
	Pacific Ninebark ( <i>Physocarpus capitatus</i> )
	Nootka Rose ( <i>Rosa nootkana</i> )
	Black Cottonwood ( <i>Populus trichocarpa</i> )
	Western Hemlock ( <i>Tsuga heterophylla</i> )
	Big-leaf Maple ( <i>Acer macrophyllum</i> )

Using larger potted plants is more expensive, but will increase the chance of success of establishment, especially when trying to suppress invasive species (Pearson, 2013). Species that are found locally and grow well from live cuttings can be used instead of nursery plants. Native seed mix will also be spread over the upland and riparian area due to its quick establishment, which will help reduce the amount of erosion. Plants will be planted in late fall so they will not be stressed by hot and dry summer weather. For a more detailed planting plan, see Appendix E.

#### **4.2.5 Wildlife Use**

Many studies have shown that stormwater wetlands are also capable as functioning as amphibian habitat (Guderyahn & Smithers, 2014; Hamer et al., 2011; 2016; Holzer). Creating new wetland in urban areas can help reduce isolation of other populations and increase overall habitat (Biolinx Environmental Research & E. Wind Consulting, 2004). However, one of the potential negative side effects is the creation of ecological traps. Ecological traps possess characteristics of a desirable habitat, but have been too highly altered to support breeding and development, thus leading to population decline (Biolinx Environmental Research et al., 2004). It is important to take this into consideration for this wetland design since stormwater runoff is a major source of water.

## ***Amphibians***

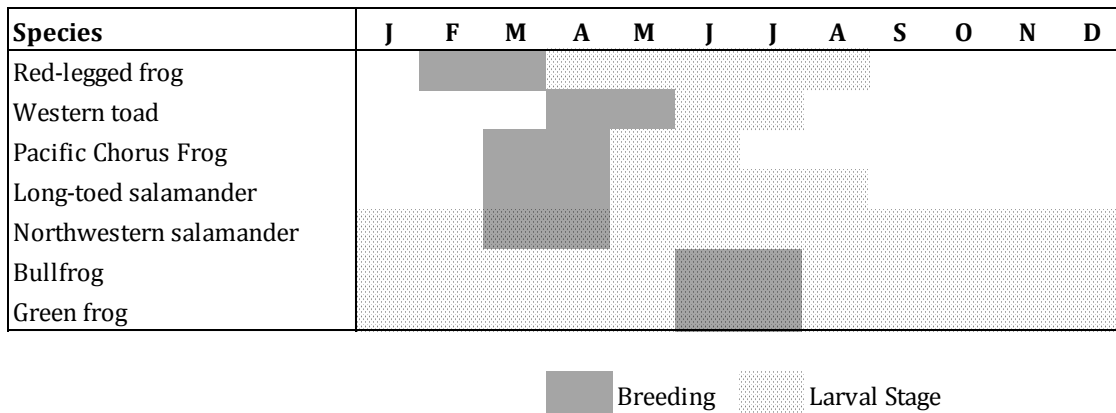
Design considerations for this wetland are focused on the northern red-legged frog and Pacific chorus frog. The northern red-legged frog has more specific habitat conditions than the Pacific chorus frog, so features will be aimed toward them. When designing habitat for these species, both aquatic and terrestrial habitat need to be considered (Table 4-4). Aquatic habitats are used for breeding and for larval development prior to metamorphosing into a terrestrial form (MacKenzie & Moran, 2004). One of the more important considerations for restoration of habitat is creating a diversity of microhabitat features in both the aquatic and terrestrial environment (Biolinx Environmental Research & E. Wind Consulting, 2004). Water bodies that have low-velocity and minimal water level fluctuations are correlated with high amphibian species richness (MacKenzie & Moran, 2004; Hawkes, 2005). The off-channel, lined design style will limit the velocity of the water flowing into the wetland, and the clay liner will keep the water level in the wetland from fluctuating rapidly. Sedge and rush species will be planted in the wetland area that will provide appropriate vegetation for oviposition. Northern red-legged frog eggs also require exposure to partial sunlight. A study in Washington State showed that egg masses were most commonly found in wetlands with gradual slopes with a south facing exposure. Trees can be planted in a less dense configuration along the southern perimeter to allow sun exposure.

Terrestrial habitat is required outside of breeding season. Amphibians generally prefer forested areas close the water and moist micro habitat (MacKenzie & Moran, 2004). Northern red-legged frogs stay within 10 to 80 metres from water during drier months and can be found up to 500 metres away from water during months with heavy rain (COSEWIC, 2015). Based on studies on amphibian use of stormwater wetlands, a forested riparian area has the highest correlation with species diversity and richness (Hamer et al., 2011; Le Viol et al., 2012; Holzer, 2014). This type of ecosystem is present north and south of the wetland. The riparian area around the wetland will be restored to provide terrestrial habitat as well. Native trees, shrubs, and grasses will be planted around the wetland. Large and coarse woody debris are also an important feature in terrestrial habitat (Biolinx Environmental Research & E. Wind Consulting, 2004). Pieces of coarse and large woody debris will be placed in the wetland and riparian area for shelter and feeding sites. Table 4-3 summarizes the aquatic and terrestrial habitat for target amphibians, other native amphibians in the area that may use the site, and invasive amphibians.

**Table 4-3:** Aquatic and terrestrial habitat preferences for amphibians in the watershed

Species	Preferred Breeding Habitat	Terrestrial Habitat	Status (BC)	Status (COSEWIC)
<b><i>Target species</i></b>				
Northern red-legged frog	ponds (ephemeral or permanent), 30 to 500 cm deep, at least 60 cm away from the shore	forested riparian area	blue	Special Concern
Pacific Chorus Frog	shallow wetlands, often ephemeral	woodlands, meadows, pastures	yellow	N/A
<b><i>Potential native species</i></b>				
Western toad	large range of aquatic habitats, 5-200 cm deep	forested areas, dense shrub cover, meadows	yellow	N/A
Long toed salamander	large shallow lakes	moist forests close to water	yellow	not at risk
Northwestern salamander	permanent ponds or streams, lays eggs 5-20 cm deep on sticks or vegetation	meadows to forests	yellow	not at risk
<b><i>Potential invasive species</i></b>				
Bullfrog	permanent ponds	highly aquatic, rarely leave water	exotic	N/A
Green frog	permanent ponds	highly aquatic, rarely leave water	exotic	N/A

While this wetland is being designed for two specific amphibians, other desirable and non-desirable may still be present. The wetland may also be suitable habitat for native species such as the long toed salamander and northwestern salamander. However, there is potential for invasive species to colonize the area. The American bullfrog is an invasive species in British Columbia that negatively impacts native species. They are effective predators due to their comparatively large size to native amphibians. However, unlike the native frogs, they require two seasons for tadpoles to reach metamorphosis. Therefore if wetlands are ephemeral, this prevents bullfrogs from breeding (BC Frogwatch Factsheets, n.d.). The lined wetland area is designed to be small enough, that water will evaporate during drier summer months. The green frog is also an invasive species with similar habitat preferences to the American bullfrog. Based on breeding habits, if the wetland is dry for a period of time between September and December, it will prevent green frogs and bullfrogs from using the habitat (Figure 4-5).



**Figure 4-5:** Amphibian aquatic habitat use (Frogwatch BC, n.d.; Mackenzie & Moran, 2004)

With respect to the potential contaminants entering the water, the off channel design will prevent the contaminants in the first flush from entering the wetland area. Additionally, studies that have examined multiple contaminants in stormwater ponds have found that deicing salts have the most detrimental effect on amphibians (Gallagher et al., 2014). Salinity measurements at the inlet of the tributary culvert were 0.33 ppt and 0.31 ppt when measured in winter when there was snow on the ground and salt use was likely high. This is equal to chloride concentration of approximately 165 mg/L and 155 mg/L. Two sampling events also occurred when there was almost no snow on the ground and during light rainfall. The salinity at the culvert in these events was 0.18 ppt and 0.2 ppt which are equal to chloride concentrations of 90 mg/L and 100 mg/L, respectively. The Canadian Water Quality Guidelines for the Protection of Aquatic Health state that 120 mg/L of chloride is the maximum value for long-term exposure for (CCME, 2011). However, BCIT should consider alternative methods to de-icing salt to reduce the amount of salt entering the system. This will be beneficial to the entire Guichon Creek system.

### ***Small mammals***

Since bats were detected during a survey on by Guichon Creek on the BCIT campus, bat boxes will be installed on trees adjacent to the wetland. Bats will also help keep the mosquito population under control, which can be a concern to the public. Burrowing animals are not a major concern in this wetland, since the berm will have gradual enough slopes.

### ***Fish***

Creation of fish habitat was not within the scope of this project, since there are still fish barriers between Still Creek and Guichon Creek. However, there are beneficial effects to the fish population in Guichon Creek through improvement of hydrological functions. Restoring lateral connectivity through creation of new floodplain habitat and use of urban stormwater techniques are two

techniques that will help maintain resilience of the ecosystem as the effects of climate change continue (Beechie et al., 2012).

#### **4.2.6 Climate Change**

The predicted effects of climate change on the Lower Mainland include more intense extreme events, drier summers, and more rainfall in fall and winter (Metro Vancouver, 2016). If salmon restoration efforts continue on Guichon Creek, designing for climate change is an important consideration. The best way to mitigate the effects of climate change is to restore lateral, vertical and longitudinal connectivity within a river (Beechie et al., 2012).

The creation of this wetland will ameliorate some of the effects of extreme events by providing an overflow area and regulating flows. Since the wetland is lined, it will also ensure there is water present during drier times.

#### **4.3 Stewardship and Outreach**

Public participation and awareness is essential to the success of the success of restoration projects (Clewett & Aronson, 2013; Herringshaw et al., 2010). There are already existing stewardship events on Guichon Creek, and this project can create opportunities to have additional events. The public can be involved in planting of vegetation around the wetland. Invitations to participate in planting stewardship events for the wetland can be distributed to neighbourhoods within the catchment area of the wetland. This creates a forum to discuss effects of urbanization on streams and show people where runoff from their neighbourhood ends up. Through these events, people can be encouraged to consider using alternatives to de-icing salts and being aware of what is entering the storm sewer. Forming that connection between people and their environment is an important step to creating interest and involvement in environmental issues.

The Ecological Restoration Program could participate in the construction phase of this project. This could be similar to the wetland building trip to Logan Lake that the undergraduate Ecosystem Restoration program participates in every year.

Since the wetland will be located next to the existing walking path that runs along Guichon Creek, there is opportunity to install interpretive signage in an area with existing foot traffic.

## 4.4 Data Limitations

Due to the time constraints on this project, there are limitations on the work done as well as additional factors that should be considered before implementation of this restoration plan. With the collection of the additional baseline data stated below, there is an increased chance project success.

### Limitations in SWMM Modelling

As is the case for most computer modelling programs, certain parameters have to be estimated using the data available. Parameters physical characteristics such as catchment area, slope, percent impervious area, and Manning's coefficient were estimated based on aerial imagery and contour maps obtained from the City of Burnaby. This can cause the model results to vary from the actual results. However, the main purpose of modelling the runoff in this area was to compare results between the current conditions and conditions with stormwater management practices implemented.

Additionally, based on the nature of the wetland outlet, it is difficult to quantify the effects it will have on the flow in the stream. It was estimated that 50% of the flow would go through the natural dam structure. The absence of the liner from 0.4 m to 0.6 m in the wetland was not able to be modelled within this program either.

### Water Quality Data

Contaminants in the runoff, in addition to road salt, need to be considered before the wetland is constructed. This includes metals that are found in urban runoff, such as lead, zinc, and copper. It is important that the water quality in the wetland meets the requirements to support aquatic life. Contaminant modelling can be integrated into the EPA SWMM model. However, this was not within the scope of this project.

Sampling events were also limited to the winter season. The values obtained during these sampling events may not be representative of actual values due to an uncharacteristic amount of snow and snowmelt during the winter. Additional water quality monitoring should be conducted before implementation of the restoration treatments to ensure an adequate amount of baseline data. This will allow for more informed decision making about amphibian habitat suitability. A detailed monitoring plan can be found in section 6.4.

## Groundwater Data

Piezometers were not installed on site to monitor groundwater levels. To have an accurate prediction of the wetland hydrology, groundwater levels should be monitored. The hydrogeology of the site was inferred from mottling in the soils surrounding the site. Installing monitoring wells would allow for the comparison on groundwater levels before and after the project is implemented (Figure 4-6). Since one of the goals of creating this wetland is increasing groundwater infiltration, they would be necessary to monitor if this goal is being achieved.



**Figure 4-6:** Suggested groundwater monitoring locations on restoration site

Three wells are located to the north, west and east of the site to determine groundwater levels and direction of flow. One is located on the west side of Guichon Creek, which will be out of the zone of influence of the wetland. This will serve as a control site to account to year to year fluctuations.

## **5.0 IMPLEMENTATION PLAN**

### **5.1 Consultation Process**

Since the wetland is located on the BCIT campus in Burnaby, BCIT and The City of Burnaby would be consulted if this project moves forward. This project is also located on unceded Coast Salish territory belonging to Musqueam, Tsleil-Waututh, and Squamish Nations and they will be consulted if BCIT decides to move forward with this project (BCIT, n.d.). The design recommendations in this report are open for changes during the consultation process if this project moves forward.



## 5.2 Permits

Before construction can begin, it is necessary to obtain any relevant permits or approvals from the municipal, provincial and federal government. This project will have to adhere to the Fisheries Act and the Riparian Area Regulations. Short term water use permit and a Change Approval will be required by the provincial Water Sustainability Act.

## 5.3 Schedule

The project schedule will be divided into the following general stages:

- (1) Preconstruction monitoring and invasive species removal (2 – 4 years)
- (2) Construction and site preparation (following the last fall invasive species removal event)
- (3) Monitoring and management (Ongoing)

**Table 5-1: Project Schedule**

Phase	Task	Year 1				Year 2				Year 3				Year 4				Year 5+			
		W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp	Su	F
<b>Pre-construction</b>	Water quality monitoring																				
	Invasive species removal																				
<b>Wetland construction</b>	Excavation																				
	Planting																				
<b>Post-monitoring</b>	Aftercare of plantings																				
	Water quality monitoring																				
	Structural monitoring																				
	Amphibian Surveys																				
	Invasive species monitoring																				

### Pre-construction

The length of the invasive species removal phase is dependent on the method chosen and how successful it is. Chemical method requires one treatment at the start of growing season (May) and at the end (September). Manual methods will require treatment multiple times throughout the growing season. A more in depth study of the water quality and hydrology of the site can be conducted at this time.

## Construction

Construction will take place after the last fall invasive species removal treatment. This will be within the designated cutthroat trout work window of August to October (Ministry of the Environment, 2006). Planting in the fall will also give plants enough rain to establish.

## Post-construction

Post-construction monitoring will ensure the wetland is functioning fully. It will be more intense in the first year after construction, and taper down once the system reaches equilibrium and vegetation is established (Section 6).

### **5.4 Budget and Materials**

The budget for the materials and equipment required for the construction phase of this project are summarized in this section (Table 5-2). Cost estimates for personnel involved in additional design, construction supervision, and post construction monitoring are not included in this report. Additional details on plant costs can be found in Appendix E.

The most expensive part of the project is the disposal costs of the excavated material, which accounts for 90% of the construction budget. Total volume of materials removed will be around 1,500 m<sup>3</sup> to 2,000 m<sup>3</sup>. Pairing this project with other projects on campus that require fill will reduce costs substantially.

**Table 5-2:** Construction Cost Summary

<b>Material</b>	<b>Unit</b>	<b>\$/Unit</b>	<b>Units required</b>	<b>Total</b>
Excavator	hours	\$ 150.00	40	\$ 6,000
Fill disposal	ton	\$ 80.00	3700	\$ 296,000
Top soil	yards	\$ 10.00	500	\$ 5,000
Clay liner	m <sup>2</sup>	\$ 10.00	400	\$ 4,000
Planting tools	lump sum	\$ 300.00	1	\$ 300
Straw bails	bails	\$ 5.00	100	\$ 500
Plants	lump sum	\$6,180.00	1	\$ 6,180
<b>CONSTRUCTION BUDGET:</b>				<b>\$ 317,980</b>

## 5.5 Construction Logistics

Before construction can happen, it is important to determine the location of any buried utilities. The construction of the wetland will require heavy machinery. Access will not be a problem since the site is located next to Carey Avenue. This section gives a rough step by step guide on how various stages of construction will occur.

### Excavation

**Step 1:** Flag out 0.6 m above the tributary bed elevation along the south berm to indicate how far down the excavator should dig.

**Step 2:** Once the area has been excavated to the top of the berm, the excavator can form the other side of the berm at an 8:1 slope. The deepest spot of the wetland should be at the same elevation as the bed of the tributary (0.6 m below the berm).

**Step 3:** The excavator should work from north to south and continue to excavate material. In the parking lot section, the material underneath should also be decompacted to a depth of 1 metre.

### Liner installation

**Step 1:** From deepest spot, flag out the contour that marks 0.4 metres above that location. This will be the location of the top of the liner.

**Step 2:** Remove sharp objects such as branches and large rocks that could puncture the liner.

**Step 3:** Lay down clay liner over the surface. Stake and trim any excess material.

**Step 4:** Place 0.3 m of soil on top of liner.

### Planting

**Step 1:** The entire excavated area should be covered with 0.3 m of top soil since the material underneath is too coarse. This will increase plant survival.

**Step 2:** Live stakes should be planted along the berm. Sedges and rushes should be planted around the wetland area. Potted plants and live stakes will be planted in the riparian area and upland area.

**Step 3:** Seed area with native grass mixture and then cover in straw to prevent erosion and to suppress weeds.

## 6.0 MONITORING AND MAINTENANCE

It can take several years for soil and vegetation to become fully established and for wildlife to use the habitat features (Mitsch & Gosselink, 2015). The monitoring plan will vary between the first

year of establishment and the following years. The monitoring frequencies in subsequent years may change depending on the results (Table 6-1).

**Table 6-1: Monitoring Schedule**

Characteristic	Measurement	Sampling Frequency (Year 1)	Sampling Frequency (Year 2+)
<i><b>Vegetation</b></i>			
	Invasive species patch size and density	Every 2 weeks (May - September)	Monthly (May - September)
	Planted species health	Monthly (October - April), Every 2 weeks (May - September)	Monthly (May - September)
	Photo monitoring	Seasonally	Seasonally
<i><b>Wildlife</b></i>			
	Amphibians	Monthly (February - May)	Monthly (February - May)
	Bats	Monthly (May - August)	Monthly (May - August)
	Fish	At low water levels	At low water levels
<i><b>Water</b></i>			
	Water Quality (YSI Meter)	Every 2 weeks	Monthly
	Water Quality (lab samples)	Monthly	Seasonally
	Water level in wetland	Every 2 weeks	Every 2 weeks
	Groundwater level	Monthly	Monthly
	Storm Response	As needed	As needed
<i><b>Structures</b></i>			
	Berm	Every 2 weeks or after storm	Monthly
	Outlet	Every 2 weeks or after storm	Monthly

## 6.1 Vegetation Monitoring

Continual monitoring will be required to ensure knotweed and blackberry do not re-establish on the site. Since construction and planting will occur in the fall, the site can be checked at the beginning of the next growing season in May for signs of knotweed and blackberry. If there are plants present, these areas should be noted with approximate density, so that problem areas can be monitored in the future. Any knotweed or blackberry should be immediately dug out, ensuring that all above and below ground biomass is removed. Depending on the severity of the invasive species in the first summer, the site should be monitored between once every two weeks

to once a month. Once the planted vegetation has established, it should help control the invasive species by shading it out (Dommanget et al., 2013).

The first year of growth is the more critical time for planted vegetation (Rieger et al., 2014). To ensure planted vegetation establishes successfully, an aftercare plan will be implemented. This will involve weeding around plants, watering or setting up an irrigation system during the first growing season, and control of any visible animal damage. During the first year, any dead planted vegetation should be removed and replaced.

To monitor stand structure, photo monitoring locations will be established on site with a piece of rebar. Once planting is completed, appropriate number and location of monitoring sites can be chosen.

## **6.2 Wildlife Monitoring**

### Amphibians

Presence/absence surveys will be conducted during the breeding season using time-constrained search as per RISC procedures. A minimum of three surveys should be conducted between February and April to account for the variation in breeding season (RISC, 1998b). These surveys will detect the presence of adults, egg masses, and larvae. Comparing the number of egg masses and the number of larvae of each species can give an idea of survival rates. Conducting these presence/absence surveys, combined with a well regimented water quality monitoring program will ensure the wetland is functioning as quality amphibian habitat.

The wetland should also be checked again in the fall for invasive amphibians, when all native species should have already undergone metamorphosis.

### Fish

Since there is a small resident population of cutthroat trout in Guichon Creek, there is a small possibility of fish being stranded in the wetland. When the wetland is almost dry, it should be checked for any fish.

### Bats

The bat boxes will be monitored for use. Bat houses can be observed for fifteen minutes before sunset and thirty minutes after (Community Bat Programs of BC, 2014). If they are not detected, the

area beneath the bat house can be examined for guano. Sampling should be conducted between the beginning of May and the end of August (RISC, 1998a).

### **6.3 Hydrological Monitoring**

Due to the nature of the natural dam that will be installed in the tributary, it is difficult to determine quantifiable metrics of success for this structure. The density of coarse woody debris in the dam structure may have to be altered based on its performance during storm events. It should be carefully monitored during all rainfall events in the month after construction. Under normal flows, the water level immediately upstream of the dam should remain higher than water level immediately downstream, but should not be flowing over the top of the structure. A staff gauge will be installed in the wetland to measure water levels weekly and after storm events. If water is not observed in the wetland after a storm event, the outlet structure should be adjusted to increase ponding.

Water levels in the piezometers around the wetland will also be monitored monthly to determine any changes in the groundwater table before and after construction. An increase may indicate that there are higher levels of groundwater recharge.

### **6.4 Water Quality Monitoring**

Water quality should be monitored at the culvert inlet and in the wetland. This will allow for a comparison in water quality between the two. The YSI Professional Plus water meter can be used to monitor dissolved oxygen, pH, salinity, and temperature. Metals and nutrients will require lab analysis. This water quality monitoring program will be dependent on the concentrations of metals and nutrients detected in baseline monitoring. The table below lists parameters that can affect amphibians and how frequently they should be monitored before restoration and the year after restoration. If baseline monitoring shows concentrations of metals and nutrients below the threshold as outlined in the CCME guidelines, monitoring of that parameter can be reduced to once per season (4 times per year).

**Table 6-2: Water Quality Monitoring Parameters**

Parameter	Frequency	CCME Water Quality Guidelines for Protection of Aquatic Life
Nitrogen	Monthly	1 mg/L <sup>1</sup>
Zinc	Monthly	30 µg/L
Copper	Monthly	2 µg/L (varies with hardness)
Lead	Monthly	1 µg/L (varies with hardness)
Dissolved Oxygen	Biweekly	minimum of 9.5 mg/L (cold-water species)
pH	Biweekly	6.5-9.0
Salinity	Biweekly	120 mg Cl <sup>-</sup> /L, or
Temperature	Biweekly	N/A

<sup>1</sup>Based on results from Marco et al., 1999

## 6.5 Structural Integrity

The inlets, outlets and berm structures of the wetland should be monitored to make sure they are functioning properly. The berm and slopes of the wetland should be checked more frequently in the months after construction to check if there is erosion, especially after a rainfall event. Additional planting or erosion protection measures may have to be added if there is erosion.

The slopes should also be checked for erosion. If runoff is forming rills on the slopes, additional planting or erosion control measures may have to be implemented.

## 7.0 CONCLUSION

The restoration of this area of Guichon Creek will contribute to the already existing and planned restoration efforts in the area. Continual small improvements to the watershed will have combined positive effects on the system. This project will contribute through improvement of Guichon Creek by managing a source of invasive species, improving hydrological functions in this area, and creating habitat for native amphibians such as the northern red-legged frog and the Pacific chorus frog.

In summary, the wetland will improve hydrological connectivity by increasing retention time and increasing infiltration rates. The surrounding riparian zone will act as a buffer to slow and filter campus run off before it enters the wetland. The combined effects of both will help reduce peak

flows, improve water quality and decrease the amount of runoff entering Guichon Creek. The off-channel design and riparian buffer, combined with changes in BCIT campus deicing practices, will allow this urban wetland to be used as habitat by the northern red-legged frog and the Pacific chorus frog.

Restoration in an urban environment is important to help establish and maintain relationships between us and nature. This project is an opportunity to involve students in the Ecosystem Restoration program as well as people who live in adjacent neighborhoods. It creates a forum for discussing the impacts of urbanization and what we as individuals can do to help limit our impacts on our surrounding waterways.



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## APPENDIX A – RENR 1130 SOIL PIT REPORTS

### RENR 1130

Elyse Hofs, Sonia Waiz, Cole Weststeyn

Site: 19

Date: Soil pit dug November 1, 2016

Report written November 28, 2016

#### Site description:

UTM Coordinates	Slope %	Aspect (Azimuth)	Vegetation and Land Use
10U 499987 E, 5454780 N	-8%	North facing slope (002°)	Site was located on the west side of Guichon Creek on the BCIT Campus. The main vegetation was deciduous and included big leaf maple, red alder, black cottonwood, salmonberry. The ground was covered in deciduous leaf litter

#### Soil Profile Description

Horizon	Depth (cm)	Munsell Color	Texture and % Coarse Frag.	Consistence and Structure
L	1-0	n/a	n/a	n/a
Ap	0-12	Dark Brown 7.5 YR 2.5/2	Sandy Loam 2% CF	Moist, very friable Fine crumb-like structure
Bf	12-20	Red Brown 5YR 3/4	Sandy Loam 2% CF	Moist, very friable Fine, subangular blocky
B2	20-58	Brown 10YR 4/4	Sandy Loam 15% CF	Moist, very friable Fine and medium, subangular blocky
IICgj	58-80	Light Grey 10YR 5/4 Mottling	Sandy Clay Loam 80% CF, gravelly	Loose gravel Fine particles slightly sticky, wet
W	Below 80 cm, start to hit water table			

## APPENDIX A – RENR 1130 SOIL PIT REPORTS

### Soil Profile Description - Continued

Horizon	Mottling	Horizon Boundary	Roots	Comments
L	n/a	n/a	n/a	Deciduous
Ap	n/a	Defined	Many fine roots	High OM content
Bf	n/a	Gradual	Coarse and fine roots	
B2	n/a	Gradual	Coarse roots stop in first 20 cm & fine roots stop at 45 cm.	
IICgj	Yes: fine & numerous	Defined	No Roots	
W	Below 80 cm, start to hit water table			

### Bulk Density and Porosity (Ap Layer)

Bulk Density: 0.55 Mg/m<sup>3</sup>

Porosity: 0.79

**Conclusion:** We examined various aspects of the soil horizon. We found mottling in the IICgj horizon which may indicate periods of waterlogged conditions alternating with periods of drier conditions depending on the time of year and precipitation. The site has probably been logged and moved around in the past because the original soil profile would likely have had normal forest L,F,H horizons. Our soil profile only had an L horizon suggesting that it was relatively recently disturbed.

## **APPENDIX A – RENR 1130 SOIL PIT REPORTS**

**November 1, 2016**

**Crew 20- Ryan Povarchook, Jessica Weiss, Sarah Jackson, Alex Stein**

### **Site Description**

Our soil pit was located at UMT coordinates 10U; 500006 E, 5454753 N. The surrounding area is a 40-50 year old riparian forest composed of black cottonwood, red alder, and big leaf maple, adjacent to Guichon Creek.

Understory vegetation includes trailing blackberry, sword fern, vine maple, thimbleberry, hardhack, red huckleberry, cherry sp., and large-leaved avens. Invasive species includes Himalayan blackberry, Japanese knotweed, oak sp., laurel sp., and English holly.

The slope was -65% with an aspect of 90° E. Due to relief of the steep slope, the LFH layer is greatly reduced and a hard clay layer at about 70 cm deep resulted. Despite the steep slope, we considered the soil poorly drained because of the high clay content and moisture.

### **Soil Profile Description**

L/F 7 - 0 cm Black 5 YR 2.5/1 (m); mull; slightly greasy; thin L/F layer with deciduous leaves, twigs, branches.

Ah 0 - 11 cm Dark Brown 7.5 YR 3/4 (m); sandy loam; oblique, round; loose, sticky, weak; abundant, very fine - fine roots; <2% C.F.; wavy boundary, 9 - 15 cm thick.

Bfh 11 - 22 cm Dark Yellowish Brown 10 YR 4/4 (w); silty sandy loam; sub angular, blocky, ovoid; weak - medium; semi-abundant, fine - medium roots; <2% C.F.; indeterminate wavy boundary, 10 - 15 cm thick.

Bt 22 - 70+ cm Greyish Brown 2.5 Y 5/2 (m); silty clay; few mottles, medium, prominent, greenish-grey GLEY 1 5/5 GY; angular, blocky; medium - strong, hard, rigid, slippery; no roots present; semi-concreted; 30 - 40% C.F.; indeterminate wavy boundary; 30+ cm thick.

### **Soil Profile Schematic and Field Pictures**

## APPENDIX A – RENR 1130 SOIL PIT REPORTS

7-0cm	VERY THIN-L/F
0-11cm	Ah
11-22cm	Bfh
22-70+cm	Bt

### Summary

We concluded from our field work that the horizons of our soil profile were as follows:

- Very thin L/F humus horizon due to steep slope and relief and subsequent erosion/washout.
- *Ah*: due to the rich brown colour, and again because of the steep slope which likely caused the H horizon to mix with the A horizon as the soil moved downhill.
- *Bfh*: due to the slight brownish and orange colours; in some spots iron oxide deposits were visible.
- *Bt*: due to the hard clay we encountered past 22 cm deep into the pit. Additionally, from hand texturing we observed that when moist, the clods became very soft, malleable, and slippery. We determined that the relief of the slope caused the smaller particles of clay and silt to sink down into the lower horizons, resulting in an illuviated Bt layer.



## APPENDIX B – PSAI SOIL ANALYSIS METHODS AND RESULTS

### Pacific Soil Analysis Methods

General Description		Source A page #	Source B page #	Source C page #	Source D page #
①	All soil samples are air dried or dried at less than 40 C, pinned and sieved through a 2 mm sieve.	1	1	2-3	19-20
2	All foliar samples are oven dried at 70 C, and later moisture corrected to 100 C. Tissues are ground to a powder in a coffee mill.		1		
③	Soil pH is determined potentiometrically using a Radiometer pH meter on a 1:1 soil to distilled water slurry. Estimated E.C. can be determined on this slurry using a Radiometer Conductivity cell.	3-4	3-4		
4	CaCl <sub>2</sub> pH is determined potentiometrically using a Radiometer pH meter on a 1:2 soil to 0.01 M CaCl <sub>2</sub> slurry.	3-4	3-4		143
5	Electrical conductivity is measured on a saturated paste extract. Sodium absorption ratio can be calculated after measuring the paste Ca, Mg and Na by atomic absorption spectrophotometry.	7-11	7-12	68-70	162
⑥	Total Soil, Plant, and Feed Nitrogen is determined colorimetrically using a Technicon Autoanalyser, on a semi-micro Kjeldahl digest.	32-36	20-25		
⑦	Total Carbon is determined directly on a LECO CR 12 Carbon Analyser.	M 46-48	M 37-40	M109-112	
8	Organic Carbon is determined by the Walkley-Black wet oxidation method.	42-43	33-34	115	
⑨	Available Phosphorus is determined colorimetrically using the ascorbic acid color development method on a 1:10 soil to Bray (NH <sub>4</sub> F) extract.	M 53-54	M47-48	174	
10	Olsen Phosphorus is determined as above however the extractant is Sodium Bicarbonate.	M55-57	M49-51	167-168	
11	Mehlich Phosphorus is determined as in Method 9, however the extractant is Sodium Fluoride.				43-45
⑫	Available Ca, Mg, Na, K, are determined by Perkin-Elmer Atomic Absorption Spectrophotometer on a 1:5 soil to ammonium acetate extract.			179-180	

**PSAI**

BCIT

Jan 24/2013  
P. 3/4

Sample	pH	Est E.C. mmhos cm	Lime Rqmt lbs 1000 sq ft	> 2mm %	< 2mm %	Sands %	Fines %	Total O.M. %	Total N %	C/N	Bray Avail P ppm	Avail K ppm	Avail Ca ppm	Avail Mg ppm	Avail Na ppm
Gravel mid	5.8	1.32		29.5	70.5	64.3	32.0	3.7	0.11	19.7	32	60	1000	100	240

Nutrient Legend

VL= Very Low

L= Low

M= Moderate

✓ = Adequate

SH= Slightly High

H= High

Unit # 5 - 11720 Voyageur Way, Richmond, B. C.

V6X 3G9

604-273-8226

Sample Rec'd Jan 16/2013  
B. W. Norman

[illegible]

## APPENDIX C – REFERENCE SITE WREC PROFILES

### Fm50 Cottonwood – Red alder – Salmonberry

*Populus balsamifera* – *Alnus rubra* – *Rubus spectabilis*

#### General Description

The Cottonwood – Red alder – Salmonberry Site Association is common along rivers in the Coast and Mountains. River benches that are flooded annually for moderately long periods are typical.

*Populus balsamifera* dominates the canopy but a subcanopy of *Alnus rubra* and scattered conifers is typical. The shrub layer is well-developed, often with *Rubus spectabilis* and *Cornus stolonifera* both being prominent. The herb layer can be sparse or well-developed, depending on recent flood history and cover of the canopy. *Equisetum* spp. and *Maianthemum dilatatum* are the major constituents. The moss layer is generally poorly developed. Soils are sandy Cumulic Regosols.



#### Characteristic Vegetation

**Tree layer (20 - 67 - 90)**

*Alnus rubra*, *Frax sitchensis*, *Populus balsamifera*, *Thuja plicata*

**Shrub layer (15 - 70 - 95)**

*Alnus rubra*, *Cornus stolonifera*, *Lonicera involucrata*, *Opiopanax horridus*, *Frax sitchensis*, *Rubus spectabilis*, *Sambucus racemosa*

**Herb layer (3 - 45 - 95)**

*Equisetum arvense*, *Maianthemum dilatatum*

**Moss layer (0 - 1 - 30)**

#### Wetland Edatopic Grid

		Soil Nutrient Regime					
		A	B	C	D	E	F
Soil Moisture Regime	M						
	VM						
	W						
	VW						

#### Comments

The typical floodplain successional sequence in the inner Coast and Mountains is F106 >> Fm50 >> Sitka spruce – Salmonberry forests. These communities often occur adjacent to each other, indicating the accumulation of fluvial sediments, which progressively raises benches higher above normal water flow.

Fm50 sites with silty or clayey layers within the soil profile are common. These sites often have some species more indicative of wetter sites such as *Oenanthe sarmentosa*, *Carex utriculata*, or *Scirpus microcarpus*.

The Fm50 includes several existing BEC Site Series (see Appendix 4).

## APPENDIX C – REFERENCE SITE WREC PROFILES

### Red alder – Salmonberry – Horsetail FI51

*Alnus rubra* – *Rubus spectabilis* – *Equisetum arvense*



#### General Description

Red alder – Salmonberry – Horsetail low benches are widespread in the Coast and Mountains. They occur adjacent to river courses where flood duration is lengthy and sedimentation is abundant.

*Alnus rubra* forms a closed tall shrub or low tree canopy. *Cornus stolonifera*, *Ribes bracteostum*, and *Rubus spectabilis* are prominent in the understorey. The herb layer can be sparse or well-developed depending on recent flood history. *Equisetum arvense* always persists but other species commonly occur. The moss layer is often very sparse.

Soils are typically sandy Cumulic Regosols.



#### Characteristic Vegetation

**Tree layer** (0 - 9 - 50)

*Alnus rubra*

**Shrub layer** (15 - 70 - 95)

*Alnus rubra*, *Cornus stolonifera*, *Ribes bracteostum*,  
*Rubus parviflorus*, *R. spectabilis*, *Sambucus racemosa*

**Herb layer** (2 - 17 - 50)

*Circaea alpina*, *Elymus glauca*, *Equisetum arvense*,  
*Stachys mexicana*

**Moss layer** (0 - 0 - 10)

#### Comments

Cleared high and middle bench floodplain forests will often regenerate to *A. rubra* and in these cases will represent a community successional to conifer forest. FI51 stands establish on sites with more lengthy flooding than Fm50 but also on similar sites where stand-initiating floods occur in autumn (a common occurrence in coastal watersheds). *A. rubra* drops seed in fall and will establish quickly on exposed mineral soils. *Populus balsamifera* drops seed in spring and its seedling will not establish where a thick cover of red alder already exists.

The FI51 includes several existing BEC Site Series (see Appendix 4).

#### Wetland Edatopic Grid

		Soil Nutrient Regime					
		A	B	C	D	E	F
Soil Moisture Regime	M						
	VM						
	W						
	VW						

## APPENDIX D – EPA SWMM MODELLING PARAMETERS

Subcatchment Wetland	
Property	Value
Name	Wetland
X-Coordinate	3374.750
Y-Coordinate	4737.343
Description	
Tag	
Rain Gage	3
Outlet	21
Area	10.5
Width	140
% Slope	5
% Imperv	75
N-Imperv	0.01
N-Perv	0.1
Dstore-Imperv	0.05
Dstore-Perv	0.05
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0
User-assigned name of subcatchment	

Subcatchment Predev	
Property	Value
Name	Predev
X-Coordinate	3053.453
Y-Coordinate	4736.570
Description	
Tag	
Rain Gage	3
Outlet	8
Area	10.5
Width	100
% Slope	5
% Imperv	10
N-Imperv	0.01
N-Perv	0.2
Dstore-Imperv	0.05
Dstore-Perv	0.05
%Zero-Imperv	10
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0
User-assigned name of subcatchment	

Subcatchment Current	
Property	Value
Name	Current
X-Coordinate	3225.279
Y-Coordinate	4700.879
Description	
Tag	
Rain Gage	3
Outlet	1
Area	10.5
Width	160
% Slope	5
% Imperv	75
N-Imperv	0.01
N-Perv	0.1
Dstore-Imperv	0.05
Dstore-Perv	0.05
%Zero-Imperv	25
Subarea Routing	OUTLET
Percent Routed	100
Infiltration	GREEN_AMPT
Groundwater	NO
Snow Pack	
LID Controls	0
Land Uses	0
Initial Buildup	NONE
Curb Length	0
User-assigned name of subcatchment	

## APPENDIX E – PLANTING PLAN AND COSTS

Location	Area	Elevation above wetland bottom	Planting density	Species	Size/Type
Wetland	300 m <sup>2</sup>	0.1 m – 0.4 m	2.5/m <sup>2</sup>	Baltic rush ( <i>Juncus balticus</i> ) Sitka sedge ( <i>Carex stichensis</i> )	Plug Plug
Riparian (also planted upland)	800 m <sup>2</sup>	0.4 m – 0.9 m	1/m <sup>2</sup>	Pacific Willow ( <i>Salix lucida</i> ) Red-Osier Dogwood ( <i>Cornus sericea</i> ) Black Twinberry ( <i>Lonicera involucrata</i> ) Salmonberry ( <i>Rubus spectabilis</i> ) Red elderberry ( <i>Sambucus racemosa</i> )	Live stakes Live stakes 1 gal 1 gal 1 gal
Upland	800 m <sup>2</sup>	0.9 m to edge of site	5 shrubs and 2 trees/ 10m <sup>2</sup>	Salmonberry ( <i>Rubus spectabilis</i> ) Red elderberry ( <i>Sambucus racemosa</i> ) Pacific Ninebark ( <i>Physocarpus capitatus</i> ) Nootka Rose ( <i>Rosa nootkana</i> ) Black Cottonwood ( <i>Populus trichocarpa</i> ) Western Hemlock ( <i>Tsuga heterophylla</i> ) Big-leaf Maple ( <i>Acer macrophyllum</i> )	1 gal 1 gal 1 gal 1 gal Live stakes 5 gal 5 gal

Plant Costs	Unit	Unit cost	Units required	Total
Native Grass Seed Mix	pound	\$ 25.00	20	\$ 500
Baltic rush ( <i>Juncus balticus</i> )	50 plug	\$ 0.85	375	\$ 319
Sitka sedge ( <i>Carex aquatilis</i> var. <i>stichensis</i> )	50 plug	\$ 0.85	375	\$ 319
Pacific Willow ( <i>Salix lucida</i> )	stakes	\$ -	150	\$ -
Red-Osier Dogwood ( <i>Cornus sericea</i> )	stakes	\$ -	150	\$ -
Black Twinberry ( <i>Lonicera involucrata</i> )	#1	\$ 3.25	150	\$ 488
Salmonberry ( <i>Rubus spectabilis</i> )	#1	\$ 3.25	250	\$ 813
Red elderberry ( <i>Sambucus racemosa</i> )	#1	\$ 3.25	250	\$ 813
Pacific Ninebark ( <i>Physocarpus capitatus</i> )	#1	\$ 3.25	125	\$ 406
Nootka Rose ( <i>Rosa nootkana</i> )	#1	\$ 3.25	125	\$ 406
Black Cottonwood ( <i>Populus trichocarpa</i> )	stakes	\$ -	60	\$ -
Big-leaf Maple ( <i>Acer macrophyllum</i> )	5 gal	\$ 13.75	50	\$ 688
Western Hemlock ( <i>Tsuga heterophylla</i> )	5 gal	\$ 13.75	50	\$ 688
Tax (13%)				\$ 593
Delivery	lump sum	\$ 150.00	1	\$ 150
<b>TOTAL BUDGET:</b>				<b>\$ 6,180</b>

Cost estimates for plants were obtained from a quote received from Peels Nursery in Mission, BC.