Riparian restoration of 32E Greenbelt, along Quibble Creek, to enhance canopy cover and limit urban impacts within the wildlife corridor

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Abstract

A wildlife corridor, composed of a series of connected greenways, connects Bear Creek Park and Green Timbers Urban Forest. The restoration site is situated within 32E Greenbelt adjacent to Quibble Creek (North Surrey, B.C.) which, together, act as a wildlife corridor between the two biodiversity hubs, allowing for increased movement of local species. Quibble Creek and 32E Greenbelt have been degraded by anthropogenic activities and invasive species, specifically a monoculture of Himalayan blackberry (*Rubus armeniacus*). This riparian restoration project, in partnership with the City of Surrey, aimed to enhance the wildlife habitat within the corridor by removing Himalayan blackberry and planting native tree and shrub canopy. A native plant prescription was created based on the biogeoclimatic site series, site assessments and local characteristics. Planting events were organized through the City of Surrey's ReLeaf program which included engaging local grade four students from Cindrich Elementary and Creekside Elementary schools. Additional maintenance and monitoring of the restoration site, and the greater 32E Greenbelt area was recommended to ensure increased biodiversity and abundance of native shrub and tree species.

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Introduction

1.1 Overview

Surrey, British Columbia (B.C.), has been deemed the "city of parks" with over 200 parks and many more green spaces (City of Surrey, 2020). Green Timbers Urban Forest and Bear Creek Park make up two of North Surrey's largest and most ecologically important parks. Green Timbers Urban Forest was completely logged in the early 20th century but has since become a focus of conservation and stewardship (City of Surrey, 2020). Shortly after logging took place, the surrounding residents and the B.C. Forest Service created a forestry school and nursery in order to reforest the area (GTHS, 2017). Today, this second-growth forest is protected as an Urban Forest (City of Surrey, 2020). Bear Creek Park has also experienced severe human impact over the years and is now considered a recreation park with attractions such as an art centre, an outdoor pool, and several sport fields (City of Surrey, 2020). However, Bear Creek (the major stream within Bear Creek Park) provides critically important habitat for salmonids year-round and is, therefore, allocated as a Class A stream according to the Watercourse Classification Map (City of Surrey, 2020; Parsons, 2015). This salmon-bearing stream has become a main topic within the City's educational programs which highlight the conservation of urban watersheds (McElhanney, 2017). Although both Green Timbers Urban Forest and Bear Creek Park have experienced severe anthropogenic impact, their forested areas and creeks provide critical habitat for flora and fauna within the urban city center.

Research has shown that wildlife corridors support regional flora and fauna populations and increase local biodiversity by allowing for increased movement and connectivity between greenspaces (Green *et al*., 2018; Naidoo *et al*., 2018; Vanthomme *et al*., 2018). A wildlife corridor – composed of a series of connected greenways – connects North Surrey's biodiversity hubs, Bear

Creek Park and Green Timbers Urban Forest. Together, Quibble Creek and 32E Greenbelt provide connectivity between these two green spaces (Fig. 1). Quibble Creek Watershed (a small portion of the larger Mahood Creek Watershed) spans close to 7 km^2 and runs directly through 32E Greenbelt (Metherall, 2014; Metro Vancouver LWSD, 2018). Quibble Creek drains into the Bear Creek and, therefore, provides additional upstream habitat for Coho salmon, Cutthroat trout, and other freshwater aquatic species (Metherall, 2014). Although this corridor is fairly small compared to the surrounding residential and industrial area, it remains vital to local biodiversity as corridors may increase dispersal between the two parks by up to 50% (Naidoo *et al.*, 2018).

Figure 1: Satellite map
Satellite map illustrating the wildlife corridor between Green Timbers Urban Forest and Bear Creek Park in Surrey, B.C. Quibble Creek Greenway is outlined in green, and Quibble Creek is shown in blue. Flora and fauna can, therefore, travel down the greenway and along the creek between the two parks. The orange box indicates the local of the restoration site.

The native plants within 32E Greenbelt are quickly being replaced by invasive species. Himalayan blackberry (*Rubus armeniacus*) is the most abundant invasive species found within the greenbelt (and the most prevalent at the restoration site), although English ivy (*Hedera helix*), morning glory (*Convolvulus arvensis*), knotweed (*Polygonum* spp.), and several touch-me-nots (*Impatiens* spp.) were also identified. The dense population of Himalayan blackberry along the banks of Quibble Creek has resulted in a decrease of native plant abundance. The roots of this invasive species are thick in diameter and generally shallow-rooted (Gaire *et al*., 2015; Soll, 2004). Many lateral roots grow out of the rootball, creating an extensive root system; in fact, it is possible for an individual lateral root to reach up to 10 m in length (Gaire *et al*., 2015; Soll, 2004). This wide-stretching and dense root system, along with its rapid growth rate, allows the Himalayan blackberry to store water and nutrients, thereby, limiting the growth of surrounding native plants (Gaire *et al*., 2015; Soll, 2004). The rapid growth of the thorny canes combined with its wide-stretching root system makes the removal of Himalayan blackberry difficult. The Himalayan blackberry may also be contributing to the stream bank erosion seen in several areas along Quibble Creek (Gaire *et al*., 2015). The shallow root system does not provide a strong structural hold for the streambanks, and the dense thickets prevent the establishment and success of deep-rooted shrubs and trees that do provide bank stability (Gaire *et al*., 2015). Furthermore, tree canopy cover over certain sections of Quibble Creek is sparse which has cascading effects on local air and water temperatures (Martens *et al*., 2019). The riparian canopy cover plays an essential role in the Quibble Creek food web structure as primary producers benefit from allochthonous input (tree leaves), while higher trophic levels, like the Coho salmon, require cool temperatures to survive (Martens *et al*., 2019). The extensive invasion of Himalayan blackberry and the tree canopy gaps

found along Quibble Creek within 32E Greenbelt threaten the corridor habitat and, therefore, the local species populations.

The 32E Greenbelt, which encompasses Quibble Creek, is regularly maintained by the City of Surrey including pruning along the trails and removal of any garbage in the area. However, it does not appear that local residents are regularly using the trails as garbage and large debris tend to accumulate between visits by the City of Surrey staff. It is possible that garbage is more evident in this greenbelt because the public doesn't report it to the city as often as in other green areas nearby in Surrey. Substance abuse issues and criminal activity are also evident within 32E Greenbelt as it is well-hidden from the street; this may further deter residential stewardship of the area.

This restoration project, in partnership with the City of Surrey, is interested in resolving these ecological and socio-economical issues. Overall the very urban area has led to several key issues which this restoration aims to repair, including extensive impacts of invasive species (mainly Himalayan blackberry), criminal activity, garbage and hazardous waste, erosion on streambank, and lack of shading along Quibble Creek.

1.2 Goals and Objectives

The following goals and objectives of this project aim to enhance the wildlife corridor (Quibble Creek and 32E Greenbelt) which connects Bear Creek Park and Green Timbers Urban Forest.

- Goal 1: Enhance native ecosystem components within the restoration site
    - Objective 1.1**:** Remove Himalayan blackberry (*Rubus armeniacus*)
    - Objective 1.2: Increase native tree and shrub canopy cover
    - Objective 1.3: Increase abundance and diversity of native plant species
- Goal 2: Increase local stewardship of 32E Greenbelt and Quibble Creek
    - Objective 2.1: Remove garbage and hazardous waste
    - Objective 2.2: Involve local school groups in native planting events
    - Objective 2.3: Promote stewardship of the area to local residents
- Goal 3: Enhance native wildlife habitat across 32E Greenbelt and Quibble Creek
    - Objective 3.1**:** Continue to remove Himalayan blackberry (*Rubus armeniacus*)
    - Objective 3.2: Continue to increase native tree and shrub canopy cover
    - Objective 3.3: Continue to increase abundance and diversity of native plant species

1.3 Stakeholders

The main stakeholder in this project is the City of Surrey who financed this restoration project. The Urban Forestry department aided in planning and implementing the restoration. The Releaf program in the Parks and Recreation department purchased the native plants which were installed at the restoration site as part of their elementary school planting program. The Engineering department could become a stakeholder moving forward as only they are able to do any in-stream work that may be required.

The second stakeholder is the Green Timbers Heritage Society who finances the Surrey's Natural Areas Partnership (SNAP) program. SNAP members played a large part in removing the invasive Himalayan blackberry (*Rubus armeniacus*) over three days.

Other stakeholders include the grade four students from Cindrich Elementary and Creekside Elementary who invested their time and energy to plant well over ¾ of the native vegetation now found at the restoration site. Finally, residents of the surrounding neighbourhoods who act as stewards to 32E Greenbelt and Quibble Creek are stakeholders.

Analyses of Restoration Area

2.1 Restoration Site

The restoration site was identified in June of 2019 in conjunction with the City of Surrey. It is situated between King George Blvd and 136B Street at 49º10’03”N, 122º50’41”W. The site falls within the Coastal Western Hemlock biogeoclimatic zone which is characterized by a mild climate and high precipitation throughout the year (CFCG, 2020). 32E Greenbelt and Quibble Creek are found within the transition zone between the Dry Maritime Coastal Western Hemlock Zone (CWHdm) and the Very Dry Maritime Coastal Western Hemlock subzone (CWHxm) (Green and Klinka, 1994). Therefore, the site may contain plant communities and ecological characteristics found of both the CWHxm and the CWHdm zones (Green and Klinka, 1994).

The ~325 m^2 restoration area is located on the eastern bank of Quibble Creek within 32E Greenbelt (Fig. 2). Although the majority of the creek’s banks are covered in Himalayan blackberry (*Rubus armeniacus*), this specific site was chosen as it was located under a large gap in the tree canopy. The direct sunlight had allowed the Himalayan blackberry to reach ~1.5 m in height. Its dense monoculture growth suggests that it has competitively excluded the native shrubs that may have been in the area. To access the site, trailheads are found at 136B St. and 90A Ave., or at 136B St. and 91 Ave (as seen as the pink lines in Fig. 2).

Figure 2: COSMOS map
The riparian restoration site is highlighted in red and is found on the eastern bank of Quibble Creek within 32E Greenbelt. Map created through COSMOS and provided by the City of Surrey.

2.2 Site Assessments

Several surveys and assessments of the restoration site were conducted from 9 am to 3 pm on June 22, 2019. A B.C. Ground Inspection Form (GIF) was completed for the restoration area (Government of B.C., 2020). Information including the slope, aspect, and elevation were recorded. Near the center of the restoration site, a ~70 cm-deep hole was dug. The Soil Nutrient Regime (SNR) and the Soil Moisture Regime (SMR) were determine according to the SNR and SMR keys (Green and Klinka, 1994). The texture of the soil was determined through the use of a water test using the "key to hand-texturing soil" (Green and Klinka, 1994). Furthermore, the vegetation, and corresponding percent cover, present within the 352 m_2 restoration site was recorded in order to complete the GIF. The flora species present along the eastern streambank from the restoration site to 88 Avenue (South) and to 92 Avenue (North) was recorded (Table 2). Based on the results, a site series was established for the restoration site which indicated the tree, shrub, herb and moss species that were historically found within the CWHxm and the CWHdm zones (Green and Klinka, 1994).

A line transect survey and a releve plot survey were also conducted along the Southern edge of the restoration site, as the Himalayan blackberry (*Rubus armeniacus*) thicket was too thick to enter along the majority of the site. The line transect was conducted by laying down 40m of measuring tape through the Southern edge of the site. Along the measuring tape, the plant species that intercepted the line transect were identified; the total distance that each plant species spanned along the line transect was calculated and, therefore, represents a species' percent cover. The releve plot survey was conducted by laying down a 1m by 1m quadrat within the Southern portion of the restoration site, again due to accessibility, followed by an estimation of the percent cover of each plant species. The releve plot was representative of the entire restoration site which was

overwhelmingly dominated by the Himalayan blackberry monoculture. The plant species in both of surveys were identified according to Pojar and MacKinnon's coastal plant guide and E-flora online atlas (1994).

A brief canopy cover survey was conducted in order to assess percent cover and the most common trees within the restoration site. The tree species were identified using Pojar and MacKinnon's coastal plant guide and E-flora online atlas (1994).

It is important to note that an in-stream analysis could not be completed. In-stream surveys for this site could have included assessing the water temperature and dissolved oxygen concentration; the results from these assessments could be used to indirectly measure an increase in canopy cover. The City of Surrey's Engineering and Environment department is responsible for all in-stream work and hold the required qualifications and/or permits.

Results

3.1 Results of Site Analyses

The results of the GIF can be seen in Table 1 (Green and Klinka, 1994). The vegetation within the borders of the ~325 m^2 restoration site was identified and compiled (Table 2). Additionally, flora species in the surrounding area – approximately 375 m to the South and 325 m to the North of the restoration site along the eastern streambank – were noted in Table 2. Based on this information, the site series was identified as a foamflower ecosystem (Green and Klinka, 1994). This classification held true for both CWHdm and CWHxm zones (Green and Klinka, 1994). The native flora species that were historically present at the restoration site can be determined from the foamflower site series for the CWHdm/CWHxm zones, and these species will dictate the plant prescription for the restoration site. Analysis of the tree canopy indicated a large gap in the canopy directly above the restoration site, therefore, bathing the site and creek in sunlight. The identified canopy gap will also influence the plant prescription; shrub and tree species that will fill-in the overstory canopy gap and are heat-tolerant will be considered.

Table 1: Ground Inspection Form

Results of the analyses carried out at 32E restoration site based on Green and Klinka's Ground Inspection Form (1994).

	Slope (°)	Elevation Above Sea Level (m)	Soil Nutrient Regime	Soil Moisture Regime	Soil Texture	Humus Form
32 E Greenbelt at Quibble Creek	6	60	R – rich	5 – moist	Clayey	Moder

Table 2: Species identification
Flora species identified within the restoration site and surrounding area according to according to Pojar and MacKinnon's coastal plant guide and E-flora online atlas (1994).

325 m2 restoration site at 32E Greenbelt and Quibble Creek		
Classification	**Species**	**Percent Cover (%)**
Invasive	Himalayan blackberry (*Rubus armeniacus*)	95
Native	Black cottonwood (*Populus balsamifera*)	2
	Red alder (*Alnus rubra*)	<1
	Salmonberry (*Rubus spectabilis*)	2

Surrounding Area	
Classification	**Species**
Invasive	Himalayan blackberry (*Rubus armeniacus*)
	English Ivy (*Hedera helix*)
	Touch-me-not (*Impatiens* spp)
	Morning glory (*Convolvulus arvensis*)
	Japanese knotweed (*Reynoutria japonica*)
Native	Black cottonwood (*Populus balsamifera*)
	Red alder (*Alnus rubra*)
	Paper birch (*Betula papyrifera*)
	Western redcedar (*Thuja plicata*)
	Vine maple (*Acer circinatum*)
	Red elderberry (*Sambucus racemose*)
	Indian plum (*Oemleria cerasiformis*)
	Nootka rose (*Rosa nutkana*)
	Salmonberry (*Rubus spectabilis)*
	Thimbleberry (*Rubus parviflorus*)
	Sword fern (*Polystichum munitum*)
	Spiny wood fern (*Dryopteris expansa*)

A line transect survey and a releve plot survey were also conducted along the Southern edge of the restoration site, due to accessibility issues. Only Himalayan blackberry intercepted the 40 m measuring tape, representing a species' percent cover of almost 100%. The releve plot survey showed similar results. Native plant species found within the restoration area included a salmonberry (*Rubus spectabilis*) shrub, a mature black cottonwood (*Populus balsamifera*) tree, and a red alder (*Alnus rubra*) sapling (Fig. 3). Ultimately, the 325 m^2 is dominated by invasive Himalayan blackberry.

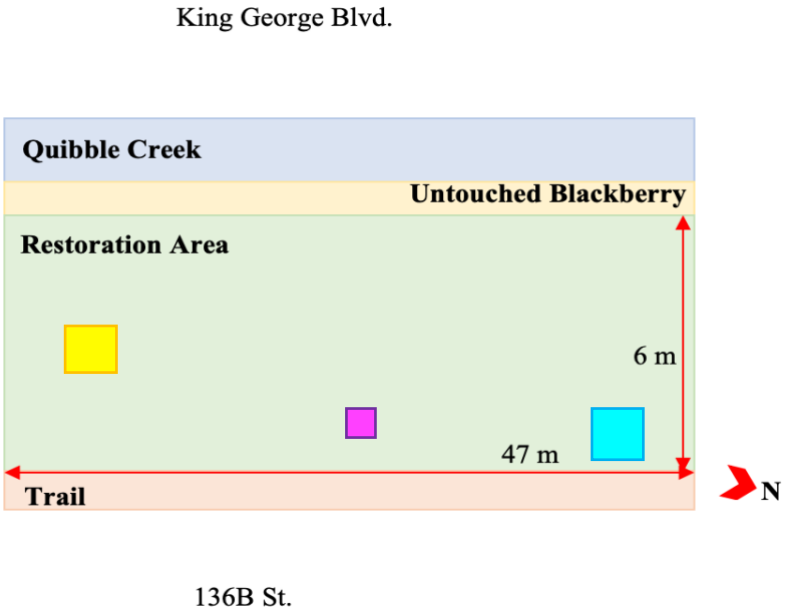

Figure 3: Restoration area
Map of the restoration site and surrounding zones within 32E Greenbelt. The yellow box represents a salmonberry (*Rubus spectabilis*) shrub. The pink box represents a red alder (*Alnus rubra*) sapling. The blue box represents a mature black cottonwood (*Populus balsamifera*) tree.

Planning, Design and Implementation

4.1 Timeline

Table 3 illustrates the timeline of this restoration project. The stakeholder refers to the City of Surrey. Monitoring (site assessment) and maintenance (invasive removal) are recommended over the next five years. Student engagement has the potential to continue over the next five years through the City of Surrey's habitat restoration programs, such as ReLeaf.

Table 3: Timeline
Timeline of the planning and implementation of the restoration at 32E Greenbelt, Quibble Creek. Stakeholder is the City of Surrey Urban Forestry Department. Student engagement could potentially continue over the next five years.

2019									
	April	May	June	July	August	September	October	November	December
Stakeholder Contact									
Site Investigation									
Site Assessment									
Design and Planning									
Invasive Removal									
Native Planting									
Student Engagement									

2020				
	January	February	March	April
Stakeholder Contact				
Site Assessment				
Student Engagement				

2020 to 2025			
	Spring	**Summer**	**Autumn**	**Winter**
Site Assessment				
Invasive Removal				
Student Engagement				

4.2 Photo-point monitoring

Photo-point monitoring was used in this project to document the initial stages of vegetation change. The photos taken from August 2019 to March 2020 captured a local-scale change from invasive to native vegetation. The materials used for photo-point monitoring include a metal rod, a tripod, a camera, a hammer and green scotch tape. The metal rod was blunt on one end and chisel-shaped on the other. Green scotch tape was wrapped above the chisel-shaped end. At each photo-point location, the metal rod was hammered into the ground just until the green tape was no longer visible; the metal rod above the ground was measured at 1.50 m in height (Fig. 4). A small tripod was fitted on top of the metal rod, bringing the total height above ground to 1.61 m (Fig. 4).

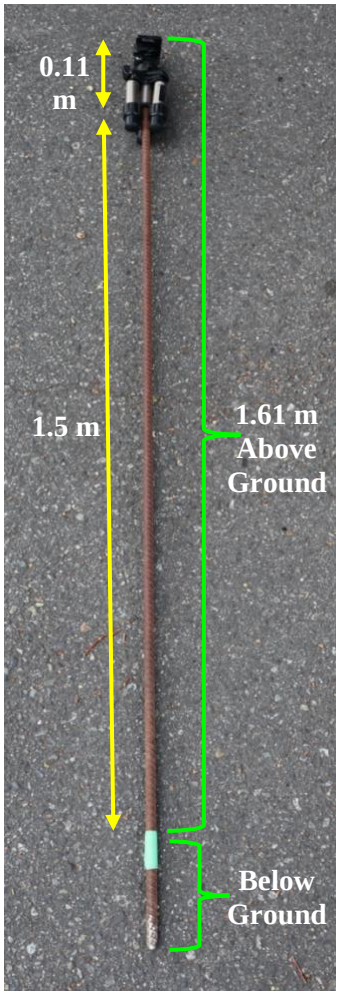

Figure 4: Photo-point monitoring materials
Materials used for photo-point monitoring. A canon camera was fitted on top of the tripod.

The pictures were taken from the eastern edge of the trail, facing the restoration site along the bank of Quibble Creek. As seen in Figure 5, the restoration site was photographed from three locations (A, B and C). At each location, two pictures were taken at different angles so that the photo-point monitoring captured the entire restoration site (Fig. 5). Location A is found on the eastern side of the trail at 49º10’05”N, 122º50’40”W, 0.6 m west of a large black cottonwood (*Populus trichocarpa*) tree that has been flagged with orange flagging tape at breast height. Location B is found on the eastern side of the trail at 49º10’03”N, 122º50’40”W, 0.3 m west of a black cottonwood (*Populus trichocarpa*) tree that has been flagged with orange flagging tape at breast height. Location C is

found on the eastern side of the trail at 49º10’02”N, 122º50’40”W, 0.3 m west of the orange flagging tape found at breast height on a thicket of Himalayan blackberry (*Rubus armeniacus*). Overall, pictures were taken over an 8-month period, from August 2019 to March 2020, as a part of the photo-point monitoring activity (Appendix B).

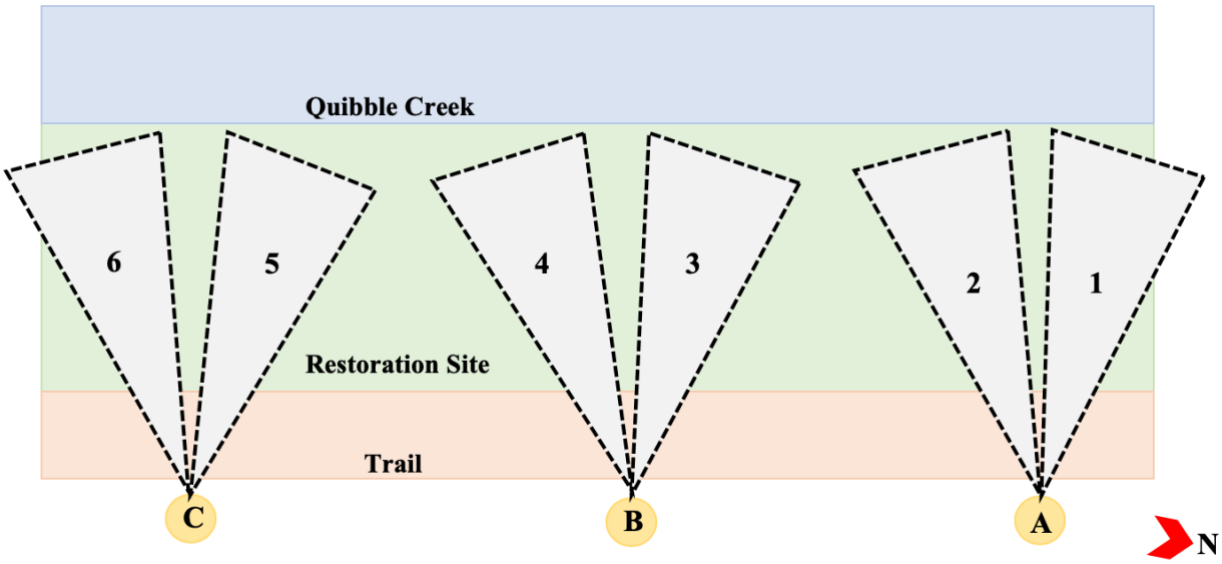

Figure 5: Photo-point monitoring set-up
Set up for photo-point monitoring at 32E Greenbelt. A, B and C indicated the three locations where the camera was placed. Numbers 1 through 6 indicate the field of view of the pictures taken.

4.3 Plant Prescription

The riparian plant prescription for the restoration site was based upon the site series classification (CWHdm/CWHxm, foamflower) and observations of the health of native species currently found along Quibble Creek. Furthermore, site characteristics (such as the open canopy and proximity to the creek) were considered. Following consultation with the City of Surrey, five tree species and five shrub species were prescribed, totaling 251 prescribed specimens (Table 4).

Table 4: Site Prescription
Flora species prescribed for the riparian restoration of 32E Greenbelt at Quibble Creek.

Prescribed Species	Classification	# of Prescribed Specimens
Bigleaf maple (*Acer macrophyllum*)	Overstory	6
Sitka spruce (*Picea sitchensis*)	Overstory	5
Western redcedar (*Thuja plicata*)	Overstory	5
Vine Maple (*Acer circinatum*)	Overstory	10
Indian plum (*Oemleria cerasiformis*)	Understory	25
Pacific ninebark (*Physocarpus capitalus*)	Understory	20
Thimbleberry (*Rubus parviflorus*)	Understory	60
Salmonberry (*Rubus spectabilis*)	Understory	100
Sword fern *(Polystichum munitum*)	Understory	20
Total prescribed tree specimens		**26**
Total prescribed shrub specimens		**225**
Total prescribed specimens		**251**

The ecological characteristics of the prescribed species indicated that they should successfully establish and grow at the restoration site. The reasoning behind a prescribed species was based on their habitat and ecological indicator information as per E-flora online atlas and Pojar and MacKinnon's coastal plant guide (1994). Bigleaf maple (*Acer macrophyllum*) is found in moist to mesic forests, with a wide-ranging SMR of 0 to 7. Bigleaf maple is a fast-growing species which will quickly increase shading over the creek and restoration site. Sitka spruce (*Picea sitchensis*) is found along river terraces with an SMR of 0 to 8. This species will also increase the canopy cover. Western redcedar (*Thuja plicata*) is found along floodplains and river terraces and has an SMR of 0 to 8. Special attention should be paid to the western redcedar specimens, as other individuals in the area appeared very dry. Vine maple (*Acer circinatum*) is found along streamsides and in wet to mesic closed and open forests. Vine maple can survive in a wide range of SMR from 0 to 7. This understory species is also shade-tolerant and will create second story canopy cover. Indian plum (*Oemleria cerasiformis*), Pacific ninebark (*Physocarpus capitalus*), Thimbleberry (*Rubus parviflorus*), and salmonberry (*Rubus spectabilis*) are found along streambanks and have wide-ranging SMRs. Sword fern (*Polystichum munnitum*) is found in moist to mesic forests and has an SMR of 0 to 8. This species is shade-tolerant and was observed in abundance along Quibble Creek. These overstory and understory species made up the original site prescription, although further alterations did occur (see Native Planting).

4.4 Garbage and Debris Removal

On August 19, 2019, SNAP staff members removed 1 cubic meter of garbage, hazardous waste and large debris from the restoration site and the surrounding area. This ensured both a safe area to work and a clean environment. Removal of debris continues to occur during site assessments. Furthermore, the City of Surrey respond to any public reports of garbage, hazardous waste or large debris.

4.5 Invasive Removal

The removal of Himalayan blackberry (*Rubus armeniacus*) took place over three days, from August 19 to 21, 2019. The invasive removal was accomplished by the Urban Forestry Department at the City of Surrey and the Habitat Restoration Teams from SNAP. On August 19, 2019, a brush saw was used to cut the chest-high Himalayan blackberry thicket to knee height. Special care was made to ensure any native plants that may have been hidden by Himalayan blackberry were left intact. Following the brush sawing, rakes and shovels were used to remove the remaining Himalayan blackberry branches and rootballs from the restoration area. All debris was removed from the site using tarps, then transported to the City of Surrey's invasive disposal bins, where the material would be incinerated. A 1 m wide strip of Himalayan blackberry directly adjacent to the stream was cut to the base, but the roots were left untouched to prevent any erosion into Quibble Creek. This 1 m strip will continue to be flush-cut until the planted species are able to shade out the Himalayan blackberry.

4.6 Native Planting

The majority of native planting took place over two days, from October 10 to 11, 2019. This planting event was coordinated by the City of Surrey's Releaf program whose staff organize and run native plantings with the help of students in local elementary schools. At this two-day planting event, grade four students from Cindrich elementary and Creekside elementary planted 244 native plants. Additional salmonberry (*Rubus spectabilis*) shrubs and Scouler's willow (*Salix scouleriana*) trees were later added by the City of Surrey to fill in any gaps in the planting area. In an unrelated project, B.C. hydro removed several trees in a nearby riparian area; the Scouler's willows are compensatory replacement trees that were required to be installed in the same watershed and were, therefore, planted in this restoration site at 32E Greenbelt. In total 289 native plants were planted at the restoration site (Table 5). Photographs of the restoration site after the native plantings can be seen in Appendix B.

Table 5: Planted Specimens
Flora species planted at the restoration site, 32E Greenbelt at Quibble Creek.

Prescribed Species	# of Prescribed Specimens	# of Planted Specimens
Bigleaf maple (*Acer macrophyllum*)	6	3
Sitka spruce (*Picea sitchensis*)	5	2
Western redcedar (*Thuja plicata*)	5	5
Vine Maple (*Acer circinatum*)	10	10
Indian plum (*Oemleria cerasiformis*)	25	25
Pacific ninebark (*Physocarpus capitalus*)	20	20
Thimbleberry (*Rubus parviflorus*)	60	60
Salmonberry (*Rubus spectabilis*)	100	124
Sword fern *(Polystichum munitum*)	20	20
Scouler's willow (*Salix scouleriana*)	-	20
Total planted tree specimens		**40**
Total planted shrub specimens		**249**
Total planted specimens		**289**

4.7 Financial Summary

Initial budgeting for the restoration site was based on the City of Surrey's plant spacing standards and tree to shrub ratio in reference to the area of the restoration site. The initial budget was calculated as $3,500. The final cost of this restoration project for the year of 2019-2020 is $4,900; this cost is broken down in Table 6.

Table 6: Financial Summary
Initial and Final expenditure of the restoration site of 2019-2020.

Initial Budget		
City of Surrey Planting Standard	$10.79 x 325 m_2	$ 3,506.75
Total Budget		
Planting Materials	Cost of tree specimens ($18.55 x 20 specimens)	$ 371.00
	Cost of shrub specimens, including willow species ($7.50 x 269 specimens)	$ 2,017.50
Contractor Services	Mulching ($5.05 x 289 specimens)	$ 1,459.45
	Weeding/year ($2.14 x 289 specimens)	$ 618.46
Labourer Services	10% of planting materials + contractor services	$ 446.64
Financial Summary		
	Total Cost	**$ 4,913.05**

Discussion

5.1 Maintenance and Monitoring

The restored site should be monitored and managed by the City of Surrey staff, university students with SNAP and, hopefully, the surrounding community over the next five years (or until the site becomes self-sustaining). Specific monitoring and management towards the completion of the previously outlined goals should be implemented. Himalayan blackberry (*Rubus armeniacus*) (and any other competing invasive) will require ongoing removal until the riparian plantings reach maturity and are able to better shade out the invasive species. Monitoring the success of the restoration should include annual site assessments during the growing seasons (spring and summer). Site assessments should include line transects, releve plots, and canopy cover surveys. These surveys should reveal overall plant health, as well as native abundance and diversity. Annual assessments that show an increase in native plant cover, an increase in tree and shrub canopy cover over Quibble Creek, and a decrease in Himalayan blackberry regrowth would meet the outlined goals and objectives for the restoration site; this would indicate an effective restoration. Water samples from Quibble Creek and wildlife surveys within 32E Greenbelt (such as songbird surveys) would be beneficial in monitoring the abundance of native wildlife species. Additional monitoring of salmon population within Quibble Creek would also be an asset.

Adaptive management is essential to ecological restoration work (Bakker *et al*., 2018; Ebberts *et al*., 2017). Adaptive management strategies for this site may include additional planting and/or summer watering. The city of Surrey, B.C., has continually surpassed record-breaking summer temperature over the past five years which has a severe impact on newly planted restoration sites. Although this restoration site is located directly on the streambank of Quibble Creek, the presently large canopy gap may lead to the death of the newly planted species during a

hot and dry summer season. Current observations indicated that the conifers along 32E Greenbelt already appear to be dry and brittle. Additional native plantings would supplement the restoration site if a die-out occurs. Additionally, site watering could be outsourced to a contractor. However, this comes at quite the cost; watering of each planted specimen would cost $4.48, totaling $1,115.52 for this restoration site. Adaptive strategies, such as fencing individual trees or fencing the entire restoration site, may be required due to the presence of beavers within Quibble Creek.

5.2 Continued Restoration

The City of Surrey's Urban Forestry Department has been tirelessly working toward the removal of invasive species for decades in the hopes of increasing biodiversity and functionality of Surrey's green spaces. It is recommended that ecological restoration continues along Quibble Creek to enhance this wildlife corridor, if the time and resources are available. Optimally, the entire greenbelt area between 88 Avenue and 92 Avenue should be undergoing active restoration and continued management over the next five years. The removal of Himalayan blackberry (*Rubus armeniacus*), as well as all other invasive species, could be accomplished by contractors, SNAP staff, and/or the Urban Forestry staff. It is recommended that native planting events in conjunction with local residents and local school groups continue to take place over the next five years, through programs such as ReLeaf, in order to promote stewardship of the area. Furthermore, the Surrey Youth Stewardship Squad could provide additional effort towards invasive removal and native planting.

5.3 Youth Outreach and Education

An incredibly important part of this restoration project revolved around involving and engaging local youth. Cindrich elementary and Creekside elementary are both located within walking distance of Quibble Creek and this restoration site. These grade four students accomplished a substantial amount of work, planting 244 specimens, and the lessons they take away from environmental education and restoration are essential to promoting sustainability for years to come. Ballard *et al*. (2017) found that involving youth in environmental education increases their interest and connection to their local environment. It was evident that the children were enjoying themselves during the plantings, and the Releaf staff provided further engagement about the importance of urban green spaces. During a presentation to the students of Creekside elementary in March, several thoughtful questions were posed regarding the long-term health of City parks. It is my belief that it is imperative for ecological restoration to be incorporated into public education in order to promote long-term sustainability and connectivity to the land.

5.4 Effectivity of Restoration

32E Greenbelt and Quibble Creek, comprising an essential wildlife corridor, have experienced severe invasion by introduced plants resulting in decreased biodiversity. The goals established by this project were as follows: enhance native ecosystem components within the restoration site, increase local stewardship of 32E Greenbelt and Quibble Creek, and continue to enhance native wildlife habitat throughout 32E Greenbelt and Quibble Creek.

Native ecosystem components within the restoration site were enhanced through the removal of invasive Himalayan blackberry (*Rubus armeniacus*) and the planting of native tree and

shrub species. By restoring the site from a blackberry monoculture to an assemblage of native riparian species, the biodiversity and abundance of native plant species have increased. The change in native species abundance has been captured through photo-point monitoring throughout this project (Appendix B). Annual site assessments will continue to measure this progress over the next five years. Local stewardship of 32E Greenbelt and Quibble Creek was promoted by engaging local school groups through native planting events. Presentations made to the grade four students at Cindrich Elementary and Creekside Elementary, both in the classroom and in the field, focused on the importance of conserving urban green spaces. The students' thoughtful questions and hard work indicated that stewardship of their local greenbelt had, in fact, increased. Finally, recommendations were made to continue restoration, adaptive management and youth engagement within 32E Greenbelt and Quibble Creek over the next five years. Further invasive removal and native tree and shrub plantings will enhance wildlife habitat within 32E Greenbelt. With additional maintenance and monitoring, the planted overstorey species should fill in the canopy gap above the restoration site and Quibble Creek over the next decade. In turn, the planted tree specimens will increase the allochthonous input entering the aquatic ecosystem, decrease streambank erosion and decrease the water temperature.

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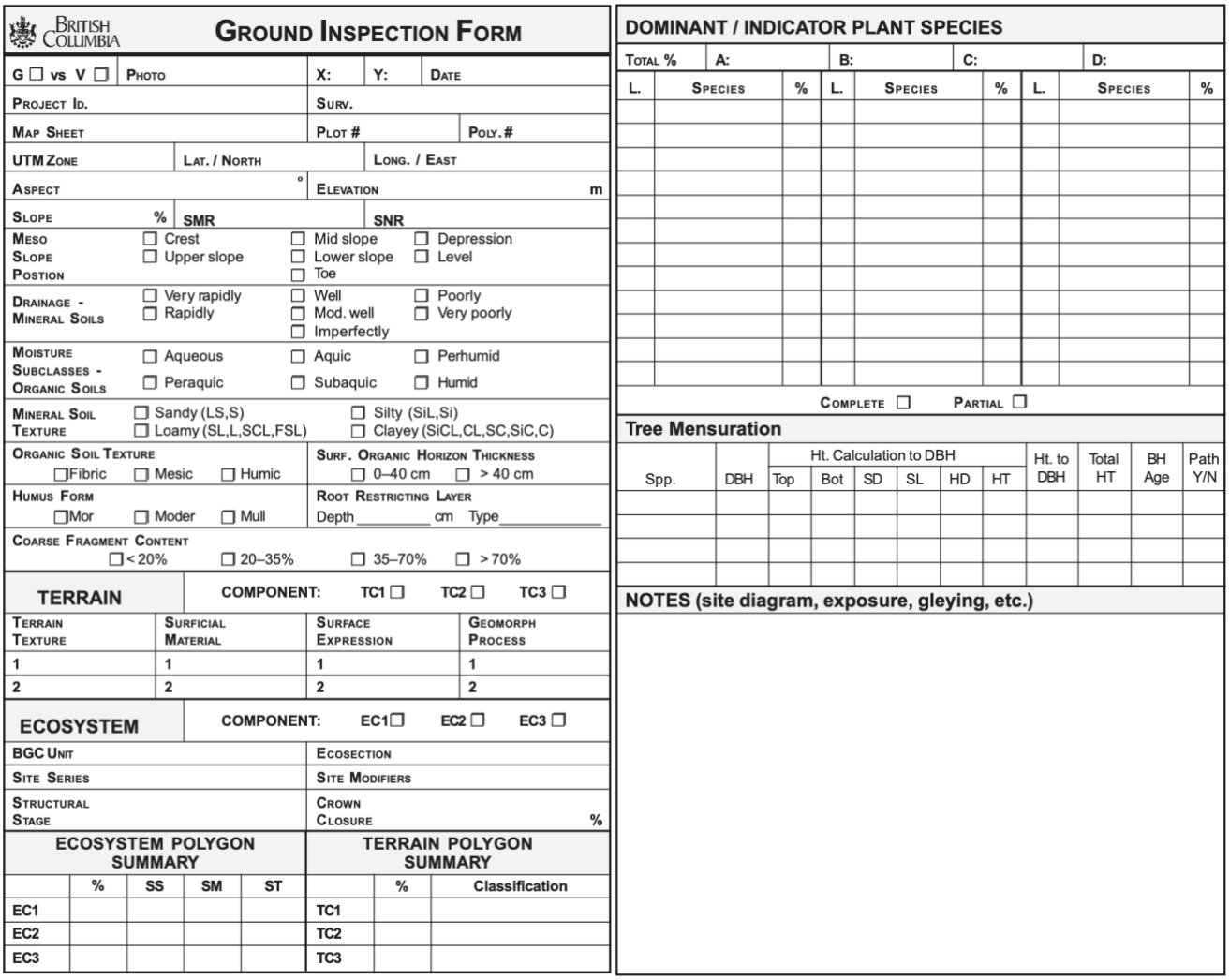
Appendices

Appendix A: B.C. Ground Inspection Form

Retrieved from: https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/ecosystems/bec/codes-standards/gif_frm98.pdf



BRITISH COLUMBIA

GROUND INSPECTION FORM

G ☐ vs V ☐	PHOTO		X:	Y:	DATE
PROJECT ID.			SURV.		
MAP SHEET			PLOT #		POLY. #
UTM ZONE	LAT. / NORTH		LONG. / EAST		
ASPECT °			ELEVATION		m
SLOPE %	SMR		SNR		

MESO SLOPE POSTION	☐ Crest ☐ Upper slope	☐ Mid slope ☐ Lower slope ☐ Toe	☐ Depression ☐ Level
DRAINAGE - MINERAL SOILS	☐ Very rapidly ☐ Rapidly	☐ Well ☐ Mod. well ☐ Imperfectly	☐ Poorly ☐ Very poorly
MOISTURE SUBCLASSES - ORGANIC SOILS	☐ Aqueous ☐ Peraquic	☐ Aquic ☐ Subaquic	☐ Perhumid ☐ Humid
MINERAL SOIL TEXTURE	☐ Sandy (LS,S) ☐ Loamy (SL,L,SCL,FSL)	☐ Silty (SiL,Si) ☐ Clayey (SiCL,CL,SC,SiC,C)	

ORGANIC SOIL TEXTURE ☐Fibric ☐ Mesic ☐ Humic

SURF. ORGANIC HORIZON THICKNESS ☐ 0–40 cm ☐ > 40 cm

HUMUS FORM ☐Mor ☐ Moder ☐ Mull

ROOT RESTRICTING LAYER Depth _____ cm Type _____

COARSE FRAGMENT CONTENT ☐ < 20% ☐ 20–35% ☐ 35–70% ☐ > 70%

TERRAIN

COMPONENT: TC1 ☐ TC2 ☐ TC3 ☐

TERRAIN TEXTURE	SURFICIAL MATERIAL	SURFACE EXPRESSION	GEOMORPH PROCESS
1	1	1	1
2	2	2	2

ECOSYSTEM

COMPONENT: EC1 ☐ EC2 ☐ EC3 ☐

BGC UNIT	ECOSECTION
SITE SERIES	SITE MODIFIERS
STRUCTURAL STAGE	CROWN CLOSURE %

ECOSYSTEM POLYGON SUMMARY

	%	SS	SM	ST
EC1				
EC2				
EC3				

TERRAIN POLYGON SUMMARY

	%	Classification
TC1		
TC2		
TC3		

DOMINANT / INDICATOR PLANT SPECIES

TOTAL % A: B: C: D:

L.	SPECIES	%	L.	SPECIES	%	L.	SPECIES	%

COMPLETE ☐ PARTIAL ☐

Tree Mensuration

Spp.	DBH	Ht. Calculation to DBH: Top	Bot	SD	SL	HD	HT	Ht. to DBH	Total HT	BH Age	Path Y/N

NOTES (site diagram, exposure, gleying, etc.)

Appendix B: 32E Greenbelt and Quibble Creek restoration site from August 2019 to March 2020. Photos captured at camera location 3, angle B (see Fig. 5).


21/02/20


30/03/20