

# **Vancouver stream restoration practices: Piloting a community-based monitoring framework along Still Creek**

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framework along Still Creek

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## **Abstract**

The number of urban stream restoration projects implemented by local governments has expanded exponentially; however, these projects are rarely monitored to assess effectiveness. Community-based monitoring can overcome monitoring challenges, and build community capacity. Still Creek located in Vancouver, BC, provides a case study for creating a community-based monitoring framework and protocol to collect information relevant to local government. The indicator framework is composed of three indicators: (1) Benthic invertebrate diversity, (2) Visual habitat assessment, and (3) Riparian terrestrial biodiversity. Volunteers for data collection were recruited through Meetup.com. Community-based monitoring comes with practical concerns and limitations; however, the data collected can inform continued adaptive management of urban stream restoration projects. Recommendations for Still Creek include establishing a maintenance schedule, with associated roles and budget; further education and awareness initiatives within the community; continued community-engagement; and continued watershed-wide and reach-scale restoration efforts.

**Keywords:** Urban Stream Restoration; Community-based Monitoring; Citizen Science; Urban Ecology; Ecological Restoration; Adaptive Management;

## **Dedication**

Dedicated to Still Creek, without which I wouldn't have had a project.

## **Acknowledgements**

I acknowledge the continued support of my family, my committee members, my “REMfam” and the entire REM community, supportive local government and not-for-profit staff, and of course the community volunteers who helped me in the field.

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## List of Acronyms

CBM	Community-based monitoring
DFO	Department of Fisheries and Oceans
EMA	Environmental Management Act
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ISMP	Integrated Stormwater Management Plan
LWMP	Liquid Waste Management Plan
MEA	Millennium Ecosystem Assessment
SER	Society for Ecological Restoration
SFU	Simon Fraser University

## Glossary

Adaptive Management	Approach to resource management in which actions are designed and carried out as experiments, to learn how a system responds to management, and increase level of certainty regarding how best to achieve desired results
Biodiversity	Variability among living organisms on earth; includes diversity within species, between species, and of ecosystems
Catchment	Collection of rainfall over a natural drainage area
Daylighting	Management practice involving opening up buried watercourses and restoring them to more natural conditions
Disturbance	Temporary change in environmental conditions that results in biophysical changes to an ecosystem
Ecological Restoration	Intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability
Ecosystem	A biological community of interacting organisms and their physical environment
Ecosystem Services	The benefits people obtain from ecosystems
Evapotranspiration	Process by which water is transferred from land to atmosphere by evaporation from soil, surfaces, and transpiration from plants
Reference state	The ecosystem characteristics, based on historical, current, and future ecological and socio-economic conditions, which ecological restoration aims to achieve
Riparian	Land area adjacent to river which is the interface between the land and water
Shifting Baseline Syndrome	Reference points and perceptions of what is normal or natural change over time
Watershed	Area of land where all the surface water drains into the same place



(Photo credit: Carolyn Prentice)

# Chapter 1. Introduction

## 1.1. Urbanization and Stream Ecosystems

Urban development leads to the fragmentation and disappearance of natural ecosystems (Forman, 2014). The United Nations predicts that the world's population will increase to more than 8 billion people by 2050, with more than 2/3 of the population living in urban areas (United Nations, 2014). To accommodate population growth, urban development increases the built environment, and the existing ecosystems become fragmented, or disappear completely (Forman, 2014). The remnant patches of ecosystems are fundamentally altered due to human influence, and thus urban areas are composed of novel ecological communities with minimal connectivity to adjacent ecosystems (Forman, 2014; Hostetler, Allen, & Meurk, 2011; Kowarik, 2011).

River ecosystems within and around urban areas are particularly influenced by human interventions historically aimed at modifying the supply of water. Urban waterways are altered through changes their channel morphology, water chemistry, hydrology, and associated habitat and biodiversity (Forman, 2014). Waterways are channelized and concretized, resulting in loss of riparian vegetated areas and reduced stream complexity (Walsh et al., 2005). Increased impervious surface area at the watershed scale decreases rainfall infiltration rates and increases urban runoff. In addition, the removal of vegetation decreases evapotranspiration rates within cities. The combination of reduced permeability and evapotranspiration in urban waterways leads to a 'flashier' hydrology, with lower base flows and higher peak flows (Walsh et al., 2005). Urban runoff also brings with it contaminants from industrial and residential processes, fundamentally altering the stream water chemistry (Walsh et al., 2005).

Human interventions may aim to mitigate, and even undue, the effects of urban development on waterways through ecological restoration. Ecological restoration as defined by the Society for Ecological Restoration (SER) (2004: p. 1), is "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability". The definition implies that the existing ecosystem has been degraded, damaged, or transformed because of direct or indirect human activities. Ecological restoration is human intervention that attempts to restore

ecosystems through a historic trajectory by building on existing ecological processes, minimizing human disturbances, and facilitating natural processes (Clewell, Aronson, & Winterhalder, 2004).

Urban stream restoration in particular describes the variety of modifications of river channels, adjacent riparian zones, and watershed catchment within urban areas aimed at reversing the negative effects of urbanization (Bernhardt & Palmer, 2007; Wohl, Lane, & Wilcox, 2015). The practice of urban stream restoration aims to improve hydrologic, geomorphic, and ecological processes by replacing the lost, damaged, or compromised elements of the natural system. The term 'restoration' is sometimes distinguished from rehabilitation or enhancement, but will be used in this paper as an all-inclusive term (Smith et al., 2016; Wohl et al., 2015).

## **1.2. Project Rationale**

Within the past thirty years the number of urban stream restoration projects, particularly in North America, Europe and Australia, has increased exponentially (Bernhardt et al., 2005; Suding, 2011). Urban stream restoration is appealing to urban planners because of the associated ecological, social and economic benefits (Bernhardt & Palmer, 2007; Forman, 2014; Suding, 2011; Zhou & Rana, 2012). Monitoring and assessment are necessary for adaptive management and to improve the theory and practice of urban stream restoration (Garda, Castleden, & Conrad, 2017; Jahnig et al., 2015; Smith et al., 2016; Wohl et al., 2015). Monitoring is commonly stated as necessary during planning, however very few projects are monitored post-implementation (Alexander & Allan, 2007; Hassett, Palmer, & Bernhardt, 2007; Jahnig et al., 2015; Nilsson et al., 2016; Suding, 2011).

Monitoring urban stream restoration requires collecting ecological data, and municipal governments lack the capacity collect such data to evaluate whether the restoration is achieving its objectives. Municipalities face challenges in required ecological expertise and funding to adequately monitor projects post-implementation (Alexander & Allan, 2007; Hassett et al., 2007). Community-based monitoring (CBM) can overcome the challenges facing municipalities for monitoring urban stream restoration, and provides valuable data to inform restoration practitioners (Conrad & Hilchey, 2011;

Garda et al., 2017). CBM also increases awareness of environmental issues, builds ecological literacy, and increases social capital (Conrad & Hilchey, 2011).

My research aims to create a community-based monitoring framework and protocol to collect ecological information relevant to municipal planners about urban stream restoration. Still Creek, an urban stream in Vancouver, British Columbia, provides a case study to develop the framework, ensure the methods are applicable, and collect relevant data. Past student research identified the value of ongoing monitoring through a citizen-science program, in efforts to decrease the burden of improving watershed functioning on local governments (Parsons, 2015). The monitoring protocol was implemented with the help of community volunteers, and the data collected provides the first comprehensive ecological evaluation for the stream. The monitoring protocol, framework, and data collected will be given to local governments to inform future decisions about restoration projects. The methods developed and data collected will contribute to the broader discourse surrounding municipal implementation of urban stream restoration, and inform future research and current practice.

### **1.3. Outline**

A literature review is presented in Chapter 2, covering the subjects of urban stream restoration ecology, urban stream restoration planning and practice, and community-based monitoring. Chapter 3 describes the case study of Still Creek and presents the indicator framework, with the associated rationale and monitoring protocol. Chapter 4 presents the data collection results, and Chapter 5 discusses the implication of the findings for community-based monitoring, informing local management around Still Creek, and urban stream restoration more broadly. Chapter 5 also includes recommendations for site-specific actions around Still Creek, and planning and management. Chapter 6 concludes the research, and provides direction for future research.

## Chapter 2. Literature Review

The literature review provides a basis for developing a framework that is able to capture the ecological changes and associated societal objectives, while addressing the capacity issues of local government through community-based monitoring. The first portion of the review characterizes underlying ecological principles and social motivations which are necessary to understand why local governments in particular implement urban stream restoration projects. The capacity issues facing municipal government are generalized, along with rationale for addressing issues through community-based monitoring. The additional societal benefits, limitations and challenges of CBM, are also described to illustrate its strengths and weaknesses.

### 2.1. Urbanization and Stream Ecology

The “Urban Stream Syndrome” summarizes the processes by which humans alter stream ecosystems in urban areas by identifying the stressors and effects (Smith et al., 2016; Walsh et al., 2005). The following ecological processes are fundamentally altered in urban streams, and characterize the urban stream syndrome:

**Water flow** The change in hydrology is the most obvious and consistent change in stream ecosystems (Walsh et al., 2005). Increased area of impervious surfaces from the built environment, and more efficient transport of runoff from subsurface by piped storm water, increases runoff and decreases infiltration. The resulting hydrology becomes “flashy”, with more frequent, larger flow events, and lower baseflows (Walsh et al., 2005).

**Water chemistry** Human activities and behaviours in industrial and residential processes introduce new chemicals and particulates into the ecosystems. Contaminants and pollutants collect in rainwater and sewers, which fundamentally alter stream water chemistry (Walsh et al., 2005). The changes in water chemistry occur even at low levels of catchment urbanization (Walsh et al., 2005).

**Stream geomorphology** The physical characteristics of waterways are altered either directly through human engineering or as a result of changes in hydrology. Channelization and concretization of streams results in loss of stream complexity. Urban

areas tend to have in stream obstructions, dams, culverts, that fragment the ecosystem (Walsh et al., 2005; Wild, Bernet, Westling, & Lerner, 2011).

***Aquatic habitat and biodiversity*** Due to combination of the above three stressors, aquatic habitat is significantly degraded. Species assemblage richness and diversity declines in algae, invertebrates, and fish with increasing urbanization (Walsh et al., 2005; Wenger et al., 2009).

***Riparian habitat and biodiversity*** Riparian areas are recognized as integral components connecting terrestrial and aquatic ecological and ecosystem processes (Warren, Potts, & Frothingham, 2015; Wilkins, Cao, Heske, & Levengood, 2015). As the built environment replaces riparian vegetation, terrestrial biodiversity decreases. In addition, disturbed ecological areas are prone to invasive species, which further displace native plants and animals and homogenize the existing riparian ecosystem (Clewell et al., 2004; Groffman et al., 2016; Page, 2006; Warren et al., 2015).

Urban stream restoration encompasses the range of human actions aimed at reversing the effects of urbanization on stream ecosystems. Restoration occurs through the removal of degrading stressors, and other interventions aimed assisting stream ecosystems along the trajectory to a more 'natural' state. The 'natural' state is often termed 'reference state', which can be compared to non-urban streams, or hypothesized pre-urban conditions (Palmer et al., 2014). The SER emphasizes that historical condition be taken into consideration, but that current, and future, and socio-economic conditions also be considered in determining a reference state (SER, 2004; Smith et al., 2016).

With socio-economic conditions taken into consideration, deciding on a reference state or condition to be restored to can become value-laden and subjective (Baker & Eckerberg, 2013; Bernhardt & Palmer, 2007; Wohl et al., 2015). Human perception of ecosystems influences how they are managed, and what people enjoy as the appearance of 'nature' may not be related to ecological quality (Nassauer, 2004). People from different backgrounds and different relationships with nature in cities will perceive nature differently, and these relationships and perceptions change over time (Chiesura, 2004; Nassauer, 2004; Westling, Surridge, Sharp, & Lerner, 2014). Indeed, the degraded state of streams is a result of anthropogenic interventions which reflected the

perception of attractiveness and a desired societal purpose at the time (Hale, 2016; Vermaat et al., 2015).

The term “shifting baseline syndrome” is used in ecology to describe how reference points and perceptions of what is ‘normal’ or ‘natural’ change over time. Each societal generation use their own experiences as references, and use that as a baseline even despite other evidence. As successive generations accept degraded ecological conditions, the standards by which to restore to ‘natural’ are lowered (Georgia Basin Inter-Regional Education Initiative, 2015; Pauly, 1995).

Choosing a reference state may become a philosophical debate (Higgs, 2005), and policymakers, managers, and restoration funders recently have focused on restoration as the provision of ecosystem services (Mekala, Jones, & MacDonald, 2015; Palmer, Hondula, et al., 2014; Suding, 2011; Vermaat et al., 2015). The Millennium Ecosystem Assessment (MEA) (2003) describes ecosystem services as “the benefits people obtain from ecosystems”. The ecosystem services concept arose independent of the concept of ecological restoration; however, the connection is natural seeing the strong historical human dependency on the river ecosystems (MEA, 2003; Palmer, Filoso, & Fanelli, 2014; Saraev, 2012; Smith et al., 2016; Suding, 2011).

The MEA (2003) categorizes services broadly into four functioning categories: Provisioning services, which are the products obtained from ecosystems; regulating services, which are the benefits from the regulation of ecosystem processes; cultural services, which are the nonmaterial benefits people obtain from ecosystems tightly bound to human values; and supporting services, the indirect ecosystem processes necessary for all other ecosystem services. The services are not mutually exclusive, and ecosystems may generate a number of different services simultaneously.

The ecosystem services provided by urban streams are summarized below:

**Table 1 Ecosystem Services provided by urban stream ecosystems**

Category	Ecosystem Service	Description
Regulating	Carbon sequestration and storage	Vegetation in urban areas sequesters and stores carbon from the atmosphere, which may be significant in influencing the global climate (de Groot, Alkemade, Braat, Hein, & Willems, 2010; Value of Nature to Canadians Study Taskforce, 2017; Vermaat et al., 2015)
	Air Filtration	Urban vegetation filters the air pollution and particulates in urban areas caused by transportation, heating of buildings, and other human activities (Bolund & Hunhammar, 1999; de Groot et al., 2010; Value of Nature to Canadians Study Taskforce, 2017).
	Climate Regulation	Vegetation and water in urban areas reduces the urban heat island effect, which is initially caused by a large area of heat absorbing surfaces in combination with high amounts of energy use in cities (Bolund & Hunhammar, 1999; Elmqvist et al., 2015; Value of Nature to Canadians Study Taskforce, 2017).
	Noise reduction	Human activities produce significant amount of noise, which can be reduced through soft ground and vegetation, and sounds of water (Bolund & Hunhammar, 1999; Value of Nature to Canadians Study Taskforce, 2017).
	Water treatment	Wetlands and greenspace assimilate large amounts of nutrients and water contaminants, remove and breakdown organic matter and other compounds, and trap particulate matter (Bolund & Hunhammar, 1999; Elmqvist et al., 2015; de Groot et al., 2010; Value of Nature to Canadians Study Taskforce, 2017).
	Flood control	Vegetation allows water to infiltrate into soils at a slower rate, and evapotranspire water to the atmosphere allowing more gradual release of water. These processes reduce risk of flooding during high-intensity rainfall events (Bolund & Hunhammar, 1999; Elmqvist et al., 2015; de Groot et al., 2010; Vermaat et al., 2015; Value of Nature to Canadians Study Taskforce, 2017).
	Erosion control	Vegetation and other organisms retain the structure of soils, and prevent erosion and excess sedimentation (de Groot et al., 2010; Value of Nature to Canadians Study Taskforce, 2017; Vermaat et al., 2015)
Cultural	Recreation	Waterways in urban areas provide space for active and passive recreation including walking, running, bicycling, wildlife viewing, and children's adventures (Bolund & Hunhammar, 1999; Ozguner, Eraslan, & Yilmaz, 2012; Value of Nature to Canadians Study Taskforce, 2017; Vermaat et al., 2015).
	Education	Natural spaces provide outdoor classrooms and laboratories, where students and local residents can learn ecological principles (Purcell, Corbin, & Hans, 2007; Value of Nature to Canadians Study Taskforce, 2017).

Category	Ecosystem Service	Description
	Aesthetic and Spiritual	Natural areas improve psychological and spiritual well-being, encompassing a sense of purpose, awe and inspiration. Citizens may value nature for its existence and scenic beauty (Chiesura, 2004; Keniger, Gaston, Irvine, & Fuller, 2013; Value of Nature to Canadians Study Taskforce, 2017; Vermaat et al., 2015).
	Sense of Place	Ecosystems increase attachment individuals have to a geographical area and social community, and neighborhoods attach a 'sense of place' to urban streams (Chiesura, 2004; Morton & Padgitt, 2005; Parsons, 2015; Smith et al., 2016; Value of Nature to Canadians Study Taskforce, 2017).
Provisioning	Food	Riparian areas along urban streams can provide space for fruit trees, urban gardening, or wild food foraging (Miller et al., 2015; Value of Nature to Canadians Study Taskforce, 2017).
	Ornamental resources	Stream ecosystems provide raw materials that may be used for a variety of artistic and ornamental purposes (Value of Nature to Canadians Study Taskforce, 2017).
Supporting	Soil formation	Soil forms through the process of rock weather and accumulation of organic matter (Value of Nature to Canadians Study Taskforce, 2017).
	Primary production	Aquatic and terrestrial plants in stream ecosystems photosynthesize solar energy and take up nutrients, forming the basis of food webs (Value of Nature to Canadians Study Taskforce, 2017).
	Nutrient cycling	Nutrients that are essential to life cycle through ecosystems, these nutrients include carbon, nitrogen, phosphorus, among others (Value of Nature to Canadians Study Taskforce, 2017).
	Habitat	Habitats provide the physical and biological conditions that an individual plant or animal needs to survive. Stream ecosystems provide a variety of habitats at different scales (Elmqvist et al., 2015; Value of Nature to Canadians Study Taskforce, 2017).

## 2.2. Urban Stream Restoration and Municipal Policy

Urban stream restoration as a municipal management tool has grown dramatically in the last two decades, and is still very young as a water management practice (Palmer, Hondula, et al., 2014; Smith et al., 2016; Wohl et al., 2015). Urban stream restoration is attractive to urban planners and local government water managers because the potential ecosystem services align with municipal responsibilities:

### ***Urban stream restoration as infrastructure and property protection***

Local government retains jurisdiction over drainage facilities which aim to convey water and reduce water drainage hazards such as flooding or erosion (Federation of Canadian

Municipalities, 2006). Urban stream restoration often still stems from a need to protect the existing built environment, can be cheaper than replacing hard engineered structures (Hassett et al., 2007; Kenney et al., 2012; Smith et al., 2016; Wild et al., 2011; Wohl et al., 2015).

***Urban stream restoration as wastewater treatment*** Local government is responsible for maintenance of wastewater treatment (Federation of Canadian Municipalities, 2006). Water quality improvements are also a primary goal reported in urban stream restoration projects, as riparian vegetation and local wetlands can effectively improve water quality (Hassett et al., 2007; Kenney et al., 2012; Palmer, Filoso, et al., 2014; Wild et al., 2011; Wohl et al., 2015).

***Urban stream restoration as active transportation*** Local government maintains jurisdiction over local transportation infrastructure, including active transportation (Federation of Canadian Municipalities, 2006). Urban greenways historically have followed waterways, and can become bicycling and pedestrian paths due to gentle grading (Searns, 1995).

***Urban stream restoration as park and green-space*** Municipalities service cultural and recreational facilities, such as arts facilities, community centers and urban parks (Federation of Canadian Municipalities, 2006). Natural areas enhance the liveability of urban areas, by providing space for outdoor sport recreational facilities, and becoming public tourist attractions (Dovetail Consulting Inc., 1996; Wild et al., 2011; Zhou & Rana, 2012).

Within municipalities, the implementation of restoration work is often planned and executed by a mix of urban planners, biologists, engineers, local stewardship groups, and community citizens themselves (Hassett et al., 2007; O'Donnell & Galat, 2008; Palmer, Hondula, et al., 2014). Reach-scale restoration projects encompass the activities implemented within the stream channel itself or along the immediate adjacent riparian area. Activities include geomorphological engineering of stream channel, bank stabilisation measures, creating in-stream physical aquatic habitat, riparian re-vegetation, and exotic species removal (Bernhardt & Palmer, 2007; Palmer, Hondula, et al., 2014; Wohl et al., 2015; Wortley, Hero, & Howes, 2013).

Daylighting is a particular practice of reach-scale restoration which involves opening up buried watercourses and restoring them to more natural conditions. Practices range from the simplest form of removing the 'roof' of a culvert, and retaining existing bank walls and natural bed material, to complete reconstruction of an entire ecosystem using bioengineering measures and other river restoration techniques (Wild et al., 2011).

Catchment-scale restoration efforts aim to address the root causes of degradation. Restoration at this scale encompasses a broader range of activities across the watershed including the control of pollutant inputs and uncontrolled runoff, with the emphasis on restoring or mimicking natural hydrologic processes. Watershed-wide initiatives aim to reduce impervious cover through water detention and re-vegetation; and using policies and bylaws to control chemical source pollutant input (Bain et al., 2014; Bernhardt & Palmer, 2007; Jähnig et al., 2010; Palmer, Hondula, et al., 2014; Walsh et al., 2016; Wohl et al., 2015). Scientific understanding of exactly how to implement process-based and catchment-scale restoration of stream in its infancy (Palmer, Hondula, et al., 2014; Wohl et al., 2015).

Despite the myriad of benefits from urban stream restoration, implementing projects in urban areas face numerous challenges:

***Ecosystem complexity*** Rivers are profoundly complex ecosystems, and the interactions between restoration activities and ecosystem functions may be unpredictable (Rubin, Kondolf, & Rios-Touma, 2017). Within the ecological sciences, there remains no agreed upon method to physically accomplish complete restoration of ecosystem processes in established urban areas (Arseneau, 2011; Suding, 2011; Warren, Reeve, & Arnold, 2016).

***Jurisdictional Complexity*** River ecosystems are influenced by myriad of human activities and behaviors. Political jurisdictions retain different administrative purposes of which no entity has complete jurisdiction over watershed variables (Baker & Eckerberg, 2013; Bengston, Fletcher, & Nelson, 2004; Bernhardt & Palmer, 2007; Molnar, 2011; Warren et al., 2016). Planning and policy is developed through the existing organizational structures which have been historically set-up for responsibilities and mandates other than ecological restoration (Baker & Eckerberg, 2013). In addition,

implementing restoration may be challenged by existing power relations (Baker & Eckerberg, 2013).

**Geographical scale** River ecosystems operate and are influenced at watershed catchment scales. Property ownership with watersheds is fragmented, and land is owned by private landowners, businesses, industry, and different levels of government. Watersheds may cross municipal boundaries which further complicates coordinating restoration efforts (Arseneau, 2011; Baker & Eckerberg, 2013; Barham, 2001; Bernhardt & Palmer, 2007; Suding, 2011).

**Temporal Scale** Political issue salience often does not correspond with the timing of ecological regeneration cycles. Political entities and restoration agencies typically have high rates of staff turnover, and short-term funding. Ecosystem processes operate at multiple temporal scales, and ecological improvements in functioning may lag behind restoration by decades (Baker & Eckerberg, 2013; Booth, 2005; Warren et al., 2016; Wohl et al., 2015).

Given the challenges of implementing urban stream restoration projects, it's not surprising that projects to date have been characterized by short-term local reach-scale projects (Arseneau, 2011; Bernhardt & Palmer, 2007; Palmer, Hondula, et al., 2014; Smith et al., 2016; Wohl et al., 2015). Project-focused funding with short-term budgets is common restoration practice in most agencies (Arseneau, 2011; Baker & Eckerberg, 2013). Most stream restoration projects involve manipulating the channel itself, or immediately areas adjacent, rather than on restoring ecological processes by addressing landscape-scale stressors. Reach-scale projects do not address root causes of impairment, and cannot remedy the 'symptoms' of water quality issues and flashy hydrology which impair stream functioning (Booth, 2005; Palmer, Hondula, et al., 2014; Smith et al., 2016; Walsh et al., 2016; Wohl et al., 2015).

Despite these limitations, short-term small-scale stream restoration projects have important societal implications. Visual changes to streamside can increase aesthetic value, and raise awareness of the streams' very existence (Wohl et al., 2015; Smith et al., 2016). Positive interactions with natural areas promotes environmental values (Church, 2013; Jorgensen & Gobster, 2010; Nassauer, 2004; Ozguner et al., 2012; Smith et al., 2016). Awareness and education garners support which allows for more

resources to be put towards larger-scale actions. Community involvement in planning and implementing smaller restoration projects builds social and intellectual capital within the community, increasing the capacity of government and organizations to undertake future projects (Garda et al., 2017; Shandas & Messer, 2008; Smith et al., 2016).

### **2.3. Adaptive Management, Monitoring, and Evaluation**

Adaptive management is an approach to resource management in which actions are designed and carried out as experiments, to learn how system responds to management, and to increase level of certainty regarding how best to achieve desired results (Holling, 1986; Murray & Marmorek, 2004). Information collected on the environmental system with respect to different implemented hypotheses is used to design future management actions (Holling, 1986). Management actions are adjusted in response to environmental change, unforeseen environmental responses, incorporating new methods, emerging research and other factors that limit the effectiveness of current approaches (Baker & Eckerberg, 2013; Parks Canada and the Canadian Parks Council, 2008; Holling, 1986; Smith et al., 2016).

Adaptive management requires monitoring post project implementation to provide information to decision-makers, researchers, and the public (Murray & Marmorek, 2004; O'Donnell & Galat, 2008; Parks Canada and the Canadian Parks Council, 2008). In projects without clear monitoring post-implementation, determination of success may be based on anecdotal evidence and emotional factors. Indeed, partially due to lack of river restoration documentation, a prominent gap between what restoration practitioners, the public, and river science experts believe as 'successful restoration' has been identified (Alexander & Allan, 2007; Hassett et al., 2007; Smith et al., 2016; Wild et al., 2011; Wohl et al., 2015).

Monitoring data provided to decision-makers allows project managers to understand the implications of actions, and links to adaptive management actions (Murray & Marmorek, 2004; O'Donnell & Galat, 2008; Parks Canada and the Canadian Parks Council, 2008). As ecological restoration is a new and growing field of research, monitoring data provides information for researchers to disseminate lessons learned, and contributes to ongoing research (Garda et al., 2017; Smith et al., 2016; Wohl et al., 2015). Data is also important to communicate to the public as justification of project

implementation, to show that management decisions are having the desired effect and justify the use of public funds (Johnston & Page, 2006; Metro Vancouver, 2014).

Despite the importance of monitoring and evaluation after project implementation, the availability of data on post-project implemented urban stream restoration projects remains scarce (Baker & Eckerberg, 2013; Garda et al., 2017; Palmer, Hondula, et al., 2014; Rubin, Kondolf, & Rios-Touma, 2017; Smith et al., 2016; Suding, 2011; Warren et al., 2016; Wohl et al., 2015). Numerous factors are responsible for lack of monitoring:

***Lack of funding*** Restoration projects are characterised by short-term budgets and project focused funding; funding is directed towards implementing new projects rather than monitoring existing ones (Alexander & Allan, 2007; Garda et al., 2017; Hassett et al., 2007; O'Donnell & Galat, 2008; Warren et al., 2016; Wild et al., 2011).

***Lack of technical expertise*** Lack of technical expertise is commonly cited as reason for lack of monitoring (O'Donnell & Galat, 2008). The evaluations found in academic literature are complicated and not easily understood by planners, stewardship groups, or others participation in restoration (Garda et al., 2017; Purcell, Friedrich, & Resh, 2002).

***Lack of standardized protocols*** Currently no standardized monitoring protocols for urban stream restoration exist, and projects that are monitored often collect data on variables which don't correspond to initial objectives (Alexander & Allan, 2007; Hassett et al., 2007; O'Donnell & Galat, 2008).

Some of the limitations responsible for lack of monitoring can be addressed through citizen-science: the process whereby citizens are involved in science as researchers (Conrad & Hilchey, 2011; Garda et al., 2017; Purcell et al., 2007). Community-based monitoring (CBM) is the process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track, and respond to issues of common community environmental concern (Conrad & Hilchey, 2011; C. T. Conrad & Daoust, 2008). CBM proves to be an effective alternative to government monitoring, because citizen-science is low cost, can be undertaken over large area during non-office hours, and can have

access to funding that might not be available for typical monitoring institutions (Conrad & Hilchey, 2011; Rosenau & Angelo, 2001).

In addition, CBM may have the following additional benefits to the community:

**Ecological literacy** Citizen-science and CBM increases scientific literacy in community members, and improved attitudes towards restoration and conservation (Conrad & Hilchey, 2011; Purcell et al., 2007). Hands-on involvement in ecological monitoring provides local government with an effective educational and awareness-raising tool (Baker & Eckerberg, 2013; Church, 2013; Dovetail Consulting Inc., 1996; Herringshaw, Thompson, & Stewart, 2010; Hostetler et al., 2011). Building ecological literacy can promote positive attitudes towards the environment (Bain et al., 2014; Herringshaw et al., 2010).

**Local knowledge** Community-based monitoring has the advantage of incorporating local knowledge that may not be available to government agencies who do not engage with ecosystems on a daily basis (Rosenau & Angelo, 2001). Incorporating local knowledge promotes two-way learning of both citizens and government officials (Herringshaw et al., 2010; McDonald, Gann, Jonson, & Dixon, 2016).

**Social Capital** CBM volunteers form effective social networks and increase social learning (Dickinson et al., 2012). Social outcomes include increasing levels of trust and improved relationships with other locals in the community, leadership-building, problem-solving, and improved relationships to nature itself (Church, 2013; Fernandez-Gimenez, Ballard, & Sturtevant, 2008; Herringshaw et al., 2010).

**Democracy and public participation** Citizen-science promotes public engagement and participatory democratization of the environment. Citizens in communities with CBM tend to be more engaged in local issues, participate more in community development, and have more influence on policy makers (Church, 2013; Conrad & Hilchey, 2011). Involved volunteers have an avenue for voicing values and concerns to inform future restoration projects (Herringshaw, et al., 2010).

However, CBM comes with significant challenges:

**Organizational challenges** Maintaining sustained community participation in long-term ecological monitoring projects remains challenging. CBM is dependent on volunteer interest and enthusiasm, and organizations may have difficulty in coordinating individuals and maintaining activities (Conrad & Daoust, 2008; Dickinson et al., 2012; Fernandez-Gimenez et al., 2008; Purcell et al., 2007). In addition, the repetition required for robust monitoring may only be appealing to a subset of volunteers (Sullivan & Molles, 2016).

**Poorly collected data and mistrust of data** Information collected by lay people may be biased, inaccurate, or lost. Data collection may also be redundant, and have been already collected by government agencies or research institutions (Conrad & Hilchey, 2011; Rosenau & Angelo, 2001). Scientists and government often question the credibility of CBM data and the capacity of citizen-scientists; information may not be taken seriously by decision-makers (Conrad & Hilchey, 2011; Rosenau & Angelo, 2001)..

**Project reporting** Reporting is a critical step in adaptive management and community-based monitoring, necessary for ‘closing the loop’ and ensuring that monitoring information is used for assessment and changing management practices (Garda et al., 2017; Holling, 1986; Murray & Marmorek, 2004). The CBM literature notes that community groups generally need better documentation and communication of results (Sullivan & Molles, 2016; Garda et al., 2017; Conrad & Daoust, 2008).

**Not ‘Free’** Volunteer collected data is low-cost, but community-based monitoring literature cautions that it is not ‘free’ labour. Effective CBM may require resources to deal with volunteers and manage the collected data (Yarnell & Gayton, 2003). Government, scientists, and educational institution personnel may work with community groups to build up trust (Yarnell & Gayton, 2003). Groups may additionally need a champion to encourage continued engagement (Yarnell & Gayton, 2003).

Despite these challenges, it’s been noted by practitioners and academics that citizen-science is effective at engaging the community in ecological restoration, which is crucial to sustaining efforts and future successes (Bain et al., 2014; Baker & Eckerberg, 2013; Garda et al., 2017; Herringshaw et al., 2010; Higgs, 2005; Shandas & Messer, 2008). Recent ecological restoration frameworks highlight the need to promote sense of

stewardship by local communities by including multiple stakeholders in design, implementation, monitoring, and assessment of restoration projects (McDonald et al., 2016; Parks Canada and the Canadian Parks Council, 2008; Smith et al., 2016; Warren et al., 2016). The literature calls for more project assessments and standardized monitoring within all areas of governance, including academic, municipal government, and stewardship groups (Bain et al., 2014; Garda et al., 2017; Palmer, Hondula, et al., 2014; Rios-Touma, Prescott, Axtell, & Kondolf, 2015; Smith et al., 2016; Suding, 2011; Wohl et al., 2015; Wortley et al., 2013).

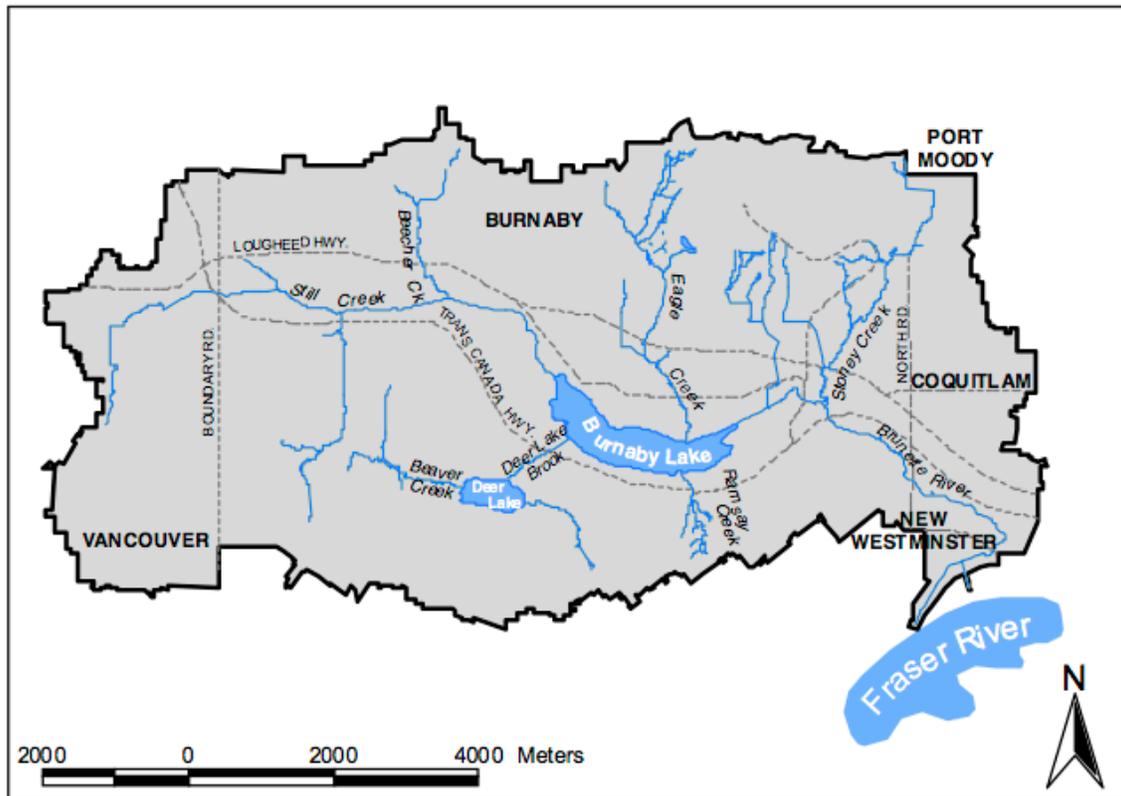
## **Chapter 3. Methods**

### **3.1. Still Creek Case Study**

The Vancouver portion of the watershed of Still Creek was chosen as a case study to develop a community-based monitoring framework and protocol for urban stream restoration. The stream displays the characteristics typical of a highly-urbanized stream (City of Vancouver Planning Department, 2002; Greater Vancouver Regional District, City of Burnaby, & City of Vancouver, 2007). Various levels of government and community groups have been involved in restoration actions over the past twenty years (Parsons, 2015). To date, monitoring and data collection has been informal and uncoordinated, and there has been no formal evaluation of restoration activities (Metro Vancouver, 2014; Parsons, 2015). Stewardship groups and community organizations are actively involved in activities around Still Creek, which provides an opportunity to engage local citizens in the development and use of monitoring methods. Government, academia, and community groups have identified the need for monitoring data; and standardized monitoring methods (Metro Vancouver, 2014; Parsons, 2015; Vancouver Board of Parks and Recreation, 2016).

#### **3.1.1. Current Physical Description of Still Creek**

The Still Creek Watershed is located within the Brunette Basin, also known as the Central Valley of Burrard Peninsula (Greater Vancouver Regional District, 1996). Still Creek forms the upper main stem which continues through Burnaby Lake to become the Brunette River system, flowing into the Fraser River (City of Vancouver Planning Department, 2002). The main Still Creek-Brunette River channel is approximately 17 km in length, and drops 32 m (City of Vancouver Planning Department, 2002). The Brunette Basin is a lowland watershed, heavily urbanized, with only about 20% of the watershed park, undeveloped or open space (Greater Vancouver Regional District, 1996). The Still Creek catchment contributes about half the water supply to Burnaby Lake (Greater Vancouver Regional District, 1996). The Brunette Watershed significant source of contaminants to Fraser River, an important economic resource for the Province (Greater Vancouver Regional District, 2001).



**Figure 1 Still Creek within the Brunette Basin watershed**  
 Photo: Brunette Basin Coordinating Committee, 2001.

The Still Creek watershed covers an area of about 28 km<sup>2</sup>, with two thirds in Burnaby, and one third in City of Vancouver (Greater Vancouver Regional District et al., 2007). The Still Creek upper watershed in Vancouver is approximately 1,050 hectares. The Still Creek subwatershed in Vancouver is characterized by dense industrial, commercial, and residential land-use (Greater Vancouver Regional District, 2001), with about 68% of the upper Still Creek watershed impervious surfaces (City of Vancouver Planning Department, 2002). The watershed lacks significant numbers of trees. Industry and utilities are concentrated along the stream corridor, with an almost 100% impervious surface area (City of Vancouver Planning Department, 2002).

Approximately 70% of the original channels and tributaries are in subsurface pipes, with only about 3 km remain open within Vancouver (City of Vancouver Planning Department, 2002). The waters originate in Burnaby’s Metrotown Area, and around 50th Avenue in Vancouver through enclosed stormwater trunk sewers and culverts (City of

Vancouver Planning Department, 2002). The stream daylights at an outfall culvert in Renfrew Ravine, near 29th Avenue.

The Vancouver portion of the stream displays characteristics of urbanized stream ecosystem:

**Geomorphology** The stream flows through a mix of naturalized, channelized, and culverted reaches. Along the Grandview Boundary Industrial Area, the channel has been straightened to fit within narrow right-of-way (City of Vancouver Planning Department, 2002). Natural banks have been replaced with retaining walls, and concrete banks, with few meanders and little streambed complexity (City of Vancouver Planning Department, 2002).

**Hydrology** The winter storm flows are 'flashy', with extreme high peak wet weather events of short duration. These flows result in flooding, down cutting bank erosion, instability, and excess sediment loading. A significant amount of land could be flooded in larger rain events, and could be larger because of climate change (City of Vancouver Planning Department, 2002). The summer flows are low, creating high water temperatures and low dissolved oxygen concentrations (Greater Vancouver Regional District, 2001).

**Water Quality** Still Creek has historically been contaminated with trace metals, organic contaminants, PCBs, fecal coliform, and excess nutrient loading of phosphorus and nitrogen (Greater Vancouver Regional District, 1996). Contaminations result from fertilizer and pesticide use, as well as animal waste, and human sewage within the watershed. These contaminants accumulate on roads, parking lots, lawns, driveways, and other surfaces, and urban runoff after rain transports pollutants which are released through storm sewers outfalls (Greater Vancouver Regional District, 1996).

**Terrestrial riparian biodiversity** Only 26% of the riparian stream length is vegetated, with only 4.6% greater than 30m. Renfrew Ravine, the only 'significant intact and relatively healthy' portion of the riparian area. Most of the riparian zone is dominated by invasive species such as *Rubus armeniacus* (Himalayan Blackberry) and *Phalaris arundinacea* (Reed Canarygrass) (Vancouver, 2002).

***Aquatic biodiversity*** Aquatic biodiversity within the stream is limited, though spawning chum salmon have returned since 2012 (City of Vancouver, 2017). The Brunette River supports resident *Oncorhynchus clarkia* (cutthroat trout) and spawning *Oncorhynchus kisutch* (coho salmon) and *Oncorhynchus keta* (chum salmon). The water quality, flashy hydrology, simple geomorphology, and lack of intact riparian vegetation impede aquatic productivity in the stream (City of Vancouver Planning Department, 2002).

The Still Creek watershed ecosystem prior to urban settlement was composed of old growth coniferous rainforest trees, with swamps and marshes in the lowland portions (AXYS Environmental Consulting Ltd., 2005; Greater Vancouver Regional District, 2001). It is estimated that within the city, 87% of Vancouver's original forest cover has been converted to urban development (City of Vancouver, 2015).

Historically, Still Creek was an important salmon bearing stream with coho and chum runs, and the creek drains into the Fraser River, which remains commercially important for the Province of British Columbia (Greater Vancouver Regional District, 2001; Garibaldi & Turner, 2004). The economic history of Vancouver is tied to salmon, and stories include a legendary abundance within the region (Metro Vancouver, 2011). Salmon are a keystone species in forest ecosystems central to the food web, providing nutrients to riparian vegetation and terrestrial wildlife (Garibaldi & Turner, 2004; Willson & Halupka, 1995). Salmon continue to be an important cultural icon for the lower mainland of British Columbia (Metro Vancouver, 2011).

Birds are another notable culturally and economically important species in the lower mainland of BC (City of Vancouver, 2015). Birds are often integral to local ecosystems, providing pollinating services, pest control and seed dispersal (City of Vancouver, 2015). Birding tourism contributes to local economies, and experiencing birds physically and emotionally links Vancouver residents with nature (City of Vancouver, 2015). The lower mainland region is connected to major migratory routes, and a diversity of habitats (City of Vancouver, 2015). Locally, Sampson & Watson (2004) documented the use of riparian green corridor along Still Creek by bird species.

### 3.1.2. Key Stakeholders in the Still Creek Watershed

In Canada, the responsibility for watershed management is distributed among different levels of government and private property owners. Authority and jurisdiction over waterways is split between the federal and provincial government, and local governments are delegated authority by the province over community-scale water management. Still Creek is influenced by management decisions made by all levels of government; the federal government, Province of British Columbia, Metro Vancouver regional government, and the City of Vancouver and City of Burnaby actively plan and implement projects affecting the creek (Greater Vancouver Regional District, 1996). In addition, private property owners influence through behaviours, and community groups including Still Moon Arts Society and Evergreen, work with government and independently on community environmental initiatives the area (City of Vancouver Planning Department, 2002).

**Federal Government Department of Fisheries and Oceans (DFO)** The DFO primarily influences activity in Still Creek through regulating activities that impact fish bearing waterways through the federal *Fisheries Act* (1985). Infrastructure Canada and Transport Canada regulate wastewater and transportation infrastructure, and also may provide funding for projects.

**The Province of British Columbia (Province)** The Province influences Still Creek through the *Riparian Areas Protection Act* (1997), which requires development setbacks from streams, and the *Environmental Management Act* (2003) (EMA), which regulates pollution by solid and liquid waste. The EMA requires Metro Vancouver create Liquid Waste Management Plans (LWMP) identifying improvements in wastewater discharges (Metro Vancouver, 2010).

**Metro Vancouver** Metro Vancouver develops Regional Growth Strategies in conjunction with municipalities, which include urban containment boundaries, and dedicated regional parklands including greenways. Metro Vancouver is responsible for liquid waste management through the development of LWMP, which includes sanitary wastewater and stormwater. Under the LWMP, municipalities are required to develop Integrated Stormwater Management Plans (ISMP) for all open watercourses (Metro Vancouver, 2010).

**City of Burnaby** Burnaby has authority over land-use decisions within the Burnaby portion of Still Creek watershed. The City regulates development through the Official Community Plan (1998), zoning, building code, and regulatory bylaws. Burnaby also owns and maintains smaller sewer connections, civic parklands, and rights-of-way along open watercourses (Local Government Act, 2015).

**The City of Vancouver** Vancouver has authority over land-use decisions within the Vancouver portion of the Still Creek watershed, through city-wide plans, neighbourhood plans, zoning bylaws, building code, and regulatory bylaws. The city also owns and maintains smaller sewer connections, and rights-of-way along open watercourses (Vancouver Charter, 1953). The Riparian Area Regulation doesn't apply to Vancouver (City of Vancouver, 2004; City of Vancouver Planning Department, 2002).

**The Vancouver Board of Parks and Recreation (Park Board)** The Parks Board has authority over parklands within Vancouver area, and manages park land-use, landscaping, and programming. Renfrew Ravine Park and Renfrew Community Park are owned by the Parks Board (Vancouver Board of Parks and Recreation, 2012, 2013).

**Still Moon Arts Society** Still Moon Arts Society is a local not-for-profit organizes place-making events and designs artistic installations around Still Creek and Renfrew Ravine to build environmental awareness. Still Moon works with local educational institutions to incorporate environmental issues into educational curriculum (Still Moon Arts Society, 2017).

**Evergreen** Evergreen is a national not-for-profit that builds environmental awareness around Still Creek through the 'Uncover Your Creeks' program. Evergreen also provides a platform for citizen-science and community-based monitoring (Evergreen, 2017).

**Academic Institutions** British Columbia Institute of Technology (BCIT) has been involved in Still Creek through student research on the creek and associated tributaries (Baker & Perkin, 2014). Students from the School of Resource and Environmental Management at Simon Fraser University have researched the policy, planning, and management history of Still Creek (Berry, 2016; Parsons, 2015).

### 3.1.3. Urban Stream Restoration in Still Creek

The *Still Creek-Brunette Basin Issues and Proposed Actions* (1996) started a discussion between various levels of government on the condition of Still Creek and Brunette Basin. Concurrently, the LWMP (1996) was approved, which led to the *Brunette Basin Watershed Plan* (2001). The *Brunette Basin Watershed Plan* was the first collaborative planning effort between municipalities within the Brunette Basin, the Province, DFO, BCIT, and University of British Columbia (UBC) (Greater Vancouver Regional District, 1996, 2001).

At the local level, the City of Vancouver established the Still Creek Greenway Enhancement Fund in 2000 through leasing of buildings to film studios (City of Vancouver Planning Department, 2002). The *Still Creek Rehabilitation and Enhancement Study* was approved in 2002, focusing on the portion of Still Creek flowing through Grandview Boundary Industrial Area. The study operates at two scales: through short-term actions along the riparian corridor, and long-term actions at the watershed scale. Objectives of the 10-year actions include stormwater management, enhanced recreation opportunities, increased awareness, and increased greenspace. The objectives of the 10-50 year actions include improved runoff water quality, enhanced ecosystem health through riparian habitat and tree planting, improvement to liveability, bringing nature back into city, decreased stormwater peak flows and volumes and flood risk, improved runoff water quality (City of Vancouver Planning Department, 2002).

Mandated by Metro Vancouver through the LWMP, the 2007 ISMP was jointly developed by Burnaby, Vancouver and Metro Vancouver. ISMPs aim to integrate rainwater management and other ecological objectives with land-use planning (Berry, 2016). Every ISMP is unique, as are the suite of recommendations that come out of them (Metro Vancouver, 2014). Within the Still Creek ISMP, specific reaches are described with proposed actions for ecological restoration. Objectives include reduced flood impacts on property and stream channel; reduced bank erosion; protected and restored streamside and aquatic habitat; increase urban forest and terrestrial habitats; improved water quality; improved native species biodiversity; connecting people with watershed; and providing stream-related education (GVRD et al., 2007).

Neighbourhood plans which influence Still Creek include the Vancouver Board of Parks and Recreation's *Renfrew Ravine and Community Park Master Plan* (2013), and the City of Vancouver's *Renfrew Collingwood Community Vision* (2004). The community vision references the *Still Creek Rehabilitation and Enhancement Plan* (2002) and includes goals to add more park space along restored riparian areas along Still Creek (City of Vancouver, 2004). The master plan for Renfrew park spaces recommends addition of native trees, rainwater management strategies, reductions in impermeable surfacing, reforestation, removal of invasive species, and increasing native vegetation and biodiversity, particularly by enhancing the urban forest (Vancouver Board of Parks and Recreation, 2013). In-stream creek restoration actions include modifying the creek bed to provide areas of refuge for aquatic life and providing natural stream geomorphology. Vegetation restoration actions include removing invasive plants, planting native plants, notably trees, and extending native plantings beyond the creek in the community park to blend with the ravine.

More recently, city-wide and regional planning initiatives have focused specifically on ecological objectives with local implications for Still Creek. The *Biodiversity Strategy* (2016), and *Rewilding Strategy* (2014) approved by the Vancouver Board of Parks and Recreation, identified portions of Still Creek and associated riparian area as a biodiversity hotspot within the City. Objectives include protecting existing trees and increasing canopy cover, and protecting and restoring natural habitats and species including aquatic and terrestrial species. The *Biodiversity Strategy* (2016) particularly notes the threat of invasive species to biodiversity (Vancouver Board of Parks and Recreation, 2016). The *Ecological Health Action Plan* released by Metro Vancouver (2011) includes goals for supporting salmon in the city through restoring natural hydrological regimes of watersheds, and integrating riparian habitat standards into new developments.

Ecological restoration actions within the Vancouver portion of Still Creek were implemented by the city itself on city-owned right-of-ways and through re-developments. Projects were funded through the Still Creek Greenway Enhancement Fund, in conjunction with funding from higher levels of government and developers (Rousseau & Verde, 2008).

Specific reach-scale ecological restoration projects in Vancouver include:

**3003 Grandview** In 2005, the first improvement along 3003 Grandview Highway was endorsed by GVRD and existing Streamkeepers groups, and approved by Vancouver's City Council. Construction and re-naturalization work was implemented through Kerr Wood Leidel, and vegetation replanting was coordinated through Evergreen (Weidner & Verde, 2005).

**3400 Cornett Road** In 2007, council approved a project along 3400 Cornett Road. Project actions included widening of streamside riparian areas, creating habitat features, a pedestrian greenway along creek, replacing of invasive species with native shrubs and trees, and improvements to the streambed. The council approval included annual horticultural maintenance funding, and community groups like the Still Creek Stewardship Society, Evergreen and students provided in-kind support (Rousseau & Verde, 2007).

**3300 Cornett Road** In 2009, daylighting of Still Creek was completed as part of new Canadian Tire development rezoning at 2820 Bentall street completed in 2009 (Rousseau & Verde, 2008).

**2900 Nootka Street** In 2008, the 2900 section of Nootka St south of Grandview highway was approved for restoration. Actions included creating a pedestrian trail, water quality treatment pond, signage and viewing educational opportunities, replacement of invasive species with native vegetation, and improvements to stream bed and riparian area. The pathway was created from permeable asphalt as a pilot project (Rousseau & Verde, 2008).

## 3.2. Ecological Indicators

Ecological indicators provide information on the ecological condition of an ecosystem to inform management (Niemeijer & de Groot, 2008). Frameworks for choosing indicators commonly divide ecological indicators for stream restoration into pressure indicators, associated with the causes of environmental change; and state or response indicators, associated with the effects and changes that take place as a consequence (Johnston & Page, 2006; Niemeijer & de Groot, 2008). Indicators can be selected based on a range of criteria (See Table 2), and selecting indicators may require trade-offs (Niemeijer & de Groot, 2008; The Ecological Monitoring and Assessment

Network & Canadian Nature Federation, 2003). Methods for assessing ecological indicators include a mix of quantitative and qualitative measures, but for the most part focus on quantitative characteristics. The number of ecological parameters that can be measured exceeds what is reasonable (Woolsey et al., 2007), and acquiring useful information doesn't require high resolution data for every possible ecological attribute (Garda, Castleden, & Conrad, 2017).

**Table 2 Environmental indicator selection criteria (Niemeijer & de Groot, 2008)**

Criterion	Count	Description/explanation
<b>Scientific dimension</b>		
Analytically soundness	4	Strong scientific and conceptual basis
Credible	1	Scientifically credible
Integrative	1	The full suit of indicators should cover key aspects/components/gradients
General importance	1	Bear on a fundamental process or widespread change
<b>Historic dimension</b>		
Historical record	2	Existing historical record of comparative data
Reliability	2	Proven track record
<b>Systemic dimension</b>		
Anticipatory	1	Signify an impending change in key characteristics of the system
Predictable	1	Respond in a predictable manner to changes and stresses
Robustness	1	Be relatively insensitive to expected source of interference
Sensitive to stresses	1	Sensitive to stresses on the system
Space-bound	1	Sensitive to changes in space
Time-bound	4	Sensitive to changes within policy time frames
Uncertainty about level	1	High uncertainty about the level of the indicator means we can really gain something from studying it
<b>Intrinsic dimension</b>		
Measurability	4	Measurable in qualitative or quantitative terms
Portability	1	Be repeatable and reproducible in different contexts
Specificity	1	Clearly and unambiguously defined
Statistical properties	3	Have excellent statistical properties that allow unambiguous interpretation
Universality	1	Applicable to many areas, situations, and scales
<b>Financial and practical dimensions</b>		
Costs, benefits and cost-effectiveness	1	Benefits of the information provided by the indicator should outweigh the costs of usage
Data requirements and availability	3	Manageable data requirements (collection) or good availability of existing data
Necessary skills	1	Not require excessive data collection skills
Operationally simplicity	2	Simple to measure, manage and analyse
Resource demand	5	Achievable in terms of the available resources
Time demand	1	Achievable in the available time
<b>Policy and management dimensions</b>		
Comprehensible	2	Simply and easily understood by target audience
International compatibility	2	Be compatible with indicators developed and used in other regions
Linkable to societal dimension	1	Linkable to socio-economic developments and societal indicators
Links with management	3	Well established links with specific management practise or interventions
Progress towards targets	1	Links to quantitative or qualitative targets set in policy documents
Quantified	1	Information should be quantified in such a way that it significance is apparent
Relevance	4	Relevance for the issue and target audience at hand
Spatial and temporal scales of applicability	2	Provide information at the right spatial and temporal scales
Thresholds	1	Thresholds that can be used to determine when to take action
User-driven	1	User-driven to be relevant to target-audience
Source: Based on Schomaker (1997), OECD (2001), NRC (2000), Riley (2000), Dale and Beyeler (2001), CBD (1999), Pannell and Glenn (2000), Kurtz et al. (2001), and EEA (2005a).		

Urban stream restoration projects frequently do not justify the appropriateness of monitoring metrics (Rubin, Kondolf, & Rios-Touma, 2017). Indicators for monitoring of the Still Creek restoration efforts were chosen to be appropriate for community-based monitoring, and the following selection criteria were taken into consideration:

- *Restoration Objectives* Monitoring indicators should be chosen to correspond with management and planning objectives (Murray & Marmorek, 2004; O'Donnell & Galat, 2008; Woolsey et al., 2005, 2007).
- *Available Resources* Monitoring indicator methods depend on financial resources and technical capacity, which are limited in CBM (Garda et al., 2017; Parkyn et al., 2010; Woolsey et al., 2005).
- *Standardized* Standardized monitoring protocols for similar types of projects allow for meaningful comparisons of results and producing meaningful information (Alexander & Allan, 2007; Garda et al., 2017; C. Johnston & Page, 2006; Parks Canada and the Canadian Parks Council, 2008).
- *Useful Information* The data collected should provide information to be used by community groups, local government, and other actors involved in planning and implementing restoration projects; and for communicating with managers and the public (Garda et al., 2017; C. Johnston & Page, 2006)
- *Human scale* Human environmental values are derived from experience, and monitoring indicators involving hands-on or on-the-ground activities with natural sites fosters stronger education and awareness (Church, 2013; Evergreen, 2015; Herringshaw, Thompson, & Stewart, 2010; Jorgensen & Gobster, 2010; Rosenau & Angelo, 2001).

### **3.3. Indicator Framework**

The community-based monitoring framework developed for the urban stream restoration of Still Creek is composed of three indicators: (1) Benthic invertebrate diversity, (2) Visual habitat assessment, and (3) Riparian terrestrial biodiversity. These indicators were chosen because they met the criteria outlined above, and their justification is outlined in more detail below. Certain indicators which provide comprehensive data and are recognized in the literature as important landscape-scale variables, such as impervious surface area and continuous stream discharge (Bowker Creek Initiative, 2011; Palmer, Hondula, & Koch, 2014; Rubin et al., 2017; Woolsey et al., 2007), were eliminated because they did not meet the criteria of human scale and available resources. Stream flow in particular is noted as a “master variable” in driving the dynamics, processes, and thus all other ecological variables (Palmer et al., 2014: p.

249). Because ecological variables are interrelated, the information that would have been collected through stream discharge and impervious surface area will be partially captured through other indicators.

***Benthic invertebrate diversity*** Benthic macro-invertebrates are primary consumers, living beneath the stream-bed surface and feeding on algae and microflora, dead leaves, wood, and each other. These organisms in turn become food for fish, reptiles, amphibians, and birds (Bowker Creek Initiative, 2011; Parkyn et al., 2010; Taccogna & Munro, 1995). Certain taxa have well-known sensitivities to particular environmental conditions, and deteriorating water quality will result in declines of certain species (Parkyn et al., 2010; Taccogna & Munro, 1995). Invertebrates generally live for over a year as aquatic forms, and are not highly mobile, thus reflecting environmental conditions over many months in the place where they are found (Parkyn et al., 2010). Because of these characteristics, benthic macroinvertebrates are good indicators of ecosystem health and ecological integrity.

Benthic invertebrate diversity measures progress towards the urban stream restoration objectives of improved water quality, and increases in aquatic biodiversity (City of Vancouver Planning Department, 2002; Greater Vancouver Regional District, City of Burnaby, & City of Vancouver, 2007; Vancouver Board of Parks and Recreation, 2016). In addition, benthic macro invertebrates are visible, easily caught, and fairly easily identified without the need for specialized equipment (Evergreen, 2015; Parkyn et al., 2010). Invertebrates have been used to monitor biological outcomes of urban stream restoration in the academic literature (Palmer, Hondula, et al., 2014), and citizen-science (Conrad & Hilchey, 2011; Evergreen, 2015); standardized protocols exist for government and stewardship groups in British Columbia (Metro Vancouver, 2014; Taccogna & Munro, 1995).

***Visual habitat assessment*** Visual habitat assessments characterize the physical features of the stream, including geomorphology, and identify features used by different life stages of salmonid species which are characteristic of streams in forested watersheds (Johnston & Slaney, 1996; Natural Resources Conservation Service, 1998; Taccogna & Munro, 1995). Habitat features include: cascades, riffles, glides, and pools. Cascades and riffles are faster moving turbulent water, with the distinction of cascades dropping over a certain length. Glides are moving waters with a smooth water surface,

and pools are deeper non-moving water habitats within the river (Johnston & Slaney, 1996).

The visual habitat assessment measures progress towards the objectives of increased aquatic habitat, and improved stream geomorphology (City of Vancouver Planning Department, 2002; Greater Vancouver Regional District et al., 2007). Methods for visual aquatic habitat assessment do not require extensive materials or expertise. The Level 1 Fish Habitat Assessment Protocol is a standardized method developed by the British Columbia Ministry of Environment, Lands, and Parks (1996), and was created for evaluating opportunities to restore salmonid stocks in streams. Similar methods have been developed for stewardship groups, including the United States Department of Agriculture Stream Visual Assessment Protocol (1998), and the Pacific Streamkeepers aquatic habitat assessment (2000) (Natural Resources Conservation Service, 1998; Parkyn et al., 2010; Taccogna & Munro, 1995). Physical attribute assessments, including geomorphology, substrate, and aquatic habitat suitability, are also common measures used in academic literature for evaluating stream restoration (Palmer, Hondula, et al., 2014).

***Riparian terrestrial biodiversity*** Vegetation forms the main structure of parks, and offers terrestrial habitat to wildlife within urban areas (Hermy & Cornelis, 2000). Riparian areas classified as urban parks and greenways provide wildlife corridors connecting other green-spaces (Searns, 1995; Tzoulas et al., 2007). Connectivity of riparian vegetation along streams underlies biogeochemical processes and water infiltration necessary for river ecosystem functioning (Palmer, Hondula, et al., 2014). Riparian vegetation biodiversity provides information on terrestrial biodiversity, invasive species presence, and habitat availability (Hermy & Cornelis, 2000; Koning, 1999). Riparian vegetation monitoring methods aim to collect data on the abundance and species of both overstorey and understorey vegetation within fixed areas (Hermy & Cornelis, 2000).

Monitoring riparian vegetation biodiversity measures progress towards the objectives of increasing terrestrial biodiversity, increasing wildlife habitat, and reducing invasive plant species (City of Vancouver Planning Department, 2002; Greater Vancouver Regional District et al., 2007; Vancouver Board of Parks and Recreation, 2016). Community groups are often involved in planting riparian vegetation, and removal

of non-native species (Evergreen, 2017; Garda et al., 2017; Palmer, Hondula, et al., 2014; Vancouver Board of Parks and Recreation, 2014). Community-based monitoring in the riparian buffer provides opportunities for hands-on and experiential ecological learning (Herringshaw et al., 2010; Vancouver Board of Parks and Recreation, 2016). The methods used are based on Canadian and U.S. national, B.C. provincial, and community stewardship guidelines for monitoring biodiversity in forests, riparian areas, and urban parks (Chan, 2016; Hermy & Cornelis, 2000; Johansson, 2007; Koning, 1999; National Riparian Technical Team, 2014; Roberts-Pichette & Gillespie, 1999; Voth et al., 2015).

### **3.4. Community Volunteers and Meetup**

To undertake community-based monitoring, and ensure that the methods were useable by community members, volunteers were recruited in the collection of data. The field work opportunity was promoted through local community organizations including Still Moon Arts Society, Evergreen, and Let's Talk Science. Let's Talk Science is a national not-for-profit with the mandate of improving science education through connecting university students to local youth.

To reach out to volunteers who may have not previously had experience in environmental stewardship, volunteers were also recruited using the online site Meetup.com. Meetup.com is a for-profit internet company launched in 2002 to enable users to 'meet up' with other community members with similar interests. Users create an account, and based on location and selected topics, the website suggests various Meetup groups. Meetup group creators and organizers pay a monthly fee to use the website, and new Meetups are advertised to users who are already part of Meetups of similar topics (Meetup.com, 2017). The website provides no resources for training those who run Meetups, and does not monitor who attends the Meetups or how the activities are organized. Meetup activities range from well-funded highly organized meetings to small informal get-togethers. Meetup can generate significant social capital, by expanding participants' social networks and encouraging participants to become more civically engaged, resulting in an increase in collective power for those with similar interests (Vaughn, 2015).

## **3.5. Ecological Monitoring Methods**

### **3.5.1. Benthic Invertebrates**

Insect benthic invertebrates are particularly sensitive to variations in water quality. The sensitive benthic invertebrate species are composed of three orders: Ephemeroptera, Plecoptera, and Trichoptera (or mayflies, stoneflies, and caddisflies, respectively), and are grouped together as ETP (Parkyn et al., 2010; Taccogna & Munro, 1995). The EPT total ratio is the total number of EPT organisms compared to the total number of all invertebrates counted, and is recommended for those with limited experience in benthic invertebrate identification (Parkyn et al., 2010; Taccogna & Munro, 1995).

The benthic invertebrate sampling methods used in this research were based off the Pacific Streamkeepers methodology, along with references from other community-based monitoring protocols and government guidelines (Beatty, McDonald, Westcott, & Perrin, 2006; Parkyn et al., 2010; Taccogna & Munro, 1995). The Streamkeepers methodology recommends at least 2 individuals conduct the surveys (Taccogna & Munro, 1995). Sampling should not be conducted within 2-3 weeks after a flood, because of dangerous conditions and increased likelihood that communities will be altered (Beatty et al., 2006; Parkyn et al., 2010; Taccogna & Munro, 1995). The sites sampled corresponded to vegetation transect locations, while also ensuring that a range of habitat types were sampled (Beatty et al., 2006).

The materials required for sampling benthic invertebrates include a surber sampler or D-net, scrub brush or nail brush, tweezers, and white shallow ice cube trays, which were provided in Evergreen's Streamkeepers kit (Taccogna & Munro, 1995). The net was placed downstream in the substrate on the edge of the sampling area. The substrate was stirred in the net for about 2 minutes, and stones and debris larger than 5 cm were brushed gently. The net was then taken out of the water, and on the bank turned inside out into a bucket of cool stream water. The invertebrates and debris were emptied into a bucket by rinsing and shaking the net, ensuring that the entire sample was in the bucket. This procedure was repeated twice more within the sampling area.

The bucket filled with water, debris, and invertebrates was poured into shallow white ice-cube trays filled with clear stream water. The invertebrates were sorted by placing invertebrates into separate compartments of the tray based on differences in appearance. The invertebrates were identified based on the Streamkeepers field identification chart (Taccogna & Munro, 1995). The number of identifiable taxa, along with the counts of invertebrates found, were recorded. The data was used to calculate an index of benthic invertebrate biodiversity.

### **3.5.2. Fish Habitat Assessment Protocol**

A visual fish habitat assessment quantitatively describes the following stream characteristics: habitat type, length, width, depth, canopy cover, dominant substrate, ground cover, and boulders or large woody debris. These quantitative descriptions indicate available salmonid habitat. The assessment methods used were based on the modified Level 1 FHAP and Pacific Streamkeepers methodology, and the materials required are a 50m measuring tape and a metre stick (Johnston & Slaney, 1996; Taccogna & Munro, 1995). The visual habitat assessment does not consider other factors, such as chemical or biological stressors, that may limit salmon populations. In addition, the FHAP does not evaluate the habitat suitability for all possible aquatic species, nor evaluate the aquatic or terrestrial biodiversity (Johnston & Slaney, 1996).

Starting at the point where Still Creek is first daylighted in Renfrew Ravine, the habitat features were identified and recorded by walking downstream. For each habitat feature, the stream characteristics were recorded; the length and width were measured using the measuring tape, and the depth measured using the meter stick. The dominant substrate, ground cover, canopy cover, and presence of other objects were estimated visually. Any barriers, such as culverts or drops, were also recorded. The overall habitat quality of the stream was determined by combining the quality of each feature type. The survey was performed with two people at a time, one person recording and one person taking measurements.

### **3.5.3. Vegetation Biodiversity Survey**

Riparian areas are highly physically heterogeneous, and vegetation composition generally changes over a gradient from the streambank towards the edge of riparian

area (Hermy & Cornelis, 2000; Johansson, 2007; National Riparian Technical Team, 2014; Purcell et al., 2007; Roberts-Pichette & Gillespie, 1999). To capture this variability, transects were established perpendicular to the stream, extending from the edge of the stream to the edge of vegetated riparian area (National Riparian Technical Team, 2014; Purcell et al., 2007). Discontinuous transects were used to save resources and time, with discrete points were taken at predetermined distances along the transect bearing (Roberts-Pichette & Gillespie, 1999; Sampson & Watson, 2004).

Plots were used as points of measurement along the transect. Though square plots are the standard at the national monitoring level (Roberts-Pichette & Gillespie, 1999), circular plots were used to correlate with BC provincial restoration guidelines, and other local biodiversity monitoring methods (Chan, 2016; Koning, 1999; Voth et al., 2015). Circular plots were created by measuring a plot radius length from a center point. Though larger plots reduced unintentional sampling bias, smaller plots are easier to establish, and more useful when measuring limited areas (Roberts-Pichette & Gillespie, 1999). The plot radius of 5.64 m was used for a resulting area of 100 m<sup>2</sup>, to obtain comparable data to Voth (2015), Chan (2016), and Hermy & Cornelis (2000).

All vegetation within the plot was identified by species, and classified as percent cover, which is a measure of abundance (Gonsalves & Miller, 2011; Hermy & Cornelis, 2000; Koning, 1999; Purcell et al., 2007; Roberts-Pichette & Gillespie, 1999). Similar to other protocols, total stem count of every plant within the area was not feasible, and so a visual estimate of the species cover was used (Koning, 1999; Sampson & Watson, 2004; Voth et al., 2015; Sampson & Watson, 2004). Percent cover is the projected area occupied by the leaves and stems of vegetation species, and the total cover may add up to more than 100% (Roberts-Pichette & Gillespie, 1999; Sampson & Watson, 2004). Grasses, mosses, and lichens were not identified to a species level due to resource limitations, and plants that were not identifiable were given an arbitrary label (Voth et al., 2015).

Plots should be randomly distributed to reduce bias (Roberts-Pichette & Gillespie, 1999). Randomness was introduced through stratified random placement of transects every 200m. The stream was divided into 200m segments, and one transect was randomly placed within each 200m segment, through a randomly generated number between 0-200. The number of transects and plots was based on the time and resources

that were available to monitor, the heterogeneity of the area, and a minimum plot area representative of the total vegetated reach area (Hermy & Cornelis, 2000; National Riparian Technical Team, 2014; Roberts-Pichette & Gillespie, 1999).

## Chapter 4. Results

The developed framework includes three indicators to monitor the Still Creek channel and riparian area through community-based monitoring, based on the objectives and actions described in the restoration planning documents. The methods and protocol are low-cost, as the monitoring is carried out by local interested volunteers. The materials can be borrowed from local public libraries, existing environmental community groups, including Evergreen, Stoney Creek Environment Committee, and Still Moon Arts Society, and educational institutions including Simon Fraser University, and local elementary schools.

The field work was carried out over 18 non-consecutive days in June and July of 2016, and May of 2017. Vegetation surveys were carried out over 9 non-consecutive days, during May and June of 2016, when vegetation was easiest to identify. The Fish Habitat Assessment was carried out over 5 non-consecutive days, during the July low flow period 2016. Benthic invertebrate surveys were carried out over 4 non-consecutive days in May 2017.

The results are divided into sections of relatively similar length along the 3km reach of Still Creek. The sections were chosen based on the immediate land uses, restoration efforts, and management practices, similar to Page (2006), Voth (2015), and Baker & Perkin (2014), who also divided results into sites based on physical characteristics and management.

**Renfrew Ravine Park** is used primarily as a “nature sanctuary”, the park extends from 29th Ave. until 22nd Ave., with a few informal paths not actively maintained (Vancouver Board of Parks and Recreation, 2013)

**Renfrew Community Park** extends from 22nd avenue to 18th avenue, the creek is channelized and contains amenities and the trails and surrounding area are actively maintained (Vancouver Board of Parks and Recreation, 2013)

**Nootka Area** extends from where the creek is daylighted at 14th avenue until Nootka St., and again in 80m in between Nootka and Lillooet St. north of Grandview

Highway; both sections have been sites of restoration by the City of Vancouver (Crowe, 2011).

***Grandview Highway Area 1*** extends from Lillooet St. to Rupert St., running along the train line, entering under a culvert for 35m. The riparian area has not been actively restored.

***Grandview Highway Area 2*** extends from Bentall St. until the creek is culverted under Boundary Road and no longer within Vancouver. One portion from Bentall St. until Natal St. is the daylighted portion of Still Creek, which leads to the main stem (Rousseau & Verde, 2007).

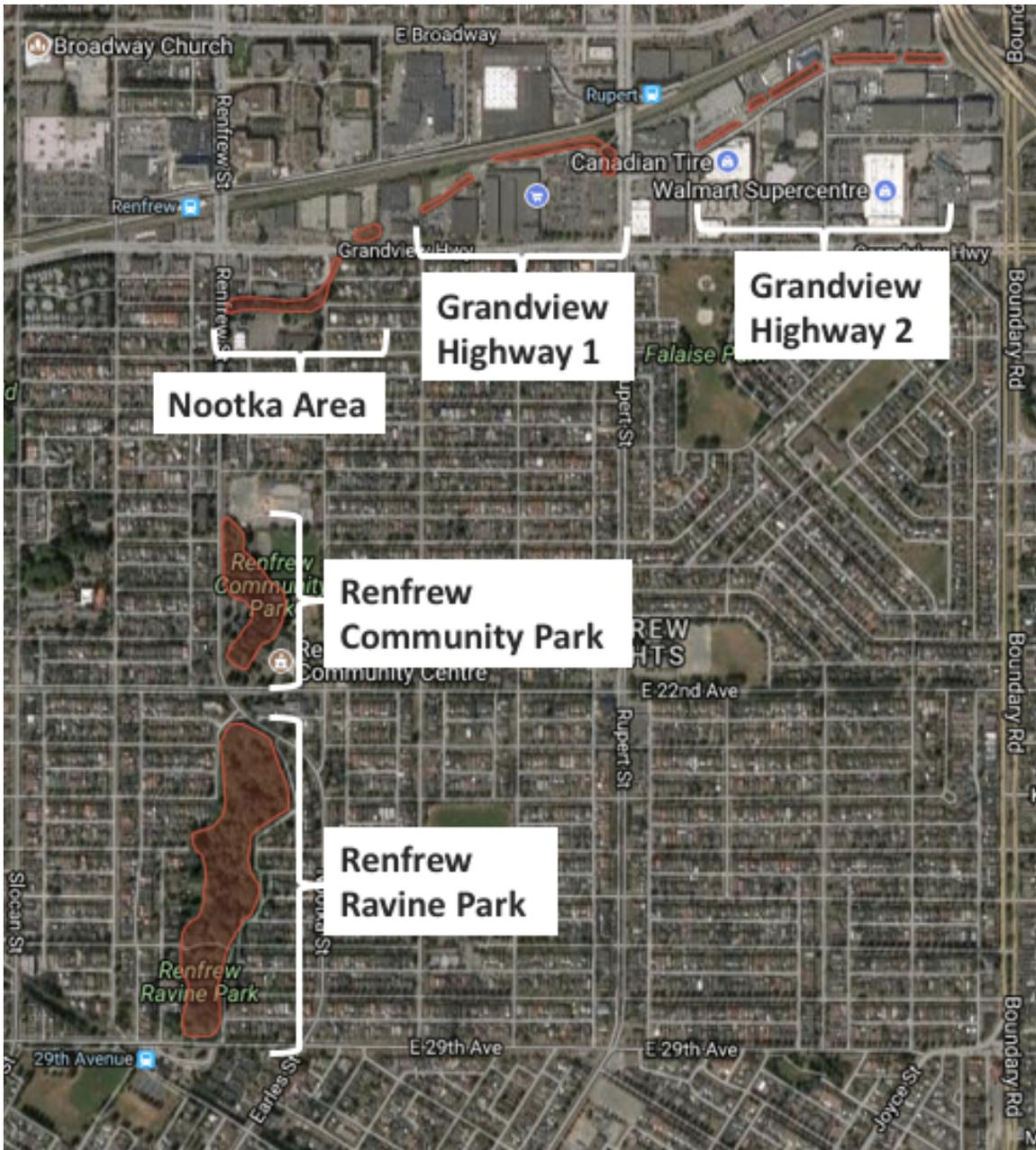


Figure 2 Still Creek reach sections

#### 4.1. Benthic Macroinvertebrates

The Pacific Streamkeepers protocol uses four indices to describe the results of benthic invertebrate surveys (Taccogna & Munro, 1995). The EPT to total ratio is the total number of EPT organisms, or low tolerant invertebrates, divided by the total number of all invertebrates counted. The pollution tolerance index is created by grouping and then adding benthic invertebrates according to their tolerance of organic pollution. The

EPT Index is the number of taxa identified within the EPT orders. Finally, the predominant taxon ratio is the number of individuals in the taxon with the highest number of organisms, divided by the total number of invertebrates. The predominant taxon ratio is a measure of diversity. Each of these indices are assigned a score which represents stream health according to standards developed by the streamkeepers methodology (Taccogna & Munro, 1995).

### ***Renfrew Ravine Park***

Two sites were sampled at Renfrew Ravine, along transect 1 and transect 3. Due to time constraints transect 2 was unable to be sampled. The first site was dominated by aquatic worms, with an EPT/Total ratio of 0, pollution tolerance index of 4, number of EPT taxa of 0, and a predominant taxa ratio of 0.97. The second site still had a EPT/Total ratio of 0.06, pollution tolerant index of 10, and 3 EPT taxa, with predominant taxa ratio of 0.79.

### ***Renfrew Community Park***

One site was sampled in Renfrew Community Park. The EPT/Total ratio was 0.42, the pollution tolerant index was 13, the number of EPT taxa found was 2, and the predominant taxa ratio was 0.42.

### ***Nootka Area***

Two sites were sampled within the Nootka Area, along transect 9 and 10. The first site had a EPT/Total ratio of 0.52, a pollution tolerant index of 8, the number of EPT taxa found was 2, and with predominant taxa dominance of 0.52. The second site had EPT/Total ratio of 0.59, and pollution tolerance index of 11, EPT taxa number of 4, and Predominant taxa ratio of 0.59.

### ***Grandview Highway Area 1***

Three sites were sampled along Grandview highway, from around Cornett to Rupert. The first site had a EPT/Total ratio of 0.20, pollution tolerant index of 7, EPT taxa of 2, and predominant taxa ratio of 0.73. The second site had EPT/Total ratio of 0.22, pollution tolerant index of 11, EPT taxa of 2, and predominant taxa ratio of 0.68. The third site had EPT/Total ratio of 0.77, pollution tolerant index 7, EPT taxa 4, and predominant taxa 0.77.

## **Grandview Highway Area 2**

Two sites were sampled from Rupert to Boundary. The first site had EPT/total ratio of 0.68, a pollution tolerant index of 19, EPT taxa of 4, and predominant taxa ratio of 0.68. The last site had EPT/Total ratio of 0.51, pollution tolerant index of 17, EPT taxa 2, and predominant taxa ratio of 0.511.

**Table 3 Summary table for benthic invertebrate survey results**

	<b>EPT / Total ratio</b>	<b>Pollution Tolerance Index</b>	<b>EPT Taxa</b>	<b>Predominant Taxa Ratio</b>
Renfrew Ravine site 1	0	4	0	0.97
Renfrew Ravine site 2	0.06	10	3	0.79
Renfrew Community Park site 1	0.42	13	2	0.42
Nootka Area site 1	0.52	8	2	0.52
Nootka Area site 2	0.59	11	4	0.59
Grandview Highway Area 1 site 1	0.2	7	2	0.73
Grandview Highway Area 1 site 2	0.22	11	2	0.68
Grandview Highway Area 1 site 3	0.77	7	4	0.77
Grandview Highway Area 2 site 1	0.68	19	4	0.68
Grandview Highway Area 2 site 2	0.51	17	2	0.51

## **4.2. FHAP Results**

The FHAP and streamkeepers methodology both have similar indices for describing physical stream characteristics. Indices include the percent pool area, average number of channel widths per pool, woody debris count, stream canopy cover, off-channel aquatic habitat, and any barriers to aquatic connectivity (Johnston & Slaney, 1996; Taccogna & Munro, 1995).

### ***Renfrew Ravine***

Renfrew Ravine open stream length is 355m. The pool % area within the Renfrew ravine is 11.6 %, with an average number of channel widths per pool of 14. The habitat features are dominated by riffles and glides. The large woody debris (LWD) count was 52, and average canopy cover along the reach was 42%. There were no off-channel habitats, and no pools greater depth than 1m. The minimum total riparian area was around 60m, and the maximum around 140 m. Streambed material was composed primarily of

boulders, cobbles with interspersed gravel. A culvert of 90m separates the ravine, and the stream enters another culvert before re-emerging in Renfrew Community Park.

### ***Renfrew Community Park***

Within Renfrew Community Park the open stream length is 291m. The pool area is 13.8%, with average number of channel widths per pool of 14. The LWD count was 0, and average canopy cover along the reach was 36%. There were no off-channel habitats and no pools greater than 1m. The minimum riparian area was 30m, and maximum 70m. The stream flows under 3 bridges. The last 50m of the reach, which occur where the riparian area is thinnest, the substrate is hard flattened concrete, and the wetted depth was 4cm. The substrate is a mix of boulders, gravel, and hard bedrock throughout the reach. The stream reach enters a 390m long culvert along that runs along Renfrew St.

### ***Nootka Area***

The Nootka Area reach length is 307m. The pool area is 10.81, with average channel widths per distance to pool at 18. Habitat features dominated by glides, cascades. The LWD count was 1, and canopy cover 36%. The riparian width was about 10-25m. The banks along this portion of the stream are a mix of reinforced with concrete and boulders, and vegetation. The substrate is a mix of boulders, cobbles, gravel, with underlying concrete. The stream flows under a small pedestrian bridge, and enters a twin culvert of 40m under Grandview highway. In the section north of Grandview Highway, the stream diverts into two parallel channels, and one pool measured greater than 1m.

### ***Grandview Highway Area 1***

The reach length is 390m. The pool area is 2%, and the average channel widths per pool is 52. The canopy cover is 12%, with 0 LWD count, and the riparian area on both sides is at 15m. The stream is dominated by riffles and glides with no off-channel. The substrate is predominantly bedrock, and concrete, with interspersed sand and gravel. The streambanks return to reinforced cement boulder banks. The stream flows under a 60m bridge. At Rupert St, the stream enters a metal grated culvert for 160m.

## **Grandview Highway Area 2**

The remaining length of the stream until boundary road covers a distance of 426m. The riparian area width ranges from 15-20m. The pool habitat area is about 12%, and the average channel widths per pool is 18. Aquatic features are dominated by riffles and glides, with no LWD count, and average canopy cover of 5%. There is no off-channel aquatic habitat, and no pools greater than 1m. Substrate is sand, gravel and boulder, interspersed with concrete and some bedrock. This portion of the stream flows under two culverts and two bridges.

**Table 4 Summary table for Fish Habitat Assessment Protocol Results**

	Pool Area %	Channel widths per pool	Large Woody Debris	Canopy Cover	Pools > 1m or Off-channel habitat
Renfrew Ravine	11.6	14	52	42	0
Renfrew Community Park	13.8	14	0	36	0
Nootka Area	10.8	18	1	36	1
Grandview Highway Area 1	2	52	0	12	0
Grandview Highway Area 2	12	18	0	5	0

### **4.3. Terrestrial Biodiversity**

Terrestrial vegetation survey indices included total foliar percent cover, the Shannon-Wiener Index for plant species biodiversity, tree percent cover, and invasive species percent cover. Total foliar cover was used as a measure of vegetation structure diversity, as a higher total foliar cover means more overlapping vegetation, and thus more vertical diversity (Lemay & Staudhammer, 2005).

#### **Renfrew Ravine Park**

The riparian area was largest in Renfrew Ravine. A total of 11 vegetation plots were surveyed. Total vegetation cover ranged from lowest of 172% cover to highest of 326% cover. The Shannon-Wiener Index ranged from 1.48-2.66. The tree cover ranged from 0-100%. Trees are dominated by Red Alder and Red Cedar. Common native shrubs and ferns include Salmonberry, Vine Maple, Sword Fern, Lady Fern, and Western Dogwood. The invasive species cover ranged from the lowest of 10% cover to high of 78% of the total cover. Most common invasive species include Himalayan Blackberry, *Fallopia*

*japonica* (Japanese Knotweed), *Ilex aquifolium* (English Holly) and *Hedera helix* (English Ivy).

### **Renfrew Community Park**

In Renfrew Community Park, a total of 4 plots were surveyed. Total vegetation cover ranged from 99% to 169%. The Shannon-Wiener Index ranged from 1.21-2.32. Trees are dominated by Red Cedar, Red Alder, Douglas Maple, large Vine Maple, and Bitter Cherry. Tree cover ranged from 30-105%. Native shrubs included salmonberry, vine maple, sword fern and lady fern. The common invasive species were Himalayan Blackberry, English Holly, and English Laurel with some herbs including Buttercup, Dandelion, and Plantain. The invasive species cover ranged from a low of 4% to high of 17%.

### **Nootka Area**

In the Nootka Area, 2 vegetation plots were surveyed. The total cover ranged from 52% to 271%. The plot with 52% cover was half paved. The Shannon-Wiener Index from 1.73-2.42. Tree cover ranged from 0-90%; trees included Willow, Red Cedar, Douglas Fir, and Red Alder. Native shrubs were dominated by Western Dogwood, Salmonberry, and Nootka Rose. Invasive cover ranged from 0 (in the plot that was half paved) to 27%. The invasive species present included Himalayan Blackberry, Buttercup, and Morning Glory.

### **Grandview Highway Area 1**

Along Grandview highway from Lillooet to Rupert, three transects crossed vegetation, however, transect 10 could not be surveyed due to private property concerns. Using binoculars, rough estimates of the vegetation were taken. Four plots were taken over transect 11 and transect 12. Total vegetation cover ranged from 58% to 173%. The Shannon-Wiener Index ranged from 0.55 to 1.42. Tree cover ranged from 0% to 100%, and included Oak and Maple. Invasive cover ranged from 21% to 86%, dominated by Himalayan Blackberry.

### **Grandview Highway Area 2**

Along Grandview Highway from Rupert to Boundary, three transects crossed vegetation. Transect 15, similar to transect 10, had limitations on vegetation surveying

due to private property concerns. Similarly, binoculars were used to roughly estimate the vegetation cover from in stream. Total cover ranged from 105% to 177%. The Shannon-Wiener Index ranged from 0.50-1.92. The tree cover ranged from 0% to 52%, including Cottonwood, Red Cedar, Willow, and Sitka Spruce. The invasive species cover ranged from 44% to 86%, dominated by Himalayan Blackberry.

**Table 5 Summary table for vegetation biodiversity survey results**

	Total Vegetation Cover	Shannon- Weiner Index	Tree cover	Invasive species
Renfrew Ravine Park	172-326	1.48-2.66	0-100	10-78
Renfrew Community Park	99-169	1.21-2.32	30-105	4-17
Nootka Area	52-271	1.73-2.42	0-90	0-27
Grandview Highway Area 1	58-173	0.55-1.42	0-100	21-86
Grandview Highway Area 2	105-177	0.50-1.92	0-52	44-86

## **Chapter 5. Discussion**

The monitoring framework and data collected in this study can form protocol and establish baseline data set for future community-based monitoring, with the intent of building community capacity and informing adaptive management. The discussion is divided into three sections: (1) Community-based monitoring, (2) Informing Still Creek planning and management, and (3) Still Creek as Urban Stream Restoration

### **5.1. Community-based Monitoring**

#### **5.1.1. Practical concerns and limitations**

The protocol was developed to reduce the need for time-intensive data collection, however time constraints still posed a limitation in this research. Since materials were borrowed from community groups, libraries, and educational institutions, often there were limits to the length of time equipment could be borrowed. For example, the benthic invertebrate sampling net had to be returned before one final site was surveyed.

The ecological data collection, particularly vegetation surveys, were influenced by location access, similar to other community-based ecological monitoring studies (Garda et al., 2017; Purcell et al., 2007). Urban areas have a high percentage of privately owned land, which the general public does not have access to. For example, the riparian areas that corresponded to transect 10 and transect 15 were not able to be accessed except through 80m culvert under the stream, because of private property concerns from industry. The vegetation could be surveyed from within the stream, but this limited the accuracy of data collection.

In addition to private property concerns, safety of volunteers and associated liability can also be a challenge in urban areas. Meetup.com does not provide insurance, and government and community groups may be hesitant to engage in monitoring if safety is an issue. Still Creek, like many urban streams, have utilities and transportation corridors run along them (Searns, 1995; Translink, 2014). The train runs immediately adjacent to portions of the stream, and it was not deemed safe to lead volunteers beside the train tracks. Safety concerns could limit government and organizational involvement of community members, if the city is liable to any accidents.

### **5.1.2. Community-based monitoring benefits**

Community-based monitoring can be an opportunity to discuss more complex ecological concepts, and challenge cultural and aesthetic views of what nature in urban areas should look like (Herringshaw et al., 2010). The intent of this research is not to go into detail about the subjects discussed, and I did not evaluate how much information volunteers retained from the experience. However, it is important to note that the community-based monitoring activities provided an opportunity to share the historical and socioeconomic context and complexities behind Still Creek's current condition, in addition to experiential ecological learning.

The interactions in CBM also provide further opportunity for knowledge to be co-produced, through incorporating local knowledge (Groffman et al., 2016). For those who influence decision-making in restoration planning and implementation, this information could prove extremely valuable, and CBM could provide in-depth engagement which contrasts with other forms of public engagement (Conrad & Hilchey, 2011; Herringshaw et al., 2010). Again, the intent of this paper was not to capture local knowledge; however anecdotally noted that many volunteers provided valuable local knowledge about birds, of which my own expertise is limited.

## **5.2. Informing Management and Planning in Still Creek**

The literature emphasizes that effective adaptive management requires objectives and goals to be stated clearly with benchmarks to assess project trajectory, and that monitoring should be designed before agreeing on management benchmarks (Arseneau, 2011; Baker & Eckerberg, 2013; McDonald, Gann, Jonson, & Dixon, 2016; Murray & Marmorek, 2004; O'Donnell & Galat, 2008; Rubin et al., 2017; Schiff, Benoit, & Macbroom, 2011; Smith et al., 2016; Sullivan & Molles, 2016). The planning and policy documents guiding the restoration of Still Creek do not include quantifiable benchmarks. When no benchmarks exist, the literature assesses stream restoration as a shift away from a degraded state, instead of as a trend towards some determined quantified reference ecosystem (Bain et al., 2014; Wortley, Hero, & Howes, 2013; Vermaat et al., 2015). Similar to other urban stream restoration projects, evaluating restoration actions based on the planning and policy documents may be subjective (Hassett, Palmer, & Bernhardt, 2007; O'Donnell & Galat, 2008; Rubin et al., 2017).

No comparable pre-restoration dataset exists for Still Creek, similar to over half of urban stream restoration projects, and thus no statistical comparisons can be made (Rubin et al., 2017). However, previous studies have independently examined ecological characteristics of Still Creek and its tributaries, and other urban parks in Vancouver, such as invasive species and vegetation (Azevedo et al., 2013; Page, 2006; Sampson & Watson, 2004; Voth et al., 2015) and physical aquatic habitat assessment (Baker & Perkin, 2014). In addition, the fish habitat assessment protocol, benthic invertebrate surveys, and biodiversity indices have associated standards based on professional judgement and data collected across a wide variety of ecosystems in BC (Johnston & Slaney, 1996; Taccogna & Munro, 1995; Timberline Forest Inventory Consultants Ltd., 2003; Voth et al., 2015). The results from previous local studies and existing standards will be discussed in the context of the Still Creek data collected.

The following discussion overview of Still Creek is interpreted according to the framework, beginning with the fish habitat assessment protocol, vegetation surveys, and benthic invertebrate sampling. The intent of this research paper is not to criticize restoration efforts, but provide a monitoring framework that can be used by communities and government to track urban stream ecosystem health over time. In this section, I provide assessment based on my interpretation of the data compared to previous studies and standard protocols.

### **5.2.1. Benthic Invertebrates**

Benthic invertebrates assemblages have been found to respond to instream restoration measures, and to broader watershed-wide variables (Bain et al., 2014; Davis, Weaver, Parks, & Lydy, 2003; Doll, Jennings, Spooner, Penrose, & Usset, 2015; Miller, Budy, & Schmidt, 2010; Morley & Karr, 2002; Page, L. S. Fore, Eymann, & Johnston, 2008; Wilkins, Cao, Heske, & Levenson, 2015). Benthic invertebrates are also sensitive to both physical habitat and water chemistry, making it difficult to attribute changes to specific factors (Page et al., 2008; Rubin et al., 2017). The changes in benthic invertebrate assemblages within Still Creek are likely impacted by watershed-wide conditions, as well as local biological and physical changes. However, benthic invertebrates remain indicator of general stream health within the academic and government literature (Bain et al., 2014; Metro Vancouver, 2014; Page et al., 2008; Rubin et al., 2017).

One potential limitation of the benthic invertebrate sampling method used is the lack of replicate samples taken at the same site. Page et al. (2008) found that single surber samples, when enough individuals were collected, yielded similar results to replicate sampling, and was much less time intensive. However, when the individual samples yielded low total numbers of benthic invertebrates, which was the case in some sites along Still Creek, the sampling method has the potential to be inaccurate. Due to the nature of the monitoring protocol, it was not feasible to collect replicate samples.

The pollution tolerance index ranged from the lowest of 4, which represents poor polluted conditions, at the daylighting in Renfrew ravine, to a high of 19, or acceptable, nearing boundary along Grandview highway. Notably, the first transect in Renfrew Ravine was dominated completely by high tolerant taxa, with no low tolerant taxa, indicating very poor water quality. The extremely low diversity at this site could be due to historically contaminated substrate sediment, as the site is located near the first sewer outfall.

The taxon within the EPT groups are grouped together to measure good water quality, because they are often rare and less likely to be collected (Page et al., 2008). More experienced individuals can identify more taxa, and taxa can be distinguished more carefully from each other in a lab, and thus this index has large potential to be biased (Page et al., 2008; Taccogna & Munro, 1995). The EPT taxa ranged from a low of 0, which represents poor taxa, at Renfrew ravine, to a high of 4 within the Nootka Area, representing acceptable conditions. Because the EPT taxon were distinguished with a magnifying glass, and most volunteers did not have prior experience identifying benthic invertebrates, the data collected for taxon identification has high potential of being inaccurate.

The EPT/Total ratio varied from low of 0, again at Renfrew, which represents poor stream conditions to high of 0.77 at Grandview Highway 2, which can be considered good (Taccogna & Munro, 1995). However, the EPT to total ratio depended entirely on the numbers of mayflies, since no caddisflies or stoneflies were found at any sites. Out of the low tolerant organisms, stoneflies and caddisflies tend to disappear first as physical and biological disturbances occur (Page et al., 2008; Taccogna & Munro, 1995). The lack of caddisflies and stoneflies could indicate organic nutrient enrichment, which has been associated with high quantities of mayflies (Page et al., 2008).

Streams with good habitat and water quality have high diversity and evenness within the organisms, and low diversity may suggest water quality or habitat problems. As diversity declines, a few taxa dominate the assemblage as opportunistic species less particular about where they live replace other species requiring special foods or particular types of habitat (Page et al., 2008). The predominant taxa and diversity ratio ranged from poor conditions of dominated by mainly one species, with ratio of 0.97, again at the first Renfrew site, to marginal and acceptable conditions throughout the remainder of the stream (range of 0.4-0.8).

Sometimes individual indices or ratios from the streamkeepers evaluation may suggest contradictory stream conditions, general site rating evens out results, however the indices were generally consistent across sites (Taccogna & Munro, 1995). None of the sites that were sampled within the length of still creek were 'good' by the standards of streamkeepers, and only one site was 'acceptable'. These results indicate general poor quality of aquatic stream habitat in terms of water quality, and aquatic biodiversity throughout the stream, as compared to standards in British Columbia (Taccogna & Munro, 1995).

### **5.2.2. Fish Habitat Assessment Protocol**

The Pacific Streamkeepers Federation describes good physical habitat as on average pool-riffle sequence repeated every six times the bankfull width, and S-shaped meander repeated every twelve times, with lots of instream cover including stable logs, stumps, and undercut banks with root masses important for fish and other animals (Taccogna & Munro, 1995). Streams with good aquatic habitat quality generally have pools that range from greater than 30-55% pool area, with less than 2 channel widths per pool. Streams with poor aquatic habitat generally have less than 20% pool area, with pool frequency greater than 4 channel widths per pool.

Pool area is important for salmonid habitat use, pools important summer and winter rearing habitat. Along the entire reach of the Still Creek waterway from daylighting at Renfrew Ravine to Boundary, the pool area remained below 20% of the total wetted stream area, which represents poor habitat (Johnston & Slaney, 1996; Taccogna & Munro, 1995). The pool area was highest in Renfrew Ravine, and lowest along the

Grandview Highway portions of the creek, which were dominated by riffles and glides, due to straightening of the channel.

Though the fish habitat assessment data is particular for salmon, the poor habitat demonstrates the lack of channel complexity. Forested watersheds typically have highly complex channels, with large variety of aquatic habitats promoting aquatic biodiversity. In addition to limited stream complexity, the stream contains significant physical stream barriers in the form of culverts which impede the movement of both salmon and other aquatic wildlife. However, restoration actions to create off-channel fish habitat are limited by property boundaries, and the existing infrastructure that runs along the watercourse (AXYS, 2005).

Canopy cover shading along Still Creek was on average above 30% throughout Renfrew Ravine, Renfrew Community Park, and the Nootka Area; the highest canopy cover occurred throughout Renfrew. The lowest canopy cover occurred throughout the Grandview highway portions of the creek, especially the portion between Rupert and boundary, where the canopy cover average was 5%. Woody debris was highest in Renfrew Ravine, there were less than 1 throughout the other reaches, and thus limited aquatic habitat. Though the low woody debris can be explained by lack of trees and canopy cover along Grandview Highway; Another possible factor influencing lack of LWD in both Renfrew Community Park and along Grandview Highway is the removal of dead vegetation and other stream obstructions within the park due to flood risks (AXYS, 2005).

Streambed material in streams with good physical habitat should reflect variety of substrate sizes, with larger substrates such as boulders, cobble, and gravel, providing more stability and better fish and aquatic invertebrate habitat than fine sediments and sand (Taccogna & Munro, 1995). Underlying substrate was 'fair' throughout most of the reach, with cobbles, boulders and gravel. However, sections of the stream were dominated by underlying concrete, bedrock, or sand. In addition, large portions of the stream reaches were still reinforced through hard infrastructure banks, rather than vegetated riparian areas, which indicate signs of previous erosion (Johnston & Slaney, 1996; Taccogna & Munro, 1995).

### 5.2.3. Riparian Vegetation

Of the 240 vertebrate species in BC, over 40% use habitats provided by vegetation and stand structural diversity found adjacent to streams, lakes, and wetlands (Koning, 1999). Riparian forests are critical to healthy streams by shading, contributing leaves, and other detritus, providing large logs for instream cover (Page, 2006; Taccogna & Munro, 1995). Riparian areas along streams are important corridors for wildlife in urban areas, enhancing vegetative integrity of natural greenways significantly enhance urban biodiversity (Hennings & Edge, 2003; Pennington, 2003; Savard, Clergeau, & Mennechez, 2000). Good quality riparian buffer zones will have a variety of multi-layer vegetation structure composed of herbs, shrubs, and trees; vary horizontally through a variety of patch habitats; and contain standing and downed wood (Koning, 1999; Page, 2006; Taccogna & Munro, 1995).

The Still Creek watershed was historically forested with coniferous old-growth forest. Coniferous or mixed coniferous-deciduous riparian forest contributes to health of small streams by supporting regionally adapted plant and animal communities, less susceptible to invasive species establishment and growth than deciduous forest (AXYS Environmental Consulting Ltd., 2005; Page, 2006). Tree cover within plots varied from 0%-105%, and total foliar cover varied from 52% to 326%. The highest foliar cover was found in Renfrew Ravine, and the lowest was in the Nootka Area, specifically the plot that was half paved. With no benchmark, I assume that areas with higher tree and foliar cover will have greater terrestrial biodiversity potential (Lemay & Staudhammer, 2005).

The tree canopy is dominated by Red Alder and planted deciduous species, with less representation of Red Cedar, Douglas Fir, Hemlock, and Spruce; which is similar to other vegetation studies conducted in urban parks within Vancouver and Burnaby (Azevedo et al., 2013; Sampson & Watson, 2004; Voth et al., 2015). Alders and other deciduous species can be an indication of early successional stage of forest, or disturbance (Azevedo et al., 2013; Sampson & Watson, 2004). Notable planted large non-native trees were found along the Grandview Highway, which still may provide valuable habitat services, including Willows, Oak and Maple.

Shannon-Wiener's Index is an accepted measure of terrestrial species biodiversity (Timberline Forest Inventory Consultants Ltd., 2003; Voth et al., 2015).

Within the riparian vegetation plots varied from a low of 0.50 to a high of 2.6. In targets set for measuring stand diversity, the Shannon-Wiener target for biodiversity is above 1.5, (Timberline Forest Inventory Consultants Ltd., 2003; Voth et al., 2015). The average Shannon-Weiner index for all plots was 1.6. All plots sampled within Renfrew Ravine Park were above 1.5, which could be an indication of higher biodiversity. However, in contrast, every plot along Grandview highway from Lillooet St. to Rupert St. was below this standard.

The hydrological variability in riparian areas that promotes species richness also increases susceptibility to plant species invasion (Warren, Potts, & Frothingham, 2015). The invasive species foliar cover varied substantially throughout the riparian reaches of Still Creek. Throughout the riparian area invasive species varied from a low of 0% to high of 86%, generally lower invasive ratios were found in Renfrew Ravine and highest along Grandview highway reaches. In Renfrew Community Park plots, the invasive foliar cover was not greater than 17%, potentially due to active removal through regular maintenance. Voth (2015) found that park areas with active management resulted in lower invasive species cover.

The most consistent invasive species with the greatest percent cover was Himalayan Blackberry, similar to other urban vegetation studies in Vancouver and Burnaby (Azevedo et al., 2013; Page, 2006; Sampson & Watson, 2004; Voth et al., 2015). Himalayan Blackberry forms monotypic patches and reduces structural diversity, generally reducing the complexity of available habitat, and limits species diversity and richness (Page, 2006; Sampson & Watson, 2004). Himalayan Blackberry is sometimes perceived as high-quality habitat for birds, however Page (2006) noted that there was contradictory evidence of the importance of blackberry as habitat.

### **5.3. Still Creek as Urban Stream Restoration**

The Vancouver portion of Still Creek continues to display characteristics typical of an urban stream; however, the ecosystem may still be responding to restoration actions. Water quality and evidence of biological changes may take many decades before being evident, and certain restoration actions along Still Creek have only been implemented in the past five years (Roni, Hanson, & Beechie, 2008; Wild, Bernet, Westling, & Lerner, 2011; Wohl, Lane, & Wilcox, 2015). Though the restoration planning

was initiated in 1996, the first project in implementing the Still Creek Enhancement Plan occurred in 2005, and the most recently restored section in 2011 (Crowe, 2011; Weidner & Verde, 2005). Long-term monitoring, of over 20 years after actions, may be necessary to fully assess the influence of actions (Purcell et al., 2007; Rubin et al., 2017; Wortley, Hero, & Howes, 2013).

From the academic literature on assessments of urban stream restoration, Rubin et al. (p. 2, 2017) notes that “the most universal insight is the importance of understanding complexity of stream systems, and potential responses to restoration”. Ecologists point out that while local improvements are important, reach-scale changes do not sufficiently address primary degrading factors, which may be watershed-wide, and the stressors may operate at larger spatial and temporal scales (Palmer, Filoso, & Fanelli, 2014; Schiff et al., 2011; Violin et al., 2011; Wilkins et al., 2015). Indeed, local site conditions are often formed by larger scale processes, and so positive local improvements could be threatened (Bain et al., 2014; Schiff et al., 2011). In Still Creek, any local physical improvements in stream substrates and riparian re-vegetation efforts could be threatened due to extreme high-flow events and invasive species, processes which occur primarily outside the immediate channel.

The opportunities for ecological restoration actions in Still Creek, at the reach-scale level, let alone the watershed level, are limited by socioeconomic barriers. These constraints of both physical and social urban infrastructures create challenges for effective urban stream restoration. In the case of Still Creek, restoring riparian corridors and creating off-channel habitat are limited by private property and existing land-use. Fire programs discourage placement of trees close to buildings, and encourage removal of understory vegetation (AXYS, 2005). Vegetation may be cleared along walkways to improve sightlines and reduce crime (AXYS, 2005). These municipal priorities threaten riparian re-vegetation initiatives. In addition, increasing in stream structural complexity through large woody debris interferes with stormwater flow mandates, potentially increasing local flood risk (AXYS, 2005).

In light of constraints to watershed-wide restoration, culture is important to consider, as views of nature by individuals influence guiding vision of what a ‘restored’ ecosystem should be. In Vancouver, for example, invasive holly and ivy are not considered undesirable; conversely raccoons and coyotes, native predators, are

considered problem species (AXYS, 2005; Page, 2006). Aesthetic values may skew stakeholders' interpretation of a healthy stream, and instill a false sense of accomplishment or complacency even if ecological processes and function not fully restored (Wohl et al., 2015; Smith et al., 2016).

However, aesthetically pleasing landscapes provide cultural services and these areas valued for their appearance more likely to exist in the long-term in human dominated landscapes (Vermaat et al., 2015; Kennedy et al., 2012; Johnson et al., 2014; Higgs, 2005). Indeed, the cultural and aesthetic benefits may economically justify the costs of stream restoration efforts, even if the increases in other ecological functioning services (such as the regulating services of flood protection, water quality treatment, heat island reduction) are not being achieved (Vermaat et al., 2015; Kennedy et al., 2012). Any restoration activities that feedback into promoting positive community action can be a powerful benefit, and the literature suggests a need to emphasize human connection to the natural environment (Bain et al., 2014; Smith et al., 2016; Warren, Reeve, & Arnold, 2016; Wohl et al., 2015).

Easy access to nature promotes a human connection to the natural environment, and can be encouraged through active and passive interactions (Ozguner et al., 2012); however, the benefits of enhanced access may increase potential disturbance to flora and fauna (Schiff, Benoit, Macbroom, 2001; Wrestling et al., 2014). Indeed, previous recommendations to improve Still Creek's ecological condition include eliminating trails which disturb habitat and facilitate spread of invasive species (Sampson & Watson, 2004). Public consultation over Renfrew Parks Master Plan highlighted this conflict, through responses indicating residents wanted both to limit access to creek to preserve ecological integrity, and more access to creek for nature viewing (Vancouver Board of Parks and Recreation, 2013).

Cultural and ecological considerations demonstrate the importance of continued maintenance after any positive physical or biological changes have occurred. Concerns were expressed in the Renfrew Ravine Park Plan over lack of maintenance and management of vegetation in the parks (Vancouver Board of Parks and Recreation, 2013). Pleasing aesthetics may be achieved through a minimum evidence of care, such as pruning of overgrown vegetation including grass, and removal of litter (Herringshaw et al., 2010; Johnson, Faggi, Voigt, Schnellinger, & Breuste, 2014; Nassauer, 2004;

Ozguner et al., 2012). Nassauer (2004) advocated for just enough highly visible care to act as a threshold and perceived as attractive, while maintaining ecological integrity.

In addition to positive public perception, ecological restoration may also require continued active management to maintain ecological integrity. The concept of continued intervention may seem counter to the principle of ecological restoration itself (Palmer, Filoso, et al., 2014), however, may be necessary to counteract other active influences of human activities (McDonald et al., 2016; Page, 2006; Purcell et al., 2007). For example, successful establishment of natural plant communities along the Still Creek riparian area may require monitoring and maintenance in perpetuity to prevent invasive (Page, 2006).

## **5.4. Recommendations for Still Creek planning and management**

### **5.4.1. Recommendation 1: Establish maintenance schedule, and associated roles and budget, for sites that have been enhanced or restored.**

The maintenance of restored sites is necessary for both cultural and ecological continuity. Site maintenance could include activities such as removing garbage from the riparian area and channel, removing invasive vegetation to encourage native plant species growth, replanting of dead native species, and maintaining enough care to have the appearance of an aesthetically pleasing site. Maintenance activities could also focus on channel morphology if it is still being affected by flashy hydrology. Actions could include ensuring adequate substrate to promote aquatic biodiversity, and preventing erosion through physical structures if the existing or newly planted riparian vegetation is unstable. Maintenance activities should not detract from the ecological condition, for instance by removing standing dead trees used by wildlife, or removing large woody debris instream. Limiting these activities may require reconsideration or further research into health, safety, and liability concerns.

### **5.4.2. Recommendation 2: Promote education and awareness in the community and government.**

Cultural considerations of a 'restored' ecosystem may not correspond to ecological functioning and processes, and initiatives to raise awareness throughout

government and the broader community may be necessary. A greater ecological literacy within all stakeholders would benefit the overall stream condition. Water quality, for instance, is influenced by many variables throughout the watershed. Education and awareness could be promoted through traditional methods such as flyers, pamphlets, signage, and information provided at community events. Arts-based initiatives, citizen-science, and involving youth may also reach broader community than through traditional means alone.

#### **5.4.3. Recommendation 3: Continued community engagement and involvement.**

Community groups and community members are a valuable resource and adjunct to government. Local residents have valuable information and may provide innovative solutions or ideas to ecological restoration projects. Local residents, organizations, businesses or industries can be allies in restoration projects, and be involved in the maintenance after sites have been restored. Interested neighbors and businesses immediately adjacent to riparian areas can take ownership of these areas. Many strategies exist for continued community engagement throughout the urban stream restoration process, and should be considered.

#### **5.4.4. Recommendation 4: Continued overall watershed-wide and reach-scale restoration efforts.**

Just because the condition of urban streams has not reached the condition of forested watersheds after various restoration actions, doesn't mean that these actions should be considered a failure or abandoned. Improvements may take time and commitment on the part of governments and organizations. Considerations for watershed health can be incorporated into all policies and bylaws that have an effect on urban streams, including building codes, development permitting, and regulatory bylaws. Redevelopment, new developments, utility corridor construction, and road and sewer infrastructure repair provide opportunities for all stakeholders to engage in restoration. By considering watershed ecological dynamics and processes within local government policies, ecologically beneficial structures and behaviors can be incorporated into all changes within the watershed.

## 5.5. Still Creek reach-scale site specific recommendations

### ***Renfrew Ravine Park***

Strategies to improve the ecological condition of Renfrew Ravine Park have been outlined in the *Renfrew Ravine and Community Parks Master Plan (2013)*. Additional actions to improve the ecological condition of Still Creek and Renfrew Ravine Park include:

- A development permit area with a redevelopment fee for properties within a certain distance of the park, which would be earmarked specifically for restoration actions
- Focused education and awareness initiatives for neighborhood blocks adjacent to the park to encourage place-based stewardship
- Educational field trips and workshops with schools and community hubs within a certain distance of the park; for example, schools could adopt portions of Renfrew Ravine and steward and maintain them as part of outdoor education or biology classes

### ***Renfrew Community Park***

Similar to Renfrew Community Park, strategies to improve ecological condition have been outlined in the *Renfrew Ravine and Community Parks Master Plan (2013)*. Additional actions to improve ecological condition of Still Creek and Renfrew Community Park include:

- Increase planting of shrub layer vegetation, and limit maintenance actions that remove large woody debris and standing dead trees; this action may require further research into health and safety concerns of flooding and fire risk
- Increase forested riparian area into lawn green-spaces that are not currently being used as sports fields
- Not-for-profit partnerships with existing library and community center could develop activities to promote awareness and education; if there is limited capacity for community center to partner on activities, these centers could actively promote existing activities
- A development permit area with a redevelopment fee for properties within a certain distance of the park, which would be earmarked specifically for restoration actions

## **Nootka Area**

The Nootka area is a site of ongoing restoration by the City of Vancouver on the public right-of-ways. Additional recommendations include:

- Creating a collaborative maintenance and stewardship effort composed of residents and government employees to maintain existing restored sites
- Incentivize conservation easements of immediately adjacent properties for the purpose of riparian restoration, or pilot green infrastructure projects on lawn space
- A development permit area with a redevelopment fee for properties within a certain distance of the park, which would be earmarked specifically for restoration actions

## **Grandview Highway 1**

The site specific Grandview Highway Area 1 restoration actions are outlined in the *Still Creek Rehabilitation and Enhancement Plan (2002)*. Additional recommendations include:

- Outreach and engagement with industries within the Grandview Boundary Industrial Area to encourage industries to steward adjacent riparian areas; for example, Superstore employees could be involved in native species replanting as a corporate team-building exercise, and employees could assist with maintenance
- Incentivize construction of pervious surface areas and green infrastructure within parking lots as pilot projects through tax breaks
- Encourage federal government and Translink to collaborate on invasive species removal, riparian replanting, and other maintenance activities along the central valley greenway and train tracks
- Partner with community groups to remove invasive species and plant native tree species; this may require further research into private property and health and safety concerns
- Organize event or activity in celebration of salmon return to raise awareness

## **Grandview Highway 2**

The site specific Grandview Highway 2 restoration actions are also outlined in the 2002 *Still Creek Rehabilitation and Enhancement Plan*. The culvert under Rupert street poses the next significant barrier to fish migration further upstream.

- Require any construction, development, or infrastructure repair near the Rupert culvert to include restoration actions, or require payment into earmarked fund for fish passage improvements through the Rupert culvert
- Engage Canadian Tire in maintenance and stewardship of the newly daylighted portion of Still Creek; for example, employees could be involved in native species replanting as a corporate team-building exercise, and employees could assist with maintenance
- Engage the Vancouver Film Studios in maintenance and stewardship of riparian areas within their property leasing zone
- Partner with community groups to remove invasive species and plant native tree species; this may require further research into private property and health and safety concerns

## Chapter 6. Conclusion

A framework for CBM of urban stream restoration was developed including using three indicators (1) benthic invertebrate surveys, (2) fish habitat assessment protocol, and (3) riparian vegetation surveys. The data collected on the ecological condition of Still Creek can be used to inform current and future management and planning practices. The framework may be used on other stream restoration projects of similar scope and scale. Though CBM may have limitations, the data was able to provide a baseline of the ecological condition of Still Creek, to which future monitoring can be compared. In addition, future CBM can be an opportunity to engage the community and build capacity and positive environmental awareness. A lack of full restoration 'success' in Still Creek does not mean that ecological restoration is not feasible in the future. The vision for Still Creek should not be abandoned, and the actions implemented around Still Creek are restorative in their intent, aiming to move Still Creek along a trajectory towards an improved ecological recovery.

### 6.1. Future Research

The research field of urban ecology, including topics in urban stream restoration and community-based monitoring, is still relatively recent; however, the literature around these topics is increasing exponentially. Several questions for future research around Still Creek and in the research field emerged throughout this project. The following is a list of interesting questions in social science, policy, and ecological sciences:

- What are First Nations perceptions and interests in relation to urban stream restoration?
- How can the limitations of citizen-science, including the accuracy of data collection, reporting, and trust, be addressed?
- How does ecological literacy and perception of urban stream restoration change before and after participating in community-based monitoring?
- What are the regulatory and policy changes that could be made to encourage ecological restoration while responding to concerns of liability risk?
- What are the observable social impacts that occur in behavior after urban stream restoration projects have been implemented?

- What are the perceptions of residents, industries, and businesses towards urban streams after restoration projects have been implemented?
- What are the barriers and challenges to creating a watershed committee, and how can these be addressed?
- Is there a relationship between benthic invertebrate diversity and invasive species cover?
- What potential trophic cascades could result from the re-introduction of salmon?
- What are the most effective maintenance methods for invasive species removal and native riparian planting and maintenance?
- How has stream discharge and impervious surface area changed historically in the Still Creek watershed?
- What is the relationship between green-spaces in the Still Creek watershed and bird diversity?
- Which areas in the upland watershed would be most effective for small-scale watershed-wide restoration pilot projects in terms of improved ecological condition?
- Which areas in the upland watershed would be most feasible for small-scale watershed-wide restoration pilot projects in terms of social viability?

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