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Lessons Learned from Rainwater Management Strategies Used in the Olympic Village Development

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List of Abbreviations and Acronyms

CSO	Combined Sewer Outflow
CoV	City of Vancouver
GI	Green Infrastructure
GCAP	Greenest City Action Plan
IRMP	Integrated Water Management Plan
LEED	Leadership in Energy and Environmental Design
ODP	Official Development Plan
RWH	Rainwater Harvesting
SEFC	Southeast False Creek

Executive Summary

This report reviews a four month research project about Green Infrastructure (GI) in Olympic Village from a multi-faceted stakeholder perspective in the City of Vancouver. The objectives of this research were to investigate, evaluate and document the successes, challenges and lessons learned from the deployment of various green infrastructure strategies in the Olympic Village. This was done via research, field observations and interviews with Olympic Village residents, property managers, strata councils, and City of Vancouver (CoV) staff who were involved with the design and construction of the Village.

The GI practices in Olympic Village are: intensive and extensive green roofs, rainwater harvesting systems, soil cells, infiltration galleries, a constructed wetland, a bioswale and permeable pavers.

Research interviews with stakeholders yielded four project deliverables:

1. **Qualitative performance assessments** of the seven different GI practices implemented in Olympic Village
2. **A synthesis of the elements to replicate or improve of these practices**
3. **Four lessons learned about current GI performance** in the Olympic Village
4. **Four recommendations for future GI policy and practice development**.

This report also contains a review of the GI studies and assessments of Olympic Village that have been done thus far, as well as a review of the relevant policy and planning context for GI in the Olympic Village, and the City of Vancouver more broadly.

This research found that elements of green infrastructure to replicate are:

- Creating spaces where life can thrive
- Promoting access to nature where rainwater is managed in new ways
- Accessibility to green spaces with recreational value, such as rooftop gardens
- Creating space in urban environments for underground tree root growth

Elements to improve upon are:

- Educational campaigns for residents about the function and purpose of surrounding GI
- Include access for maintenance and inspection in original design
- Include straightforward post-construction maintenance plans for GI practice life cycles
- Increase resident understanding of a GI system's purpose and how it operates

The four lessons learned from this research and their corresponding recommendations are:

Lessons Learned	Recommendations for Future GI Practices
1. **GI Requires Specific, Purposeful Maintenance Regimes**	**Create maintenance plans that fully take into account the purpose and function of each practice.**
2. **Life Cycle Design is Critical for Performance**	**Design practice for efficient maintenance and operations.**
3. **Knowledge Transmission Leads to Higher Performance**	**Emphasize importance of collaboration in each phase of the GI development process.**
4. **Resident Engagement Increases Their Commitment and Appreciation of GI**	**Focus on greater community outreach regarding the aesthetic requirements for GI practices.**

Introduction and Context

Introduction and Context

Urban Green Infrastructure Overview

Globally, we are seeing rapid urbanization and population growth rates. Growing numbers in urban centres has led to a greater need for development than ever before. We are truly living in the generation of cities. And with development comes greater expanses of impermeable areas in the form of buildings, pavement, asphalt and concrete. These make up all of our roads, highways, driveways, sidewalks and building roofs, which adds up to a drastic reduction in land through which water can easily be absorbed into the ground.

Difficulties in rainwater management are directly linked to these types of land use changes. As there is now an increase in rainwater flowing into the storm sewer, this water can overwhelm the sewer network and also contain high concentrations of urban pollutants. These pollutants, such as litter, hydrocarbons like car oil or grease, and pet waste, flow directly into the nearest waterbody. In contrast to wastewater, stormwater is not treated, and thus all of this urban runoff can impact regional water quality, urban waterway integrity and ecological health.

The Hinge Park wetland in Olympic Village filters street stormwater as it flows through the wetland.

The umbrella term **Green Infrastructure** describes a number of tools and practices that have been developed to combat these water quality and ecological consequences. A definition of green infrastructure from Metro Vancouver (2016a) is:

> *"**Green infrastructure** refers to the natural vegetation, soils, and bioengineered solutions that collectively provide society with a broad array of products and services for healthy living. **Natural areas such as forests, wetlands and floodplains, and engineered systems like green roofs and rain gardens conserve natural resources and mitigate negative environmental effects**, benefiting both people and wildlife."*

A more concise definition describes green infrastructure as "an approach to water management that protects, restores, or mimics the natural water cycle" (American Rivers 2017). However, while this concise definition describes the purpose behind green infrastructure practices, it does not include the motivations and benefits, which include: improved social sustainability, citizen wellbeing and city liveability.

Traditional stormwater infrastructure is designed to move stormwater immediately out of urban centres, which is contrary to how water functions in a natural system where it infiltrates into soil, evaporates, is absorbed by plants or trees, or discharges into nearby waterbodies. Green infrastructure, on the other hand, is designed to capture and treat urban water at the source while delivering environmental, economic and social benefits (EPA 2016). It is an emerging approach to managing urban rainwater and stormwater more effectively and can mitigate water quality problems, in addition to addressing: the urban heat island effect, flooding risks, urban green spaces and overall city liveability. Examples of specific practices that can do this include: increasing urban greenery and green roofs, infiltration areas, permeable surfaces, and above ground water retention channels such as bioswales. Addressing the limits of conventional approaches to stormwater infrastructure is essential when thinking about the types of unprecedented issues that cities are facing today.

Green infrastructure is an emerging interdisciplinary approach within the larger field of urban water management, which has long been associated with single purpose and centralized approaches that can ignore opportunities for socio-ecological sustainability. There are significant obstacles for integrating new ideas into the traditional structures that manage municipal water.

Funding and investment are challenges when planning for new city services or built amenities, due to regulated budget timescales and structures. Another limitation is the extent to which ecosystems are valued publically, because citizen networks are essential in sustaining resilient ecosystems (Schaffler & Swilling 2013). This context sets the stage for the benefits and challenges associated with green infrastructure in present day urban settings.

Notably, there is a growing number of cities and municipalities that are integrating ideas of stormwater and rainwater management into their urban design and planning regulations. Indeed, the American National Association of City Transportation Officials released the Urban Street Stormwater guide (June 2017), which is based on green infrastructure practices for public streets, learned and tested in cities across the United States. Elsewhere, in the Ditch city of Rotterdam, city officials are overturning traditional approaches to stormwater and flood management, and emphasizing a new approach to living with water. The “Room for River” campaign has made significant strides in creating new spaces for urban rivers while also increasing public amenities, such as a reservoir for floodwater that doubled as the site for the World Rowing Championships in 2016 (Kimmelman 2017). The City of Vancouver fits into this picture as another municipality striving to become more conscious of urban water management through green infrastructure.

Vancouver’s Creekside Community Centre uses recycled rainwater for toilet water flushing.

Green Infrastructure in Vancouver

The City of Vancouver (CoV) is in pursuit of “staying on the leading edge of urban sustainability” and becoming the greenest city on earth by 2020 (CoV 2017). However, CoV has been focused on designing and creating a sustainable and greener city for decades. As the definitions and best practices associated with “sustainable” and “green” have evolved, so has the City’s approach to building a liveable and progressive city. One major stride in this direction was the Olympic Village, also known as “the Village,” built as a legacy of the 2010 Olympic and Paralympic Games.

Research Objectives

The research objective of this project is to investigate, evaluate and document the successes, challenges and lessons learned from the deployment of various green infrastructure strategies in the Olympic Village. This was done via research, field observations and interviews with Olympic Village residents, property managers, strata councils, and CoV staff who were involved with the design and construction of the Village.

Three sub-objectives of this study were to: (1) create maps of the drainage area and green infrastructure (GI) practice capacity in the Village, (2) consolidate the findings of a number of other related studies for the area related to GI, and (3) make recommendations applicable to future storm water planning, design, maintenance and operations.

Ultimately, the goal of this project is to provide insight into any lessons learned from the Olympic Village in order to help guide future upscaling of green infrastructure implementation throughout the City of Vancouver, specifically in reference to the City's Integrated Rainwater Management Plan.

Olympic Village Context

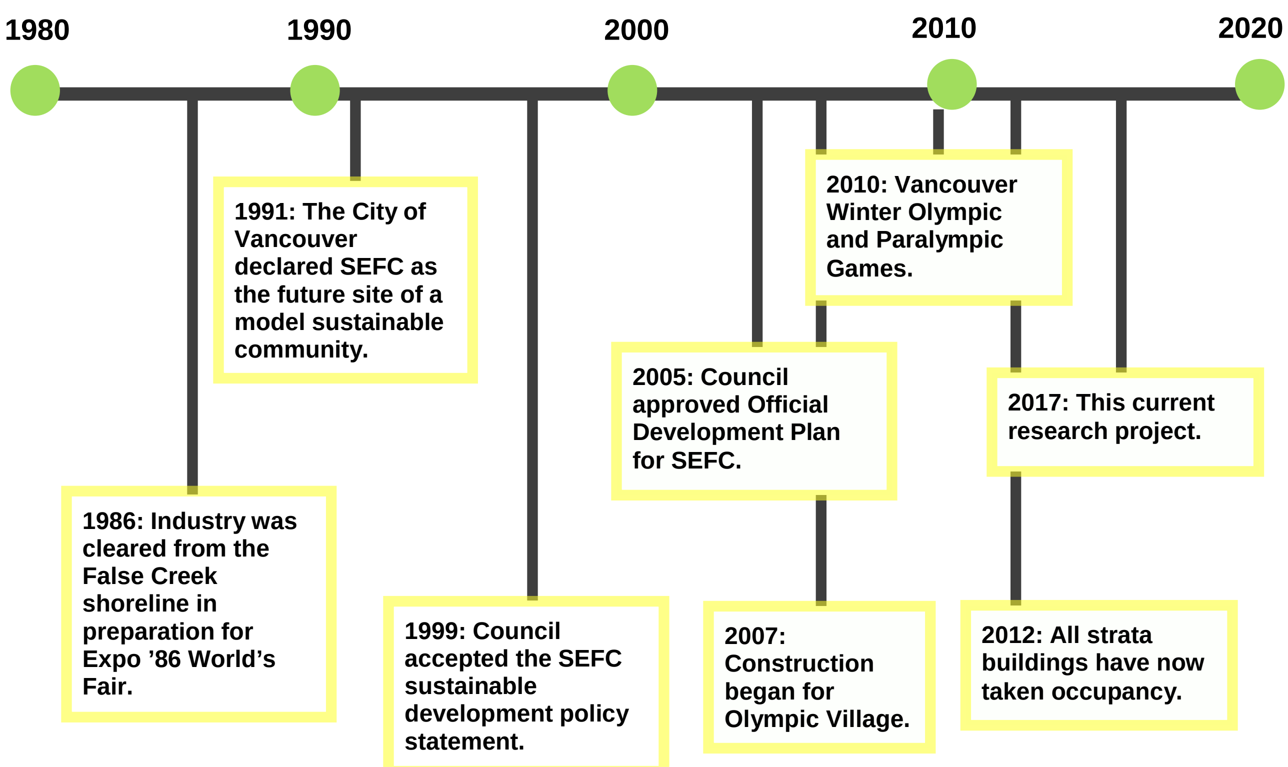

Figure 1: The Olympic Village timeline (adapted from the Challenge Series 2010).

In 1990, the City of Vancouver acquired the SEFC lands from industry, and in 1991 declared the area would be a future model sustainable community (The Challenge Series 2010). In 2005, Vancouver's city council approved the Official Development Plan (ODP) for SEFC, which in addition to addressing development and land use changes, outlined four sustainability strategies for the site (CoV 2007). Furthermore, the SEFC Plan stipulated the following as a key objective:

> *"Establish a **foundation of urban design principles**, sustainability principles, and environmental, social, and economic **sustainability strategies** to enable the development of SEFC as a complete community, and to **serve as a learning experience for application of such principles and strategies on a broader scale**."*

Figure 2: Community plan for the Olympic Village, including transportation and green infrastructure elements. Source: Green Building Brain 2012.

For the purposes of this report, the environmental sustainability strategies related to water are most relevant. The ODP laid out specific considerations for rainwater reuse, stormwater collection, drought tolerant landscaping and the uptake of urban agriculture; all of which are represented in the design of the Olympic Village. A key line of thinking was that no potable water would be used for irrigation (The Challenge Series 2010).

The design motivations for the Olympic Village in the mid-2000s were numerous and complex, but three key themes stand out: (1) environmental and social sustainability, (2) contaminated site remediation and (3) flagship development for the Olympic Games. These goals presented a daunting challenge for the industrial contaminated site area to become a model sustainable community within the tight deadlines associated with the 2010 Olympics.

The Olympic Village struggled to move beyond a tumultuous financial history. The City of Vancouver took over the project and its debt in 2009 from Millennium Properties Ltd, who went into voluntary receivership, while Ernst & Young and Rennie Marketing Systems became the project receivers. This political context meant there were significant marketing challenges associated with selling and renting out the residential and commercial units in the Village. Indeed, the area was described as having a "ghost-town feel about it" in 2011 (Mason 2011). However, soon the draw of the Village from an urban planning and design perspective, as well as its beautiful waterfront location, won out and now the neighbourhood is booming.

Sustainability and Rainwater Management in Olympic Village

In order to address the larger objectives of the SEFC development, the area boasts a number of sustainability practices that intersect to create the model sustainable community:

Key Sustainability Elements in Southeast False Creek:

- **100% LEED certified buildings** (ranging from Gold to Platinum designation)
- The Neighbourhood Energy Utility serving the area provides **heat from waste thermal energy** captured from sewage
- Public and private green infrastructure practices such as **green roofs and permeable pavers** (see Figure 2)
- **Native planting and landscaping** for increased local habitat and biodiversity benefits
- Increased accessibility to **walking paths, cycling paths and public transit routes**
- The nearby **Habitat Compensation Island** was constructed in False Creek (as per negotiated agreements with the Department of Oceans and Fisheries) to protect shoreline habitats
- **Increased neighbourhood social interaction and community network opportunities** through public parks, plazas and gardens

The green roofs and drainage areas in Olympic Village are displayed below in Figure 3 and summarized in Table 1. The City of Vancouver stipulated that at least 50% of the roof area of Olympic Village must be vegetated and the rainwater that falls on building roofs and podiums must be collected and stored in basement cisterns for multiple uses (The Challenge Series 2010). Green roofs can take many forms but will always have a lining and root barrier, a growing medium and plants. The two main categories of green roofs are intensive and extensive:

Extensive Green Roof:

- **Not accessible — Only accessible to professional maintenance workers and property managers**
- **Thinner growing medium and usually a light layer of vegetation with shallow roots.**

Intensive Green Roof:

- **Accessible — Gardens on building roofs are an example of an intensive green roof**
- **Thicker growing medium and supports deep rooted plants, such as trees and shrubs**

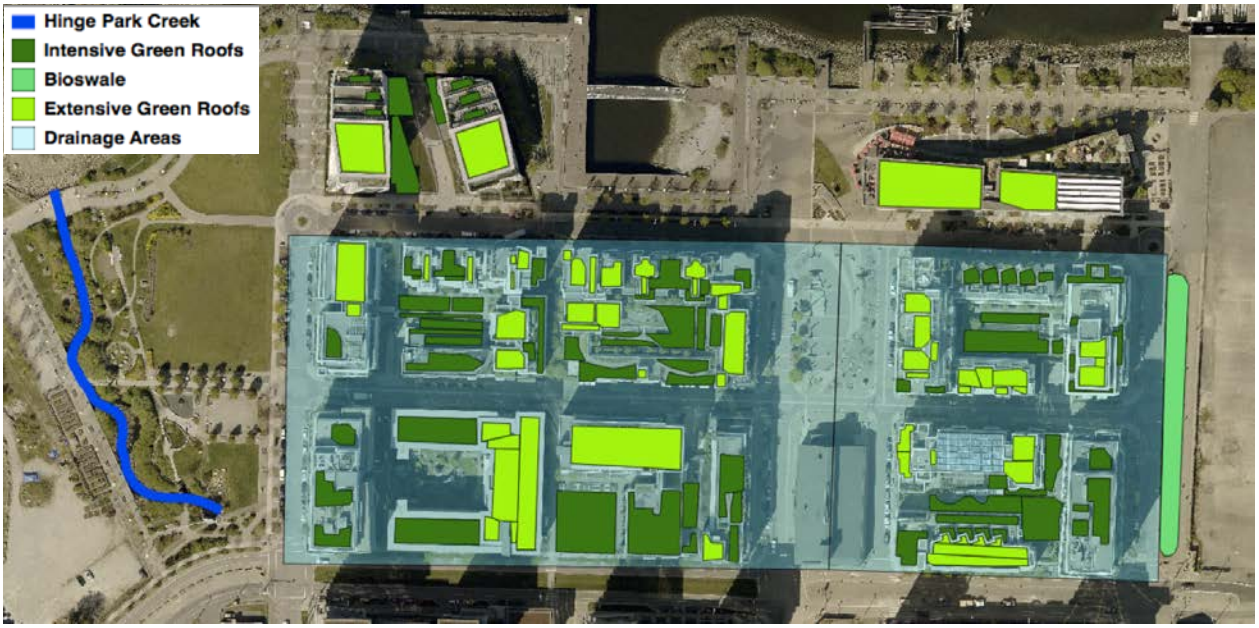

Figure 3: Map of the extensive and intensive green roofs, Hinge Park wetland and drainage areas in Olympic Village. Source: Author, QGIS 2.18.

When the land use, political and social history of the Olympic Village are combined with the green infrastructure and sustainability goals from the original SEFC Plan, a very interesting and complicated context emerges. The design and development of the neighbourhood was heavily scrutinized in its early years; however there has been little performance assessment of the Village since then. The goal of this report is to fill this gap and provide current lessons learned from the model sustainable community, with a focus on green infrastructure practice and policy development. Indeed, as the SEFC Plan stated this development was meant "to serve as a learning experience for application of such principles and strategies on a broader scale" (CoV 2007).

Table 1: Summary of drainage areas produced from GIS mapping exercise. The West drainage area makes up ~62% (approximately 2/3) of the total drainage area of the site and drains into Hinge Park, while the East drainage area (approximately 1/3) drains into the bioswale.

Green Infrastructure Practice	Land Use Designation	Area	% Area
West Drainage Area (Hinge Park side)	Public (street runoff)	30022 m^2	63%
East Drainage Area (bioswale side)	Public (streets runoff)	17922 m^2	37%

Looking Back on Green Infrastructure in Vancouver

Looking Back on Green Infrastructure in Vancouver

The Hinge Park wetland on a wet day (May 2017).

Policy and Planning Context

In order to fully understand the context of green infrastructure, it is important to look back on the activities and policies that have structured the water infrastructure landscape of Vancouver today. Many of the forward thinking sustainability goals for the Olympic Village have now been codified into the City's multi-faceted development policy.

Integrated Rainwater Management Plan

The Integrated Rainwater Management Plan (IRMP) has been a regulatory requirement for all municipalities in Metro Vancouver since 2010, however integrated rainwater management has been a regional policy driver since the mid-2000s. CoV's IRMP was approved by Council in 2016, and aligns with the goals of the Greenest City Action Plan (GCAP 2011). Notably, the main target of the IRMP is to clarify the Clean Water goal of the GCAP, to specify increasing the quality of Vancouver's water *being released to the environment* by celebrating rainwater as a resource (CoV 2016a).

The Green Infrastructure Implementation Team (CoV Engineering Services) was created to implement the IRMP and lead initiatives to meet the IRMP regulations. The IRMP sets a target for the City to treat 90% of urban runoff and capture (through infiltration, evapotranspiration or reuse) with the following objectives:

- SOAK in the first 24 mm of rainfall
- CLEAN up the next 24 mm of rainfall
- CONVEY rainfall greater than 48 mm in safe runoff routes

Long-term Goals for Parks and Green Space

The Board of Parks and Recreation has long been associated with initiatives aimed at improving the city's access to nature. The Vancouver Park Board is the only elected body of its kind in Canada, and controls over 230 parks as well as an expansive public recreation system. One of the 4 goals in the Park Board's vision is to be a Leader in Greening, by promoting sustainable operations, greener spaces, and healthy ecosystems (Vancouver Parks Board 2012). Due in part to programs and campaigns led by the Park Board, the City of Vancouver is a forerunner in maintaining urban greenery and public spaces where water and biodiversity are successfully integrated into the urban fabric of the City.

Pilot Projects in Public Right-of-Way

A specific example of the City's efforts towards more effective urban water management in streets is the Country Lane Pilot Project, which explored replacing traditional lane paving with water permeable surfaces. A second example of ongoing, city-wide rainwater and stormwater management is the separation of sanitary and storm sewers. This program is aimed at eliminating all of Vancouver's Combined Sewer Outflows (CSOs) by 2050 (Crowe 2014). Combined sewer systems carry both sewage and stormwater together to a wastewater treatment plant, however during storm events stormwater can overload the system, meaning that stormwater and sewage overflow directly from outfalls into receiving waterways. The goal of this initiative is to transition from a combined system, where sewage and stormwater runoff flow in one pipe, to a separated system, where sewage and runoff are collected in different pipes. As of 2014, the City is on track to complete 60% of this project by 2020 (Crowe 2014). It is important to note as well that stormwater, while cleaner than sanitary wastewater, will still carry surface pollution from streets and properties unto receiving waterbodies. Practices like rain gardens and permeable pavement are designed to clean and treat stormwater in order to avoid pollutants reaching these waters.

Greenest City Action Plan

Another important driver for Vancouver policy for sustainable urban water management is the Greenest City Action Plan (GCAP), approved by council in 2011. The GCAP is the ambitious plan for the City to become the greenest city in the world by 2020. This plan shaped the city's agenda towards realising a resilient and healthy city for future generations. The GCAP has 10 goals, two of which, amongst others, are very relevant for this project: Clean Water and Access to Nature. The Clean Water goal addresses drinking water quality and per capita water consumption, and the Access to Nature goal is in pursuit of more trees and walkability to green spaces in Vancouver (CoV 2011).

Outside of the specific targets, the existence of these two goals and the GCAP broadly, has been influential in motivating new and improved plans for a greener, more resilient city. For the purposes of this research, some of these new plans include: the Urban Forest Strategy (City of Vancouver & Parks Board, 2014), the Biodiversity Strategy (Parks Board, 2016), and the Integrated Rainwater Management Plan (IRMP) (City of Vancouver, 2016). The IRMP in particular has notable significance for this project, and is detailed in the next section.

Rezoning Policy for Sustainable Large Developments

Council approved the current version of the Rezoning Policy for Sustainable Large Developments in 2013, which outlines the sustainability requirements for developments categorized as "large," defined as: occupying land parcels of 8000 m^2 or more, or containing 45,000 m^2 or more of new development floor area (CoV 2014). Two out of eight criteria categories of this policy are: Access to Nature and Rainwater Management. Deliverables under the Access to Nature objective include: attention to opportunities for growing large trees and creating habitat on site. All of these aims are relevant to the Olympic Village example now because there was special attention paid to tree growth, wetlands, parks, and creating accessible habitats, aspects which this report aims to evaluate.

The Rainwater Management objective requires a Rainwater Management Plan which “recognizes rainwater as a resource to enhance the community and environment” (CoV 2014). This section of the policy outlines that rainwater quality be managed by treating 90% of average annual runoff volume, which is modelled after industry best practice. These policy elements are important when considering the context of development in Vancouver, and where the emphasis of the umbrella term “sustainability” is placed, when moving forward with large-scale projects.

Assessments of Green Infrastructure in Olympic Village

In addition to policies guiding development, there are a number of studies and consultancy reports which give additional insight into how green infrastructure practices have performed and how their role in the community has evolved. This section acts as a review of the work that has been done thus far on these themes in the Olympic Village.

Tree Growth Rates and Performance

Urban trees play an important role as a green infrastructure practice. A study done in coastal B.C found that urban trees reduce stormwater runoff, reduces the intensity of rainfall reaching the ground, and cause delays in precipitation reaching the ground, called “interception loss” (Asadian & Weiler 2009). In the fall of 2009, 180 trees were planted in Southeast False Creek’s Olympic Village with 7000 soil cells that provided root space for trees to grow (DeepRoot 2015, DeepRoot 2017). These cells are engineered to provide space for tree root growth in healthy soil beneath paving, specifically for dense urban areas. The three most prevalent factors limiting tree growth are soil moisture availability, soil aeration and soil drainage — all of which are impacted by soil compaction (DeepRoot 2015). Soil cells address these problems for growing trees in urban environments, and were a key infrastructure element in the landscape design of Olympic Village.

A DeepRoot study was done in 2015 to assess the growth and performance of trees planted in soil cells in built landscapes. A small number of trees in SEFC were underperforming, seemingly because they were not irrigated and were in areas with little access to water. Trees that showed a higher level of performance were those that had larger areas of pavement which drained into the tree planting beds (DeepRoot 2015). Notably, for the City of Vancouver, the trees planted in Olympic village are growing at two times the rate of other trees that were planted at the same time in 2009 without soil cells (Farmand & Albi 2013).

Effective Impervious Area

Along with the Official Development Plan for Southeast False Creek, Council also approved a list of sustainability indicators and targets for the area (CoV 2005). The sole indicator for stormwater management was Effective Impervious area (EIA), which is the percentage of site drainage area that is directly connected to a storm drainage system. The target for the Village was to have less than 40% EIA (CoV 2005). A report by Golder Associates (2015) states that the "Olympic Village does achieve their sustainability benefits implied by [the] EIA target, achieving an overall EIA of 35%." The study did two separate assessments, one for public lands (streets and public spaces), and one for private lands. It was found that for public lands the EIA is 33% and for private lands the EIA is 37%.

A colourful mural brightens up the Creekside community garden

Sustainability and Stormwater Assessments

According to this research, the City of Vancouver has done two assessments with regards to sustainability and stormwater infrastructure. In 2015 an internal report entitled "Southeast False Creek Sustainability Assessment Report," was drafted to outline research completed and any preliminary findings on the environmental sustainability indicators laid out by the plans for SEFC. This 2017 assessment of Olympic Village builds on the research started by the City in 2015.

A second assessment, specifically related to green stormwater infrastructure, was completed by another Greenest City Scholar in 2016, entitled "Green Stormwater Infrastructure on City Streets." This report sought to investigate green infrastructure on city streets and their benefits and challenges through a peer municipality survey, literature review, case study analysis and lifecycle cost estimation (Jin 2016). The study provided several recommendations for green infrastructure implementation for the City of Vancouver, two of which are: (1) develop a green infrastructure maintenance program to ensure infrastructure performance and longevity, and (2) support increased collaboration between the City, communities and other organizations. The 2016 report provides context and foundational research for this 2017 project because it offers insight into green infrastructure as an emerging trend in rainwater management for the City of Vancouver and other peer municipalities. The next section builds on this policy and literature context, and delves into the original research of this report about the most recent green infrastructure assessment of Vancouver's Olympic Village through stakeholder interviews and engagement.

Engaging Green Infrastructure Stakeholders


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Engaging Green Infrastructure Stakeholders in Olympic Village

Methodology

Stakeholder Interviews

25 semi-structured stakeholder interviews were conducted to explore perspectives about GI performance in Olympic Village between April and July 2017. The participants were from a range of perspectives, including: Olympic Village residents, property managers, strata council, City of Vancouver staff and other experts (refer to Table 2).

Table 2: Detailed breakdown of research participants based on their affiliation or relevance to green infrastructure in Olympic Village.

Participant	Sector	Number of Interviews
Local government, City of Vancouver	Engineering Services	4
	Planning, Development, and Sustainability	2
	Real Estate and Facilities Management	1
Community services	Board of Parks and Recreation	2
Olympic Village residents	Private residents	5
	Strata council presidents	6
Property managers	Commercial property managers	1
	Private property managers	1
Experts	Academic	1
	Streets engineer	1
	Permeable paver manufacturer representative	1
	TOTAL	**25**

The strategy when choosing research participants was to get a wide range of perspectives on the different green infrastructure practices in the Village, across private and public lands. Residents, strata councils and property managers were chosen to inform on the extensive and intensive green roofs and the accompanying rainwater harvesting systems that were implemented on private land. It was important to sample across the Village from as many residential and commercial buildings as possible because each building has different features. Some buildings have extensive, inaccessible green roofs, while others have large resident-accessible gardens, an example of an intensive green roof. Furthermore, some buildings have units that are owned while some are rental buildings, or buildings can be a mix, thus providing residents with different experiences.

Section of the sea wall in front of Olympic Village.

City staff and experts were chosen in order to gain insight on the practices installed on public land, such as soil cells and the bioswale. Multiple departments at the City were interviewed to get a range of views from the different roles that were responsible for the Olympic Village development. Within Engineering Services, representatives from branches involved in Streets, Sewers and Transportation were interviewed. It is important to note that the Olympic Village design, planning and implementation process was managed out of the Project Management Office as a special team, and thus current City roles may no longer be directly applicable. Expert perspectives were sought in order to fill information gaps and gain additional understanding about some of the technical and maintenance details for the green infrastructure practices, as well as to inform the interview questionnaire writing process.

Qualitative Analysis

Following the completion of the interviewing process, interview notes, as well as in-depth field notes and observations were synthesized. Data was then thematically coded and organized into a database according to references to: specific green infrastructure practices, infrastructure failures or success, larger policy discussions and the motivations behind the Olympic Village project. This database was then analyzed to produce the main lessons learned and corresponding recommendations for future green infrastructure implementation and policy development. Quantifiable answers, such as maintenance costs and resident valuations of private GO practices, were also analyzed and yielded the figures included in the following results section.

Stakeholder Interview Findings

The following section outlines the main strengths and weaknesses of each green infrastructure practice that was implemented in Olympic Village, according to findings from stakeholder interviews. Practices are separated based on public or private land designation and each table summarizes research findings according to individual practices.

Figure 4: Spatial distribution and extent of all underground green infrastructure practices and the bioswale in Olympic Village. Source: City of Vancouver, VanMap.

Main Takeaways

The following two tables summarize the main takeaways from stakeholder interviews in reference to GI practice successes and challenges. This section offers conclusions in terms of what green infrastructure elements can be replicated or improved upon for future rainwater management in Vancouver, according to interview findings from the Olympic Village.

Successes: Elements to Replicate

Table 3: Summary of successes for green infrastructure practices.

Practice	Successes Identified	Elements to Replicate
Hinge Park constructed wetland	· Remediated contaminated site: increases in biodiversity · Celebrations of water	· Create spaces where life can thrive · Access to nature where rainwater is managed in new ways

Practice	Successes Identified	Elements to Replicate
Intensive Green Roofs	· Residents feel connected to their green spaces	· Accessible green roofs with recreational value
Soil Cells	· Sidewalks are not heaving · Trees are flourishing	· Creating space in urban environments for tree root growth

Challenges: Elements to Improve

Table 4: Summary of challenges for green infrastructure practices.

Practice	Issues Identified	Elements for Improvement
Extensive Green Roofs	· Residents are not aware of them or do not understand their purpose · Are blamed for unattractive toilet water colour when paired with rainwater harvesting for toilet flushing	· Conduct educational campaigns for residents about the function and purpose of their green roof
Infiltration Galleries	· Designed without a way to maintain, clean or inspect	· Include access for maintenance and inspection in original design
Rainwater Harvesting (RWH) Systems	· Included water treatment systems that provided unsatisfactory toilet water colour to residents · Little information and knowledge transferred to building management in the hand-off from system designers to owners	· Include straightforward post-construction maintenance plans for the life cycle of the RWH system · Increase resident understanding of the system’s purpose and how it operates

Green Infrastructure: Public Land

Hinge Park Wetland

Hinge Park Wetland Performance Assessment

Strengths

- Successful daylighted storm sewer and capped contaminated site
- A popular natural and green oasis in the City
- Notable increases in biodiversity, such as the return of herring, and the establishment of beavers, ducks and otters

Weaknesses

- No quantitative data measuring water quality or quantity from the wetland
- Contractor errors in original outfall construction
- Public complaints about duckweed covering the wetland surface in the summer

Hinge Park is a constructed wetland and park on the far west side of the Olympic Village (see Figure 3) that was designed to be a "**celebration of water**" (Interview 12). The reason it is included as a green infrastructure practice is because it is in fact a daylighted storm sewer that collects the majority of rainwater runoff from streets on the west side of the site and treats it by filtering it through vegetation in the Hinge Park wetland (The Challenge Series 2010). It was also installed with a circulation pump to be used during dry periods where no stormwater is flowing into the wetland. The entire Olympic Village site is graded so that the west side of the neighbourhood channels runoff into the wetland, which overflows into False Creek.

Beaver lodge in Hinge Park (June 2017).

One of the notable design successes behind Hinge Park is the increased public access to water (Diamond 2016), and this theme was echoed by multiple research participants from a range of perspectives. A finding from this research was that connecting urban and natural spaces can increase the walkability and desirability of a neighbourhood because it brings elements of the natural environment closer to city residents, creating an "oasis". The mandate behind the park was to "**build a park where life could thrive**" (Interview 6), and residents of Olympic Village agree that this mandate has indeed been successful. One resident was very excited about the park benefits in terms of access to nature, and how it made the whole neighbourhood "feel more lush and healthful" (Interview 9).

Notably, as this area was previously a contaminated industrial site, the wetland is lined in order to cap the contaminated soil and protect surface water and vegetation (Interview 6). An indicator for Hinge Park being a successfully remediated site is that the park is now "teeming with life" (Interview 3). Park planners were alarmed at the completion of the project because Habitat Island appeared to be surrounded by foamed pollution, but in fact this turned out to be the spawn of herring that had not been seen in that area for over 100 years (Interview 13). A representative from Parks Board confirmed that the park has been broadly successful in terms of biodiversity benefits, such as the beavers that moved into the wetland. These beavers are celebrated by the Olympic Village and larger Vancouver communities, and this has translated into them having an Instagram account of their own (@olympicvillagebeaver). A downside to these beavers was that they initially removed a number of trees in Hinge Park before protective fencing was installed around tree bases.

Duckweed coating the surface of Hinge Park creek (July 2017)

Outfall from Hinge Park creek into False Creek on a wet day.

It can be safely concluded that Hinge Park has achieved success in terms of access to nature. However, one specific recommendation is to introduce future monitoring in order to analyze the extent to which the wetland is collecting and treating stormwater. Research participants frequently expressed interest in obtaining quantitative data to assess Hinge Park's performance.

Another challenge for Hinge Park is around public perceptions. Throughout the dry summer months when there is little rain, the water in the wetland is quite still and thus there are some vegetation changes that arise. Every summer there is natural cycle of duckweed growth, which coats the top of the water and can look like algae, which gives rise to public complaints. Due to misinterpretation, these complaints can be directed at the Park Board and how they are mismanaging the park and the wetland (Interview 24). This may be attributed to the fact that there is little public knowledge about the function or purpose of the wetland as a daylighted storm sewer (Interview 4), thus a recommendation is to improve the public signage of Hinge Park as a green infrastructure practice.

Soil Cells

Soil Cells Performance Assessment

Strengths

- Trees are flourishing and growing at two times the rate of other Vancouver trees
- Prevents sidewalk heaving
- Creates extra space for tree roots to grow, which protects the sewers from root damage

Weaknesses

- More expensive and time consuming to install when compared to structural soil
- Type of soil cell used had a lower load bearing capacity when compared to conventional sidewalks; limits vehicles that can use the space
- Limits the space for foundations of future street additions, such as the installation of parking meters

Soil cells are installed along the sea wall and the north side of the site (refer to Figure 2). These cells have contributed to successes in terms of tree growth and size, when compared to trees built in typical sidewalk tree pits, in neighbourhoods like Yaletown (Interview 4); Olympic Village trees have been growing at double the rate of other Vancouver trees planted at the same time (Farmand & Albi 2013). Two other notable benefits frequently mentioned in interviews had to do with the soil cells protecting infrastructure assets by providing additional space for tree roots to grow, namely: the lack of sidewalk heaving and reduced sewer pipe damage. The lack of sidewalk heaving increases public safety and comfort, including accessibility for cyclists and those using wheelchairs or scooters (Interview 6).

Trees planted in soil cells along the Village sea wall are flourishing

A common thought surrounding cells seemed to be "they are a bit more expensive, but worth it" (Interview 4). Indeed soil cells are more expensive, and at times more difficult and "finicky" to install, because there are specific requirements for soil type and depth of underground space needed for the cells (Interview 13). A common mindset heard from participants who are engineers was that "simple is better," and soil cells are not considered simple by research participants. Soil cells also have the potential to limit future streets additions that need space for subsurface installation, like parking meters (Interview 6).

Another factor to consider is the load bearing capacity of soil cells. Due to the the type of soil cell used in Olympic Village, paver stones subsided when buses were driven over the sidewalks during the Olympics and had to be redone (Interview 12). This was attributed to miscommunication between the site developer and the Olympics committee about the installation timing and load bearing capacity of the sidewalks. This thought will be important moving forward for property owners who may hire window washers that use heavy equipment on sidewalks.

Bioswale

Bioswale Performance Assessment

Strengths

- Offers retention and treatment of surface runoff drainage from east side of the Village
- No observed overflow from the bioswale into the storm sewer indicates most, if not all, stormwater is filtered through the bioswale vegetation and soil

Weaknesses

- Contested maintenance plan between Parks Board and Engineering
- Much more "wild" than original plans envisioned
- Lacked budget to create the full aesthetic (ex. pedestrian bridges)

The Olympic Village bioswale was installed along Ontario St. in order to capture and treat street runoff from the east side of the Village (The Challenge Series 2010). Site grading ensures that runoff flows towards the bioswale because the Plaza and Salt Building were raised to become the highest points in the site, causing sloping to the east toward the bioswale (Interview 13).

In terms of successes, the construction of the bioswale was said to be straightforward and has been performing its stormwater function since installation (Interview 12). One participant noted that there has been no observed overflow from the north end of bioswale into the storm sewer (Interview 1). One noteworthy item here is that the planted landscape is experiencing a takeover by the invasive species colloquially known as Reed Canary Grass, which is notoriously aggressive to native plants and very hard to remove. This invasion is something to keep in mind by those responsible for the bioswale planting regime in the future.

Clogged bioswale inlets on a dry day (left) and a wet day (right) (June 2017).

The major weakness of the design is associated with maintenance. The current bioswale has become much more "wild" then plans originally dictated, and this has resulted in a high degree of dissatisfaction by residents living in the buildings near the practice and the public perception that it is abandoned (Interview 23). This wildness is related to two main considerations: maintenance and costs. According to this research, the "low" degree of maintenance associated with the bioswale is because it lies in contested territory. While it was designed by the City's Engineering Services, it is maintained by the Parks Board's horticultural team, out of which arose some disagreement regarding capacity for its maintenance. One other consideration here is that the bioswale is currently located on the edge of a construction site and temporary bike path, which could leave the impression that it is unfinished or temporary.

The Ontario St. bioswale has been described as more "wild" than originally designed.

Additionally there was some disagreement between the goals of the planners and engineers responsible for the bioswale. The budget was tight and those responsible needed to decide between the aesthetics, such as pedestrian bridges, and the function of the bioswale. As one participant put it: "do we want it to drain runoff or look nice?"

(Interview 12). The lack of clarity surrounding these goals is the most apparent weakness of this green infrastructure practice.

Permeable Pavers

Permeable Pavement Performance Assessment

Strengths

- Offer permeable parking bays to reduce Village impervious area
- Are functioning well, contrary to original skepticism and despite minimal maintenance

Weaknesses

- City budget does not have capacity for their proper maintenance
- Street maintenance budget allows for cleaning once a year, and 3-4 cleanings per year are recommended for permeable pavement depending on location
- Have higher upfront installation costs when compared to conventional concrete and asphalt
- Failed paver installations in streets with inverted crowns have sparked negative connotations across all paver types

Permeable pavers were an important installation in the public parking bays of Olympic Village in terms of reducing impervious area. They were a contentious choice because pavers have higher upfront installation costs when compared to conventional concrete or asphalt (Interview 1). Permeable pavers also require special maintenance: the City has the capacity to vacuum sweep streets once a year, however permeable pavers are recommended to be vacuum swept 3-4 per year, about once per season, to assure optimal performance (Interview 11 & 20). Therefore the installation costs and maintenance frequency are main weaknesses of permeable pavers in Olympic Village, but an interesting narrative has arisen out of some of other non-permeable pavers.

Example of conventional pavers spreading due to the inverted crown design (left) and permeable pavers performing successfully during a rainfall event (right).

Walter-Hardwick St was designed with standard non-permeable pavers and an inverted crown. This directs stormwater to flow down the center of the street and makes stormwater more visible to residents (The Challenge Series 2010). This was a controversial choice because a number of representatives from Engineering Services argued against this type of design using pavers. Presently, in several sections of the street, individual pavers have dislodged with the weight of cars pushing pavers apart (Interview 3). This was stated by a number of participants as a major design flaw of the Village, and many residents cited concerns to do with high levels of noise when cars ran over the loose pavers and even bicycles getting stuck in the gaps.

This impacts green infrastructure because the dominant narrative that came out of the Olympic Village with respect to pavers, is that pavers cause design and maintenance headaches. This perception has extended to permeable pavers, even though they have performed well in the Village. This research seeks to differentiate between the underperforming inverted crown pavers, and the successful permeable pavers in parking bays.

Indeed the permeable pavers appear to have performed well, surpassing original skepticism that they would fail. While there were a few mentions of clogging, for the most part interviews found that the permeable pavers are functioning properly under a conventional maintenance regime. While upfront costs related to paver installation are higher than traditional concrete or asphalt, the methods and materials required for permeable pavers as opposed to regular pavers are very similar, thus providing a realistic alternative to conventional pavers (Interview 8).

Infiltration Galleries

Infiltration Gallery Performance Assessment

Strengths

- An underground option for stormwater management in a space-constrained urban area
- The galleries are supplemental to the sewer system; if the galleries get clogged the water will bypass the galleries and flow to the existing storm sewer

Weaknesses

- Design lacked access for practice inspection or clean out
- Lack of inspection access means failures go unseen

Any rainwater that falls on the west side of the Village, and is not channelled to Hinge Park, enters infiltration galleries beneath 1st Avenue, where layers of gravel and sand remove contaminants before the runoff flows through the outfall into False Creek (The Challenge Series 2010). Due to the cap over contaminated soil, the practice does not infiltrate water into the soil, but filters stormwater before it runs into the storm sewer. Due to this fact, perhaps it may be necessary to change the name of the galleries to "filtration", as opposed to "infiltration," galleries. This practice was added as an additional filtration mechanism for water that was not draining to either side of the site (Interview 12). This underground option increased surface space for other elements in the space-constrained development. The design of the galleries ensured that if the practice got clogged or failed, water would bypass to the storm sewer.

Interviewees agreed that the infiltration galleries had multiple flaws and weaknesses which were not balanced by any apparent benefits; thus "were not worth the investment" (Interview 3). The biggest challenge for assessing the performance of the infiltration galleries is that the practice has no method of performance assessment (Interview 20). It is possible that the galleries are doing an excellent job of treating the stormwater runoff, but the design makes assessing the performance difficult. Numerous interviewees explained that the design did not include a maintenance plan, a rehabilitation plan or a performance assessment method, thus no real conclusions can be made about the success or failure of the galleries. One theme was clear: the lack of planning for the life cycles of the galleries are considered a weakness.

Green Infrastructure: Private Land

Intensive and Extensive Green Roofs

Green Roof Performance Assessment

Strengths

- Intensive green roofs provide celebrated spaces for rooftop garden and recreation
- No reports of roofs leaking (an original concern with the development)

Weaknesses

- Collected rainwater from green roofs has resulted in complaints about toilet water colour and smell
- Extensive green roofs are largely not appreciated or understood by residents

The distinction between intensive and extensive green roofs is important because resident experiences are very different depending on roof type. This research found that intensive green roofs were celebrated by residents and highly valued for providing recreational and gardening opportunities. This was especially prevalent in the Village Co-op, which has a large communal garden and fruit trees on the roof (Interview 15). One general concern from project planners about the large green roof area in the Village was around leaks due to roots breaking through the roof lining; however, this was never mentioned in any interviews.

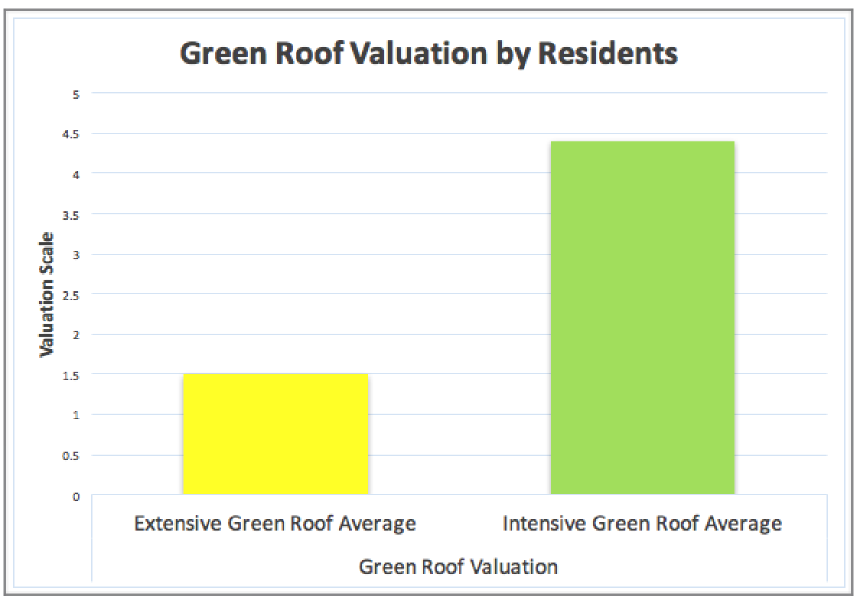


Figure 5: Green roof valuation by Olympic Village residents. Residents were asked to state how much they valued their green roof, with 5 being a highly valued and 1 being not valued at all.

When compared with resident awareness of intensive green roofs, residents are largely unaware of the function or even existence of their extensive green roofs. When residents did know about their green roof it was because of the impacts of the roofs on their toilet water quality.

Rainwater harvesting systems are installed in each building to collect water from the roof, which was then stored in cisterns in each building's basement. This water is used for both toilet flushing and private land irrigation.

It was found that buildings with extensive green roofs had more complaints about their toilet water colour than those with intensive green roofs. Participants felt that this is most likely due to the high level of interaction that residents have with their rooftop gardens, and this increases awareness about the origin of toilet water that may not be pristine.

Intensive green roof and rainwater water feature

Intensive green roof and rooftop garden on top of one of the Village rental buildings. Each resident cares for their own plot and the entirety of the garden is irrigated with potable water.

Rainwater Harvesting Systems

Rainwater Harvesting System Performance Assessment

Strengths

- Continued resource investment demonstrates the commitment of the Village to being a model sustainable community
- Designed so strata councils could make changes to the treatment system if desired

Weaknesses

- Widespread dissatisfaction with harvested rainwater colour and smell
- Significant fragmentation in knowledge about system maintenance
- Very expensive to properly maintain the system
- Toilet part replacement, water quality testing, treatment system upgrades and professional consulting were frequently required

The rainwater harvesting (RWH) systems for collecting any water that falls on building roofs and podiums were designed purposefully so that future strata councils could install or replace additional filtration systems if they were desired (The Challenge Series 2009). This design feature was beneficial because the RWH treatment systems responsible for filtering rainwater had numerous problems in terms of resident satisfaction with their toilet water colour. Four of the Village’s nine strata councils decided to replace or upgrade the water treatment systems because of issues with brown or yellow toilet water colour. This finding suggests that there is a consistent effort to maintain these green infrastructure elements because of the high investment these buildings are putting into their rainwater management systems.

This research found that one rental building invested in a number of educational programs to teach residents about the purpose and function of their rooftop garden in rainwater collection and how it is connected to toilet water colour. Following this campaign, which is ongoing because it is a rental building, they no longer received complaints about toilet water colour (Interview 18). Based on this finding, education is a tool that can be used to increase understanding and acceptance about these types of systems.

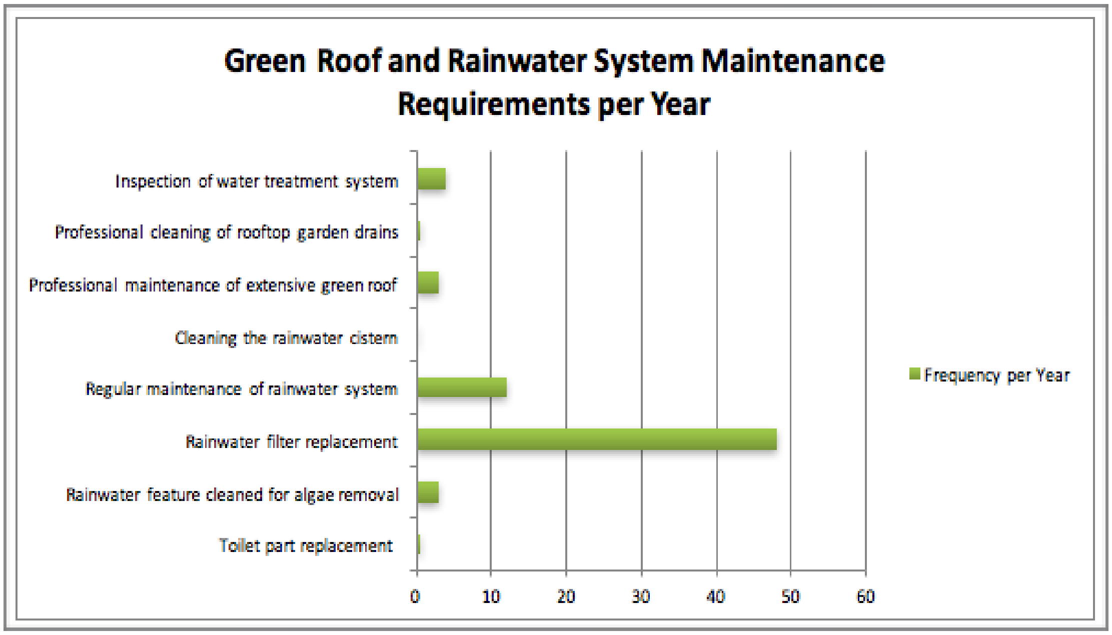


Figure 6: The frequency at which eight different maintenance activities are required for green roofs and rainwater systems, per year.

Interviewees cited numerous maintenance issues and costs that are unique to buildings with problematic RWH systems. The original treatment system used ozone treatment, however strata's updated to UV treatment (Interview 16), chlorine treatment (Interview 17 & 23), or other chemical treatment systems (Interview 19). These upgrades, which came out of the strata council's budget, have been costly, approximately $20,000 in one case (refer to Figure 7). Another cost was toilet part replacement, which was associated with chlorine water treatment affecting the rubber seals (Interview 17). These treatment upgrades were said to make toilet water clearer, however these results were not consistent throughout the year.

Interwoven in the narrative of high maintenance costs was the issue of insufficient knowledge about how the system worked and what maintenance was required, thus necessitating the hiring of professional consultants and maintenance workers, which consequently incited more costs.

The issue of knowledge transmission between experts and the non-experts responsible for RWH system maintenance and upkeep was a major concern amongst all strata council and resident interviews. Throughout the first few years of operating the Creekside Community Center, management invested heavily in technical expertise and knowledge related to the RWH system. It is the only public building in CoV that uses harvested rainwater in their toilets, which is an important example of rainwater harvesting and treatment systems being used in the public realm.

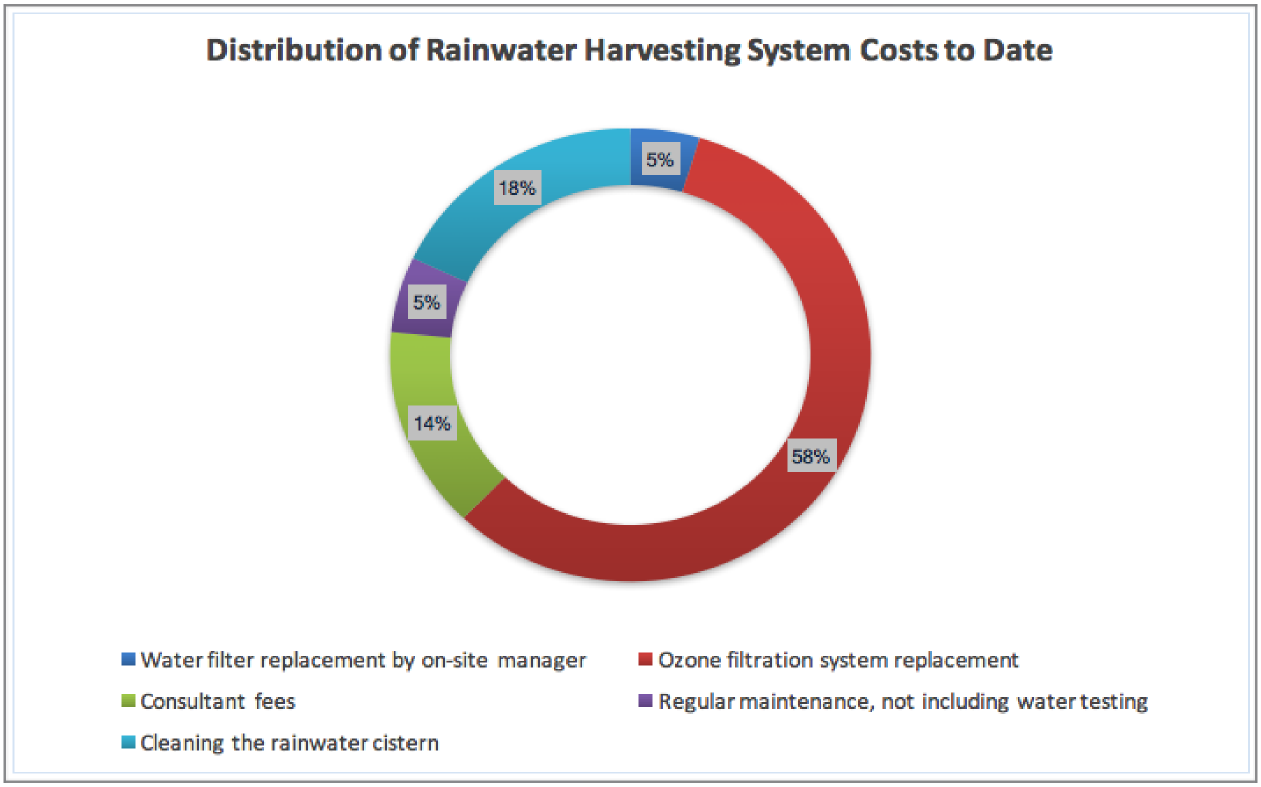


Figure 7: Graph displaying the distribution of one strata buildings costs associated with their rainwater harvesting system to date. Data: Cost of one building replacing its ozone filtration system ($16,000), Cost of hiring a consultant to recommend the upgrade ($4000), other maintenance costs: regular maintenance ($1500 to date), parts replacements ($1296 to date) and cistern cleaning ($5000 to date).

Based on this research, the key themes of success for RWH harvesting are: education, awareness and understanding of the system's purpose and requirements for maintenance. Knowledge gaps and capacity will be discussed in more detail later in the Lessons Learned and Recommendations section of this report.

Rainwater Harvesting for Edible Gardens

One key finding from this report, and an important consideration moving forward with green infrastructure, is about rainwater harvesting and watering edible gardens. This research found that in Olympic Village there is interest in using collected rainwater for irrigation. However, there is also concern about using rooftop rainwater for irrigation, mainly around the safety and health risks for young children interacting with the gardens and any water pollutants contaminating edibles from rooftop gardens. Participants emphasized that using potable water for watering edible and non-edible gardens felt like they were doing a disservice to the goals of the rainwater harvesting system. However, alternatives seemed impossible given little knowledge of the rainwater system. Importantly, residents expressed their frustration with not being able to know for sure if these concerns are legitimate, and not knowing who to ask for more information. Additionally, some residents stated that they had not known for multiple years if their irrigation was potable or non-potable and this also caused frustration.

Academic research on the safety of using rainwater on garden edibles is an ongoing field of research, and different municipalities around the world have varying recommendations. The City of Seattle encourages the use of collected rainwater for watering vegetables, but only for certain roofing material types. They explain that those with roofs made out of copper or treated wood shingles should not use collected rainwater for edible garden irrigation, however, those with enameled steel or glazed tile roofs are encouraged to water vegetables with rainwater (City of Seattle 2011). Researchers in Australia recently found that irrigating edible gardens is indeed safe and possible, as long as appropriate crops are used and soil is frequently turned over (Tom

Purple pipes labelled as containing non-potable water

et al. 2014). The British Columbia Ministry of Health released a Reclaimed Water Guide in 2013, stipulating how four different quality levels of reclaimed water could be used (BC MoE 2013). According to the Guide, reclaimed water is encouraged for the irrigation of food crops in urban settings if the water does not touch the edible portion that will be eaten raw, such as berries, or watering can be done freely if the edible portion will be cooked and not eaten raw, such as some root vegetables. Reclaimed water is very different from harvested rainwater because the water quality contaminant risks are from different sources. Reclaimed water is susceptible to heavy metal and pharmaceutical pollutants (Furumai 2008) and rainwater is susceptible to microbial pathogens (Ahmed et al. 2010). Therefore, while this Guide is not directly applicable to rainwater reuse, it is a first step in provincial guidelines about water reuse for edible garden irrigation.

Vancouver Coastal Health has released two requirements and multiple recommendations for rainwater harvesting systems, but no specific guidelines (Vancouver Coastal Health 2016). And while one requirement is that “only potable water is to be supplied to all fixtures used for human consumption, food preparation or sanitation (not including toilet /urinal flushing),” a subsequent recommendation makes the edible garden watering question a bit more clear.

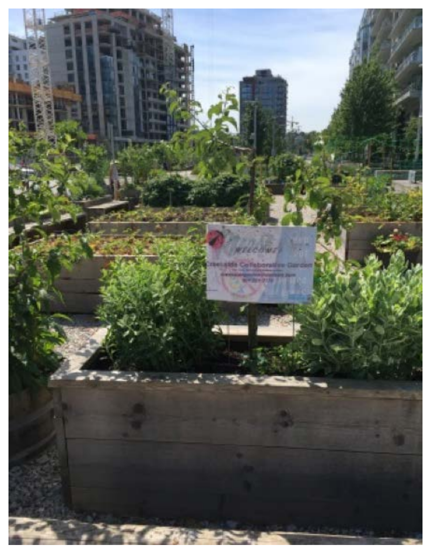
This recommendation states:

> ***"If water is used for irrigating food crops, the water should meet the appropriate quality standard." – Vancouver Coastal Health 2016***

Food crop water quality standards are well defined in the British Columbia Water Quality Guidelines (BC MoE 2017), thus it can be concluded that currently harvested rainwater can be used for edible garden irrigation if water quality guidelines are being met. A potential future initiative of the CoV could include water quality testing for rainwater harvesting systems and outreach to users on allowed uses.

Rainwater harvesting in one Olympic village building: A collection spout empties rainwater from a building roof and podium onto a gravel bed, which then is connected to the rainwater cistern in the building's basement

The Creekside community garden in Olympic Village.



Moving Forward with Green Infrastructure in Vancouver

Moving Forward with Green Infrastructure in Vancouver

Ultimately, the Olympic Village development was and is an example of early phase technologies used at the time. Early adopters of these types of technologies are expected to experience challenges. This is the foundational process of learning about novel approaches to urban design. Furthermore, some of the uncertainty about these types of systems has since been addressed since the design and construction of the Village ended in 2010. The steep learning curve associated with using these types of innovative ways of treating and capturing rainwater, any lessons learned are useful for building new knowledge about these systems.

This section builds upon both the qualitative and quantitative data analyses that have been discussed in this report so far and synthesizes the main findings to produce four lessons learned from green infrastructure evaluation in Olympic Village. These lessons learned will help guide future rainwater management mechanism design and policy development for the City of Vancouver.

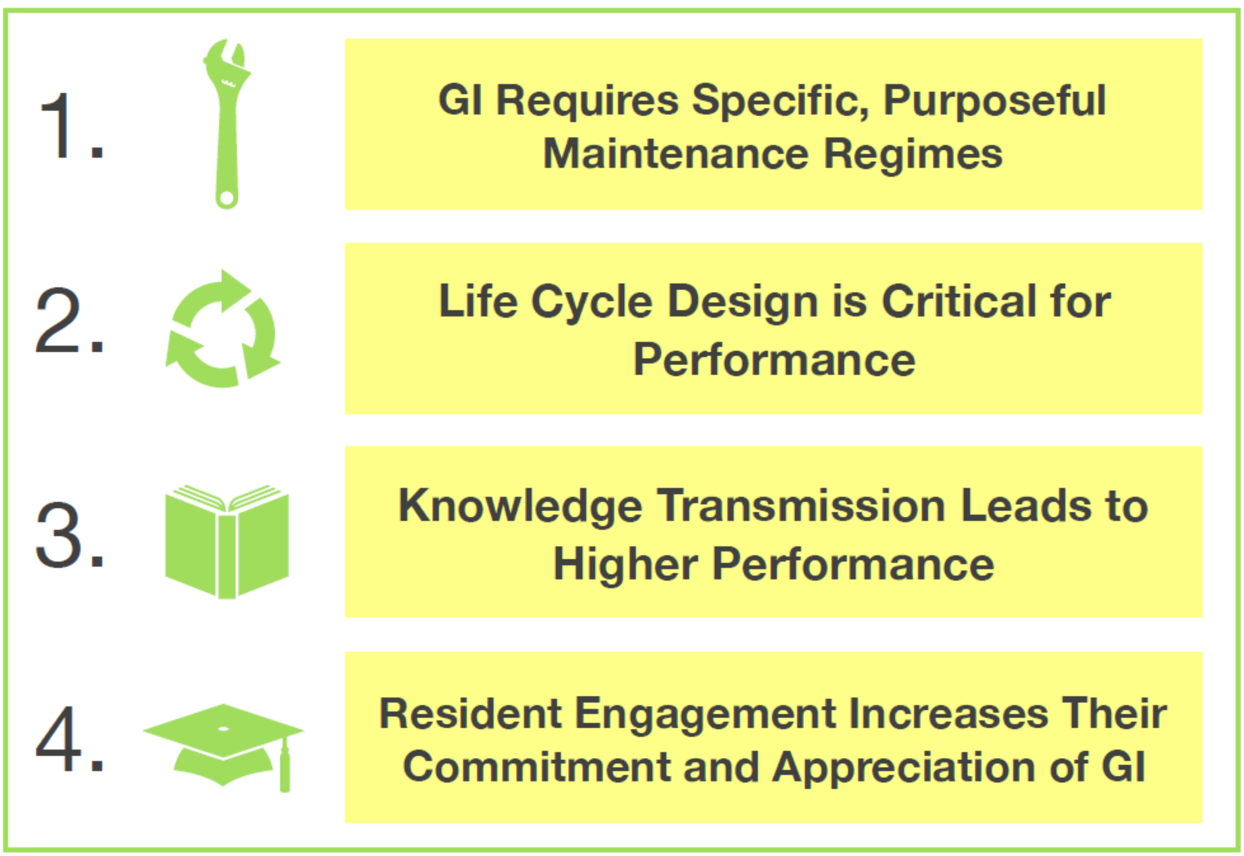
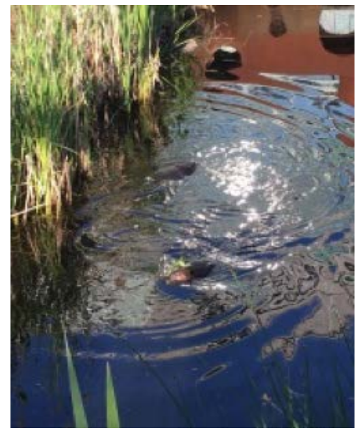


Figure 8: Four lessons learned about green infrastructure implementation in Olympic Village.

Lesson Learned #1: GI Requires Specific, Purposeful Maintenance Regimes

Green infrastructure aims to retain and treat water in urban areas, as opposed to historical approaches to stormwater management, which have attempted to move urban runoff immediately out of the system. Thus these approaches require different maintenance regimes. A key example of this comes from the maintenance of permeable pavers and how they were installed even though the capacity for their maintenance was insufficient. Regardless of their performance, these pavers are said to require cleaning 3-4 times a year, however the City has the capacity to do this once a year. Maintenance regimes need to be thought out in different ways to account for the new maintenance requirements of these types of practices. It should be noted, however, that maintenance budgets are constrained, and this rethinking process will not be a quick solution. Budget allocation and staff capacity are complicated processes that take time to restructure, thus this lesson learned comes with a note of caution surrounding expectations around timelines.



Two of the famous Olympic Village beavers out for a swim.

Recommendation: Create maintenance plans that fully take into account the purpose and function of each practice.

A recommendation from this lesson learned is to provide a thoughtful, GI-specific maintenance plan along with the design of each practice that takes into account the purpose behind each practice, and avoids these types of maintenance contestations following construction.

Lessons Learned #2: Life Cycle Design is Critical for Performance

A second lesson learned is related to maintenance, but expresses a different notion about project design and the post-construction period and life cycle of a practice. A number of green infrastructure practices in Olympic Village were fast tracked because the entire development was on a very strict deadline: the 2010 Olympics. This rush meant that the emphasis was placed on the construction phase, when a built element could be considered “finished.” However, the full functioning life cycle of a green infrastructure practice must also be considered in the design phase. For example, a practice that was not thought out in terms of its life cycle is the “filtration” galleries. Because this practice was put into the ground with limited planning for its maintenance and performance inspection, its level of functioning is unknown. Multiple participants stated that this practice was not worth the effort or cost of installation because its successes or weaknesses cannot be assessed.

Recommendation: Design practice for efficient maintenance and operations.

A recommendation is to design for efficient maintenance and operations, for the duration that a practice will be in use. For example, the City now designs subsurface filtration and infiltration practices to have easily cleaned pre-treatment, clean outs for flushing pipes, and monitoring wells to inspect performance.

Lesson Learned #3: Expert Knowledge Transmission Leads to Higher Performance

This research found a large gap between the knowledge required for sufficient upkeep of certain practices and the information that was or has been shared to those who are responsible for this upkeep. A key contribution of this research revolves around the maintenance required for rainwater harvesting systems and the strata councils who are struggling to understand how to keep them running and produce satisfactory water quality for their buildings. The council members are volunteers, and the rainwater harvesting systems require more time and energy to manage than they can provide. In the cases of private buildings that invested in educational campaigns, and public buildings that significantly invested in technical expertise, the experiences of residents and the performance of the systems were higher. This provides evidence that knowledge transmission concerning GI leads to higher performing practices and resident satisfaction.

Recommendation: Emphasize the importance of collaboration and coordination in each phase of the GI development process.

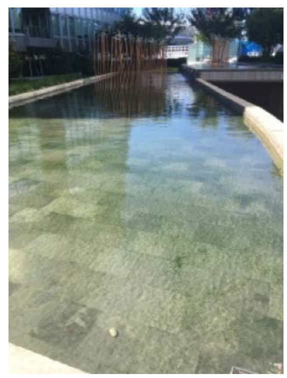
A recommendation based on this knowledge gap is to improve communication and coordination between all phases associated with development, namely: design, construction, post-construction, and ownership & operations. Emphasizing the importance of connecting these knowledge pathways between planners, designers, engineers, developers, contractors and owners, has the potential to increase satisfaction with the practice, as well as lower costs that might be associated with hiring experts otherwise. Ultimately, future private realm practices would greatly benefit from clear knowledge transmission between experts and the people operating the practice, such as strata councils, and boost the capacity of successful GI management.

Lesson Learned #4: Resident Engagement Increases Their Commitment and Appreciation of GI

A final lesson learned from this Olympic Village project is that local residents living among these types of rainwater management strategies are very interested in learning more about the buildings in which they live. Every Village resident involved in this research expressed uncertainty about multiple elements of their green roofs and rainwater harvesting systems, which was inciting frustration; however this frustration was accompanied by a high level of interest in understanding more about these systems. This curiosity has extended to buildings remaining committed to the sustainability aspects of rainwater harvesting, despite the high level of difficulty experienced with the systems. One building has had multiple problems with algae growth in their water feature that uses harvested rainwater, however they are interested in fixing the problem with an additional filter as opposed to switching to City water. The commitment to future learning and maintaining these systems presents an opportunity to increase public satisfaction and awareness of green infrastructure in the Village.

Recommendation: Focus on greater public engagement and community outreach concerning the purpose and aesthetic requirements for GI practices.

A rainwater water feature outside of Canada House shows some evidence of algae growth that will need to be cleaned.



Long-term public education campaigns surrounding both public and private green infrastructure practices is going to become a larger priority as the City scales up its implementation of green infrastructure practices. Therefore, a recommendation is to increase the outreach initiatives to the public about the purpose and benefits of green infrastructure, especially when new projects are being designed and installed. An example could be focusing on more public signage, in order to increase understanding of the ecological services that green infrastructure provides. The duckweed in the Hinge Park wetland and the wildness of the bioswale, are two examples where clear signage might be especially useful. This recommendation could reduce the amount of public complaints, and ease the public perception that some sites are being mismanaged when they have a more natural or wild appearance.

Conclusions

The objective of this project was to revisit public and expert perspectives about how green infrastructure in Olympic Village has performed over the last near decade, and produce lessons for moving forward with a city-wide green infrastructure mandate. Four lessons learned have been presented and accompanied by four recommendations which are aimed at increasing the success of future green infrastructure implementation and policy. Future green infrastructure implementation would benefit from a more targeted focus on maintenance planning, practice life cycles, collaboration with designers, operators and owners, and effective community outreach to explain the purpose of green infrastructure to residents of Vancouver.

The next decade in Vancouver will be very interesting with regards to the changing landscape of how rainwater is managed, and it is the hope of this author that this report adds new insight on how this process might look in the future. Cities all over the world are going to feel increasing pressure to conserve water quantities and improve water quality, and the paradigm of green infrastructure presents an opportunity to work to achieve those urban water goals.

The Olympic Village as seen from Downtown Vancouver. Photo Credit: CINCI.

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