Green Infrastructure for Climate Adaptation

Visualization, Economic Analysis, and Recommendations for Six Ontario Communities

Acknowledgments

The **Green Infrastructure Foundation** (GIF) partners with communities to shape healthy, resilient, and sustainable places using living green infrastructure. GIF is a charitable organization, affiliated with Green Roofs for Healthy Cities, operating across Canada and the United States. Our programs include Training and Workshops, Green Infrastructure Charrettes, the Living Architecture Performance Tool, the Journal of Living Architecture, and Events and Conferences.

Ontario Parks Association (OPA) is committed to civic beautification, the advancement, protection and conservation of parks, open space and the environment as we practice *Protecting Tomorrow Today®* in the province of Ontario. OPA is committed to educate parks professionals to exceed industry standards and actively advocate for the protection and enhancement of parks and open spaces.

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Canada

FCM FEDERATION OF CANADIAN MUNICIPALITIES FÉDÉRATION CANADIENNE DES MUNICIPALITÉS

Cover Photo: Teck Acute Care Centre, Vancouver, BC. 2018 GRHC Award Winner: Connect Landscape Architecture
Photo courtesy of ZGF Architects

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Want More Information or To Get Involved?

For more information about this program, or to find out how your community can engage

Visit greeninfrastructurefoundation.org/charrette

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Executive Summary

Introduction and Context

Green infrastructure means natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure can include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs.

Types of Green Infrastructure

We have identified four scales of green infrastructure, from largest to smallest:

1. Large natural areas, such as forests or prairies
2. Urban and suburban areas that feature a mix of living and engineered systems, such as parks, ravines, and utility corridors
3. Site and neighbourhood-specific systems that feature living and engineered elements that are designed to manage stormwater and provide other benefits, such as rain gardens, green roofs, and street trees
4. Non-living infrastructure that supports the above, such as irrigation systems, engineered soils, and soil cells

Our project largely focuses on the third category, because it is the simpest scale on which to generalize functions, costs, and benefits. To simplify our analysis, we generalized the costs and benefits of ten different types of green infrastructure on this scale:

- Green roofs
- Green walls
- Bioretention/rain gardens
- Bioswales
- Permeable surfaces
- Trees
- Wetlands
- Planters
- Lawn/turf
- Meadow/grassland

Bioswale. Source: Aaron Volkening (CC-0)

Garage Apartments Green Roof, Asheville, NC.
2019 GRHC Award Winner: Living Roofs Inc.

Trees in soil cells. Source: pxfuel (CC-0)

Tanner Springs Park in Portland, OR features an urban wetland and meadow. Source: Rohan Lilauwala

Benefits

Virtually no other investment provides as broad a range of benefits as green infrastructure. Some benefits are universal, and some must be designed for. These benefits include, but are not limited to:

- Reduced urban heat island
- Improved stormwater management: reduced runoff volume, delayed and reduced peak flow, reduced runoff temperature, improved runoff quality
- Flood risk mitigation
- Groundwater recharge
- Improved air quality
- Improved physical and mental health and well-being
- Increased local employment
- Food production
- Aesthetic improvements
- Improved access to recreational space
- Opportunities for food production
- Carbon sequestration
- Reduced energy consumption and GHG emissions
- Increased lifespan of roof membranes and other building components
- Reduced waste
- Increased lifespan of grey infrastructure like roads, sidewalks, pipes, etc.
- Improved biodiversity
- Increased property value and other real estate factors
- Increased retail sales
- Noise reduction
- Improved educational outcomes
- Reduced crime
- Biophilic related benefits resulting in reduced absenteeism, improved staff retention, and better job performance

Not all of these benefits can be measured and valued - because of this, any cost-benefit analysis of green infrastructure will **understate** its impact as an investment.

Green Infrastructure for Climate Adaptation Best Practices

Green infrastructure's unique characteristics make it ideal as part of a strategy to adapt to the impacts of climate change:

- Flexible and adaptable
- Higher employment to capital ratio
- Decentralized
- Shorter implementation period
- Function improves over time
- Requires little to no energy inputs
- Climate change mitigation benefits
- More livable communities

We have identified the following principles for incorporating green infrastructure into government and private sector planning processes:

- Early incorporation
- Appropriateness
- Scale effects
- Decentralization
- Protection and regeneration
- Reinforce natural processes
- Involvement and engagement
- Multi-functional
- Create social amenities

Additionally, we identified several best practices for the use of green infrastructure as part of a climate adaptation strategy:

- Improve and Expand Existing Green Spaces Where Possible
- Make City Streets "Green Streets"
- Green Transportation and Utility Corridors
- Create Multi-Functional Spaces
- Support Urban Agriculture
- Use Hardy Vegetation Adapted to Your Climate Zone
- Design for Biodiversity and Resilience
- Achieve Environmental Justice Goals Through Green Infrastructure
- Incorporate Job Training & Workforce Development
- Shift Paradigms
- Value Green Infrastructure as Assets
- Engage the Public
- Leverage Private Sector Investment

About this Program

While the Canadian Federal Government and some Provincial Governments are supportive of green infrastructure, its adoption at a community scale lags in Canada, especially compared to many communities in the United States.

Our experiences in the green infrastructure sector have shown that municipalities across Canada face many of the same issues: aging water infrastructure, vulnerability to surface flooding, increasing severity of weather events, increasing urban heat islands, and a lack of capacity to use green infrastructure to address these challenges. Capacity building is a proven strategy to help municipal stakeholders to address issues in areas they may not have the necessary expertise or resources to do so.

Our program consists of four broad elements to help build capacity in the municipal sector:

- The development of two training courses: *Green Infrastructure Policies, Application, and Case*

Urban agriculture can improve community cohesion and bring health benefits, along with providing environmental function. Source: Linda on Flickr

A green infrastructure charrette. Source: Green Infrastructure Foundation

Studies, and *Valuing the Benefits of Green Infrastructure: Principles and Methods*, and their delivery to municipal staff, as well as private sector and community stakeholders.

- Green Infrastructure Charrettes in six municipalities, where participants redesign develoment or redevelopment sites in their communities to scale using a menu of green infrastructure types.
- Aggregate cost benefit analyses based on methods and tools developed by us.
- This report, combining visuals generated through the charrettes with aggregate cost-benefit analyses of the redesigns, as well as best practices for using green infrastructure to adapt to climate change and leverage its many other benefits.

The goal of this program is to empower and build capacity in the municipal sector to use green infrastructure to address climate change impacts. Municipal staff will gain knowledge, skills, and resources to value, create policy for, and implement green infrastructure. A summary of the green infrastructure charrettes follow.

Green Infrastructure Charrettes

Barrie

The "Dunlop Community Hub" consists of an area generally located along Dunlop Street between Innisfil Street and Bradford Street, on the west end of downtown Barrie. The area is poised for change, with a redeveloped Fisher Auditorium and Event Centre, a new YMCA, and 600 proposed apartment units. There are opportunities for green infrastructure in the new developments, rebuilt streetscapes, city-owned land in the vicinity, as well as in the rehabilitation of adjacent Kidd's Creek. Two groups produced two different visions for the site.

Option A featured elements like daylighting Kidd's Creek, tree-lined streets and paths, an outdoor education space, and a reconfigured street network with green infrastructure elements in the streetscape. Key cost-benefit facts:

- Construction Cost: $1.38 million
- Annual Maintenance Cost: $40,365
- Job-years in construction and maintenance over 50 years: 59.3 FTE
- Net Present Value over 50 years: $10.51 million
- Simple Payback Period: 3.7 years
- It is important to consider that many important benefits are not included, such as improved property value, health impacts, flood risk mitigation, and many more. Measuring and valuing these benefits would further improve the return on investment for green infrastructure.

Option B saw 'spokes' reaching from the hub to the adjacent community, creating a central gathering space that also connect to the waterfront. They also proposed a cohesive streetscape, with minimized visual impact of parking areas. Key cost-benefit facts:

Barrie - Option A

- Construction Cost: $2.65 million
- Annual Maintenance Cost: $65,550
- Job-years in construction and maintenance over 50 years: 106.8 FTE
- Net Present Value over 50 years: $14.6 million
- Simple Payback Period: 9 years

Brampton

The site studied was the Riverstone Golf Club, recently purchased by the city, which plans to convert the clubhouse to a recreation facility. The former golf course will be re-naturalized to create a conservation area with recreational trails. There are significant opportunities to bring green infrastructure elements to these valley lands.

The group proposed a strategy featuring 10,000 trees, a naturalized floodplain linked to stormwater management wetlands, and educational and engagement elements like fruit trees, an outdoor classroom, and a composting facility. Key cost-benefit facts:

- Construction Cost: $5.5 million
- Annual Maintenance Cost: $241,600
- Job-years in construction and maintenance over 50 years: 203.5 FTE
- Net Present Value over 50 years: $27.56 million
- Simple Payback Period: 5.6 years

Guelph

Two sites were studied in Guelph. The first was the ***Baker District*** redevelopment, a City of Guelph development project aimed at transforming the existing parking lot and properties fronting the north end of Wyndham Street into a unique, dense, mixed-use development, including a new 88,000 square foot central library. The group worked within the parameters of the developer's

Barrie - Option B

Brampton

Guelph - Baker District

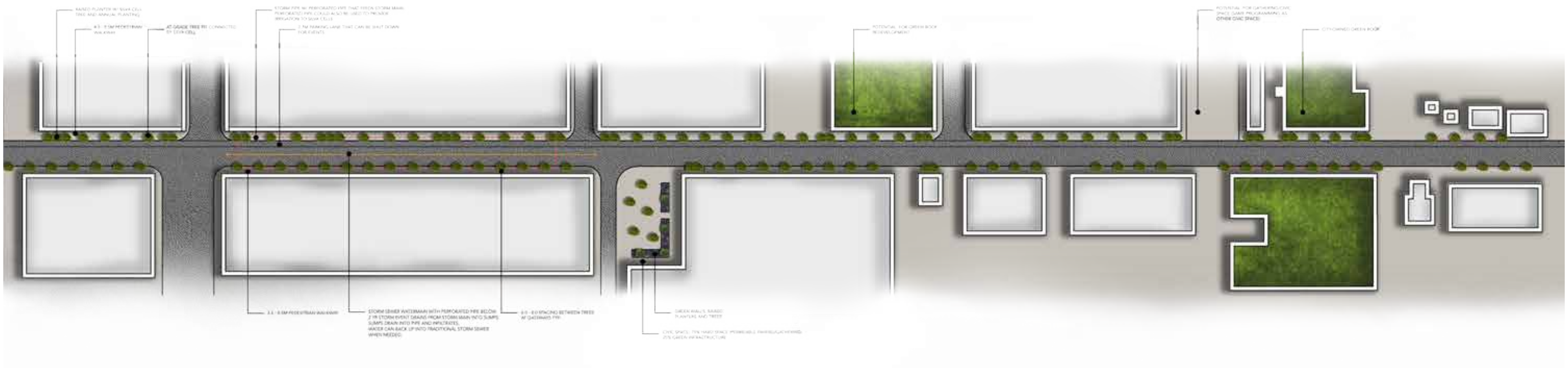
Guelph - South End Community Centre (above and right)

existing plans, considering them to be high-quality, but with room to optimize the green infrastructure portion. They identified several rooftops as ideal for green roofs, some publicly accessible. They also identified other goals, like ensuring sufficient soil volume for healthy street trees, and building partnerships with the future library and YMCA to educate about green infrastructure. Key cost-benefit facts:

- Construction Cost: $1.97 million
- Annual Maintenance Cost: $61,500
- Annual Benefits: $136,000
- Job-years in construction and maintenance over 50 years: 89.7 FTE
- Net Present Value over 50 years: $3.4 million
- Simple Payback Period: 13.3 years

The second site was the future ***South End Community Centre***, a facility that will address recreation demand and gaps throughout the city. The group identified several areas of the building and site as having potential for green infrastructure elements, proposing an 'Eco-Rec' concept - a recreation centre that provides important and much needed recreational programming and space for residents, while also performing at a high environmental level, contributing to its surrounding ecosystem, and engaging and educating the public about environmental issues. Key cost-benefit facts:

- Construction Cost: $1.68 million
- Annual Maintenance Cost: $49,000
- Job-years in construction and maintenance over 50 years: 74.6 FTE
- Net Present Value over 50 years: $5.1 million
- Simple Payback Period: 9.7 years



London - Old East Village

London

The site studied in London was the Old East Village, a historic neighbourhood focused along Dundas Street, just east of Downtown London. It has seen some revitalization in recent years, but is poised for further change, challenges, and opportunities that come with rapid transit service, infrastructure upgrades, cycling infrastructure, and development. The group proposed a green infrastructure strategy based on making Dundas a green street, with green infrastructure and an increased tree canopy. They looked at purchasing adjoining sites for parkland, and encouraging green infrastructure on private property. Key cost-benefit facts:

- Construction Cost: $3.43 million
- Annual Maintenance Cost: $56,900
- Job-years in construction and maintenance over 50 years: 110.5 FTE
- Net Present Value over 50 years: $3.1 million
- Simple Payback Period: 16.6 years

Toronto

The site chosen for study was Agincourt Mall, a large big-box

Toronto - Option A

Toronto - Option B

Toronto - Option C

mall located near the intersections of Sheppard Avenue East and Kennedy Road, in Scarborough, in Northeast Toronto. The mall is poised to be the site of one of the largest new mixed-use developments in Toronto featuring thousands of residential units along with retail. City staff identified this as an opportunity to create an integrated green infrastructure strategy on a large site that can serve as a model for others - three groups all worked on this site.

The first group's strategy (Option A) looked at managing and celebrating all water on site through water features, rain gardens, bioswales, and green streets. They proposed soil cells integrated with other green infrastructure for maximum tree soil volume and an integrated approach. Key cost-benefit facts:

- Construction Cost: $3.39 million
- Annual Maintenance Cost: $91,600
- Job-years in construction and maintenance over 50 years: 139.9 FTE
- Net Present Value over 50 years: $15.98 million
- Simple Payback Period: 7.9 years

The second group (Option B) proposed food production on the site, both through community gardens, as well as on rooftops, and also conceptualized indigenous placemaking through parks. They also proposed the relocation of utilities to under streets to minimize conflicts with trees during repairs. Key cost-benefit facts:

- Construction Cost: $395,000
- Annual Maintenance Cost: $10,300
- Job-years in construction and maintenance over 50 years: 17 FTE
- Net Present Value over 50 years: $7.59 million
- Simple Payback Period: 4.7 years

The third group (Option C) identified tree soil volumes as important. They proposed a net-zero community centre to anchor the park through education and programming. They looked at maximizing vegetation through trees, green roofs, and walls. They proposed the creation of a green corridor based on natural hydrology and existing linkages, providing an active connection to transportation hubs. Key cost-benefit facts:

- Construction Cost: $5.9 million
- Annual Maintenance Cost: $84,000
- Job-years in construction and maintenance over 50 years: 154 FTE
- Net Present Value over 50 years: $3.35 million
- Simple Payback Period: 16.8 years

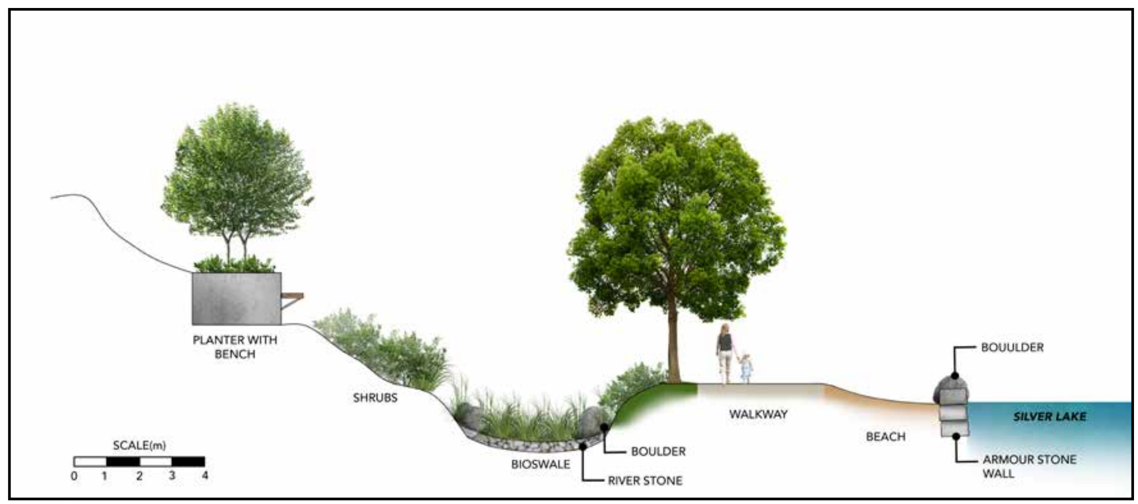
Waterloo

Two groups studied Waterloo Park, a much loved park close to uptown Waterloo that is planned for a rehabilitation, including dredging of the lake, enhancement of upstream Laurel Creek, and reconstruction of recreational areas. All these interventions create opportunities to take a green infrastructure approach.

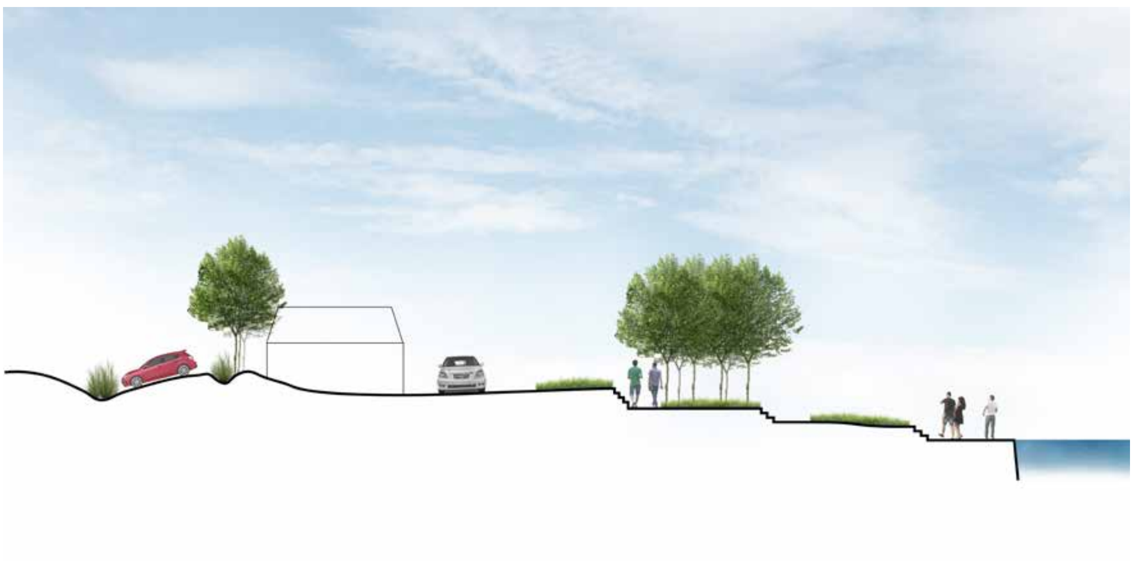
The first group (Option A) looked at creating a green corridor along the Light Rail Transit line, bioswales to slow and cleanse runoff into the lake, wetlands to address drainage and flooding issues, boulders and tall grasses to suppress geese, and an optimized central area including a lookout point and amphitheatre. Key cost-benefit facts:

- Construction Cost: $880,000
- Annual Maintenance Cost: $22,400
- Job-years in construction and maintenance over 50 years: 35.5 FTE
- Net Present Value over 50 years: $3.72 million
- Simple Payback Period: 9.9 years

The second group wanted to work within the form of the consultant's plan, as well as existing topography, focusing programming on the flat parts of the park. They proposed the use of on-street parking to minimize the impact of a large lot, and



Waterloo - Option A



Waterloo - Option B

proposed amalgamating all building functions at the top of the hill to free up space. They also proposed an enhanced slope with a terraced system. Key cost-benefit facts:

- Construction Cost: $1.6 million
- Annual Maintenance Cost: $35,700
- Job-years in construction and maintenance over 50 years: 41.5
- Net Present Value over 50 years: ($42,000)
- Simple Payback Period: 27.4 years

Conclusion and Next Steps

This project is an important initial step in valuing, conceptualizing, and implementing green infrastructure in municipalities across Canada, with the goal of realizing benefits and increasing resilience to climate change impacts. It offers an opportunity to reconsider approaches to improvements of these communities, by:

- Incorporating green infrastructure benefits into more detailed cost-benefit analyses
- Identifying strategies to increase benefits from green infrastructure in housing and other developments
- Encouraging long-term thinking when making decisions
- Capturing other important benefits not yet incorporated
- Identifying one or more design strategies and elements from the conceptual plans shown here for additional study, and implementation

By incorporating these recommendations, communities can use their limited resources to improve the efficiency of their infrastructure and receive a wider range of benefits from it. Conceptualizing and valuing green infrastructure is an important step towards its widespread use and application.

Introduction

What is Green Infrastructure

Green infrastructure is a nature-based approach to providing ecological and hydrological services using living systems, and comes with many benefits. While single-purpose grey stormwater infrastructure like pipes, catch-basins, and water treatment plants treat water as a nuisance that needs to be rapidly removed, green infrastructure is designed to replicate natural hydrology by managing water close to where it lands. This approach treats water as a resource that can be harnessed to achieve many environmental, social, and economic benefits.

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls on our roofs, streets, and parking lots in cities and their suburbs, the water cannot soak into the ground as it should and does in natural areas. Stormwater instead drains through gutters, storm sewers, and other engineered collection systems and is discharged into nearby water bodies. This stormwater runoff carries trash, bacteria, heavy metals, and other pollutants from the urban landscape. Higher flows resulting from heavy rains can also cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

When rain falls in natural, undeveloped areas, the water is absorbed and filtered by soil and plants. Stormwater runoff is cleaner and less of a problem. Green infrastructure uses vegetation, soils, and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments. At the city or county scale, green infrastructure is a patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the neighbourhood or site scale, green infrastructure includes stormwater management systems that mimic nature soak up and store water.

Green infrastructure elements can be woven into a community, from small-scale elements integrated into sites to larger scale elements spanning entire watersheds.

Green infrastructure is so varied that it functions on different scales. We have identified four scales, ranging from largest to smallest in size.

Stormwater in a conventional engineered drainage channel. Source: Bidgee (CC)

> *"Green infrastructure means natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure can include components such as natural heritage features and systems, park lands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs."*
>
> \- 2014 Ontario Provincial Policy Statement

The four scales of green infrastructure. Sources from top to bottom: National Park Service, margonaut (CC-0), Aaron Volkening (CC-0), DeepRoot

Scale Degree	Scale Size	Features	Examples of Green Infrastructure
1st	Large Natural Areas	Provide ecological and hydrological functions	Wetlands Prairies Boreal Forests
2nd	Urban and Suburban Areas	Contain different living systems that may feature a combination of natural and engineered areas	Parks Hydro Corridors Ravines
3rd	Site and Neighbourhood-Specific	Use living systems to manage stormwater and provide other benefits	Green Roofs Bioswales Street Trees
4th	Supportive Non-Living Infrastructure	Non-living infrastructure that supports living systems	Irrigation Systems Soil Cells Cisterns

For the purpose of this report, we will mainly be discussing the third scale, site and neighbourhood-specific green infrastructure systems, as this is the simplest scale on which to explore and generalize the functions and benefits of green infrastructure. Non-living infrastructure can be used to support the functionality of elements from the third scale.

To simplify our ability to analyze site and neighbourhood-specific green infrastructure, we have identified 10 generic types from literature and have divided them based on their general performance characteristics.

These types of green infrastructure can provide a multiplicity of benefits, including enhancing livability, improving energy efficiency, and counteracting the urban heat island effect. Green infrastructure can be used to naturally manage stormwater, reduce flooding risk, and improve air and water quality. It can help restore degraded habitat, reconnect people to nature, provide food and recreational opportunities, and improve overall urban aesthetic and resiliency.

Green infrastructure often costs less to install and maintain when compared to traditional, or grey, forms of infrastructure such as centralized water treatment plants, roads, and sewers. Green infrastructure can generate more green jobs than grey infrastructure, and can even foster greater community cohesiveness by engaging all stakeholders in the planning, planting, and maintenance activities.

Green Compared to Grey Infrastructure

Infrastructure is the physical framework of a community. Producing greener, more sustainable communities comes from decisions regarding the composition of that infrastructure. Green infrastructure consists of the trees, shrubs, open spaces, and soils of our natural environment, along with engineered systems that use plants to manage stormwater, whereas grey infrastructure involves roads, pipes, sidewalks, bridges, buildings, and utilities of the built environment.

While the functions of grey and green infrastructure may be complementary, they are very different. Green infrastructure utilizes the multiple benefits of vegetation to address air, energy, and water issues. It tends to require more labour and less capital, thereby providing more long-term green jobs. It also provides aesthetic and other 'soft' values that are not inherent in most grey infrastructure.

In some cases, green infrastructure may provide enough capacity to replace grey infrastructure completely. In many cases, however, green infrastructure cannot entirely replace grey infrastructure, but provides complementary options that deliver a broader spectrum of benefits than traditional approaches. Shifting the balance between grey and green infrastructure through supportive standards, policies and practices that promote green infrastructure can help us begin to reverse the ecological disruption typical of our current built environments.

Green Infrastructure in Canada

The Federal Government's Pan-Canadian Framework on Clean Growth and Climate Change supports green infrastructure, identifying its ability to reduce flooding, improve health, reduce emissions, and increase resilience of communities and ecosystems. Federally administered and/or funded programs such as the Clean Water and Wastewater Fund, the Disaster Mitigation and Adaptation Fund, the Green Municipal Fund, and the Municipalities for Climate Innovation program have begun funding green infrastructure projects, but they are in a nascent phase.

Green infrastructure is widely used in the US; the EPA advocates using green infrastructure for climate resilience, and cities like Philadelphia, New York, Washington, DC, Portland, and Seattle are investing billions in it. Despite supportive policy changes in Canada and an intuitive understanding of its benefits, green infrastructure is still an under-utilized approach, despite its ability to complement traditional grey infrastructure.

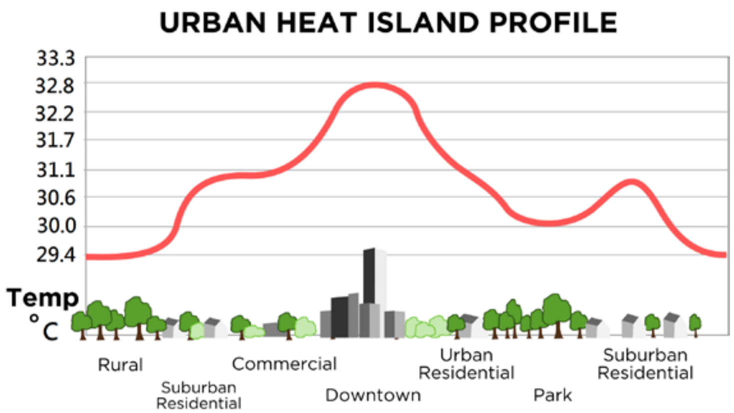
Municipal governments have identified a lack of capacity about how to value, create policy for, and implement green infrastructure as one of the biggest obstacles to its widespread use.

10 Types of Green Infrastructure

Green roofs	*Trees*
Green walls	*Wetlands*
Bioretention/rain gardens	*Planters*
Bioswales	*Lawn/turf*
Permeable surfaces	*Meadow/grassland*

Green compared to grey infrastructure. Source: pxhere (CC-0)

A rain garden. Source: Mississippi MWO



Green infrastructure replaces darker, thermally massive surfaces with plants that evapotranspire, reducing the urban heat island effect. Source: EPA

Green infrastructure has immense potential to manage stormwater. Source: DeepRoot

Greener cities help maintain healthy, active lifestyles. Source: pixabay (CC-0)

Benefits of Green Infrastructure

There are few, if any, technologies that can provide as many benefits to the public and private sectors as building and site level green infrastructure. This section provides a summary of the multiple ecological, economic, and social benefits that are common to all forms of green infrastructure (Green Infrastructure Foundation, 2018). Some benefits are typically acheived with all forms of green infrastructure (for example, carbon sequestration or a reduction in the urban heat island effect), while others must be specifically designed for (for example, designing for biodiversity will require careful species selection and the conditions that allow for a wide range of species to flourish).

Public Benefits

Urban Heat Island Mitigation

- Energy savings in buildings and resulting greenhouse gas emission reductions
- Less smog and ground-level ozone formation
- Reduction of particulate matter in the air
- More livable environment for citizens and less heat related stress
- Reduction in associated healthcare costs from improving air quality and reducing heat
- Contribution to savings on power plants and transmission infrastructure

Improvements in On-site Stormwater Management

- Reduction in the frequency of combined sewer overflow events
- Increase in life expectancy of pipes and other grey infrastructure
- Reduction in costs of erosion control
- Reduction in the frequency of flooding
- Improved water quality, leading to more fishable, swimmable, and drinkable waters
- Right-sizing of grey infrastructure

Aesthetic/Biophilic Improvements

- Healthier and more productive citizens
- Less crime and associated policing, judicial, and incarceration related expenses
- Improved economic activity
- Increased community cohesion
- Increase in walking, cycling, gardening, and running

- Beautifying unattractive building features such as storage sheds or parking garages
- Opportunities for artistic expression
- Reduced patient care costs in healthcare facilities

Urban Food Production

- Greater food security through the reduction of food deserts
- Better food quality
- Increased employment opportunities
- Reduction in transportation of food with associated air pollution, greenhouse gases, traffic, etc.

Carbon Sequestration

- Plants and growing media sequester carbon

Employment from Manufacture, Design, Installation, Maintenance, and New Uses

- Increased local employment in meaningful and accessible jobs
- Fewer social problems associated with unemployment
- Opportunities to connect employment and education, and engage underserved communities

Noise Attenuation and Sound Improvement

- Less noise entering buildings which may result in increased property values
- Biophilic sounds – like wind rushing through grass

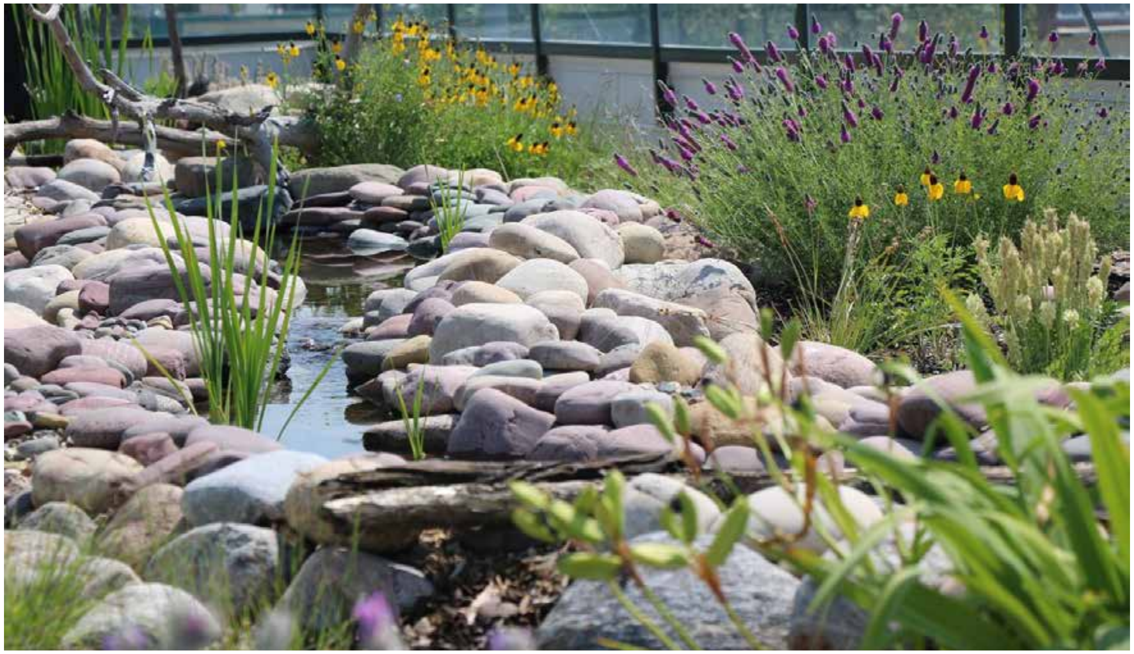
Shading

- Fewer sun related health issues (cancer, heat stress)
- Cooler, more enjoyable public and private spaces

Improvements to Building Envelope Longevity

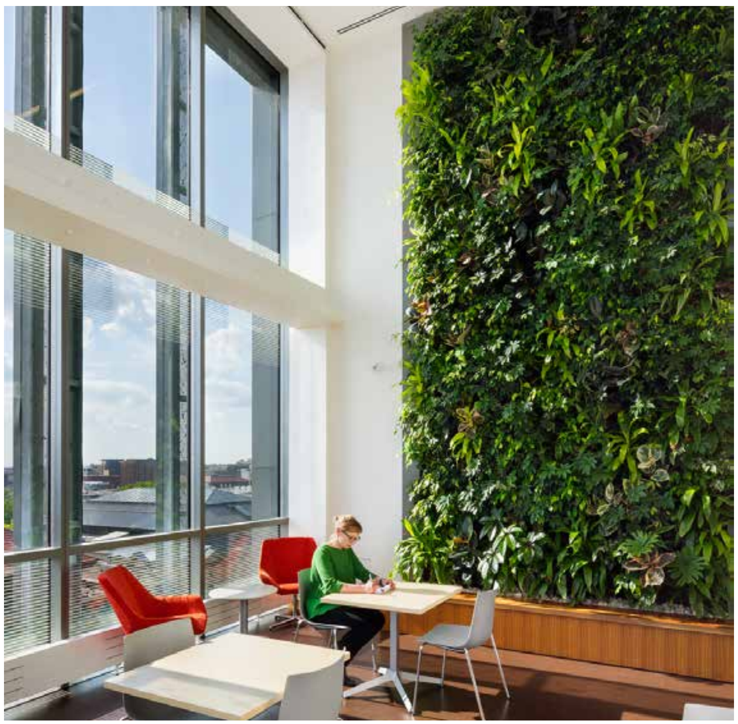
- Reduction in landfill waste
- Replacement cost savings on public buildings

Urban agriculture can improve community cohesion and bring health benefits, along with providing environmental function. Source: Linda on Flickr (CC)



Green infrastructure can reduce noise and bring biophilic sounds like running water into our communities, like this green roof on the Berry Architecture Office. 2015 GRHC Award Winner: Berry Architecture & Associates

Some types of green infrastructure, like this green roof on the KU Health Education Building, can reduce energy consumption. 2019 GRHC Award Winner: Jeffrey L. Bruce & Company



Green infrastructure can be integrated with other building systems, like the HVAC system at Weiser Hall. 2018 GRHC Award Winner: Diamond Schmitt Architects and Nedlaw Living Walls

Improved Biodiversity

- Educational/urban nature experiences
- Carbon sequestration by protecting migratory birds which support boreal forest growth
- Pollination by insects, particularly bees
- Beauty and improved recreation opportunities, such as bird watching

Incorporation of Green Products and Systems

- Improved markets for green products
- Improved markets for compost and recycled aggregates
- Lower energy intensity in the overall system
- Improved conservation of water resources

Private Benefits

- Energy savings due to reduced demand for heating and cooling from evapotranspiration and reduced heat flux through building envelopes
- Savings associated with longevity increases to waterproofing and building envelope materials
- Reduced need for on-site stormwater management equipment like storage vaults, detention basins, sand filters, pipes, catch-basins, etc.
- Reduced stormwater or impervious surface fees
- Improved property values related to better visual amenity, accessible amenities, and noise attenuation
- Improved patient recovery in hospitals
- Improved academic performance in schools
- Integration with the site for better overall stormwater management and re-use
- Improved public relations/community relations and potentially faster project approval times
- Improved rentability, saleability of properties and units
- Helps achieve certification in LEED, SITES, Living Building Challenge, and other green building certification systems
- Integration with other building systems, such as mechanical systems and solar photovoltaic panels for better energy efficiency and generation
- Biophilic related benefits resulting in reduced absenteeism, improved staff retention, and better job performance

Climate Adaptation

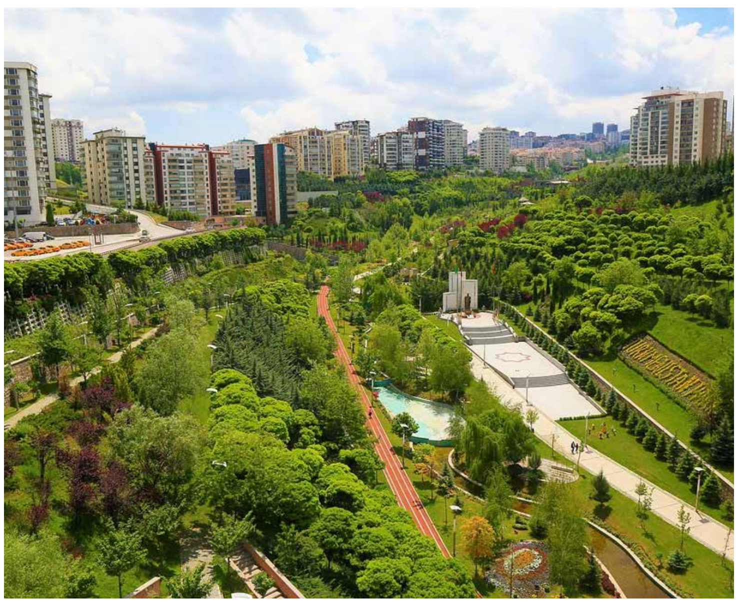
Why is green infrastructure ideal as part of a climate adaptation strategy?

Green infrastructure's characteristics make it well suited to be part of a climate adaptation strategy:

- **Flexible and adaptable**: green infrastructure can be adapted to meet the local requirements of communities. For example, a constrained and dense community could focus on high impact investments that do not require large amounts of land like green roofs or street trees planted in soil cells; a community that has issues with nutrient loading in its water bodies could focus on plants that have a proven ability to absorb excess nutrients.
- **Higher employment to capital ratio**: compared to grey infrastructure projects, which typically require a large portion of costs to be spent on materials and machinery, green infrastructure spends more on people. This makes it an ideal part of a 'just transition' away from fossil fuels, and a potential avenue of work for retrained workers and those new to the workforce.
- **Decentralized**: green infrastructure projects tend to be decentralized, with many projects working together as part of a network. A grey infrastructure approach typically contains critical elements essential to the functioning of the entire system, like a water treatment plant or pumping station. In contrast, green infrastructure's decentralized nature means that parts of the system not functioning has a much smaller effect on the functioning of the system as a whole.
- **Shorter implementation period**: grey infrastructure projects like water treatment plants or storage tunnels are typically expensive (often costing in the billions), and require long planning, design, and construction phases. Green infrastructure projects, like a rain garden or a street tree, on the other hand, can be rapidly and incrementally implemented due to their decentralized nature.
- **Function improves over time**: unlike most forms of grey infrastructure, which have a finite lifespan and that degrade in performance and function over time, many forms of green infrastructure actually get more effective over time. As vegetation matures, soil biology improves, and ecosystem succession occurs, green infrastructure can actually improve its function and appreciate as an asset.

Dense urban areas could use otherwise wasted rooftops to help adapt to climate change using green roofs. Source: ceetap (CC)

Green infrastructure projects, like this rain garden, can be part of decentralized networks. Source: Rictor Norton and David Allen (CC)



Greener and more livable cities could facilitate public support for climate adaptation. Source: Pixabay

- **Requires little to no energy inputs**: green infrastructure relies largely on solar energy in the form of photosynthesis to provide its functions. The use of external energy inputs is minimal when compared to the requirements of grey infrastructure projects.
- **Climate change mitigation benefits**: while creating the conditions for more resilient communities, green infrastructure also sequesters carbon in plant biomass and soils, while also reducing energy use directly (through lower building and infrastructure emissions), and indirectly (by reducing the urban heat island), providing climate change mitigation benefits in the process.
- **More livable communities**: improvements to the aesthetics of communities, as well as the introduction of new recreational spaces and facilities could increase public support for action on climate adaptation. By improving communities in tangible and easily apparent ways, elected officials could reduce the push-back often present against climate policy.

Principles for the successful implementation of green infrastructure

After investigating many green infrastructure initiatives underway across North America, we have identified a common set of principles for incorporating green infrastructure into government and private sector planning processes. These principles highlight the importance of including green infrastructure to complement our traditional grey infrastructure, placing more emphasis on the life-support functions provided by natural ecosystems and how to re-establish those functions in the built environment:

- **Early incorporation**: green infrastructure should be incorporated into longer-range plans at the beginning of the planning process, rather than the end. Green infrastructure can also be incorporated into short-range plans in conjunction with annual budget cycles.
- **Appropriateness**: the choice of technologies and material used should be appropriate for the users' needs, and the environmental and social context. High quality resources, such as drinking water, should be matched with the most demanding uses.
- **Scale effects**: green infrastructure should be thought of on multiple scales, from individual buildings, to the building and the site, to clusters of buildings, neighborhoods, communities, and at a macro scale, watershed, sewershed, region, and airshed. Many benefits, such as improved air quality, are only attainable by implementing individual green infrastructure projects to reach a larger scale.
- **Decentralization**: green infrastructure solutions lean towards the establishment of many smaller decentralized projects rather than a few large centralized ones. Decentralized projects

tend to be more responsive to local conditions and give rise to more adaptable systems.

- **Protection and regeneration**: protect and maximize the use of existing green infrastructure resources (i.e., existing wetlands, ravines, parks, and street trees) and regenerate and restore degraded systems where possible.
- **Reinforce natural processes**: use green infrastructure to strengthen local ecological processes rather than replace these processes. For example, bioswales contribute to stormwater runoff that mimics natural groundwater infiltration regimes.
- **Involvement and engagement**: involve all stakeholders in the process of developing green infrastructure strategies and plans. Provide support to low income stakeholders to support their participation.
- **Multifunctional**: support integration and interaction of different functions on the same site and across the entire green infrastructure network as a whole. For example, an urban forest can provide biomass to generate energy or be used to create furniture, in addition to its other benefits.
- **Create social amenities**: green infrastructure can add value to the communities they serve and society as a whole. For example, stormwater management retention ponds and swales can contribute to the biological diversity of the landscape and serve as parks and passive recreation areas.

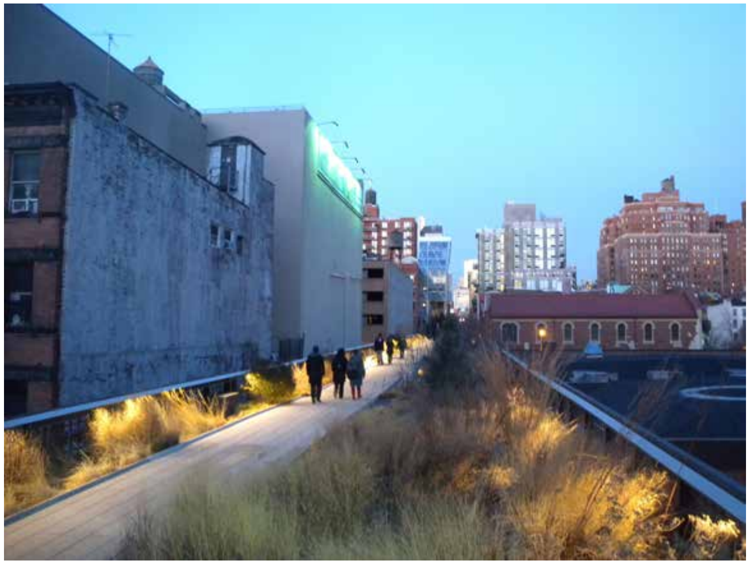
Green infrastructure works best when natural process are reinforced, not replaced - this restored wetland helps to reinforce natural hydrology. Source: Loozrboy on Flickr (CC-2.0)

Best Practices for the Use of Green Infrastructure for Climate Adaptation

We have identified a number of best practices to:

- Maximize the impact of green infrastructure
- Allocate funding in cost-effective ways
- Increase the resilience of both green infrastructure assets and communities at large
- Achieve other social, economic, and environmental goals, like more livable communities, just transitions for workers in fossil fuel industries, improved air and water quality, etc.
- Leverage public support and private investment

These best practices are:



The High Line in New York City is an example of green infrastructure that is also a well-loved social amenity. Source: Jim Henderson (CC-1.0)

Improving existing green spaces is a cost-effective green infrastructure approach. Source: US Fish and Wildlife Service

Depaving streets to increase the amount of permeable paving is an excellent way to increase resilience while improving the urban environment. Source: Crosscut

Improve and Expand Existing Green Spaces Where Possible

Urban green spaces provide a number of benefits environmentally, socially, and economically to areas where they exist and are properly maintained. In addition to enhancing an area's perceived aesthetics, green spaces provide a number of benefits including improved air quality and decreased air and surface temperatures, in turn reducing respiratory diseases and heat related distress and deaths (Salmond etc., 2016). Finally, urban green spaces can help provide a number of ecosystem benefits, such as increasing precipitation infiltration capacity, stormwater filtration (Farrugia, Hudson & McCulloch, 2013), and carbon sequestration (Demuzere et al., 2014). These benefits translate into financial savings through reduced healthcare costs (Wolch, Byrne & Newell, 2014) and weather and climate related infrastructure damages (Gill, Handley, Ennos & Pauleit, 2007)

The benefits of urban green spaces are increasingly important as climate change progresses. Precipitation events and droughts will become more severe, requiring appropriate water storage and air and surface temperature controls (Demuzere et al., 2014; Trenberth, 2011). Inner-city temperature highs will worsen, decreasing quality of life for inhabitants and increasing temperature related mortalities (Patz, Campbell-Lendrum, Holloway & Folly, 2005). Agricultural production will become increasingly strained as weather related crop failures ravage farms around the world.

As the space required to build new green spaces is limited in many developed urban areas, fitting green spaces into the urban landscape is an opportunity for many municipalities (Gill, Handley, Ennos & Pauleit, 2007). Acquiring new land for the development of green spaces is both challenging and costly. Additionally, it may be in the interest of a municipality to ensure vacant land is repurposed for uses such as housing and economic growth, further limiting the viability of new green spaces. In many cases, building upon and improving existing green space will provide sufficient benefits, at a much lower cost. This can be done through urban park revitalization projects, improving green spaces on municipality owned property, green roof and wall bylaws, and other innovative approaches.

Make City Streets "Green Streets"

Many streets feature significantly more paved areas than their use demands. Reducing the amount of paved area can reduce maintenance costs, while providing significant benefits. There are a number of different surface and green infrastructure types that can be used in lieu of concrete or pavement, depending on the climate, location, and goal. Regardless of the geographic location, increasing the amount of greened area on a municipality's streets can also be generally politically neutral, when implemented and maintained correctly (Matthews, Lo & Byrne, 2015).

Green infrastructure can provide benefits such as carbon sequestration, rainwater capture and storage, and a reduction in the urban heat island. When implementing street trees, municipalities should be aware of the desired species' climate and space requirements, using primarily native trees. Road and sidewalk conditions should also be considered in street tree design. Factors such as heavy metals and the use of road salt can significantly impact the trees, even resulting in tree failure, if runoff is too heavily polluted and able to permeate the tree soil.

Rain gardens are useful for the capture and treatment of stormwater, which is important as cities are faced with increasingly severe precipitation events. Rain gardens can help to alleviate the pressure on local stormwater treatment facilities, particularly in older municipalities with combined sewer systems. Rain gardens are also easily scaled up or down, and can help improve aesthetics and urban biodiversity. Bioswales can serve multiple purposes, some of which alleviate the problems caused by climate change such as excessive stormwater and extreme temperature highs. Bioswales are also useful for increasing street safety through traffic calming measures.

Greened streets can be promoted through updated public policy, enforcing street greening measures when publicly used sidewalks and roads are designed by private developers. Municipalities themselves can also incorporate street greening into redevelopments or repairs of roads, sidewalks, and parks.

Green Transportation and Utility Corridors

Transportation and utility corridors are essential for moving people and goods within and through urban centres. These corridors are marked by poor air quality, and very low surface permeability. Integrating green design into transportation corridors including highways, rail lines, multi-use trails, sidewalks, and roads can help to reduce air and water quality issues associated with these types of infrastructure. Utility corridors are often greened, but are functionally limited, featuring low-biodiversity lawn. Cities can improve the appeal and safety of transportation corridors by introducing new and varied vegetation such as trees, gardens, hanging or stationary planters, green roofs, and green walls. Utility corridors could be improved by introducing native meadow and prairie vegetation, rain gardens, and community gardens. Greened transportation and utility corridors can also act as migration corridors, linking patches of habitat and facilitating migration between patches for fauna.

Create Multi-Functional Spaces

Municipalities can find opportunities to create multiple functions in new and existing spaces as a way to further integrate green infrastructure into the public realm (Garvin, 2008). Many spaces including parks, sports fields, basketball courts, skate parks, public stages, golf courses, parking lots, and roofs can be designed for multiple functions. If designed properly, many of these public spaces can be designed to accumulate and store stormwater in times of heavy precipitation, and even be

Roads and utility corridors make excellent linear green corridors. Source: Ralf Treinen (above), Toronto Region Conservation Authority (below)

Green infrastructure can be created in multi-functional spaces that can be used for recreation in dry weather, but provide flood storage in extreme weather. Source: Ramboll

Both community-based and commercial urban agriculture projects can increase resilience, reduce food transportation costs, and provide access to fresh food in urban areas. 2017 GRHC Award Winner: Recover Green Roofs

designed to flood to preserve and protect higher-value uses like buildings and vital infrastructure and transportation corridors.

Greened areas of streets, parks, and recreational facilities - which in times of normal weather conditions provide recreational and resting space for pedestrians - can serve as water management areas during extreme rainfall events (Bassolino, 2019). There are a number of notable examples of this type of planning from around the world, such as the Watersquares in Rotterdam, Copenhagen's Cloud Burst Plan, and China's Sponge Parks.

Support Urban Agriculture

Climate change is expected to significantly impact the agricultural sector, increasing variability in weather and reducing the reliability of harvests (Satterthwaite, McGranahan & Tacoli, 2010). As climate change affects rural agriculture, the effects will be felt by cities, which rely on the productivity of farms and the food they produce. One way to reduce the dependence cities have on rural agriculture, is to introduce urban farming. Urban farming not only helps cities adapt to climate change, but can help to mitigate climate change as well. Additionally, it can help to alleviate economic pressures for low income residents, and low income municipalities in general. Urban agriculture, when community-based, can increase access to fresh produce, and decrease the cost of food for those who participate (Lwasa et al., 2014; Zezza & Tasciotti, 2010). This helps to build upon environmental equity and justice, areas critical to successful climate adaptation.

Municipalities can promote and progress urban farming by creating designated plots of community gardens, either through re-greened space or existing green space. Alternatively, publicly-owned buildings could have their rooftops retrofitted to support functioning urban farms. Green roof incentive policies are also excellent tools to encourage other property owners to start farm-ready green space on their roofs. Grants or tax incentives can also encourage property owners to convert underused land to community gardens, whether permanently or on a temporary basis.

To ensure that environmental and social equity is maintained, municipalities should exercise caution and careful planning when designing urban farming initiatives in low-income communities. Research has suggested that without proper protections, initiatives such as community gardens can lead to neighbourhood gentrification, inevitably barring the low-income community from the neighbourhood in which the programs were implemented for them. Community engagement and appropriate rent protections are good first steps in preventing these outcomes (Wolch, Byrne, & Newell, 2014).

Use Hardy Vegetation Adapted to Your Climate Zone

It is important that municipalities plan their green infrastructure for their climate zone and the weather they experience. Municipalities interested in taking on new green infrastructure installation or expansion projects should understand which types of vegetation will thrive in their climate zone before beginning project plans. As climate change alters the natural landscape, climate zones will shift and change the requirements of vegetation which can survive in certain areas (Burley, Beaumont, Ossola, Baumgartner, Gallagher, Laffan, & Leishman, 2019). Municipalities should ensure that they are also planning for these shifting climate zones, and use a climate zone vegetative palette suitable for the climate and weather they will experience in the future. This can be done in partnership with universities, research centres, or non-profit organizations specializing in local horticulture. Standardized lists of acceptable species in green infrastructure projects can be created to reduce the burden of choosing vegetation on future developments, public or private.

Design for Biodiversity and Resilience

Diversity and redundancy in nature is essential for resilience against possible threats such as disease, pests, and weather (Ahern, 2013). Municipalities can design for diversity and resilience by using a wide range of plant species to minimize the impact of these threats. This can include using plants of a range of species, families, forms, and types in a design, or designing an area to host a number of different fauna. This sort of biodiverse design can help to create a robust and resilient ecosystem in communities, attracting a wide range of pollinators including birds and other beneficial insects.

Achieve Environmental Justice Goals Through Green Infrastructure

Municipalities must deploy green infrastructure which achieves environmental justice goals and make low-income communities more resilient. This is an important goal as low-income communities often feature a below average tree canopy, limited access to parks, a greater urban heat island, and degraded air and water quality. These populations are also less likely to have access to air conditioning. Additionally, vulnerable populations like the elderly, children, pregnant women, and people with respiratory illnesses are especially vulnerable to climate impacts like increased instances of extreme heat, poor air quality, and increased concentrations of ground-level ozone.

Trees, green roofs, and other forms of green infrastructure can reduce the urban heat island, provide building energy savings, improve air quality and noise pollution, and therefore and improve the health and well-being of residents. Caution must be exercised when deploying these initiatives as studies

Using a wide variety of plants that support pollinator habitat can help improve biodiversity and resilience of green infrastructure projects. Source: pxfuel (CC)

The PowerCorpsPHL program provides green infrastructure job training through environmental stewardship to at-risk youth and individuals transitioning out of incarceration in Philadelphia, and features a 92% successful transition rate. Source: PowerCorpsPHL

suggest that increasing access to green space can lead to gentrification which pushes the people for whom the initiatives were implemented out of their communities. Community engagement and appropriate rent protections are good first steps in preventing these outcomes (Wolch, Byrne, & Newell, 2014).

Incorporate Job Training and Workforce Development into Green Infrastructure Plans

Climate plans can, if not properly thought out, leave workers behind. Luckily, climate change mitigation and adaptation measures such as the implementation of green infrastructure requires many jobs in installation and maintenance. These jobs typically pay a living wage, are meaningful, and do not require advanced educational qualifications. Tying job training and workforce development programs to green infrastructure investment can help achieve a just transition to a low-carbon economy, while supporting valued skilled-workers.

Green infrastructure job training and workforce development can also provide paths to employment for marginalized groups like at-risk youth and incarcerated individuals. Programs like PowerCorpsPHL (in Philadelphia), and a partnership between Cook County and the Chicago Botanic Garden (in Chicago) have demonstrated recidivism rates and successful outcomes.

Shift Paradigms

To best use the resources at hand, a shift in perspectives is required. Building practices that prevailed through the 20th Century and encouraged human dominance and control over nature must be reconsidered. In the case of stormwater, municipalities must begin to perceive it as a water resource, rather than issue, particularly as droughts and water scarcity become more common.

Green infrastructure can be used to mimic natural hydrology for the purposes of capturing, filtering, and storing stormwater for human use. There are other resources available that may be under-utilized or not utilized at all. Rainwater harvesting can be used to recharge aquifers where applicable (Nachshon, Netzer, & Livshitz, 2016). Additionally, many municipalities are crossed with buried rivers and waterways, which if daylighted could provide significant recreational and natural benefits. Another technique for coastal municipalities or those near large bodies of water is to vegetate and naturalize areas prone to flooding. This will require a shift from developing homes and businesses in these areas, and instead zoning them for beaches, parks, wildlife preserves, and other recreational purposes. The enhancement and vegetation of these and other natural areas will help to build healthier communities that are mitigating and adapted for climate change.

Value Green Infrastructure as Assets

To build the case for green infrastructure, municipalities should incorporate green infrastructure and natural assets into asset valuation and management frameworks. Research suggests that if insurance value is factored in the decision-making matrix—as ecological economics theory suggests it should—levels of ecosystem resilience that secure long-term conditions to sustain human health and well-being are more likely to be achieved (Green, Kronenberg, Andersson, Elmqvist, & Gomez-Baggethun, 2016). Proper valuation can stimulate investment in green infrastructure and help restore urban ecosystems while increasing their resilience to climate change.

Engage the Public

There is still additional work to be completed by municipalities and other levels of government to educate the public and ensure informed acceptance of green infrastructure projects. This is the case as demonstrating the benefit of green infrastructure allows for public acceptance to propel the industry forward. Methods of achieving this goal include the incorporation of green infrastructure learning into public schools to increase acceptance and knowledge among youth, outreach programs, special events celebrating green infrastructure, and the cultivation of champions among the public.

To progress, public policy needs public backing. In the case of climate change mitigation and adaptation, the community must see the benefit of the action to their own community before they can be expected to back it. Barriers to landscape and architecturally based tools for action on climate change include perceptual gaps that still exist in connecting climate change to people's personal lives. A method of engaging community members in understanding climate change impacts is by allowing them to better see it impact their own community. In essence, the visualization of climate change allows people to witness first hand the actual effects of climate change, making it a tangible problem

Engaging and educating the public is an important step to build support for green infrastructure and climate adaptation strategies. Source: 12,000 Rain Gardens in their lives. This is meant to build capacity for climate change planning through public knowledge and acceptance (Sheppard, 2015).

There are a number of methods that could be used to help visualize climate change and its causes. Some examples include labels on buildings noting their GHG emissions, public ponds and fountains which use underwater terraces to demonstrate sea level rise over time, or other installations of art or greenery depicting forest dieback, or species change (2015).

Leverage Private Sector Investment

Various policy instruments can be used to encourage these types of infrastructure in private development. Tax incentives or bylaws are examples of tools that would direct developers to introduce street greening to their plans. Municipalities can establish public private partnerships to implement green infrastructure pilot projects. This includes the development of mechanisms, markets, policies to encourage the private sector to build more green infrastructure. They can also use policies like impervious surface fees, development charges, on-site stormwater management requirements, or credit trading programs to turn public benefits into measurable private revenue streams (United States Agency for International Development, 2018).

There are also a number of monetary incentives available to municipalities to achieve these aims. Municipalities can use green bonds and other financial instruments to leverage private sector investment into green infrastructure. There is also the option to provide incentives for the private sector to develop green infrastructure as part of new developments and redevelopments (United States Agency for International Development, 2018).

Resources for green infrastructure policy making:

Green Infrastructure Foundation (2018). Introduction to Green Infrastructure: Principles, Applications and Policies (Online Training Course).

United States Environmental Protection Agency (2010). Green Infrastructure Policy Guides

Natural Resources Defense Council (2013). Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows.

Metcalf Foundation (2013). Incenting the Nature of Cities: Using Financial Approaches to Support Green Infrastructure in Ontario.

Georgetown Climate Center. Green Infrastructure Toolkit.

About this Program

Our experiences in the green infrastructure sector have shown that municipalities across Canada face many of the same issues: aging water infrastructure, vulnerability to surface flooding, increasing severity of weather events, increasing urban heat islands, and a lack of capacity to use green infrastructure to address these challenges. Capacity building is a proven strategy to help municipal stakeholders to address issues in areas they may not have the necessary expertise or resources to do so.

While the lessons learned and the resources developed are unique to each community we worked with, the findings can be scaled up and are relevant across Canada and beyond. Almost every municipality in Canada and beyond is facing some combination of the above issues, and lessons learned in partner municipalities could easily be adapted to the broader municipal sector.

Our program consisted of four broad elements:

- The development of two training courses: *Green Infrastructure Policies, Application, and Case Studies*, and *Valuing the Benefits of Green Infrastructure: Principles and Methods*, and its delivery to municipal staff and other stakeholders.
- Six Green Infrastructure Charrettes, where city staff and other experts redesign sites with green infrastructure.
- Aggregate cost-benefit analyses based on methods and tools developed by us.
- This report, which combines visuals generated through the charrettes with cost-benefit analyses of the redesigns, along with best practices for using green infrastructure to adapt to climate change and leverage its many other benefits.

The goal of this program is to build capacity in the municipal

Source: Green Infrastructure Foundation sector to use green infrastructure to address adverse climate change impacts. Municipal staff will gain knowledge, skills, and resources to value, create policy for, and implement green infrastructure.

Training Courses

Two training courses were developed, and stakeholders from municipal partners participated in a full-day training program that incorporated both courses. Courses are available online, on-demand at livingarchitectureacademy.com.

Introduction to Green Infrastructure: Principles, Applications, and Policies

Green infrastructure means natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure can include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs. Green infrastructure use is widespread across the US and Europe, but capacity in Canada to use, create policy for, incentivize, and apply green infrastructure is limited. This course is designed to build this capacity in the public and private sector by introducing green infrastructure through its types, benefits, principles, applications, and successful policies.

Learning Objectives

- Understand the range of possible benefits using green infrastructure
- Learn the principles behind incorporating green infrastructure into community building projects
- Understand the various elements and functions of green infrastructure
- Understand the barriers to green infrastructure implementation
- Understand the planning process designed to develop a comprehensive green infrastructure planning and implementation strategy
- Learn about successful policies implemented in other jurisdictions

Source: Green Infrastructure Foundation

Valuing the Benefits of Green Infrastructure: Principles and Methods

The benefits of green infrastructure (like urban trees, rain gardens, and green roofs) are well known, but difficult to value. This difficulty creates an obstacle, where green infrastructure is often not considered when making important investment and asset management decisions. The goal of this course is to help individuals, especially those in the public sector, to value the benefits provided by green infrastructure in their communities.

Learning Objectives

- Understand the range of cost & benefits possible using different types of green infrastructure
- Learn the principles behind economic valuation of these costs & benefits
- Understand the methods used to monetarily value the benefits of green infrastructure
- Learn how to apply these methods to generate values for the benefits of planned and existing green infrastructure in your community
- Learn how to utilize these valuations to educate decision makers about the benefits of green infrastructure protection, development, maintenance and management

Courses were delivered to a total of almost 150 stakeholders in our six partner communities: Barrie, Brampton, Guelph, London, Toronto, and Waterloo. Stakeholders included:

- Municipal staff from various departments (Parks, Planning, Forestry, Public Works, Water, Engineering, Development Services, Transportation, Environment, Facilities, etc.)
- Private sector representatives like developers, architects, landscape architects, engineers, etc.
- Staff from Conservation Authorities
- Representatives from non-profit organizations engaged in environmental programming in and around our partner communities

Green Infrastructure Cost-Benefit Matrix

The Green Infrastructure Cost-Benefit Matrix is a tool that allows for an aggregate-level economic analysis to be conducted. It includes two costs and ten benefits for ten different types of green infrastructure.

Costs and Benefits

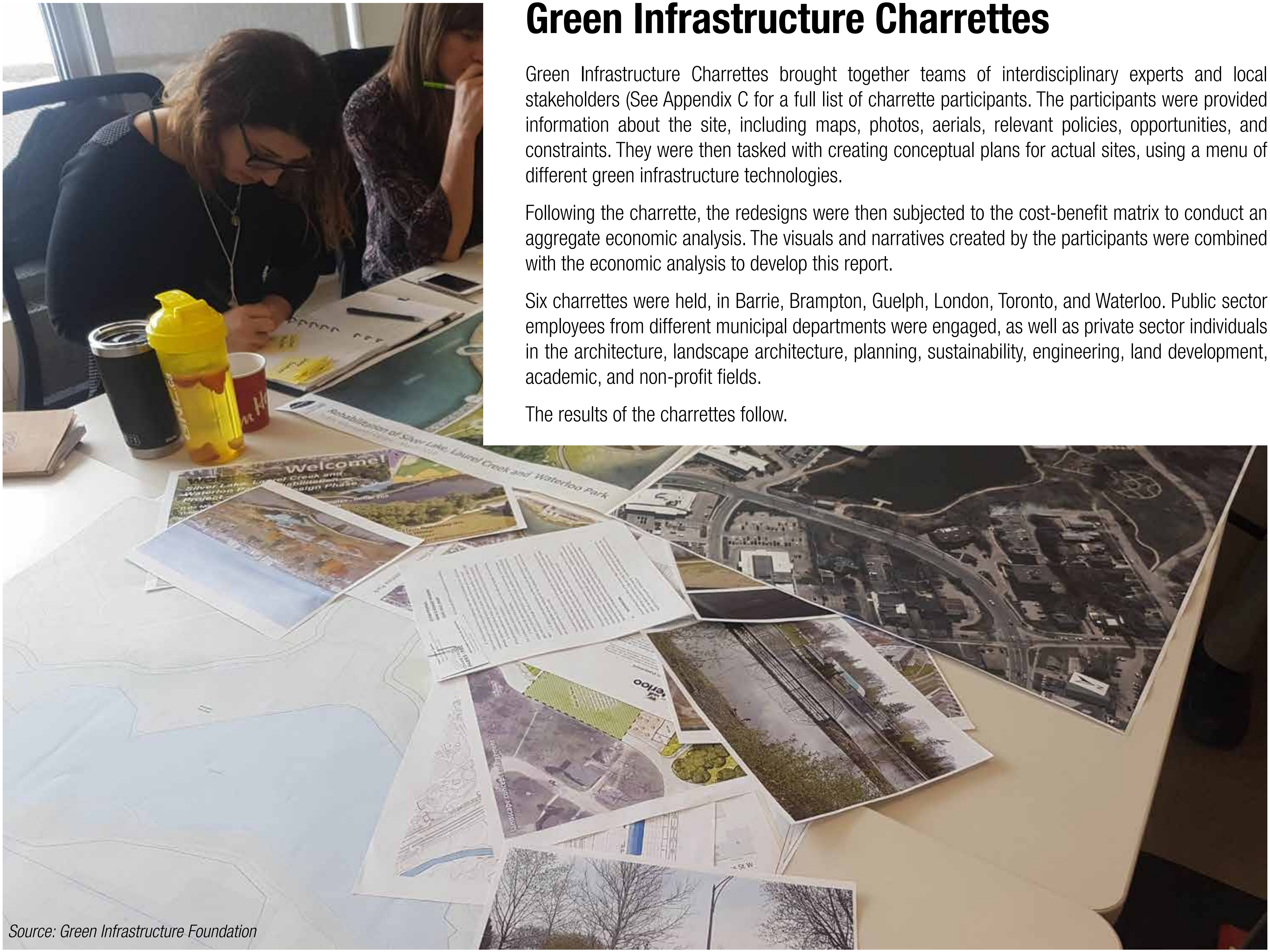
- Construction Cost
- Maintenance Cost
- Stormwater Management
- Urban Heat Island Reduction
- Energy Savings
- Air Quality Improvements
- Creation of Habitat/Biodiversity
- Greenhouse Gas Sequestration
- Increase in Roof Lifespan
- Food Production
- Construction Jobs Created
- Maintenance Jobs Created

Types of Green Infrastructure

- Trees (Small, Medium, and Large)
- Rain Gardens/Bioretention
- Bioswales
- Green Roofs (Extensive and Intensive)
- Green Walls (Green façades, Interior and Exterior Living Walls)
- Wetlands
- Planting Beds
- Lawn/Turf
- Meadows/Grasslands
- Permeable Paving

The matrix is an aggregate-level tool - meaning it is not designed to analyze a specific project, but to start a discussion and support further study. It has many limitations - the largest one is that many benefits are not monetized, leading to a very cautious analysis.

These include improved health, reduced grey infrastructure, and more - all benefits that could have a large impact at scale. For more information about the green infrastructure cost-benefit matrix, including the methods used to derive values, the assumptions behind the analyses, and its limitations, see Appendix A.



Source: Green Infrastructure Foundation

Green Infrastructure Charrettes

Green Infrastructure Charrettes brought together teams of interdisciplinary experts and local stakeholders (See Appendix C for a full list of charrette participants. The participants were provided information about the site, including maps, photos, aerials, relevant policies, opportunities, and constraints. They were then tasked with creating conceptual plans for actual sites, using a menu of different green infrastructure technologies.

Following the charrette, the redesigns were then subjected to the cost-benefit matrix to conduct an aggregate economic analysis. The visuals and narratives created by the participants were combined with the economic analysis to develop this report.

Six charrettes were held, in Barrie, Brampton, Guelph, London, Toronto, and Waterloo. Public sector employees from different municipal departments were engaged, as well as private sector individuals in the architecture, landscape architecture, planning, sustainability, engineering, land development, academic, and non-profit fields.

The results of the charrettes follow.

Barrie

Site Background

The “Dunlop Community Hub” consists of an area generally located along Dunlop Street between Innisfil Street and Bradford Street.

The City of Barrie’s vision for the west end of Downtown is one of mixed use that reinforces diversity of people but also built form and activity/programs. Council’s support for the Fisher Auditorium and Event Centre concept reinforces this vision by providing the cornerstone for a creative district. Facilitating relocation of the YMCA to the area further supports a community hub component. There may be additional social entrepreneurship synergies that emerge as this area develops. The addition of approximately 600 rental apartment units through the proposed HIP development will put more eyes on the street and also provide an important population base to support the overall vibrancy, street front commercial and creative uses envisioned for the area. This will be a tangible example of public, private and community organizations working in partnership to bring a vision to life.

As both a gateway location into Downtown Barrie and a natural extension of/to the Waterfront, staff envision a convergence of high quality site design, inspiring built form with appropriate massing, and innovation in sustainable design – all which will serve to establish the overarching vision of a new creative district and western gateway to our Downtown and Waterfront. The following provides further details regarding the surrounding site context of a number of significant cultural, residential and infrastructure improvements underway or proposed:

Kidd’s Creek Rehabilitation

The Kidd’s Creek rehabilitation project will daylight the creek and restore it to a naturalized state. The project area includes the Knight’s Inn site, as well as a portion of the lot at the south-west corner of Dunlop Street and Bradford Street. A portion of the Knight’s Inn site is also proposed to accommodate some surface parking for the W.A. Fisher Auditorium and Conference Centre.

W.A. Fisher Auditorium and Conference Centre

A signature City of Barrie building project along the Dunlop Street “creative corridor”, the W.A. Fisher Auditorium and Conference Centre will see a portion of the Barrie Central Collegiate building redeveloped into a 650-seat theatre and 400-seat event centre.

Existing conditions: Fisher Auditorium (top) and Knight’s Inn site (above), which is part of the Kidd’s Creek rehabilitation area. Source: Google Maps. Context map (below). Source: City of Barrie

Proposed HIP development rendering and map .Source: City of Barrie)

City-Owned Property with Landmark Development Opportunity

Immediately adjacent to the W.A. Fisher Auditorium to the east, will be a vacant city-owned property, approximately 1 acre, currently being prepared as a development opportunity for market.

Simcoe Street Extension

To support the above developments, an extension of Simcoe Street to Eccles Street is currently being explored. The final design and width is still to be determined.

YMCA

The YMCA will become a centre for the community in its new prominent downtown location. The YMCA will be a gathering with all of the traditional YMCA programming and also providing spaces for community organizations such as Youth Haven and the Royal Victoria Regional Health Centre.

HIP Developments

A private development site with 3 proposed residential rental apartment buildings totaling 600 units.

Dunlop Street East Improvements

In addition to the above, the City will be completing streetscape improvements on Dunlop Street, from Mulcaster Street to Toronto Street by summer of 2020. These improvements will create a flexible street to accommodate pedestrians of all abilities, allow businesses to better utilize the boulevard for outdoor retail and patios, and facilitate the use of the street for major cultural and tourism based events on a temporary basis.

Option A

Principles and Goals

- Using the history of the site as inspiration to encourage a mix of uses and integration of green elements that also highlight educational opportunities.
- Incorporate a tree lined pedestrian path, tree timeline highlighting Barrie Central achievements, to the Prince Edward façade as an outdoor education space with a focus on promoting native species including pollinators.
- Interior living wall visible from inside and outside the building.
- Extend day lighting of Kidd's Creek across Bradford Street to connect with the waterfront including pedestrian connection with natural boardwalk materials, trees and plantings.
- New building opportunity to be incorporated by land swap with redeveloped Dunlop/Bradford roundabout. Roundabout to include rain garden.
- Incorporate community garden at Toronto Street/Simcoe Street on existing vacant site, partial floodplain and Kidd's Creek open channel restoration.
- Collection of rain water in storm cistern for tree irrigation along interior roadways.
- Active transportation focus along green corridors.

Option A concept sketch

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Roof - Extensive	540 m^2
Green Roof - Intensive	160 m^2
Green Facade	700 m^2
Living Wall - Interior	40 m^2
Bioswale	2800 m^2
Rain Garden	36 m^2
Wetland	19,500 m^2
Infiltration Trench	400 m^2
Planting Beds	1,050 m^2
Trees - Small	190
Trees - Medium	110
Trees - Large	20

Cost-Benefit Analysis

- Construction Cost: $1.38 million
- Annual Maintenance Cost: $40,365
- One-Time Benefits: $384,000
- Annual Benefits: $160,000
- Job-years in construction: 24.3 FTE
- Job-years in maintenance: 0.7 FTE annually
- NPV (Net Present Value) over 10 years: $1.65 million
- NPV over 25 years: $5.73 million
- NPV over 50 years: $10.51 million
- Simple Payback Period: 3.7 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

Option B

Principles and Goals

- Achieve community connectivity beyond the scope of hub, with “spokes” to the community. Bring people from outside to the site, facilitating movement between the site and its surrounding neighbourhoods
- Develop a dynamic mix of public and private ownership
- Work within the existing constraints of the site such as existing buildings and soils. The source water protection areas on site also limit the ability to infiltrate groundwater.
- Incorporate a centralized gathering space/ gateway feature that provides a connection to the waterfront.
- Incorporate a cohesive streetscape using building massing and facade treatments, along with trees and green space.
- Minimize the visual impact of parking areas.

N

SCALE (m)

0 25 50 75 100

LEGEND

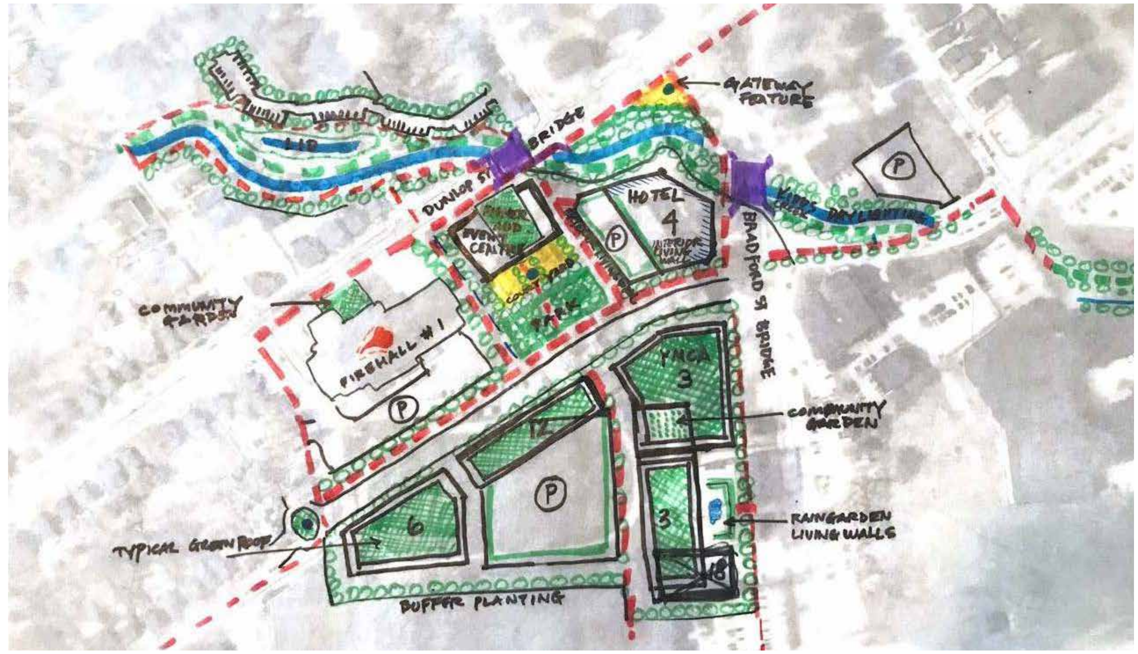
PEDESTRIAN ONLY

ACTIVE TRANSPORTATION

Barrie - Option A Concept

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Roof - Extensive	8,575 m^2
Green Facade	60 m^2
Living Wall - Interior	60 m^2
Bioswale	60 m^2
Rain Garden	150 m^2
Permeable Paving	300 m^2
Planting Beds	1,050 m^2
Lawn/Turf	1,800 m^2
Meadow/Grassland	10,500 m^2
Trees - Small	100
Trees - Medium	100
Trees - Large	180

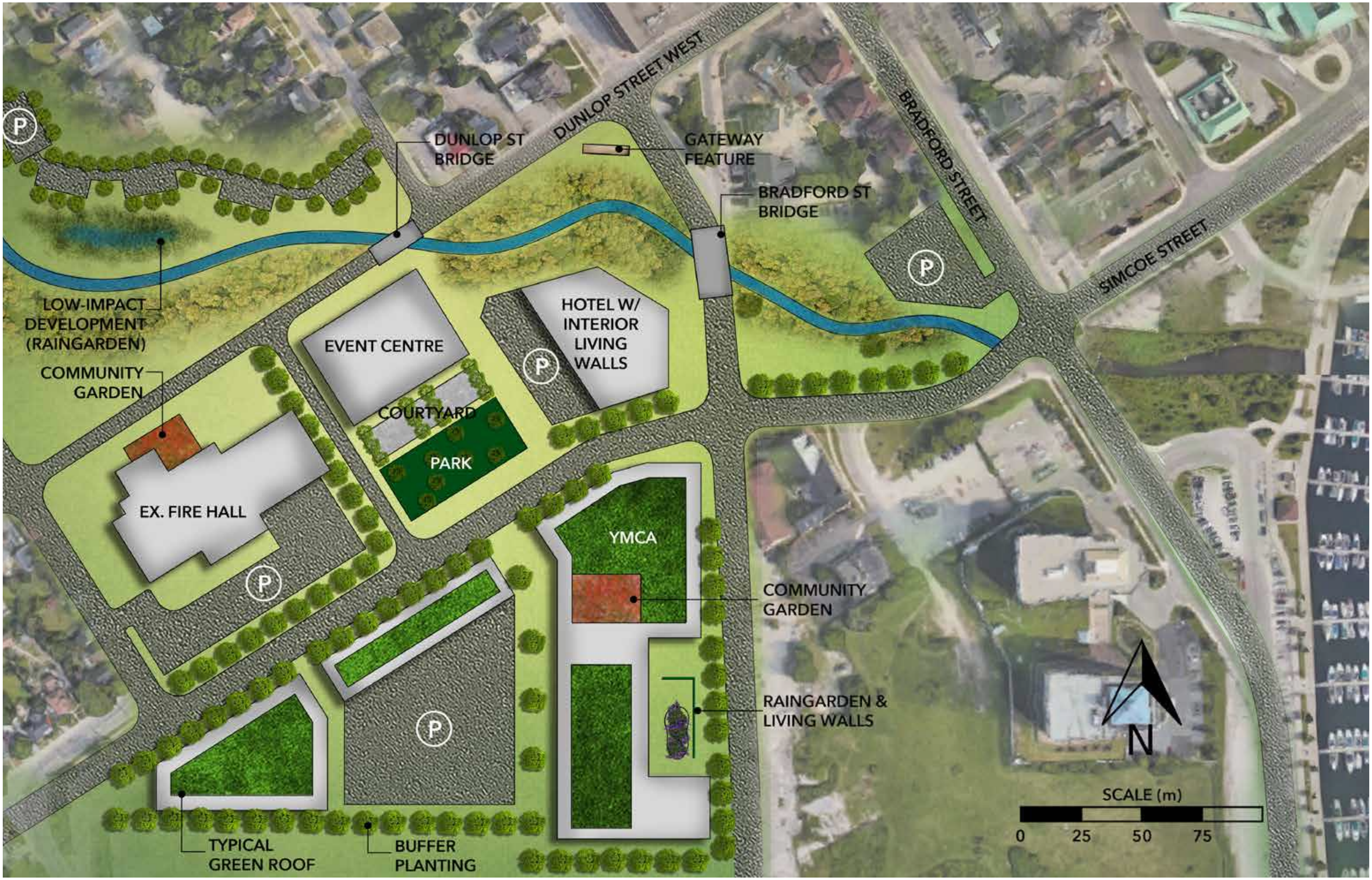


Option B concept sketch.

Cost-Benefit Analysis

- Construction Cost: $2.65 million
- Annual Maintenance Cost: $65,550
- One-Time Benefits: $435,000
- Annual Benefits: $217,000
- Job-years in construction: 46.8 FTE
- Job-years in maintenance: 1.2 FTE annually
- NPV (Net Present Value) over 10 years: $1.35 million
- NPV over 25 years: $7.73 million
- NPV over 50 years: $14.6 million
- Simple Payback Period: 9 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

Option A streetscape concept



Barrie - Option B Concept

Brampton

Site Background

In 2017, Brampton City Council authorized staff to proceed with the purchase of the Riverstone Golf Club, including the clubhouse building and surrounding valley lands.

The Riverstone Clubhouse will be converted to a 34,000-square-foot recreation facility including:

- An updated pool area, including a salt water pool
- Expanded change rooms and fitness rooms
- Several multi-purpose rooms

While the Riverstone Community Centre is intended to serve residents of all ages, there will be an emphasis on programming to meet the needs of older adults. The centre is expected to offer options similar to the Flower City Seniors Recreation Centre, with the additional benefit of aquatics and fitness facilities on site.

The valley lands (formerly the golf course) will be re-naturalized by the City, in cooperation with the Toronto and Region Conservation Authority and the Ontario Ministry of Natural Resources and Forestry, to create a conservation area with recreational trails. This will provide habitat for local wildlife and public trails to encourage active living.

Benefits

The purchase of the Riverstone property will benefit the city in many ways:

- Expanded recreation opportunities for residents on the east side of Brampton.
- Providing valuable new amenities for our growing senior population, including a salt water pool.
- By renovating an existing facility instead of building new, the City will save millions of dollars and years of construction time.
- The new conservation area will provide important ecological benefits, including protecting the West Humber tributary and providing habitat for Redside Dace, an endangered species of fish.
- Recreational opportunities at the centre and on the public trails will help to encourage an active

Existing Riverstone Clubhouse (top), and golf course (above). Source: City of Brampton lifestyle, which is important for the long-term health of our community.

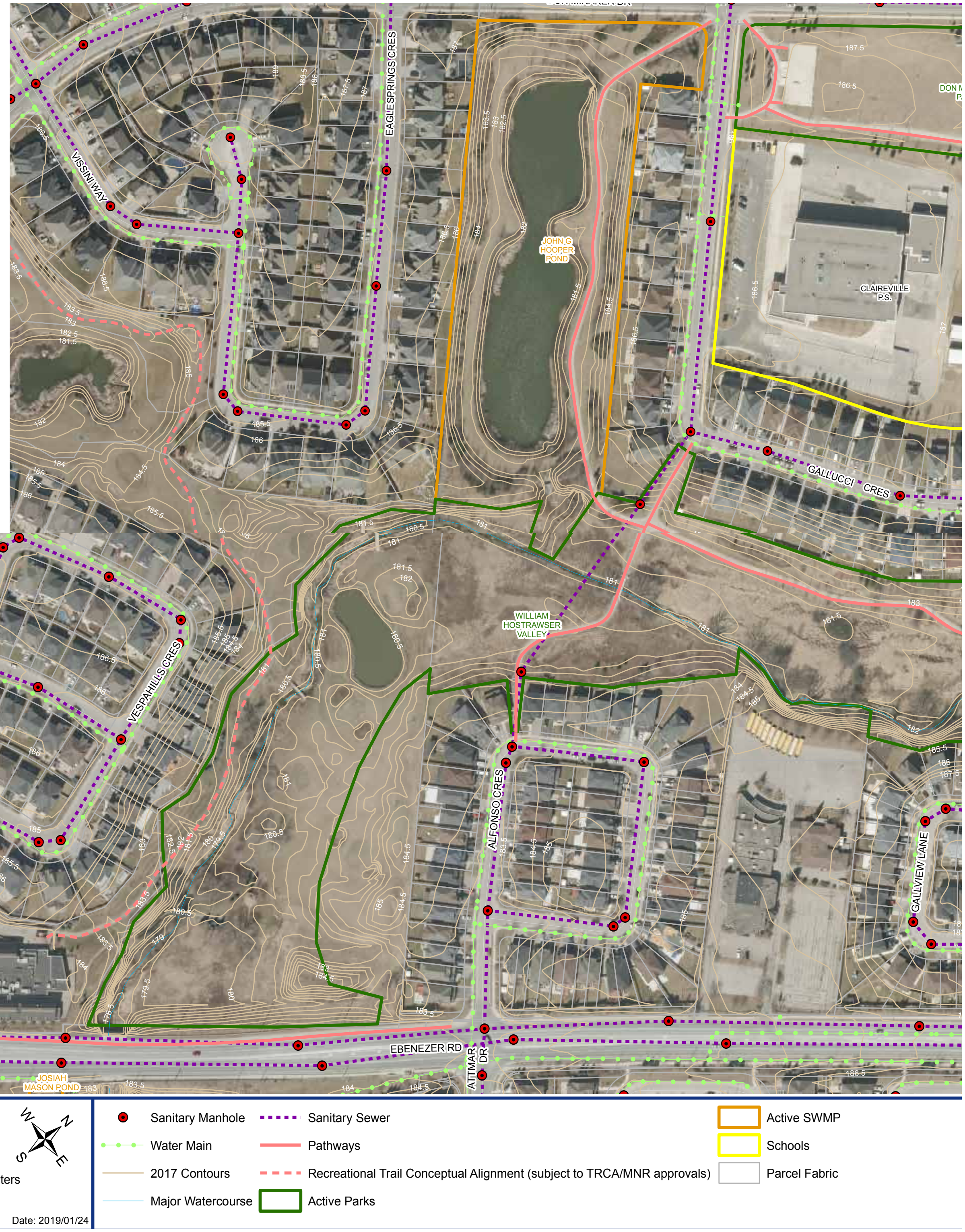
- The multi-purpose trails will provide a new connection with the Gore Meadows Community Park, Claireville Conservation Area and beyond. This will provide important new options for active transportation on the east side of the city.

Principles

- Develop an eco-park, that can connect residents to nature
- Leverage and engage outside residents groups
- Connect with local schools and senior centre to provide intergenerational programming
- Naturalize valley lands to restore a degraded ecosystem
- Increase access from the surrounding neighbourhood

Elements

- Fitness equipment
- Senior center with greenhouse
- Link to Clairville conservation area
- “10,000 trees” forested areas
- Maximize viewsheds
- Green parking lot with bioswales
- Skating rink on irrigation pond
- Educational information
- Pollinator gardens
- Naturalized meadows
- Signage
- Orchard with fruit trees
- Berry patch
- Murals on underpasses – painted by



students
- Facilities/signage at entrances
- Flood/erosion prone areas to be naturalized
- Wildlife area do not disturb
- Outdoor art installation
- Off-leash dog area
- Composting facilities – food waste from community garden, orchard and seniors centre
- Wetland areas in-line with river and linked to stormwater management ponds
- Lookout points

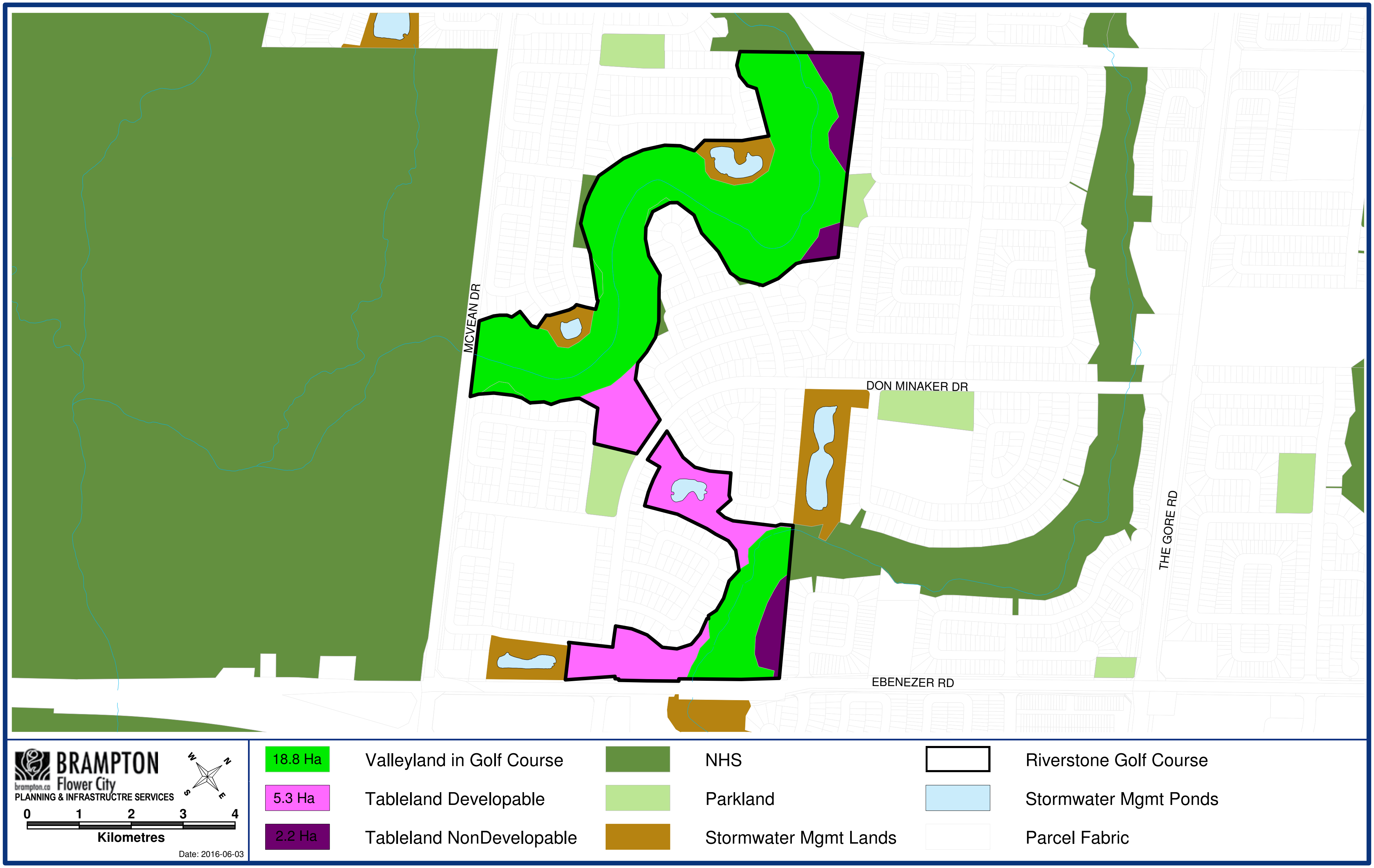
Proposed Green Infrastructure

Type of Green Infrastructure	Area
Bioswale	350 m^2
Wetland	14,400 m^2
Permeable Paving	800 m^2
Planting Beds	2,000 m^2
Lawn/Turf	19,200 m^2
Meadow/Grassland	100,000 m^2
Trees - Small	2,300
Trees - Medium	2,300
Trees - Large	2,300

Cost-Benefit Analysis

- Construction Cost: $5.5 million
- Annual Maintenance Cost: $241,600
- Job-years in construction: 97 FTE
- Job-years in maintenance: 4.3 FTE annually
- NPV (Net Present Value) over 10 years: $5 million
- NPV over 25 years: $15.34 million
- NPV over 50 years: $27.56 million
- Simple Payback Period: 5.6 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

Brampton concept sketch


MCVEAN DR
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Date: 2016-06-03
18.8 Ha
Valleyland in Golf Course
5.3 Ha
Tableland Developable
2.2 Ha
Tableland NonDevelopable
NHS
Parkland
Stormwater Mgmt Lands
Riverstone Golf Course
Stormwater Mgmt Ponds
Parcel Fabric

Brampton - Concept

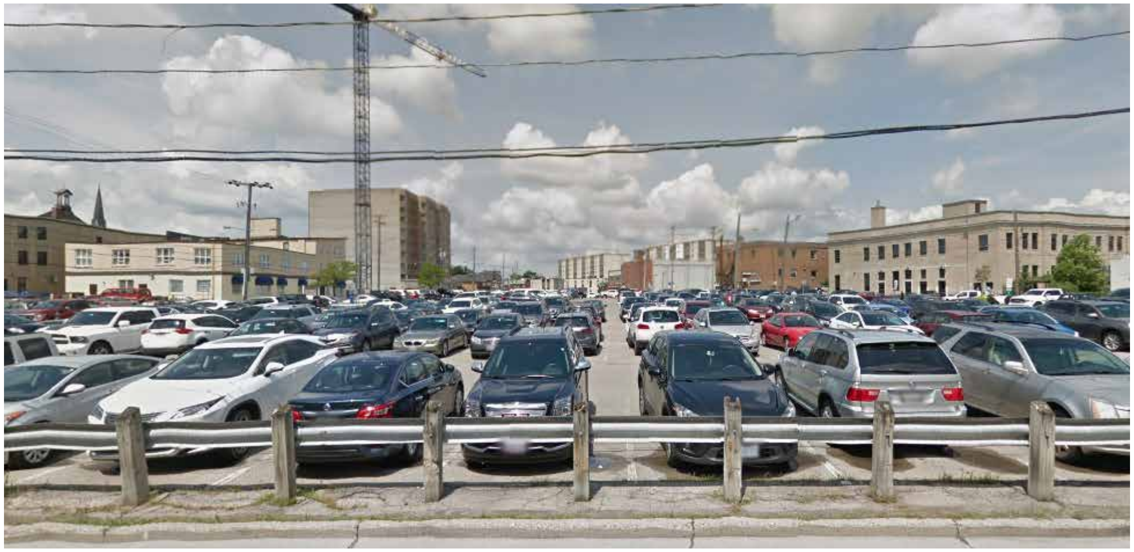
Guelph

Site A - Baker District

Site Background

The Baker District redevelopment is a City of Guelph development project aimed at transforming the existing parking lot and properties fronting the north end of Wyndham Street into a unique mixed-use development, including a new 88,000 sf central library. The Downtown Secondary Plan envisions the Baker District redevelopment becoming a model of urban intensification that drives visitors to the downtown and encourages business to thrive within its boundaries by combining residential and commercial spaces. The city has explored concepts for the site, formally endorsing the 2009 concept and the 2014 concept, which would achieve:

- Increases to downtown visitation
- Increases to downtown population
- Improvements to connectivity for pedestrians, cyclists, and vehicles
- Establishment of new architectural landmarks
- Adding additional public parking
- Incorporation of best practices in environmental design
- Availability of affordable housing



Much of the site is currently occupied by parking lots. Source: Google Maps

Opportunities

- Seven distinct rooftop areas (2 for north residential area; library; 3 for south residential area; 1 for mixed use/ commercial/parking)
- Public open space between the building structures, including access to Wyndham Street
- Frontage on Baker Street
- Vertical surfaces of buildings

Constraints

- Water infiltration opportunities may be limited due to ground water sensitivity
- Need to maintain vehicular and pedestrian traffic at street level

Goals

The Baker District redevelopment is being planned as a One Planet Living community. One Planet Living is a planning and sustainability framework based on a desire to reduce the impact of the way we live, build, and consume. Research has shown that if everyone lives like North Americans, we would need 5 planets' worth of resources to support ourselves. We only have one planet and need to act accordingly. One Planet Living proves a sustainability framework comprising ten principles to reach this end.

They are:

- Health and happiness
- Equity and local economy
- Culture and community
- Land use and wildlife

Windmill Development's Baker District Proposal

- Sustainable water
- Local and sustainable food
- Sustainable materials
- Sustainable transport
- Zero waste
- Zero carbon

Principles

The group participants developed several guiding principles and targeted goals for their proposals to improve the redevelopment:

- Connectivity to river, natural systems, and trails
- Active transportation
- Ability to convert parking to other use in the long term
- Improved pedestrian connection to Wyndham & Quebec Streets
- Maximize the amount of potential plant biomass
- Access to green space with a focus on equity
- Create rooftop amenity spaces
- Outdoor space designed for enjoyment in all seasons
- Connect indoor and outdoor spaces
- Net-Zero ready construction

- Solar PV-integrated green roofs
- Sufficient soil volume for street trees
- Active uses adjacent to green
- Maximize green views
- Good sightlines for security
- Affordable housing and retail
- Third pipe grey water
- Water re-use for toilet flushing
- Recycled storm water
- Stormwater treatment train
- Non-potable water for irrigation
- Daylight and celebrate stormwater infrastructure
- Leverage the proposed library, college, and YMCA to educate and engage the public about green infrastructure and the other green features of the project

Elements

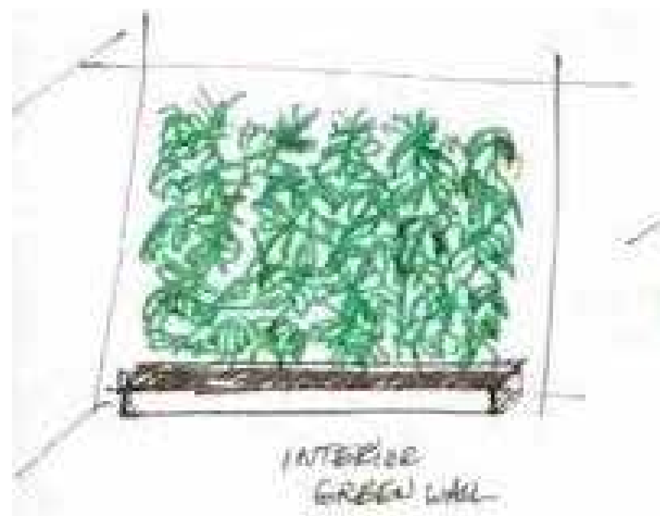
The group proposed a number of green infrastructure elements, working within the parameters of the existing development proposal, which they viewed as high quality.
8 different roof spaces:

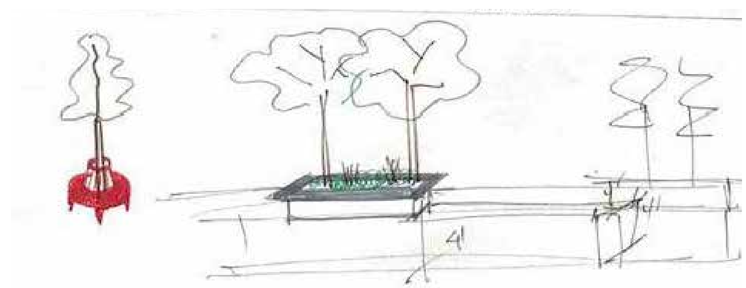
- 1 space at 2 storeys
- 1 space at 3 storeys
- 3 large spaces at 4 storeys
- 1 space at 5 storeys
- 1 at 11 storeys
- 1 at 12 storeys

- Roofs at levels 2-5 could potentially be public use
- Roof 2 is directly publicly accessible (don't have to go through a leased space to get there) 24/7
- Roof 3 could be used for active uses, and is directly linked to the YMCA
- Roof 4a features unobstructed southern exposure and could be a good spot for community gardens producing food for residents
- Roof 4b is connected to the proposed institutional uses, and could be used as a patio or food production space linked to a restaurant or cafeteria
- Roof 4c may be subject to micro-climate impacts (shade, wind, etc). It could be used as an amenity space for residents, featuring areas of green roof along with raised planters featuring trees used as windbreaks
- Roof 5 is a good candidate for an extensive green roof with rainwater capture
- Roofs 11 and 12 could feature solar PV panels & extensive green roofs

Opportunities for ground level green infrastructure:

- Bioswales
- Street trees with soil cells, irrigated using captured rainwater, along with surface water directed to drain into soil cells
- Functional benches specifically designed to go around street trees help to protect the trees and secure their long-term health
- The Urban Square would also technically be a green roof because it's above parking structure. Trees can be used as windbreaks at north end
- Living wall – 2 storeys high inside the library





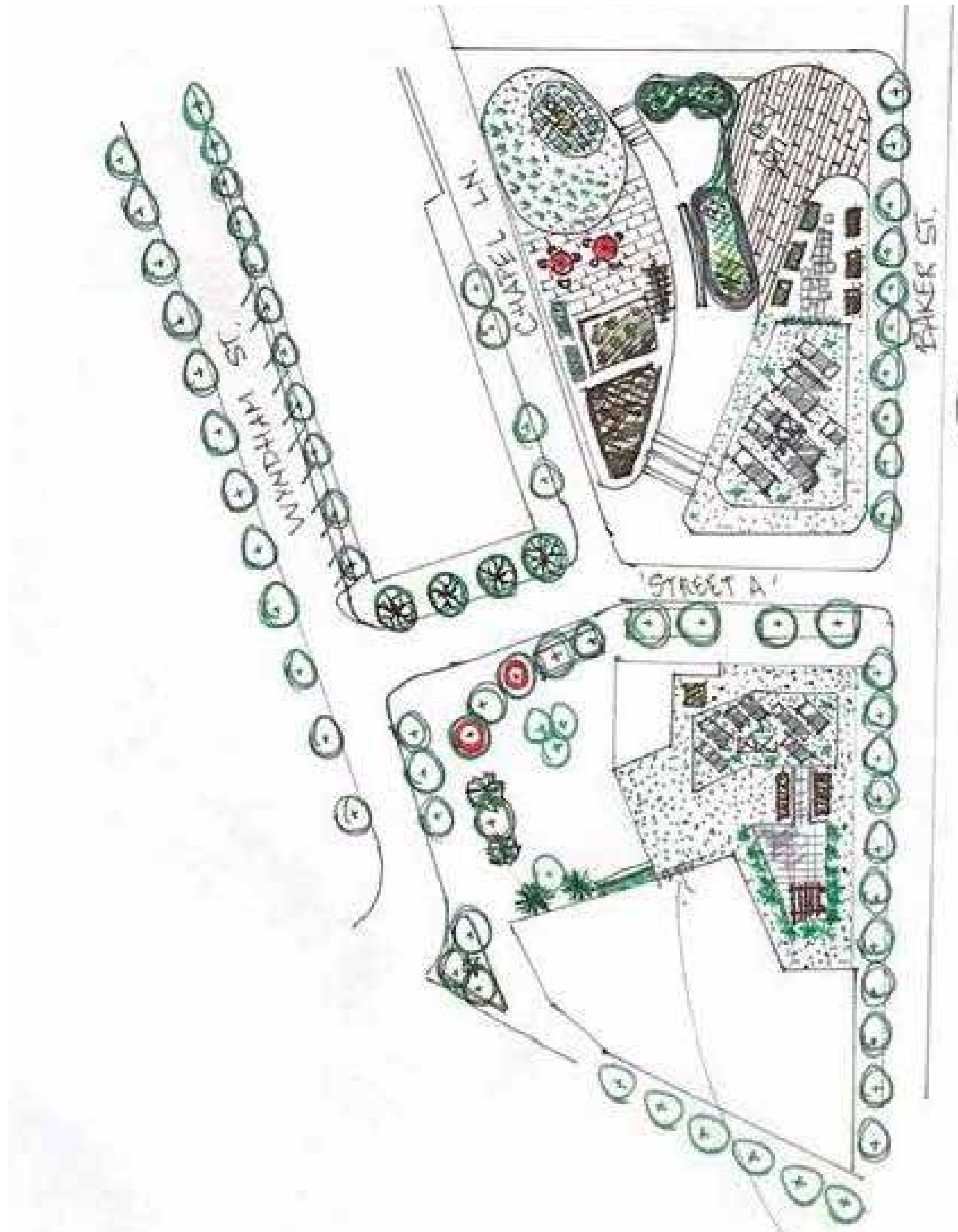
Living wall and tree planter concepts

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Roof - Extensive	1,695 m^2
Green Roof - Intensive	2,395 m^2
Living Wall - Interior	70 m^2
Green Facade	42 m^2
Bioswale	1,920 m^2
Planting Beds	160 m^2
Trees - Small	55
Trees - Large	28

Cost-Benefit Analysis

- Construction Cost: $1.97 million
- Annual Maintenance Cost: $61,500
- One-Time Benefits: $301,000
- Annual Benefits: $136,000
- Job-years in construction: 34.7 FTE
- Job-years in maintenance: 1.1 FTE annually
- NPV (Net Present Value) over 10 years: ($814,000)
- NPV over 25 years: $1.3 million
- NPV over 50 years: $3.4 million
- Simple Payback Period: 13.7 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods.



Baker District concept plan.

Guelph - Baker District Concept

Site B - South End Community Centre

Site Background

Connected, healthy, and resilient communities depend on community spaces that facilitate recreation and social gathering. Guelph's fast-growing South End is escalating the community's need for a multi-use community centre – a facility that will address immediate and future recreation demand and gaps throughout the city. The proposed 150,000 square foot community centre will feature the following:

- Twin pad arena
- Aquatic complex
- Double gym
- Multi-use program and meeting space
- Indoor walking track and warm-up area

Opportunities

- Parking lot and associated boulevard areas
- Boulevard areas along walkway to Poppy Dr. W
- Areas beside walkway to main entrance
- Roof areas
- Areas to the west of the planned building footprint (south of Bishop Macdonnell Catholic High School running track, south of the building footprint, and at the extreme southeast corner

Constraints

- Water infiltration opportunities may be limited due to ground water sensitivity
- Need to maintain parking per the site plan

Goals

- The facility will be designed to meet LEED certification

A rendering of the proposed new South End Community Centre. Source: City of Guelph

Principles and Elements

The group proposed a concept called 'EcoRec', a recreation centre that provides important and much needed recreational programming and space for residents, while also performing at a high environmental level, contributing to its surrounding ecosystem, and engaging and educating the public about environmental issues. Elements of their proposal include:

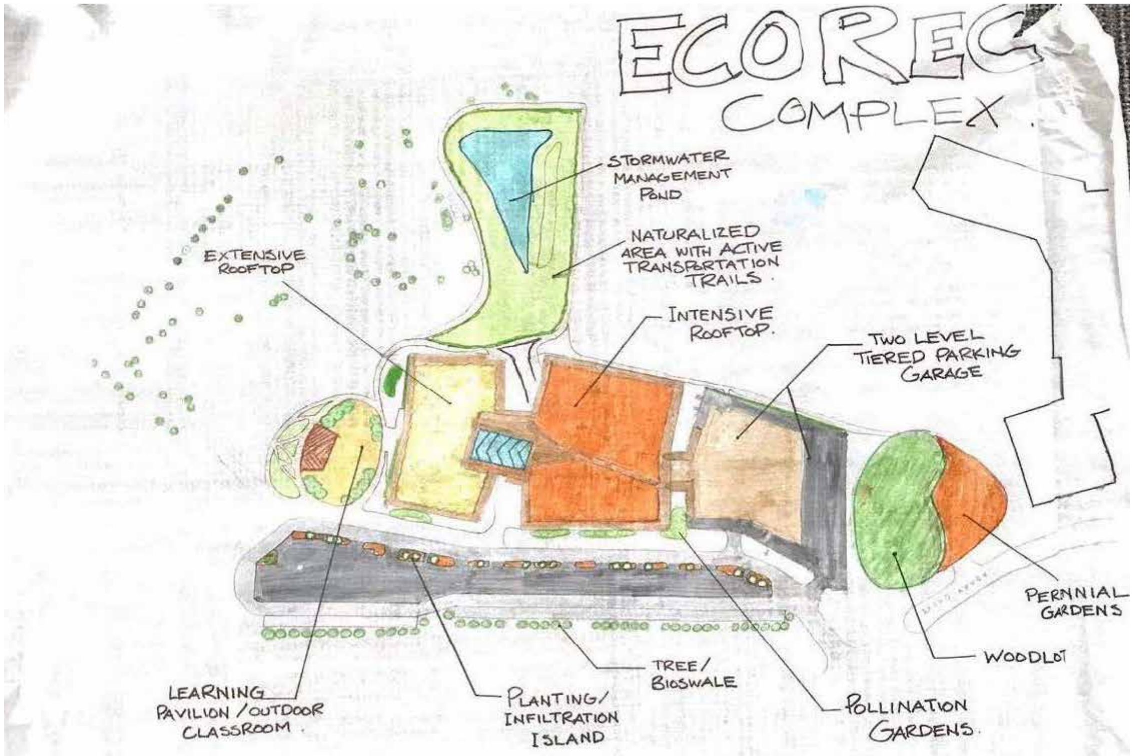
- Managing stormwater on-site using a stormwater pond surrounded by trails, green roofs, rain gardens, and bioswales
- Supporting pollinator habitat through the use of perennial gardens and pollinator gardens featuring biodiverse plantings
- Creating an extensive roof, as well as an intensive roof that is also accessible from the second level of the parking structure
- Developing a learning pavilion that can be used as an outdoor classroom to teach students and other members of the public about the environmental features of this project and about the surrounding ecosystems

Proposed Green Infrastructure

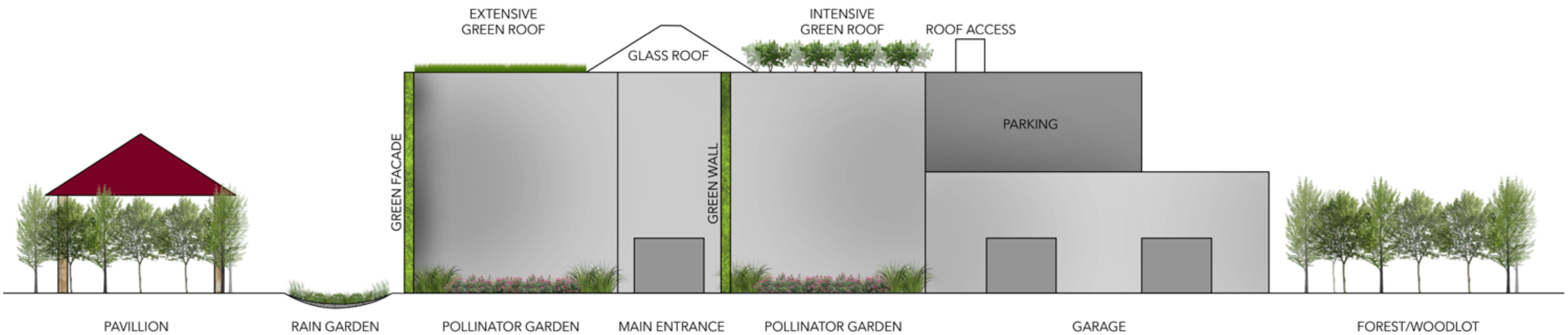
Type of Green Infrastructure	Area
Green Roof - Extensive	2,700 m^2
Green Roof - Intensive	1,800 m^2
Living Wall - Interior	70 m^2
Wetland	4,060 m^2
Rain Garden	400 m^2
Meadow/Grassland	2,400 m^2
Bioswale	400 m^2
Trees - Small	100
Trees - Medium	40
Trees - Large	40

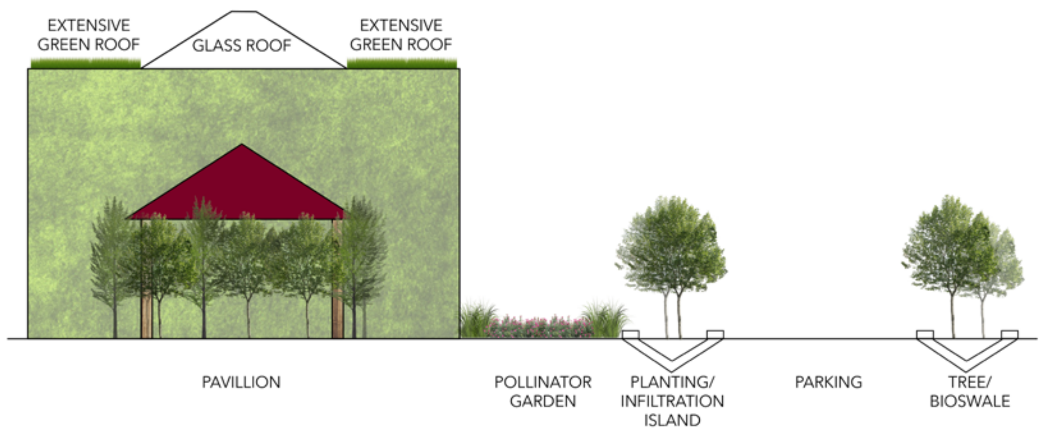
Cost-Benefit Analysis

- Construction Cost: $1.68 million
- Annual Maintenance Cost: $49,000
- One-Time Benefits: $423,500
- Annual Benefits: $115,000
- Job-years in construction: 29.6 FTE
- Job-years in maintenance: 0.9 FTE annually
- NPV (Net Present Value) over 10 years: ($194,900)
- NPV over 25 years: $2.4 million
- NPV over 50 years: $5.1 million
- Simple Payback Period: 9.7 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

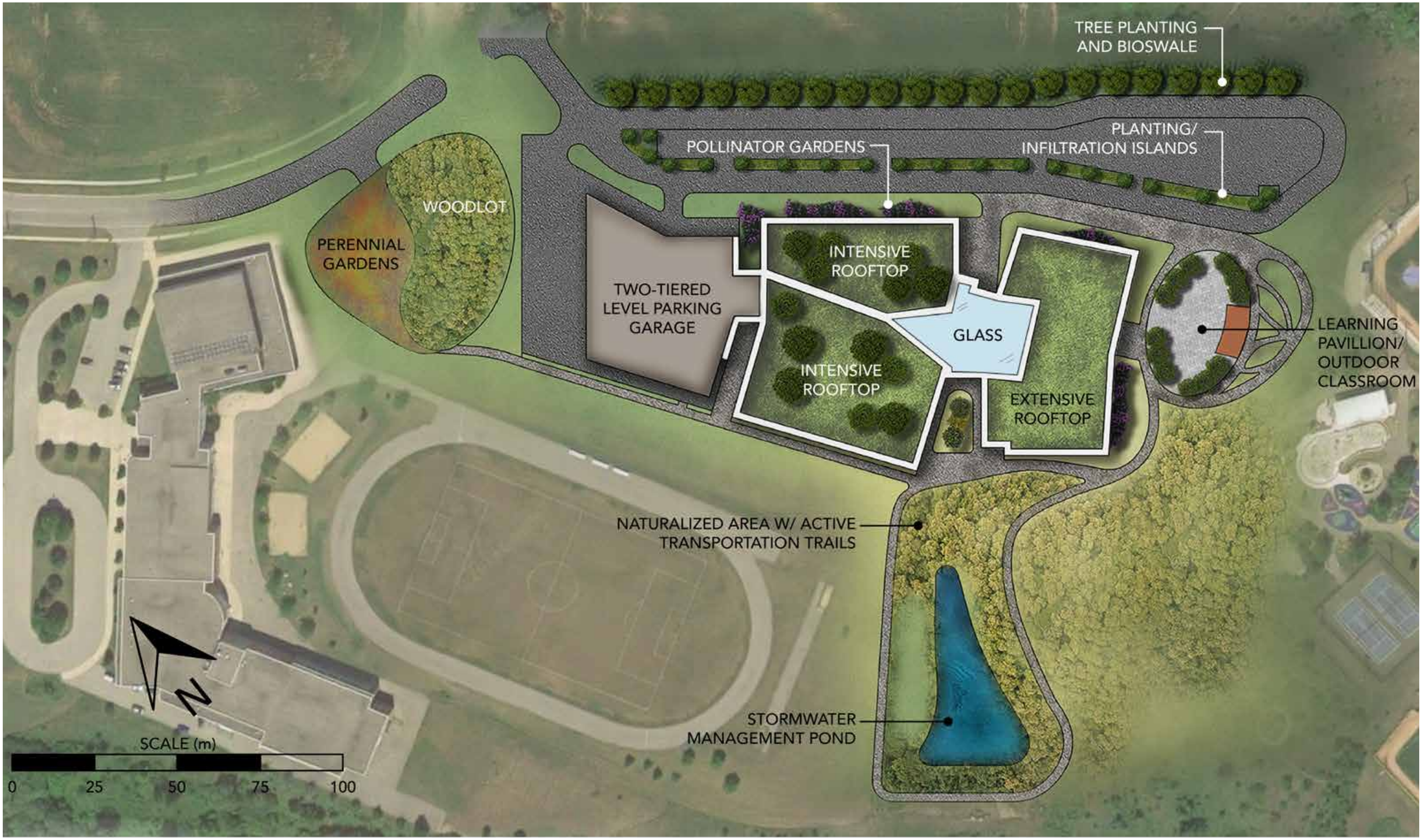


South End Community Centre Concept Sketch





South End Community Centre Elevation Concept



Guelph - South End Community Centre Concept

London

Site Background

The Old East Village is a historic neighbourhood focused along Dundas Street, just east of Downtown London. The neighbourhood is vibrant, dense, and features a passionate and engaged population. It has seen some revitalization in recent years, but is poised for further change, challenges, and opportunities that come with rapid transit service, infrastructure upgrades, cycling infrastructure, and development. The City of London is currently developing the Old East Village Dundas Street Corridor Secondary Plan to guide change in this neighbourhood.

Opportunities

- Active community
- Sandy soil– infiltration opportunities
- Utilities all under road, gas adjacent to building

Constraints

- Narrow right-of-way with competing priorities for space – parking, patios, bike lanes, sidewalks, trees, etc.
- Undesirable activity in neighbourhood – needles often found in planting beds
- Higher level of service required – busy street with constraints regarding traffic

Goals

The group proposed a green infrastructure strategy focused on a few goals:

- Accommodating competing uses while greening where possible
- Create an anchor public space for the neighbourhood

The existing streetscape is dominated by paved surfaces and is lacking in tree canopy. Source: Google Maps

- Create a more vibrant, flexible, and pedestrian friendly environment to draw activity and improve public safety
- Encourage private property greening like green roofs and walls on new developments and city owned property

Elements

The group's strategy comprised of several elements:

Private Property Greening

- Purchase adjoining sites using parkland acquisition fund to support civil space and green infrastructure
- Expand tree canopy on public property
- Encourage green roofs and walls on new developments and city owned properties

Trees

- There is a need to set and articulate the desired level of service – do we want a green street with trees or a naked street? Planting trees in this context will require greater resources than in others. The City of London's policy for Dundas is of an active public corridor with shade and street trees, along with plantings
- Raised planters for healthier trees - use at neighbourhood edges
- Trees in a continuous tree trench at grade with permeable paving between trees – opportunities for stormwater management and sufficient soil volume
- Solar cells in trees for pin lights
- More information on costs and resources needed to maintain trees in this environment. Currently, the city budgets $20.47 annually per tree for maintenance, but there are added costs associated with maintaining trees in this condition

Third Pipe System

- Run-off is collected by a traditional storm sewer system (private drain connections and catch-basins)
- Stormwater is then conveyed to a downstream manhole
- The manhole is fitted with a perforated pipe at a lower elevation than the traditional storm sewer which allows flows to be infiltrated through the perforated pipe (like a French drain; surrounded by clear stone and geotextile fabric)
- If the flows overwhelm the perforated pipe (which is capped at the downstream end to force infiltration), flows will rise in the manhole and will be conveyed by the traditional storm sewer to the next manhole where the process will be repeated.

Civic Space

- 75% hard surface gathering space with permeable pavers/concrete.
- 25% green infrastructure in the form of bioswale and tree planting pits/silva cell.
- Bioswale should be 6m wide with hard surface and curbed edges. Interior is 2% sloped to center line with a perforated pipe connecting bioswale to road network storm system.
- Green wall at periphery of civic spaces will be located on second story to minimize vandalism and operational issues (needles). First story backdrop will be a mosaic art display similar to others in the old east village.

Pedestrian spaces on road

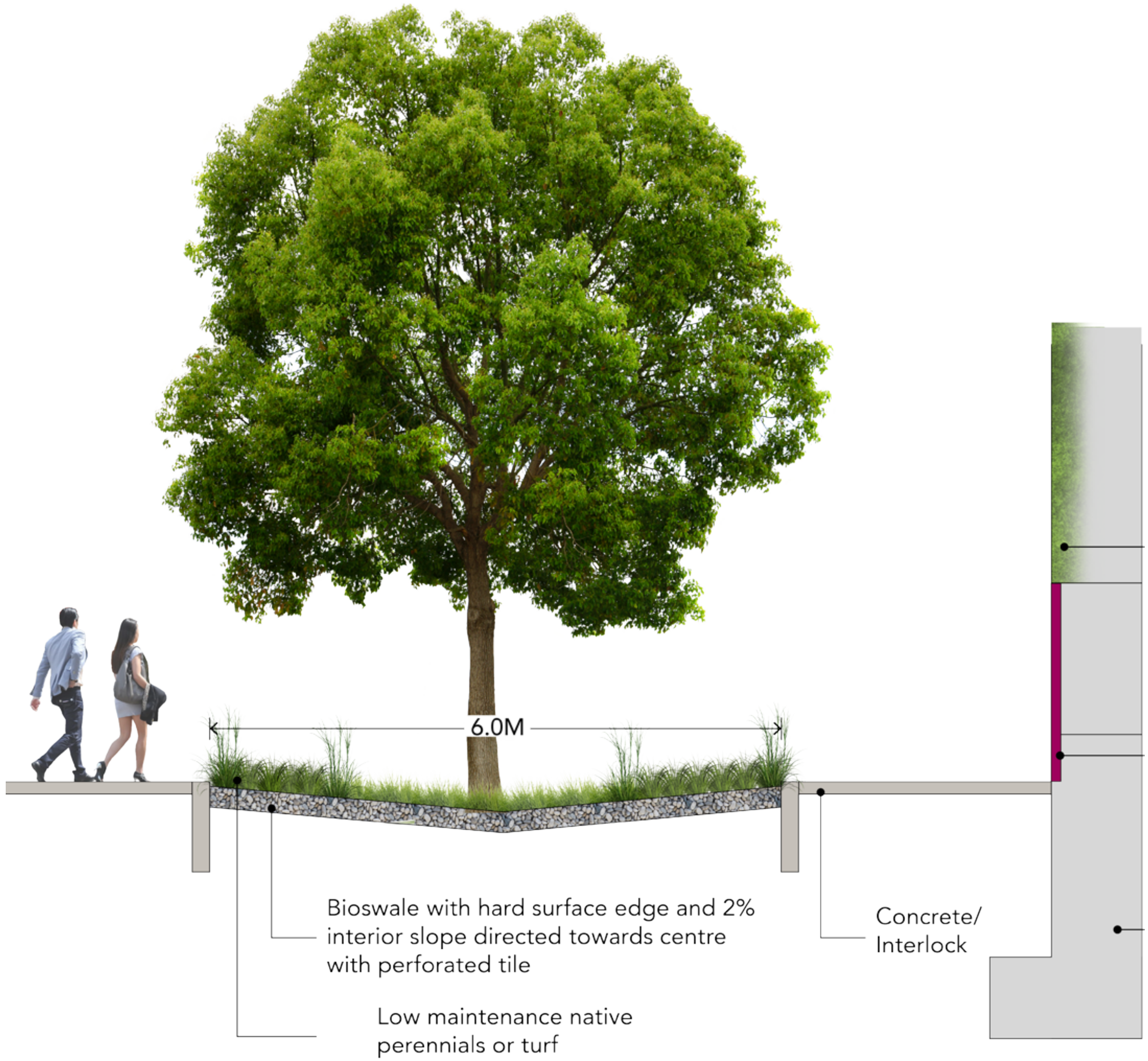
- 4.5-5.5 meters wide on north side. Wide enough to accommodate both trees in continuous soil cells and raised tree islands. Islands at entrance point to each block.
- 3.5-4.5 meters wide on south side with enough room for continuous soil cells.

Proposed Green Infrastructure

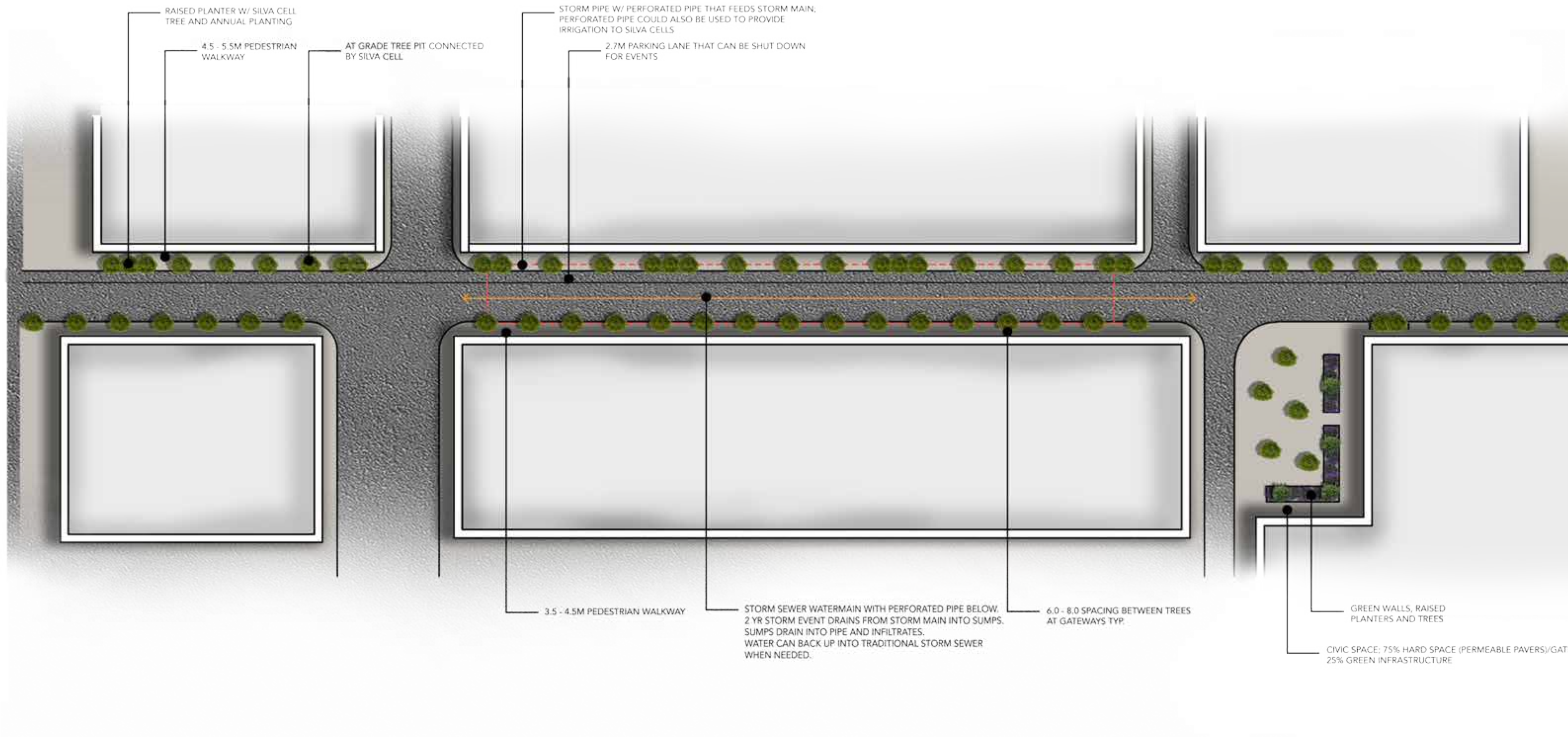
Type of Green Infrastructure	Area
Green Roof - Extensive	10,750 m^2
Green Facade	240 m^2
Bioswales	5,800 m^2
Permeable Paving	2,700 m^2
Trees - Medium	100

Cost-Benefit Analysis

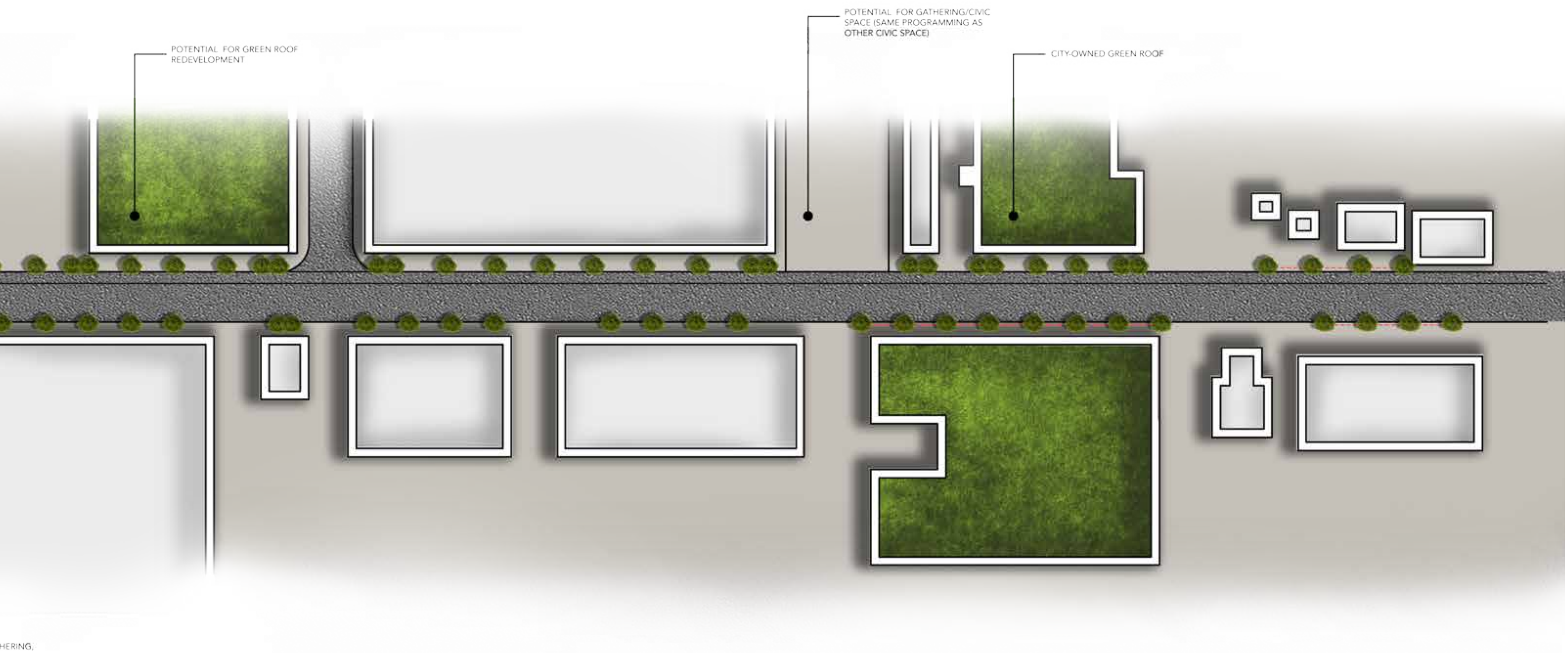
- Construction Cost: $3.43 million
- Annual Maintenance Cost: $56,900
- Job-years in construction: 60.5 FTE
- Job-years in maintenance: 1 FTE annually
- NPV (Net Present Value) over 10 years: ($2.4 million)
- NPV over 25 years: $627,600
- NPV over 50 years: $3.1 million
- Simple Payback Period: 16.6 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods



Proposed sidewalk section

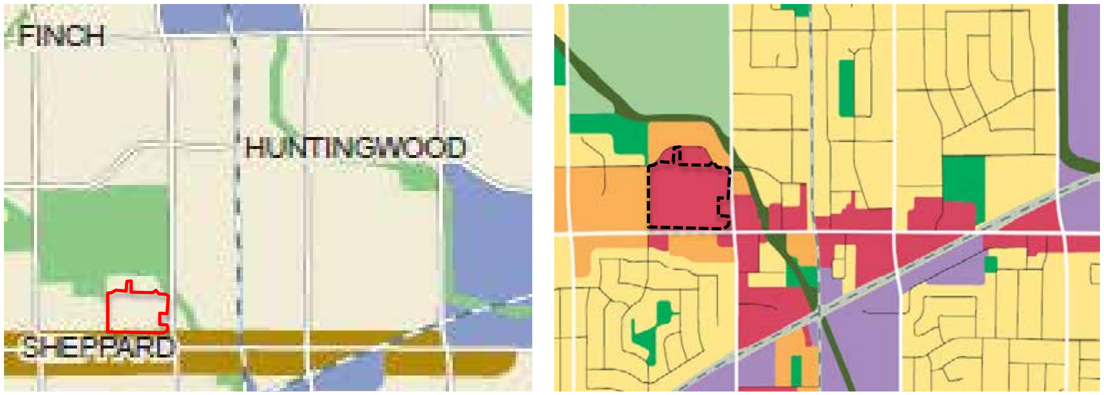


London - Concept

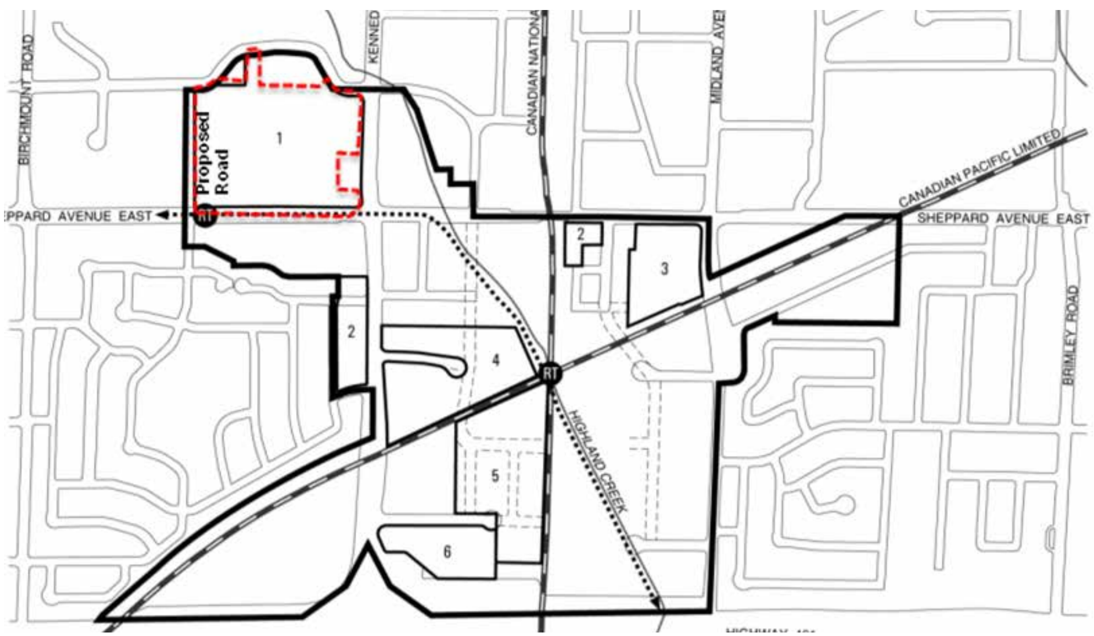


London - Concept

Toronto



The official plan designates Sheppard as an 'Avenue' - growth corridor supported by transit; and the site as a mixed-use area, featuring a mix of uses including residential and commercial (above); the Agincourt Secondary Plan states that the mall lands are to transition from a suburban shopping centre to a more intense urban form (below). Source: City of Toronto. Context and site maps demonsrate existing conditions (facing page). Source: Google Maps



Site Background

Agincourt Mall is a large big-box mall located near the intersections of Sheppard Avenue East and Kennedy Road, in Scarborough, in Northeast Toronto.

In 2017, a development application was submitted to permit the comprehensive development of the Agincourt Mall lands. The master plan is for a new mixed-use community that includes parks and open spaces, residential, commercial, office, and community space.

In response, the city initiated a Planning Framework Review for the area, focused on the city's desires for the redevelopment of the site and the integration with surrounding areas, based on input from all stakeholders.

Opportunities

- Higher order transit close by – Agincourt GO station and planned LRT along Sheppard Ave East
- Mixed-use zoning along a designated 'Avenue' (growth corridor supported by transit)
- Large site – 10.5 hectares
- Opportunities to create an integrated green infrastructure strategy that can serve as a model for other sites

Constraints

- Applicant's resubmission has over 4700 units – city's preferred alternative is 4000


N

The applicant's original submission (above); the City's preferred alternative (below). Source: City of Toronto

- Max building height is 48 storeys – potential for shadows
- Intensive residential uses mean intensive park uses
- City's desire to not 'encumber parks' with stormwater runoff from outside the site

Goals

Create a complete, connected, safe, vibrant and transit-oriented community that recognizes the unique and diverse character of the Agincourt area and contributes towards making it a great place to live, work, play and shop.

Guiding Principles:

- Create a Complete Community
- Create a Vibrant & Diverse Community
- Create a Connected Community
- Create a Green and Sustainable Community
- Create a Community Focal Point on the Agincourt Mall Lands

The site is viewed through the lens of several policies, including the Growth Plan for the Greater Golden Horseshoe, the City of Toronto Official Plan, the Agincourt Secondary Plan, and relevant zoning by-laws for the site.

The proposed green infrastructure strategy is looking at a treatment train approach - silva cells on site and an oil grit separator located at the site outlet, with goals of meeting the city and TRCA erosion control and quality control measures:

- Retain the first 5mm of volume from municipal roads
- Provide Total Suspended Solid (TSS) removal efficiency of 80% for the site
- Release the municipal right-of-way and parks uncontrolled
- Provide roof and underground storage on private blocks to meet the target 2 year pre-development peak flow at the site outlet under 100 year storm conditions

City staff have noted that there is no standard or agreement for silva cells and trees over water mains (there is the possibility of developing one for this site). They also noted the high cost of silva cells, when many boulevards are wide enough for cheaper options like larger tree trenches. There are also many other additional opportunities for stormwater management that were not explored, such as parks and privately owned public spaces (POPS).

Staff asked all groups to retain the parks and open space plan of the preferred alternative. Having the park located on the west end of the site creates better connections to the existing park network of Ron Watson Park, so that a person can walk from Ron Watson Park all the way down to Sheppard Avenue, experiencing a park like setting through the Agincourt Mall site.

Sheppard Park located along the street provides open space on an important street for people to gather as well as provide visual enhancement to Sheppard, which was an important request from the charette in making Sheppard Avenue beautiful.

This is a true parks and open space network, so a resident walking either in a East-West direction to Agincourt GO Station or North-South direction experiences green space and amenity, creating a pleasant neighbourhood.

In addition, having the Central Park located along the west side and Sheppard Park located on Sheppard Avenue was the most advantageous locations for maximizing sunlight exposure to both parks throughout the day (this was a key parameter in the evaluation framework).

The applicant's resubmission (top), and the proposed public realm network (above). Source: City of Toronto

The site is dominated by large parking lots and is almost entirely impervious. It is surrounded by many mid-rise and high rise apartment buildings. Source: Google Maps

Option A

Elements

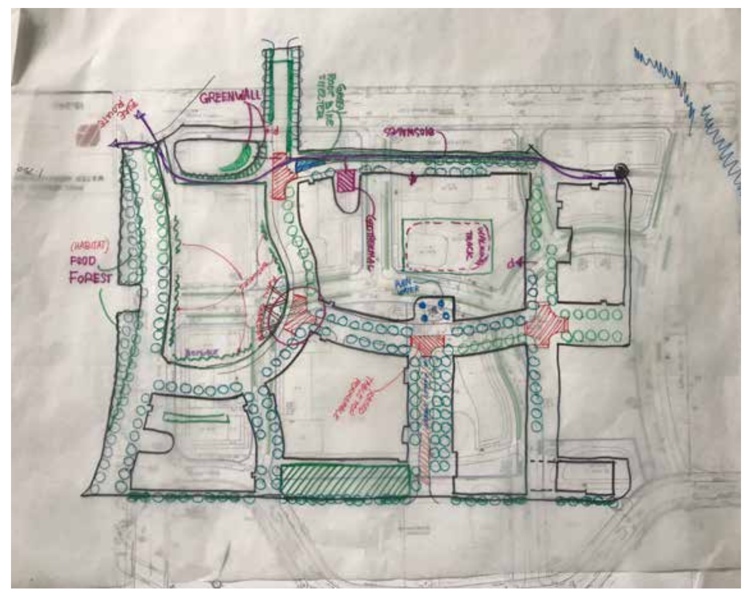
- Permeable paving over soil cells
- Green infrastructure to enhance the development while managing water on site
- Celebrate water
- Canopy that directs stormwater to water feature
- Rain garden in park
- Bioswales along mixed-use path
- Incorporate park more meaningfully in relation to the entire development
- Reconfigure streets to handle higher volumes of water
- Balance multiple interests – roads, trees, intimate urban spaces. Integration to spill over park boundary but not park itself due to future programming. Too much design of the park at this stage could backfire
- Soil cells augmented with other types of systems
- Large water feature as the focal point of the retail square
- Create protected spaces for shelter from the elements
- Green up all lands, not just active/animated areas
- Bioswales underneath pathways
- Support green roofs

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Roof - Extensive	1,695 m^2
Green Roof - Intensive	2,395 m^2
Rain Garden	750 m^2
Bioswale	8,450 m^2
Permeable Paving	1,200 m^2
Trees - Small	100 in urban forest
Trees - Medium	100 in urban forest, 200 in silva cells
Trees - Large	100 in urban forest, 80 in parks

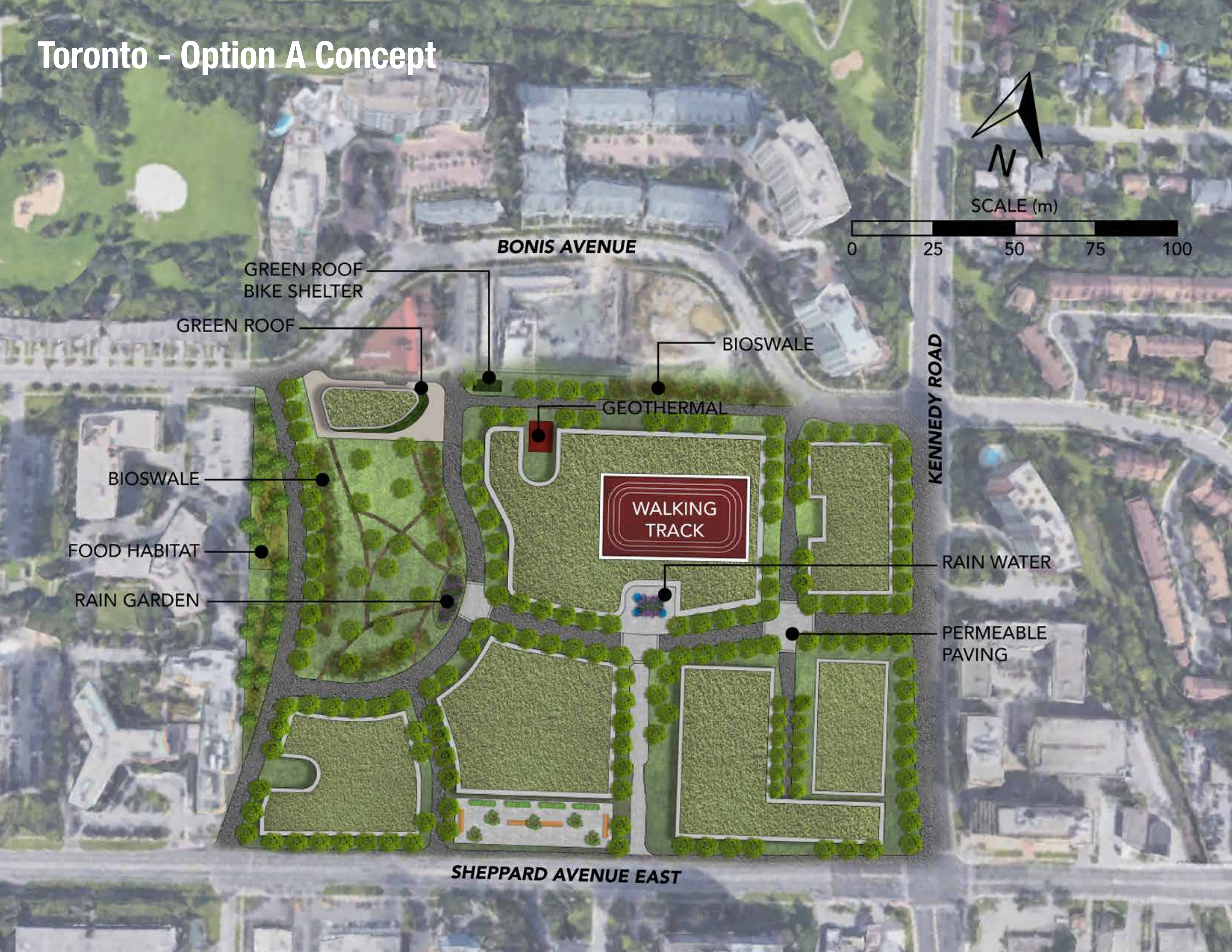
Cost-Benefit Analysis

- Construction Cost: $3.39 million
- Annual Maintenance Cost: $91,600
- Job-years in construction: 59.9 FTE
- Job-years in maintenance: 1.6 FTE annually
- NPV (Net Present Value) over 10 years: $151,500
- NPV over 25 years: $7.55 million
- NPV over 50 years: $15.98 million
- Simple Payback Period: 7.9 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods



Option A conceptual sketch.

Toronto - Option A Concept



Option B

Elements

- Permaculture – community gardens. Consider rooftop of large retail/commercial building for community food production and outreach
- Soil volume requirements for trees integrated with soil volume requirements for managing stormwater
- Expose green infrastructure elements where possibility for visibility and education
- Visual connection to stormwater management through the use of a water feature
- Proposed relocation of utilities to minimize conflicts with soil cells during repairs or maintenance
- Incorporate indigenous placemaking in parks – healing gardens, outdoor classrooms. Promote education, signage, and art where possible
- Tree planting on public and private property
- Permeable paver on main street, create European feel

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Facade	70 m^2
Rain Garden	750 m^2
Permeable Paving	1,200 m^2
Trees - Large	200
Meadow/Grasslands	2,400 m^2

Cost-Benefit Analysis

- Construction Cost: $395,000
- Annual Maintenance Cost: $10,300
- Job-years in construction: 7 FTE
- Job-years in maintenance: 0.2 FTE annually
- NPV (Net Present Value) over 10 years: $1.05 million
- NPV over 25 years: $4.05 million
- NPV over 50 years: $7.59 million
- Simple Payback Period: 4.7 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

Option B Conceptual Sketch.

Toronto - Option B Concept

Option C

Elements

- Soil volumes to support large trees along the right of way
    - Supports stormwater detention and filtration
    - Provides naturalized canopy coverage
    - Enhances ecosystem services to the area
    - Mitigates extreme temperatures in the summers
- Park anchored by a Net Zero/Passive community center
    - Serves as function, education, and potential programming site
    - Serves as a home for community gardens
- Identify vision zero opportunities at major intersections
    - Line external streets with trees and plantings to provide traffic calming
- Outward facing green walls, vertical gardens, and amenity terraces
    - Enhance marketability of the community as sustainable along main boulevards
    - Establish the redevelopment as a “green oasis”
    - Introduce a degree of verticality into the sustainability
    - Opportunity for private community gardens
- Integration of non-calculated sustainability features: PV, building mounted wind turbines, and thermal grids
- Education and outreach opportunities
    - Demonstrational sculptures integrated into hydrology infiltration; draw inspiration from Evergreen Brickworks
    - Provide PV lit guided pathways through parks and trails
    - Establish aesthetic consistencies between zones via pavers
    - Utilize specific iconography to denote waterways, infiltrations, and other GI
    - Program parks for fun!
    - Enhance resident wellbeing and interface with sustainable techniques and technologies
- Green corridor/parkway
    - Connecting Sheppard Park, Central Park, Ron Watson Park, and West Highland Creek Ravine
    - Creates pedestrian trails and pathways connecting amenity spaces and local transit options
    - Allows for daylighting of neighbourhood water management
    - Works with natural landscape hydrology
    - Creates connected pollinator/biodiversity pathways

Working with the established vision for the Agincourt redevelopment of creating a complete, connected, safe, vibrant, and transit-oriented community, we have sought to enhance the existing green features and existing planning with additional infiltrations aimed at improving neighbourhood sustainability, cohesion, and understanding.

Establishing a contiguous greenway, connecting park areas in and around the neighbourhood with the larger nearby ravine was an important way to improve pedestrian interactivity and safety. Connecting Sheppard Park, Central Park, Ron Watson Park, towards the southeastern ravine and West Highland

Option C Conceptual Sketch

Toronto - Option C Concept

Creek both creates a distributed green infrastructure network, established a naturalized pathway between amenity spaces, local transit, and residential areas as well as mimicking the native hydrology. This pathway also allows the ability to daylight the naturalized treatment train across the site, assisting in broader efforts to educate the public on the sustainability and efficiency features in the community.

Incorporating public education and art installations allows the development to communicate to the public how these infiltrations function and improve the overall community. Using iconography, sculptural art, and other design aesthetics to directly and indirectly communicate the location and impacts of the sustainability features connects the public with the infiltrations and how they function.

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Extensive Green Roof	23,050 m^2
Rain Garden	1,180 m^2
Bioswale	2956 m^2
Permeable Paving	2,600 m^2
Planting Bed	2,380 m^2 (380 m^2 for agriculture)
Lawn/Turf	7,200 m^2
Meadow/Grasslands	350 m^2
Small Trees	40
Medium Trees	40
Large Trees	40

Cost-Benefit Analysis

- Construction Cost: $5.9 million
- Annual Maintenance Cost: $84,000
- Job-years in construction: 104 FTE
- Job-years in maintenance: 1 FTE annually
- NPV (Net Present Value) over 10 years: ($4.1 million)
- NPV over 25 years: $126,000
- NPV over 50 years: $3.35 million
- Simple Payback Period: 16.8 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

Source: Green Infrastructure Foundation

Waterloo

Image of Silver Lake and Waterloo Park (above), aerial imagery of the study area. Source: City of Waterloo

Site Background

Waterloo Park, known as the jewel of the city, has a lake, animal farm, picnic areas, splash pad, sport fields, playgrounds and more. It is located in close proximity to Uptown Waterloo.

In 2018, a Class Environmental Assessment Study was completed on Waterloo Park - Silver Lake and Laurel Creek to determine the preferred rehabilitation option for the watershed, with the following components:

- Dredging and reconfiguration of the lake to improve circulation, water quality and aesthetics
- Facilitation of regular sediment management
- Enhancement of Laurel Creek upstream of Silver Lake to improve water quality, fish habitat, riparian zones and to reduce erosion
- Reconstruction of recreational areas surrounding Silver Lake and Park, improvement to pedestrian circulation, and introduction of new water features

Parts of Waterloo Park are also planned for reconstruction - improvements will include new walkways, lighting, amenities, features of interest and improved pedestrian circulation.

The groups participating in the charrette were tasked with looking at this reconstruction through the lens of green infrastructure, while considering the proposal by the city's landscape architectural consultants.

Their goal was to identify how to leverage the assets of the park while restoring ecological and hydrological function to the site and maximizing its environmental performance while retaining its character and status as a well-loved and visited park.

Opportunities

- Existing cultural assets - Old School House, Pottery Studio, Zoo
- Waterloo Park and Silver Lake are much-loved city assets

- Adjacent Light Rail Transit Corridor
- Trail system provides active transportation opportunities

Constraints

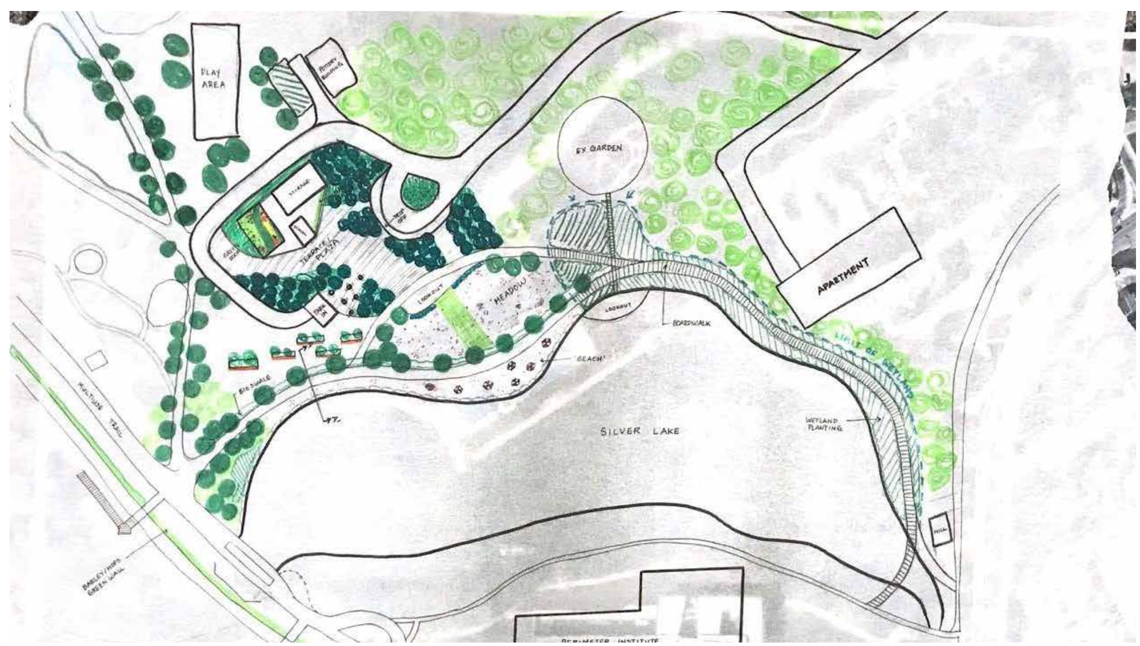
- Geese are an issue and management will be required
- Drainage problems around 'English Gardens'
- Steep grades in central area
- Water quality needs to be improved
- Access to Forebay Area (west of lake) needs to be preserved

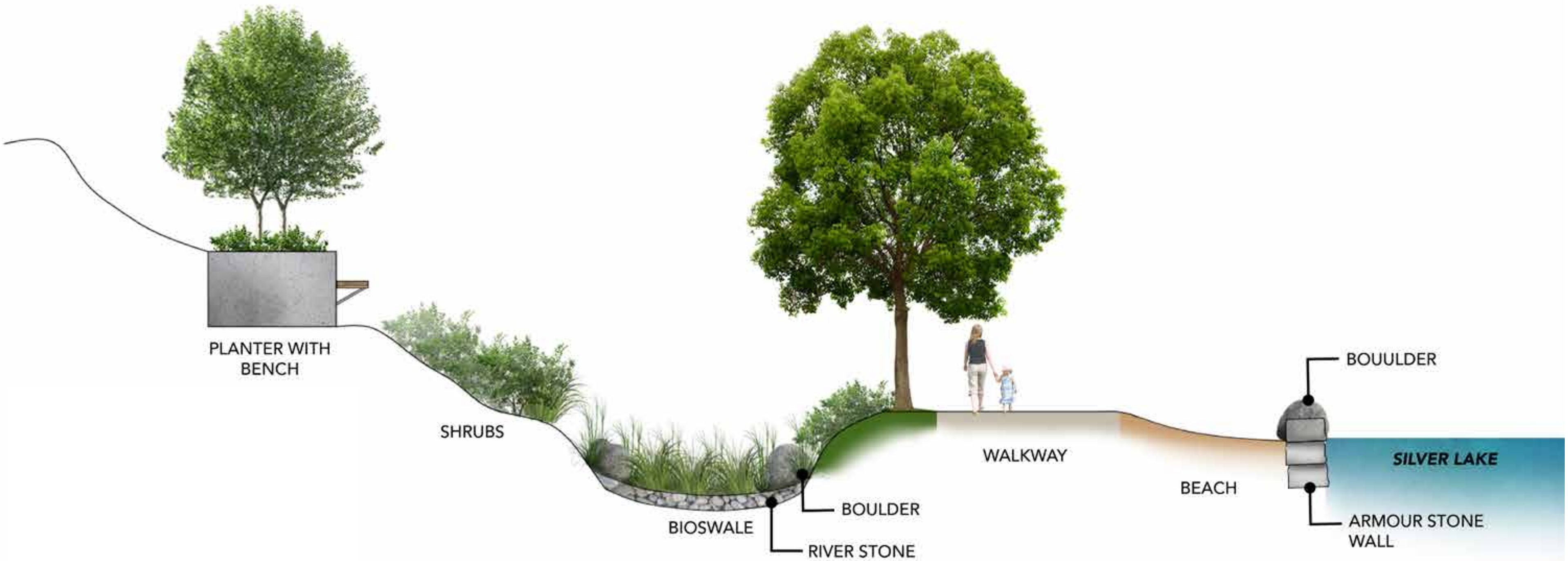
Option A

Elements

- Remove existing parking lot
- Create a green corridor along Light Rail Transit – creative idea: grow barley and hops (and use it in an in-park brewery)
- Create bioswales that include a mix of boulders and trees in the area between the Zoo and the lake
- Make connections between Uptown and the park with cycling & pedestrian pathways that are curvilinear but fairly direct
- Create a multi-use common area (aka public terrace) near school house where potters could have sales
- Permeable hardscaping used instead of traditional paving
- Add trees in lower area near picnic area (while preserving sight lines) – in central area create meadow area
- Incorporate natural play areas into forested area
- Add wetlands to the east end of Park to address drainage problems and floodplain overflow – area to extend down from surrounding area of formal gardens down to lake and along

Consultant's proposed plan for Silver Lake and Waterloo Park reconstruction (above)Source: City of Waterloo
Option A conceptual sketch (below)





Option A Section

the perimeter of the lake to its outlet (Grist Mill area)

- Maintain sight lines towards Uptown Sq.
- Include lookout onto lake below gardens
- 2nd lookout below path below common area
- Use central area as amphitheater – possibly use it for movies – floating screen in Silver Lake
- Add trees and or high grasses to suppress geese
- Move playground closer to zoo, schoolhouse and washroom area
- Preserve existing trees in east end of park (as much possible)
- Add Green Wall as an accent at edge of common area adjacent to buildings (terrace)
- Expand school house with modern addition that complements heritage and has a green roof AND interior green wall
- Relocate parking lot closer to Young St entrance
- Keep beach area in conceptual design from PIC – but add in boulders (see geese suppression)
- Retaining wall following Northern perimeter of Lake to include a green façade – hops idea again?
- Permeable parking and trees next to Potter's studio

Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Roof - Extensive	240 m^2
Living Wall - Interior	34 m^2
Bioswale	540 m^2
Permeable Paving	4,000 m^2
Trees - Small	60
Trees - Medium	50
Trees - Large	125
Wetland	6,965 m^2
Turf/Lawn	2,500 m^2
Meadow/Grassland	3,030 m^2

Cost-Benefit Analysis

- Construction Cost: $880,000
- Annual Maintenance Cost: $22,400
- Job-years in construction: 15.5 FTE
- Job-years in maintenance: 0.4 FTE annually
- NPV (Net Present Value) over 10 years: $1.1 million
- NPV over 25 years: ($166,000)
- NPV over 50 years: $3.72 million
- Simple Payback Period: 9.9 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods.

Option B

Elements

- Maintain the form of consultant's plan
- Work within the topography - water flows downhill
- Create prominence at the top of the slope
- Programming possibilities on the flat parts of the park
- Parking is a contentious issue - manage it sensitively through the use of on-street/parallel parking
- Amalgamate building functions at the top of the hill
- Move historic school to knot garden
- Enhance slope with terraced system

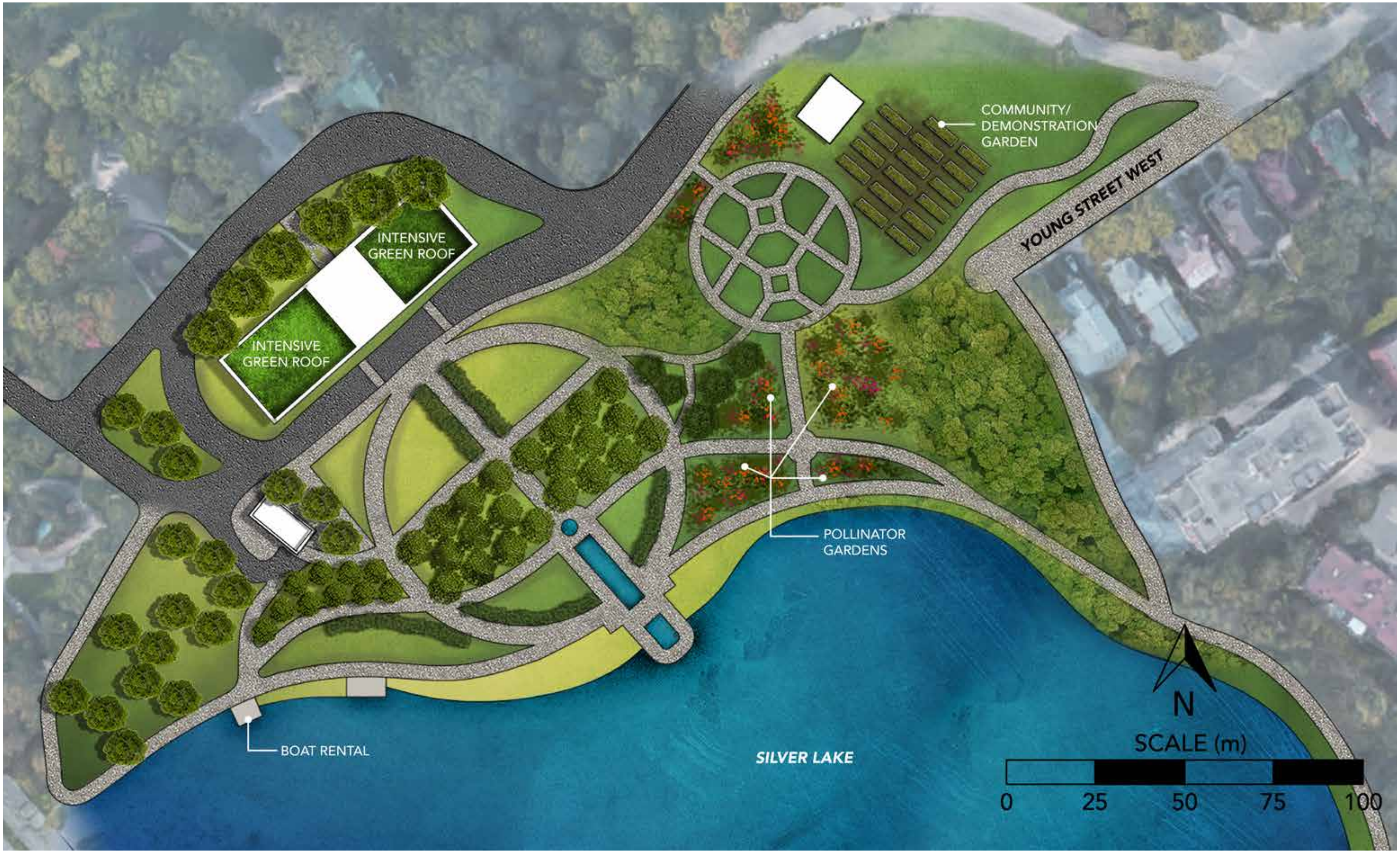
Proposed Green Infrastructure

Type of Green Infrastructure	Area
Green Roof - Extensive	150 m^2
Green Roof - Intensive	1,000 m^2
Green Facade	30 m^2
Bioswale	835 m^2
Permeable Paving	6,930 m^2
Trees - Small	30
Trees - Medium	48
Planting Bed	2,200 m^2
Turf/Lawn	3,300 m^2
Meadow/Grassland	2,765 m^2

Cost-Benefit Analysis

- Construction Cost: $1.51 million
- Annual Maintenance Cost: $33,800
- Job-years in construction: 26.7 FTE
- Job-years in maintenance: 0.6 FTE annually
- NPV (Net Present Value) over 10 years: ($1.2 million)
- NPV over 25 years: ($625,000)
- NPV over 50 years: ($42,000)
- Simple Payback Period: 27.4 years
- It is important to consider that many important benefits are not included: amenity space for residents, health impacts, increased property value, reduced flood risk, etc.
- See more information in Appendix for detailed results and methods

Option B Section



Waterloo - Option B Concept

Conclusion and Next Steps

Green infrastucture investments can engage the community, like this example of rain garden being constructed (above). Source: NOAA

Conceptualizing and valuing green infrastructure is an important step towards its widespread use and application. Source: Green Infrastructure Foundation

This project is an important initial step in valuing, conceptualizing, and implementing green infrastructure in not just the participating communities, but in municipalities across Ontario and the rest of Canada. Underpinning these goals is the aim to improve environmental performance and increase resilience to climate change impacts.

This project offers an opportunity for stakeholders to reconsider approaches to improvements of these communities. They could take the following steps:

- Incorporate green infrastructure costs and benefits into more detailed analyses
- Identify strategies to increase benefits from green infrastructure in housing and other developments (e.g. using green roofs as event spaces, producing high value food products like micro-greens, using green infrastructure to meet regulatory requirements or avoid other spending)
- Encourage long-term thinking when making decisions, for example, by considering the impact of climate change on any planned or existing infrastructure
- Capture other important benefits not incorporated into the cost-benefit analysis in this report
- While keeping in mind budgetary constraints, identify one or more design strategies and elements from the conceptual plans here for additional study, and implementation

By incorporating some or all of these recommendations, communities can use their limited resources to improve the efficiency of their infrastructure and receive a wider range of benefits from it. Green infrastructure also presents an opportunity to achieve environmental benefits and meet sustainability goals while cost-sharing with the private sector, reducing long-term costs for both sectors.

Green infrastructure's flexibility and decentralized nature makes it an ideal part of a climate change strategy, an area in which Federal and Provincial Funding is likely to be available in the coming years. This project hopes to advance that discussion and encourage stakeholders to think about how to move towards greener, healthier communities. For more information and best practices around the use of green infrastructure for climate adaptation, see the next section.

Conceptualizing and valuing green infrastructure is an important step towards its widespread use and application. For more information on capacity building activities moving forward, visit greeninfrastructurefoundation.org or ontarioparksassociation.ca.

Appendices

Appendix A: Green Infrastructure Cost-Benefit Matrix (Background)

One of the challenges facing the greater utilization of green infrastructure is that society does not properly value the many benefits they provide. This lack of valuation means that green infrastructure is often not incorporated into decisions around investment or asset management.

The Green Infrastructure Cost-Benefit Matrix was developed to help policy makers and community leaders better understand the many costs and benefits associated with green infrastructure investment at an aggregate scale. It also provides a financial context and approximate values for the design work that emerged from the Charrette.

The values that the Matrix uses are averages, reflecting large-scale implementation, rather than project-specific values. Because of this, the goal of the cost-benefit analysis for the site redesigns is not so much about hitting the bullseye but rather about starting a conversation about the tangible benefits that green infrastructure can offer. The cost-benefit analysis aims to help spur and facilitate engagement with political leaders, community leaders and government officials in communities focused on the valuation of green infrastructure investments and future policy directions.

The Matrix is a unique and valuable tool that can help promote better infrastructure planning and investment. Monetizing the multi-dimensional benefits of green infrastructure is complex and challenging. These challenges can be addressed by conducting cost-benefit analyses at an aggregate level and focusing on dollars/square metre valuations.

While the lack of precision is an acknowledged limitation of the cost-benefit matrix, the financial analysis of benefits provided is extremely conservative.

There are many limitations that must be taken into account when the plans and aggregate cost-benefit analyses are considered:

- Costs and benefits are on an aggregate basis, not a project basis, and are based on many assumptions and generalizations
- This is an extremely cautious analysis - all the costs (of the green infrastructure elements) have been included, but many important benefits (increased amenity space, health benefits, improved productivity, increased community cohesion, increased property value, etc.) have not been incorporated into the cost-benefit analysis
- Concepts were created with limited information, and may not be technically feasible (though many elements will be)
- The cost of conventional infrastructure was not considered - in many cases, a green approach will provide a multitude of additional benefits while also being more cost-effective
- The impacts of climate change and green infrastructure's ability to reduce vulnerabilities to its impact are not considered
- The fact that green infrastructure performance often improves over time is not factored into performance assessments

Despite these limitations, this project offers an opportunity for stakeholders to reconsider approaches to improvements of these communities.

The Green Infrastructure Cost-Benefit Matrix encapsulates a wide range of economic and biophysical research data tied to ten generic types of green infrastructure. The Matrix comprises the following components:

- Ten green infrastructure types (broken into fifteen subtypes)
- Two cost values per square metre derived from literature and peer reviews for capital and maintenance
- Ten benefit values for each type of generic green infrastructure
- Values for most costs and benefits are expressed in dollars

per square metre of implemented green infrastructure

- Values for job creation are expressed in job-years (i.e. one job-year is equivalent to one person employed full-time for one year) based on the investment made
- Values are expressed as one time capital cost or benefit or an annual cost or benefit

The Matrix expresses most costs and benefits in dollars per square metre. This facilitates the ability to quickly provide aggregate estimates of significant green infrastructure deployment at various scales. Expressing monetary values in terms of area also provides the basis for calculating the cost and benefits of study area redesigns from the Charrette. For example, Charrette design teams may call for 1,000 square metres of extensive green roof to be developed. The area (1,000 square metres) provides the basis for estimating the resulting costs and benefits from the values ($/m2) in the Matrix.

For purposes of the Charrette, a cost-benefit analysis is provided that is on a first cost basis, at five years, at twenty-five years, and at fifty years.

The Matrix assumes a real discount rate of 2.5%, similar to the discount rate used by the Ontario Government for capital projects. Monetary values presented in the literature have not been adjusted for currency differences or the impact of inflation except where it has been deemed that the gap in time has become too significant.

Cost-Benefit Valuation Methods

The Green Infrastructure Cost-Benefit Matrix is based on five stages of data aggregation and simplification, which are described below:

1. Type Definition

The first stage of aggregation involves the identification of commonly accepted generic green infrastructure types drawn from the literature. Each type is simplified. For example, vegetated buffer strips were added into the typology of 'Lawn/turf' based on their similar properties. While there are hundreds of species of trees with different properties, the subcategories of small, medium and large are used – the area of the canopy at maturity is used in value calculations. There are several categories of wetland in the literature but only one is used.

This is justified because the Charrette is not focused on one project, such as a building or a proposed park, but on a much larger area. Furthermore, in order to be able to administer the Charrette in one day, and to derive average values, the types of green infrastructure had to be simplified. Site-specific design and cost-benefit evaluation would require a level of design detail and performance research more appropriate to a later stage.

The generic types of green infrastructure included in the Matrix are as follows:

- Green Roofs (Extensive and Intensive)
- Green Walls (Green Facades, Interior and Exterior Living Walls)
- Rain Garden
- Bioswale
- Permeable/Porous Paver
- Small, Medium and Large Trees
- Wetlands
- Planting Beds
- Meadow/Grassland
- Lawn/Turf

2. Benefit Identification

The second stage of aggregation concerns a comprehensive identification of benefits associated with green infrastructure that are quantifiable and non-quantifiable as seen in the literature. The values included in the Matrix cover a very wide variety of public and private costs and benefits. Some benefits are common to all green infrastructure types while others are only applicable to certain types. For example, active recreational turf will not provide habitat value.

A comprehensive listing of public and private benefits resulting from green infrastructure is as follows:

- Waste diversion
- Aesthetic improvement
- New amenity spaces
- Increased property value

- Increased rental income
- Increased retail sales
- Horticultural therapy
- Increased productivity
- Increased recreational activity
- Reduction of the urban heat island
- Energy efficiency
- Carbon sequestration
- Blockage of electromagnetic radiation
- Improved air quality (particulates and chemicals)
- Shading
- Stormwater management: quality and quantity benefits
- Noise/ sound reduction
- Improved soundscape
- Increased biodiversity (flora and fauna)
- Integrated water management
- Improved marketability of development
- Educational opportunities
- Increased membrane durability
- Increased pavement durability
- Reduced grey infrastructure capital costs
- Improved human health and well-being (physical and mental)
- Fire retardation
- Local and regional job creation
- Enhanced photovoltaic panel performance
- Food production
- Biomass for energy production

Each of these benefits was evaluated according to its ability to be monetized. Only benefits that could be quantified and monetized were chosen for inclusion in the Matrix. It is however, a goal of the project to create a framework within which new benefits can be added as more research is published on quantitative data. Although all costs for green infrastructure can be quantified, not all benefits can be. The following costs and benefits are included in the Matrix at this stage in its development:

- Cost: Total Capital Investment
- Cost: Annual Maintenance
- Benefit: Annual - Stormwater Management
- Benefit: Capital - Biodiversity and Habitat
- Benefit: Annual - Increase in Air Quality
- Benefit: Annual - Green House Gas Sequestration
- Benefit: Annual - Reduction in Urban Heat Island
- Benefit: Annual - Reduction in Building Energy Use
- Benefit: Capital - Job Creation (Construction)
- Benefit: Annual - Job Creation (Maintenance)
- Benefit: Annual - Urban Food Production
- Benefit: Annual – Increase in Roof Lifespan

3. Benefit Valuation

The third stage of aggregation involves applying monetary values to performance. Average ecosystem, (biophysical) service values (such as litres of stormwater retained) are monetized. The literature referenced utilizes a variety of market and non-market valuation techniques to accomplish this. These values vary considerably from community to community, particularly given the different regulatory and economic approaches to financing and operating grey infrastructure such as stormwater management and electricity production.

4. Performance Ability

The fourth stage of aggregation involves estimates of performance. Generic performance values were derived from the literature about green infrastructure ecosystem services performance. The exact performance of green infrastructure technology may vary, because it is a function of its design characteristics as well as its location. For example, a tree on the north side of a building will provide less energy savings than one located on the south side. A green roof can eliminate anywhere from 40 to 90% of the total stormwater runoff, depending on its design and the duration and frequency of the rainfall events in the region. Hence, further simplification is necessary in order to arrive at average cost and benefit values used in the Matrix.

5. Final Valuation

The fifth stage involves a combining of both the third and the fourth stages. Performance values (litres of stormwater) are combined with monetary values ($/litre retained) for the benefit in question. When combined, a final valuation for each benefit specific to each form of green infrastructure's performance is obtained. These values are presented in a range of high, medium, and low values due to ranges in performance as well as ranges in benefit valuation.

During the Charrette process participants were asked to redesign neighbourhoods using the fifteen generic types of green infrastructure used in the Matrix. This process involved exact scaled measurements to properly allow for cost-benefit analyses following the Charrette.

Cost-Benefit Analysis Assumptions

A number of assumptions were made to facilitate the cost-benefit analyses used in this report:

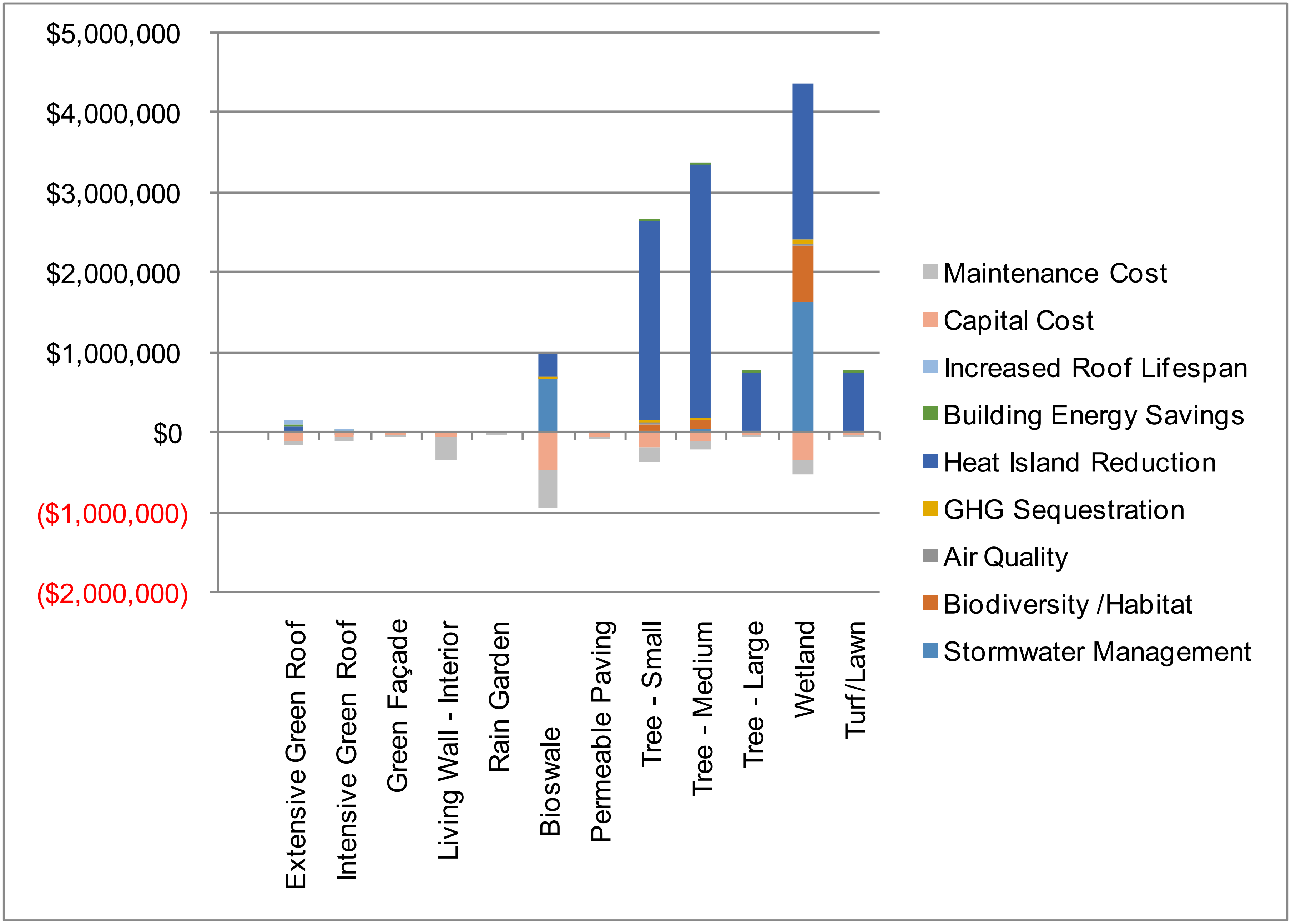
- Discount rate: 3.25%. Selected as the average of long-term bond yield rates in Ontario. Some may argue that a lower 'social discount rate' should be used, since many of these are long-term public investments with long-term benefits.
- Inflation rate: 1.57%. Selected as the average inflation over the past 10 years.
- Time frame: 50 years. Selected as green infrastructure is a long-term investment, often made by municipal governments that should have a long-term outlook. Results for shorter time periods are also provided, but we recommend using 50 years for evaluating the cost-effectiveness of green infrastructure investments.
- Valuation Methods: Over 50 studies were examined to determine values for each variable. Values were selected, and weighted using the judgment of the report authors, and peer-reviewed in 2014 as part of the development of the Green Infrastructure Cost-Benefit Matrix.
- Performance levels: Values from the previously mentioned studies were analyzed to determine the appropriate values to use for this analysis. This likely does not reflect the on-the-ground performance that these types of green infrastructure will have in these communities, i.e. local hydrology, soils, and other conditions were not factored into analyses about stormwater management, etc. Further project-specific modeling and/or study is recommended for greater accuracy.

Appendix B - Cost-Benefit Matrix Results

Barrie - Option A

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	540 m^2	($144,333)	$148,280	$3,947	1.91	0.47
Intensive Green Roof	160 m^2	($101,826)	$67,753	($34,073)	0.85	0.70
Green Façade	70 m^2	($34,049)	$4,027	($30,022)	0.19	0.31
Living Wall - Interior	40 m^2	($343,593)	$73	($343,521)	0.95	3.78
Rain Garden	36 m^2	($10,369)	$12,010	$1,642	0.07	0.08
Bioswale	2,800 m^2	($939,081)	$983,439	$44,358	7.98	6.35
Permeable Paving	400 m^2	($50,459)	$27,048	($23,411)	0.84	0.04
Tree - Small	190 trees	($348,386)	$2,686,868	$2,338,481	3.35	2.07
Tree - Medium	250 trees	($201,991)	$3,396,521	$3,194,531	1.94	1.20
Tree - Large	20 trees	($27,262)	$776,353	$749,091	0.21	0.20
Wetland	19,500 m^2	($508,037)	$4,368,801	$3,860,764	5.84	2.31
Turf/Lawn	800 m^2	($27,262)	$776,353	$749,091	0.17	0.33
TOTAL	**74,510 m^2**	**($2,736,649)**	**$13,247,526**	**$10,510,877**	**24.28**	**17.85**

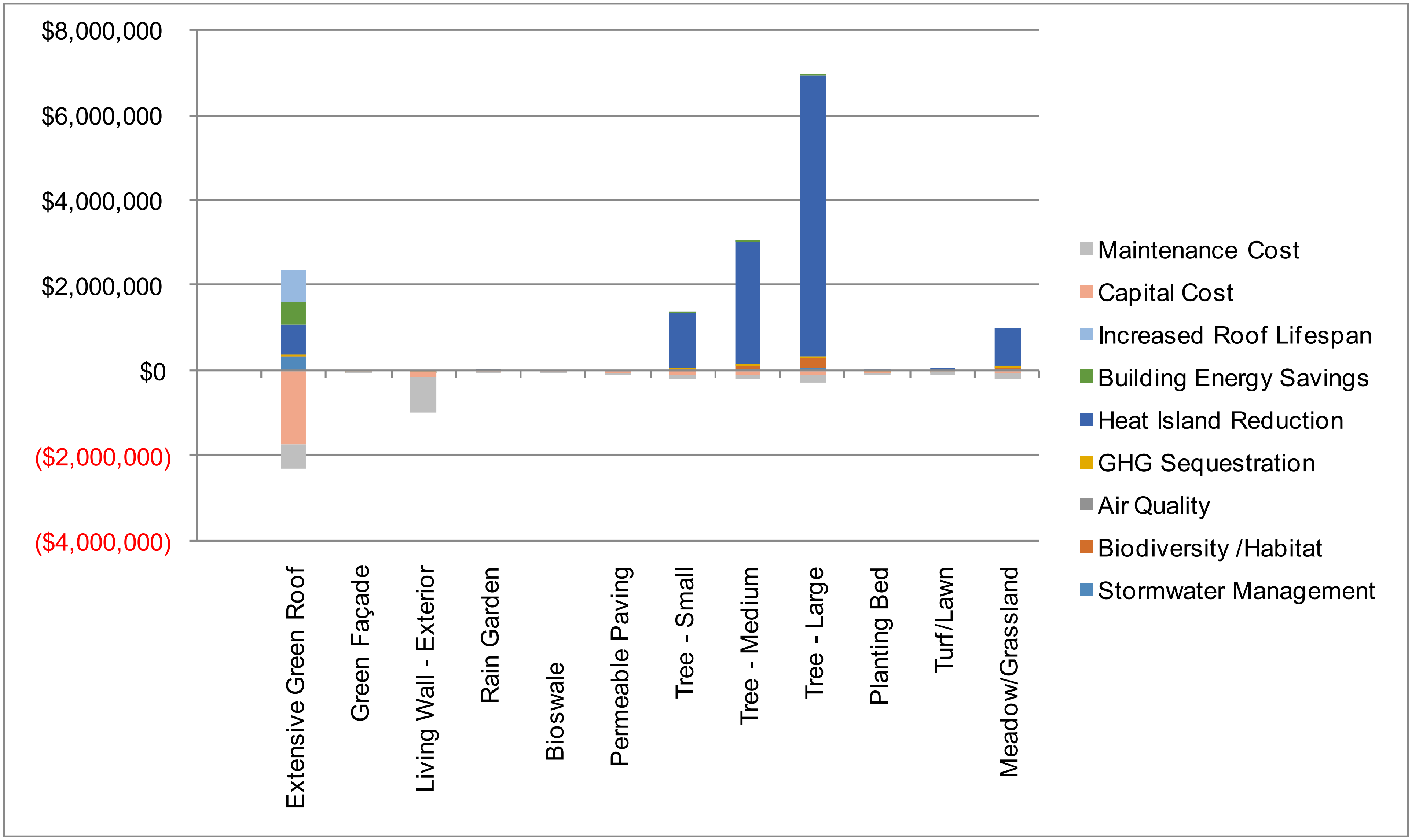
Barrie Option A - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Barrie - Option B

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	8,575 m^2	($2,291,950)	$2,354,631	$62,681	30.26	7.53
Green Façade	60 m^2	($29,185)	$3,452	($25,733)	0.16	0.26
Living Wall - Exterior	116 m^2	($965,205)	$7,142	($958,064)	2.20	10.96
Rain Garden	150 m^2	($43,204)	$50,044	$6,840	0.30	0.34
Bioswale	60 m^2	($20,123)	$21,074	$951	0.17	0.14
Permeable Paving	300 m^2	($37,844)	$20,286	($17,558)	0.63	0.03
Tree - Small	100 trees	($183,359)	$1,414,127	$1,230,767	1.77	1.09
Tree - Medium	100 trees	($183,630)	$3,087,784	$2,904,154	1.76	1.09
Tree - Large	180 trees	($245,362)	$6,987,309	$6,741,948	1.90	1.79
Planting Bed	300 m^2	($95,774)	$33,305	($62,469)	0.77	0.68
Turf/Lawn	1,800 m^2	($78,641)	$108,270	$29,629	0.37	0.75
Meadow/Grassland	10,500 m^2	($174,617)	$1,007,528	$832,911	0.65	1.80
TOTAL	**105,899 m^2**	**($4,348,894)**	**$15,094,950**	**$10,746,056**	**40.95**	**26.46**

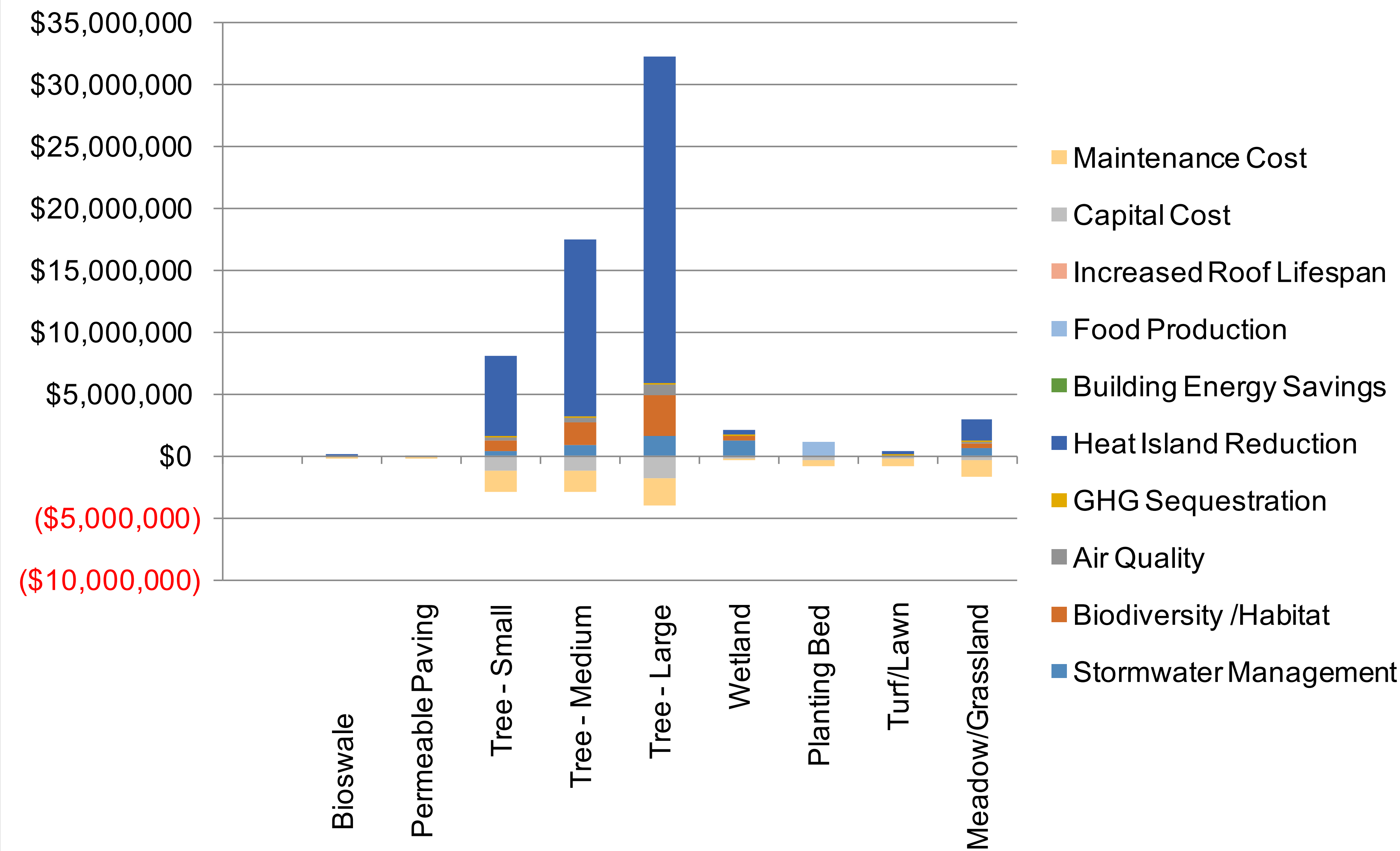
Barrie Option B - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Brampton

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Bioswale	350 m^2	($117,385)	$90,747	($26,639)	1.00	0.79
Permeable Paving	800 m^2	($100,918)	$54,095	($46,823)	1.67	0.08
Tree - Small	2,000 trees	($2,868,265)	$4,248,340	$1,380,075	21.20	21.75
Tree - Medium	2,000 trees	($2,872,103)	$10,227,307	$7,355,204	21.15	21.84
Tree - Large	2,940 trees	($4,007,638)	$21,385,447	$17,377,809	31.08	29.31
Wetland	14,400 m^2	($375,166)	$1,902,081	$1,526,915	4.31	1.71
Planting Bed	2,000 m^2	($783,134)	$1,114,654	$331,520	6.46	5.44
Turf/Lawn	19,200 m^2	($838,836)	$233,593	($605,242)	3.97	8.01
Meadow/Grassland	100,000 m^2	($1,663,016)	$1,932,320	$269,304	6.19	17.12
TOTAL	**1,630,146 m2**	**($13,626,460)**	**$41,188,584**	**$27,562,124**	**97.04**	**106.04**

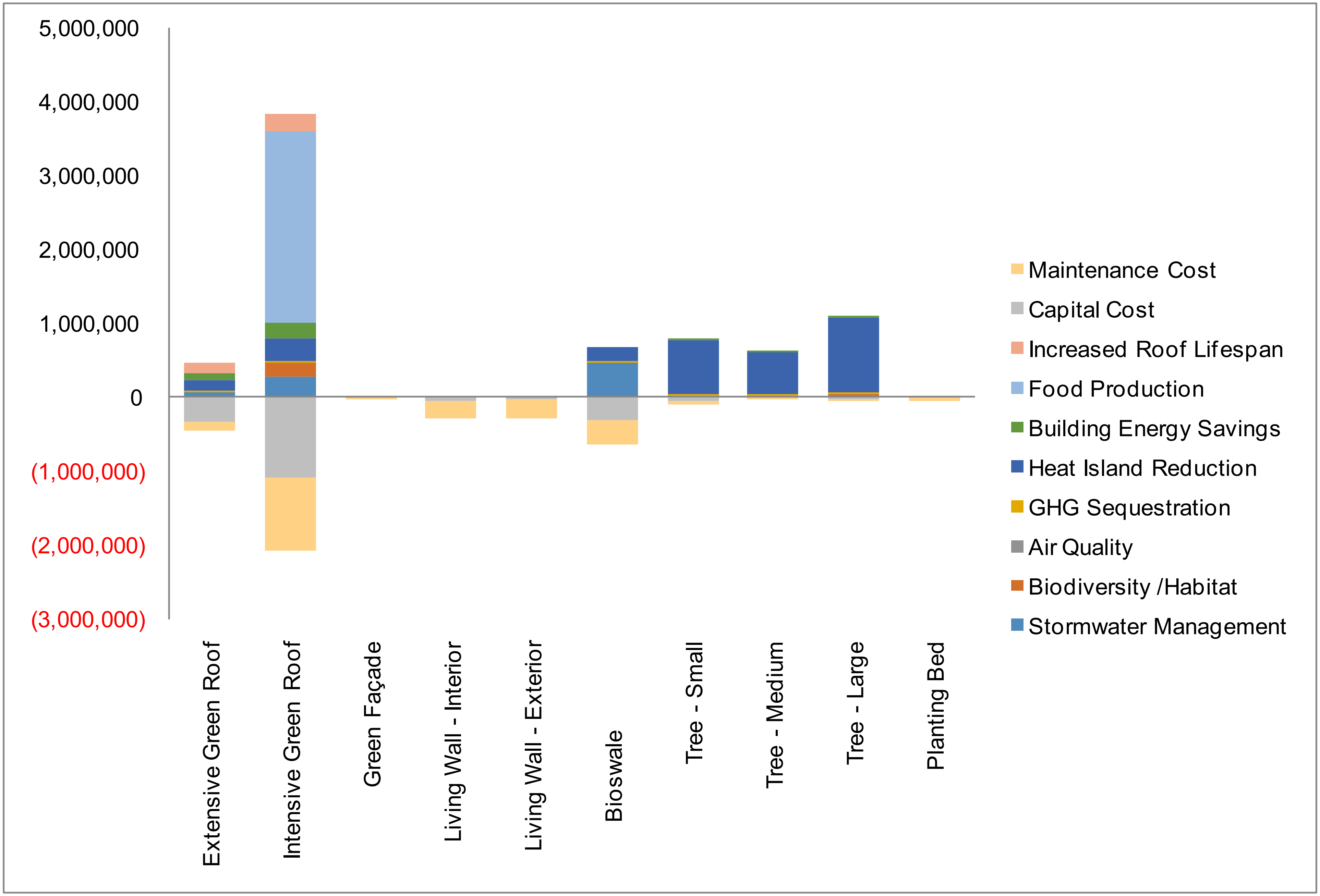
Brampton - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Guelph - Baker District

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	1,695 m^2	($453,044)	$465,434	$12,390	5.98	1.49
Intensive Green Roof	2,935 m^2	($2,088,001)	$3,833,243	$1,745,242	19.42	12.88
Green Façade	42 m^2	($20,429)	$2,416	($18,013)	0.11	0.18
Living Wall - Interior	35 m^2	($300,644)	$64	($300,581)	0.83	3.31
Living Wall - Exterior	35 m^2	($291,226)	$2,155	($289,071)	0.66	3.31
Bioswale	1,920 m^2	($643,941)	$674,358	$30,417	5.47	4.36
Tree - Small	55 trees	($100,846)	$777,756	$676,910	0.97	0.60
Tree - Medium	20 trees	($36,729)	$617,611	$580,882	0.35	0.22
Tree - Large	28 trees	($49,380)	$1,087,003	$1,037,623	0.49	0.28
Planting Bed	160	($51,079)	$17,763	($33,317)	0.41	0.36
TOTAL	**24,972 m^2**	**($4,035,321)**	**$7,477,803**	**$3,442,482**	**34.71**	**26.99**

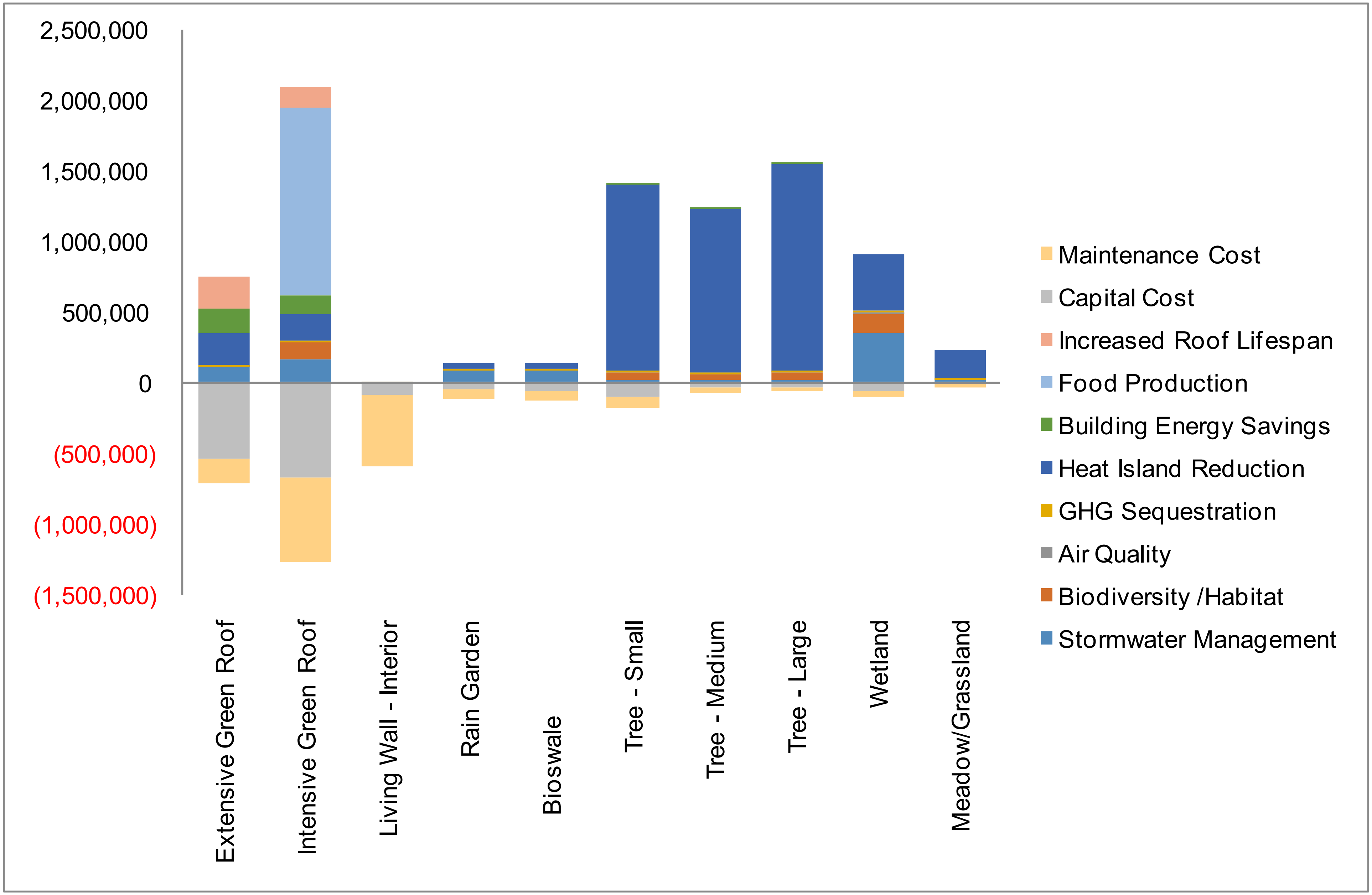
Guelph Baker District - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Guelph - South End Community Centre

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	2,700 m^2	($721,664)	$741,400	$19,736	9.53	2.37
Intensive Green Roof	1,800 m^2	($1,280,546)	$2,094,427	$813,881	11.91	7.90
Living Wall - Interior	70 m^2	($601,288)	$127	($601,161)	1.66	6.62
Rain Garden	400 m^2	($115,210)	$133,450	$18,240	0.81	0.91
Bioswale	400 m^2	($134,154)	$140,491	$6,337	1.14	0.91
Tree - Small	100 trees	($183,359)	$1,414,127	$1,230,767	1.77	1.09
Tree - Medium	40 trees	($73,450)	$1,235,086	$1,161,636	0.71	0.44
Tree - Large	40 trees	($70,536)	$1,552,705	$1,482,169	0.71	0.40
Wetland	4,060 m^2	($105,776)	$909,607	$803,831	1.22	0.48
Meadow/Grassland	2,400 m^2	($39,912)	$230,292	$190,380	0.15	0.41
TOTAL	**42,553 m2**	**($3,325,897)**	**$8,451,712**	**$5,125,816**	**29.59**	**21.52**

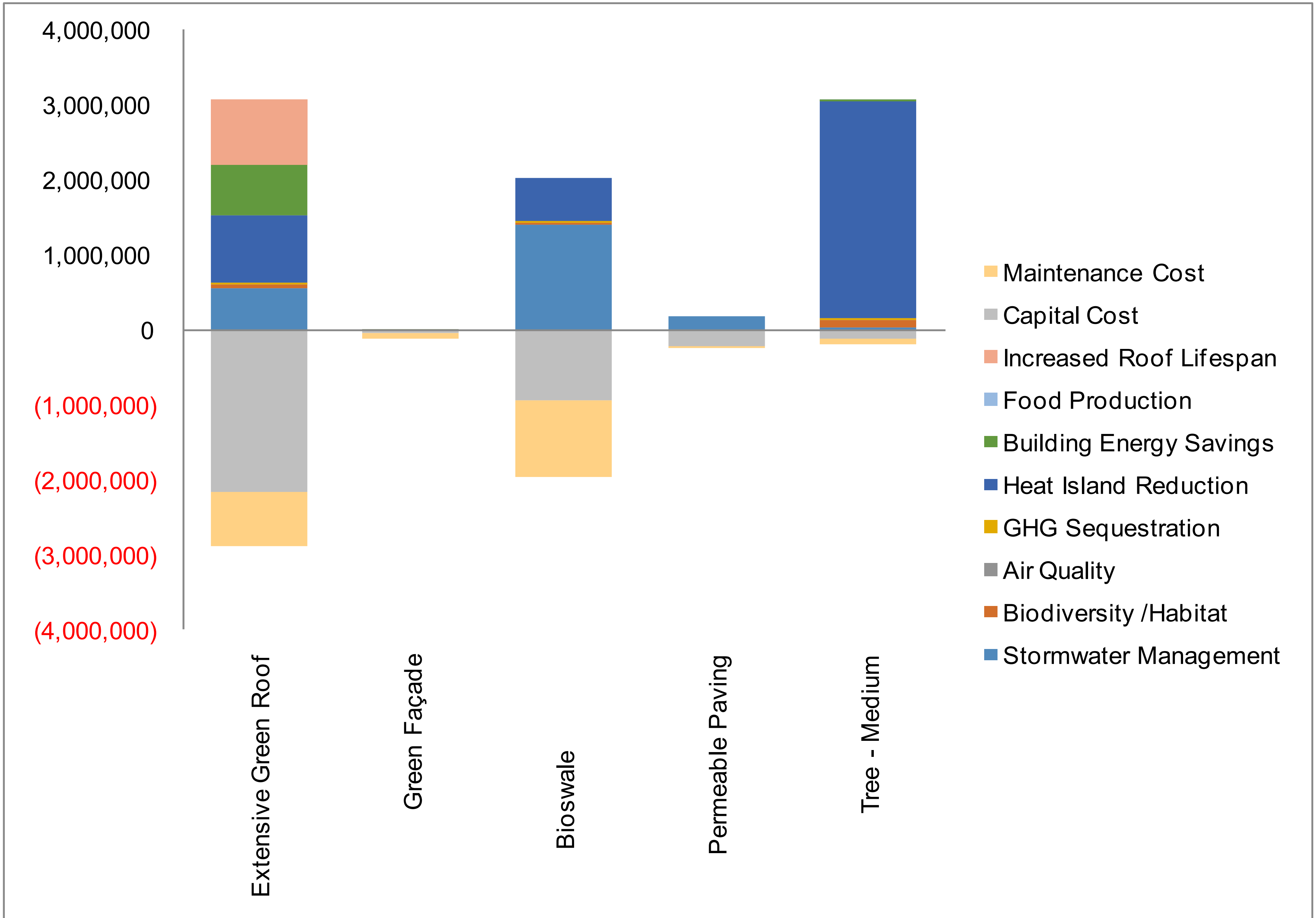
Guelph South End Community Centre - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



London

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	10,750 m^2	($2,873,291)	$3,082,063	$208,772	37.94	9.44
Green Façade	240 m^2	($116,739)	$13,807	($102,932)	0.64	1.05
Bioswale	5,800 m^2	($1,945,240)	$2,037,123	$91,884	16.53	13.16
Permeable Paving	2,700 m^2	($221,611)	$182,572	($39,039)	3.59	0.24
Tree - Medium	100 trees	($183,630)	$3,087,784	$2,904,154	1.76	1.09
TOTAL	**38,126 m^2**	**($2,832,059)**	**$5,448,918**	**$2,616,860**	**28.78**	**15.67**

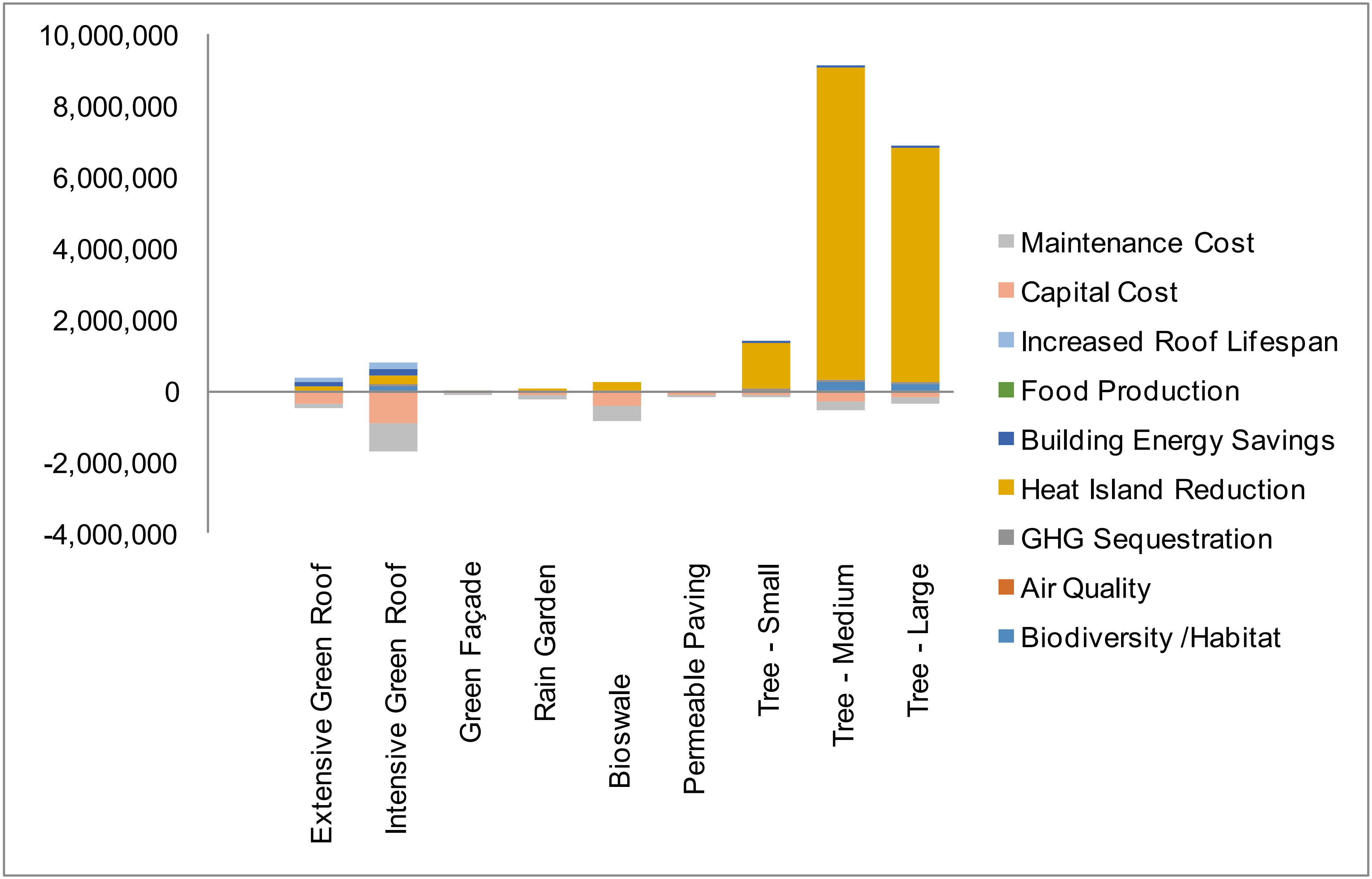
London - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Toronto - Option A

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	1,695 m^2	($453,044)	$465,434	$12,390	5.98	1.49
Intensive Green Roof	2,395 m^2	($1,703,837)	$1,014,185	($689,652)	15.85	10.51
Green Façade	240 m^2	($116,739)	$13,807	($102,932)	0.64	1.05
Rain Garden	750 m^2	($216,020)	$250,219	$34,199	1.51	1.70
Bioswale	2,450 m^2	($821,696)	$860,509	$38,813	6.98	5.56
Permeable Paving	1,200 m^2	($98,494)	$81,143	($17,351)	1.60	0.11
Tree - Small	100 trees	($183,359)	$1,414,127	$1,230,767	1.77	1.09
Tree - Medium	300 trees	($550,890)	$9,263,352	$8,712,461	5.29	3.28
Tree - Large	180 trees	($317,422)	$6,987,419	$6,669,997	3.17	1.79
TOTAL	**137,995 m^2**	**($4,461,502)**	**$20,350,194**	**$15,888,692**	**42.78**	**26.58**

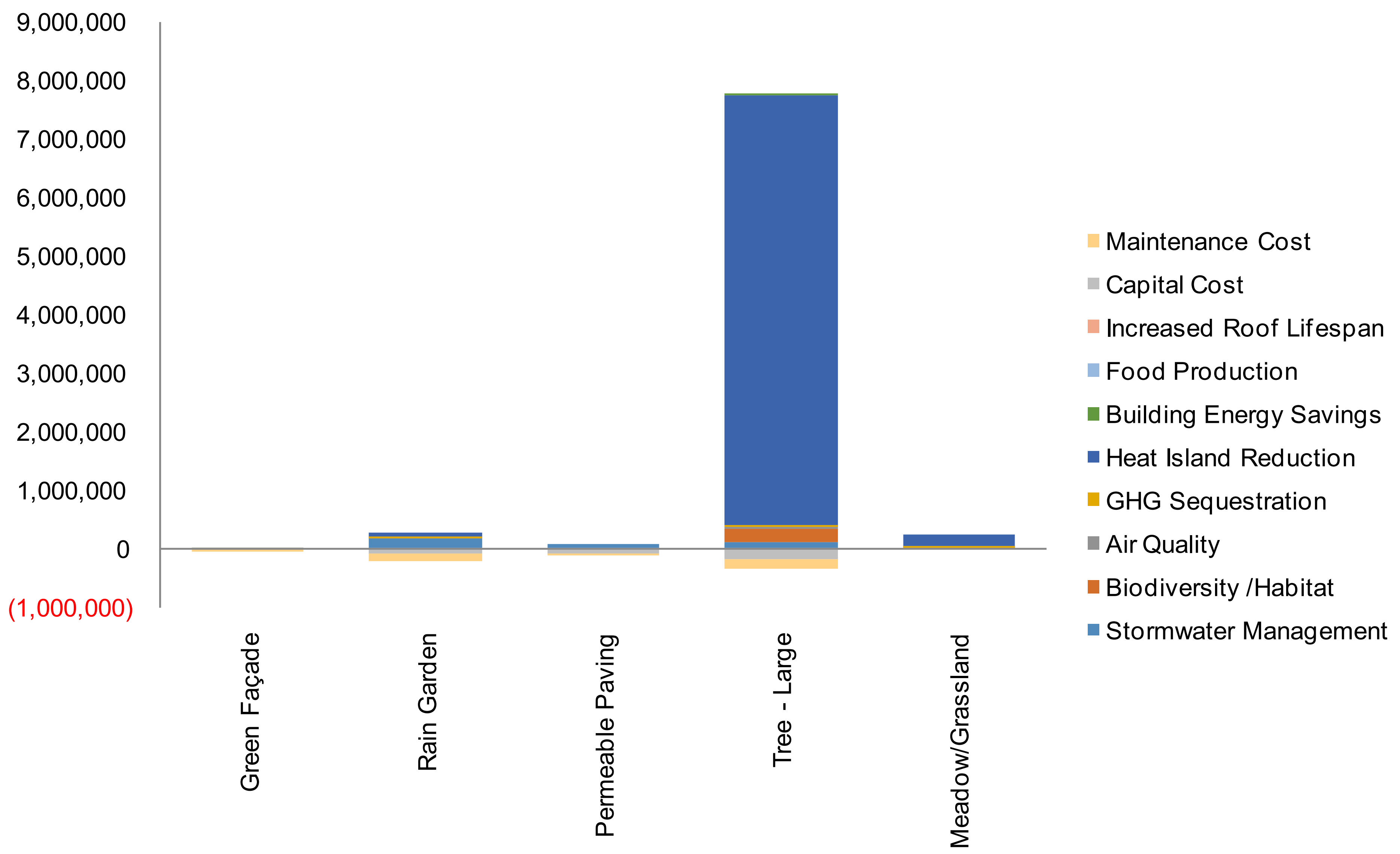
Toronto Option A - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Toronto - Option B

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Green Façade	70 m^2	($34,049)	$4,027	($30,022)	0.19	0.31
Rain Garden	750 m^2	($216,020)	$250,219	$34,199	1.51	1.70
Permeable Paving	1,200 m^2	($98,494)	$81,143	($17,351)	1.60	0.11
Tree - Large	200 m^2	($352,691)	$7,763,799	$7,411,108	3.53	1.99
Meadow/Grassland	2,400 m^2	($39,912)	$230,292	$190,380	0.15	0.41
TOTAL	**61,202 m^2**	**($741,166)**	**$8,329,479**	**$7,588,314**	**6.97**	**4.52**

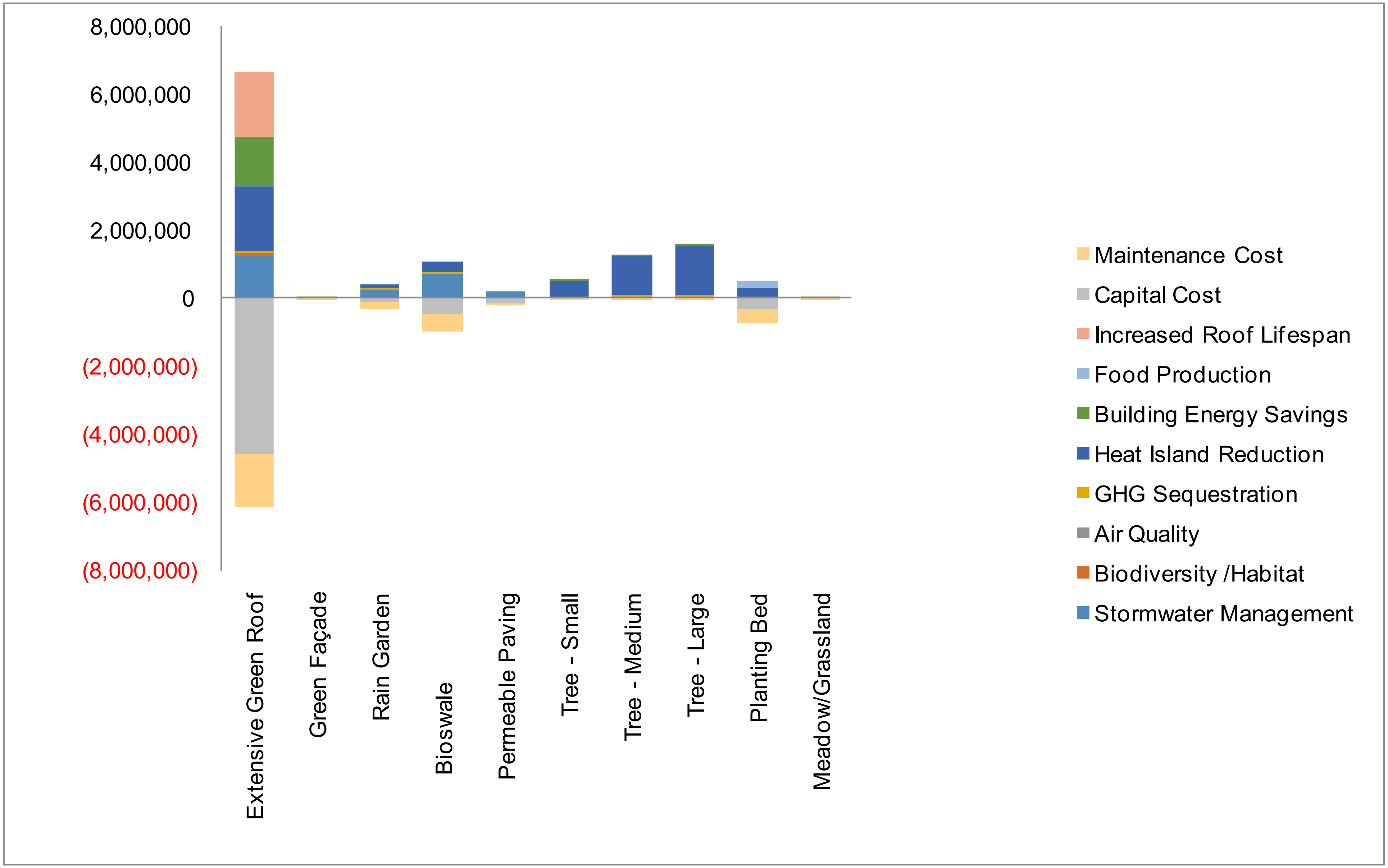
Toronto Option B - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Toronto - Option C

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	23,050 m^2	($6,160,870)	$6,608,516	$447,646	81.35	20.23
Green Façade	70 m^2	($34,049)	$4,027	($30,022)	0.19	0.31
Rain Garden	1,180 m^2	($339,871)	$393,677	$53,807	2.38	2.68
Bioswale	2,956 m^2	($991,402)	$1,038,230	$46,829	8.42	6.71
Permeable Paving	2,600 m^2	($213,404)	$175,810	($37,593)	3.46	0.23
Tree - Small	40 trees	($73,344)	$565,651	$492,307	0.71	0.43
Tree - Medium	40 trees	($73,452)	$1,235,114	$1,161,661	0.71	0.44
Tree - Large	40 trees	($70,538)	$1,552,760	$1,482,222	0.71	0.40
Planting Bed	2,380 m^2	($759,806)	$468,759	($291,047)	6.10	5.40
Meadow/Grassland	350 m^2	($5,821)	$33,584	$27,764	0.02	0.06
TOTAL	**57,116 m^2**	**($8,722,555)**	**$12,076,128**	**$3,353,572**	**104.04**	**36.89**

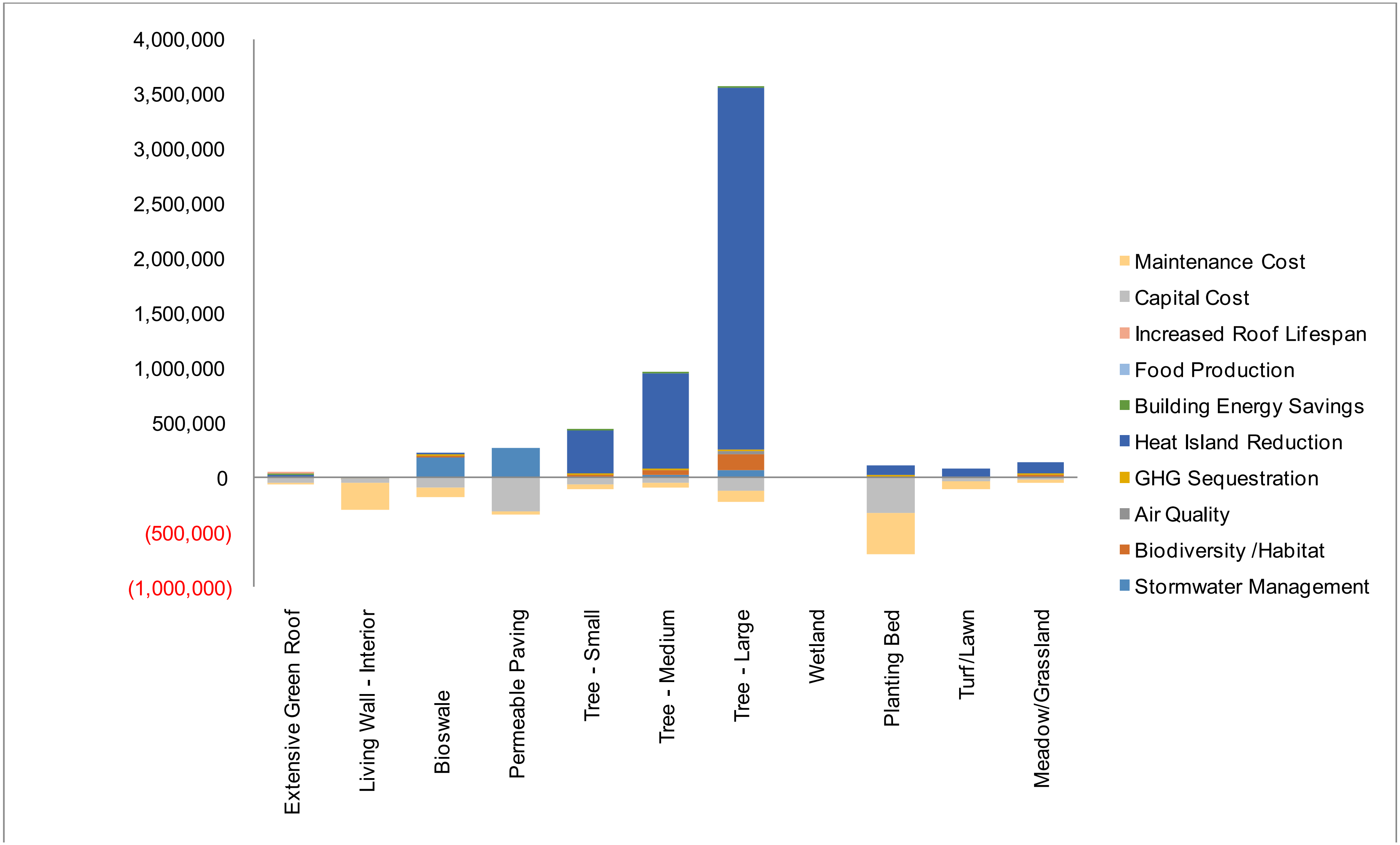
Toronto Option C - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Waterloo - Option A

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	**Area**	**Net Present Value of Costs**	**Net Present Value of Benefits**	**Net Present Value**	**Full-Time Equivalent Jobs (Capital)**	**Full-Time Equivalent Jobs (Operational)**
Extensive Green Roof	240 m^2	($64,148)	$56,815	($7,333)	0.85	0.21
Living Wall - Interior	34 m^2	($292,054)	$62	($291,993)	0.81	3.21
Bioswale	540 m^2	($181,109)	$229,332	$48,223	1.54	1.23
Permeable Paving	4,000 m^2	($328,313)	$270,477	($57,836)	5.32	0.35
Tree - Small	60 trees	($110,016)	$449,151	$339,135	1.06	0.65
Tree - Medium	50 trees	($91,815)	$960,573	$868,758	0.88	0.55
Tree - Large	125 trees	($220,432)	$3,571,054	$3,350,622	2.20	1.25
Planting Bed	2,200 m^2	($702,342)	$112,311	($590,031)	5.64	4.99
Turf/Lawn	2,500 m^2	($109,223)	$83,731	($25,493)	0.52	1.04
Meadow/Grassland	3,030 m^2	($50,389)	$139,321	$88,932	0.19	0.52
TOTAL	**65532 m^2**	**($2,149,841)**	**$5,872,826**	**$3,722,985**	**19.00**	**14.00**

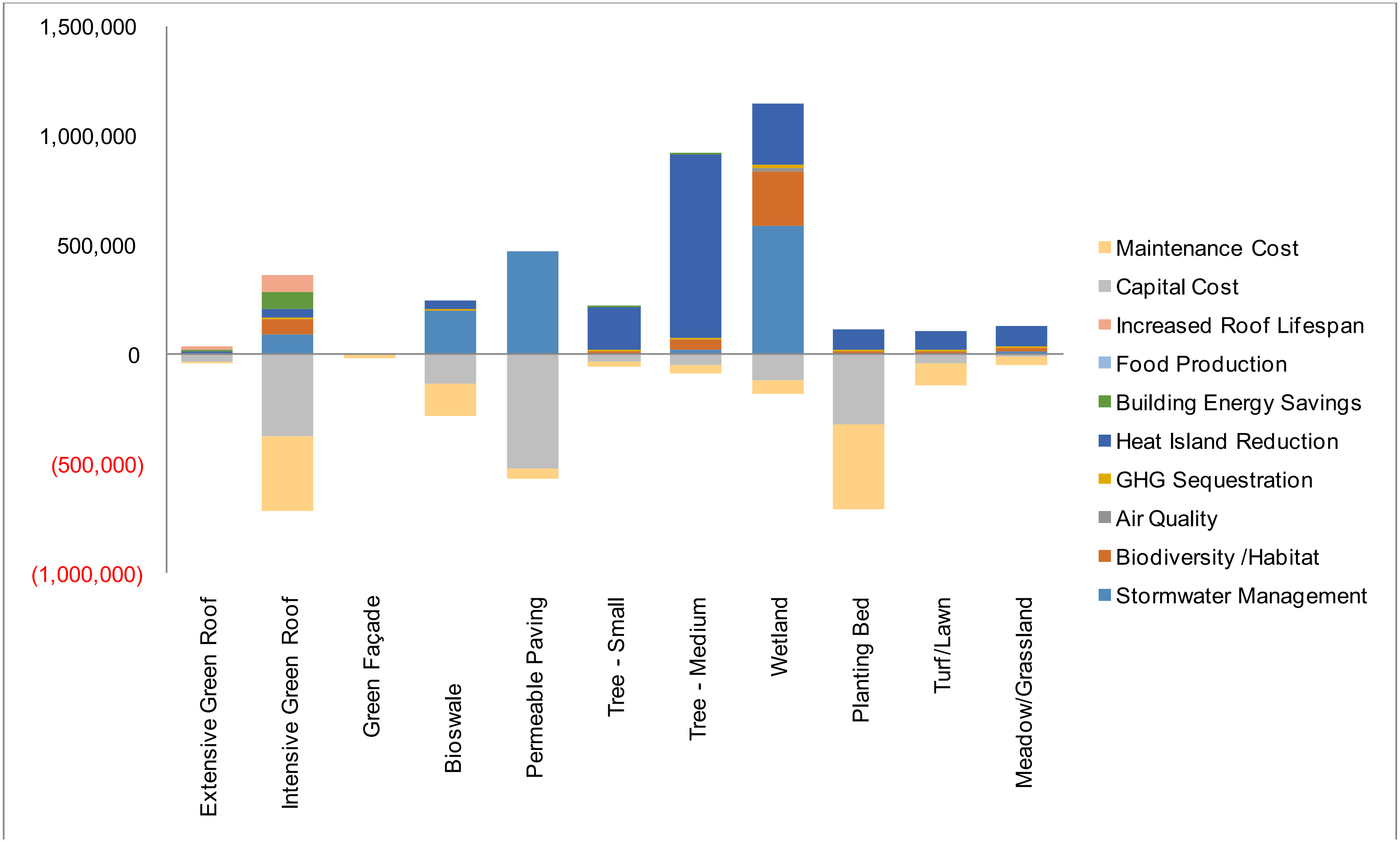
Waterloo Option A - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Waterloo - Option B

Net Present Value and Jobs of Green Infrastructure on Site (over 50 years)						
Type of Green Infrastructure	Area	Net Present Value of Costs	Net Present Value of Benefits	Net Present Value	Full-Time Equivalent Jobs (Capital)	Full-Time Equivalent Jobs (Operational)
Extensive Green Roof	150 m^2	($40,092)	$35,509	($4,583)	0.53	0.13
Intensive Green Roof	1,000 m^2	($711,414)	$363,493	($347,921)	6.62	4.39
Green Façade	30 m^2	($14,592)	$878	($13,714)	0.08	0.13
Bioswale	835 m^2	($280,047)	$243,204	($36,843)	2.38	1.89
Permeable Paving	6,930 m^2	($568,803)	$468,602	($100,201)	9.21	0.61
Tree - Small	30 trees	($55,008)	$224,575	$169,568	0.53	0.33
Tree - Medium	48 trees	($88,142)	$922,150	$834,008	0.85	0.52
Planting Bed	2,200 m^2	($702,342)	$112,311	($590,031)	5.64	4.99
Turf/Lawn	3,300 m^2	($144,175)	$110,525	($33,650)	0.68	1.38
Meadow/Grassland	2,765 m^2	($45,982)	$127,137	$81,154	0.17	0.47
TOTAL	**31,160 m^2**	**($2,650,598)**	**$2,608,384**	**($42,214)**	**26.69**	**14.85**

Waterloo Option B - Breakdown of Benefits by Green Infrastructure Type (over 50 years)



Appendix C: Green Infrastructure Charrette Participants

Barrie

- Jenn Court; Green Infrastructure Ontario Coalition
- Jordan Lambie; City of Barrie
- Celeste Kitsemetry; City of Barrie
- Michelle Banfield; City of Barrie
- Edward Terry; City of Barrie
- Jen Porter; City of Barrie
- Steve Rose; City of Barrie
- Mike McConnell; City of Barrie
- Clare Maher; City of Barrie
- Nadine Rush; City of Barrie
- Angela MacLean; City of Barrie
- Craig Stevens; Downtown Barrie Business Association
- Tom Hogenbirk; Lake Simcoe Region Conservation Authority
- Alison Edwards; Nottawasaga Valley Conservation Authority
- Kory Chisholm; MHBC Planning

Brampton

- Jake Mete; City of Brampton
- Natalie Fleishman; City of Brampton
- Werner Kuemmling; City of Brampton
- Michael Hoy; City of Brampton
- Rosemary Keenan; Sierra Club Peel
- Cindy Chambers; City of Brampton
- Brian Macklin; City of Brampton
- David Laing; Brampton Environmental Advisory Committee

Guelph

- Alex Chapman; City of Guelph
- Vadim Sabetski; City of Guelph
- Martin Neumann; City of Guelph
- Arun Hindupur; City of Guelph
- Mario Martinez; City of Guelph
- Dave Beaton; City of Guelph
- Timea Filer; City of Guelph
- Mary Angelo; City of Guelph
- Alexandra Marson; City of Guelph
- Bashar Sayyed; City of Guelph
- Michael Mousa; Urban Equation
- Martin Jewett; City of Guelph
- Stacey Laughlin; City of Guelph
- Jim Hall; City of Guelph
- Bryan McPherson; Landactive

London

- Andy Beaton; City of London
- Paula Bustard; City of London
- Dianna Clark; City of London
- Pat Donnelly; City of London
- Stephanie Wilson; City of London
- Jeff Bruin; City of London
- Michelle Morris; City of London
- Amanda Lockwood; City of London
- Jake Helm; City of London
- Melissa Campbell; City of London
- Karl Grabowski; City of London
- Andrew Macpherson; City of London

Toronto

- Kristina Hausmanis; City of Toronto
- Alex Rudolfs; City of Toronto
- Andrew Particka; City of Toronto
- Bettina Takacs; City of Toronto
- Carol Martin; City of Toronto
- Corinne Fox; City of Toronto
- Danka Sobot; City of Toronto
- Darrell Wunder; City of Toronto
- Diane Leal; City of Toronto
- Hazel Breton; City of Toronto
- Inna Olchovski; City of Toronto
- Jen-Sion Tan; City of Toronto
- Jessica Kwan; City of Toronto
- John Stuckless; City of Toronto
- Laurel Christie; City of Toronto
- Maili Sedore; City of Toronto
- Nima Arbabi; City of Toronto
- Peter Simon; City of Toronto
- Richard Lucey; City of Toronto
- Sasha Terry; City of Toronto
- Xue Pei; City of Toronto
- Pezhman Imani; City of Toronto
- Nicole O'Connor; SKA
- Ron Richards; RG Richards and Associates
- Steve Bishop; North American Development Group
- Mark Golakovich; SKA
- Ihab Daakour; GPAIA
- Caitlin Allan; Bousfields

Waterloo

- Jeff Silcox-Childs; City of Waterloo
- Andrea Bazler; City of Waterloo
- Barb Magee Turner; City of Waterloo
- Anna Lee Sangster; City of Waterloo
- Gavin Vermeer; City of Waterloo
- Robyn McMullen; City of Waterloo
- Ronda Werner; City of Waterloo
- Susan Bolt; City of Waterloo
- Daniel Waters; City of Waterloo
- Patrick Gilbride, REEP Green Solutions

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