RAIN CITY STRATEGY

CITY OF VANCOUVER

BUILDING A CITY WE LOVE

Rain City Strategy:

A green rainwater infrastructure and rainwater management initiative

City of Vancouver
November 5, 2019

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Cover photo credit: Wendy de Hoog

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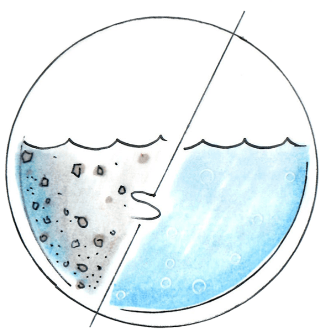
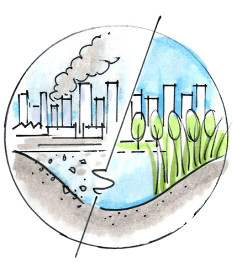


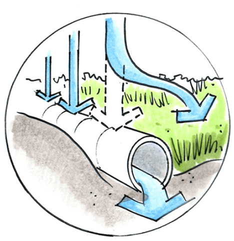
Goals:

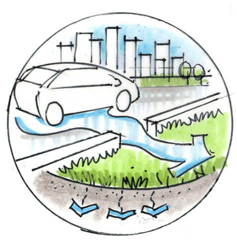
Improve and protect Vancouver's water quality

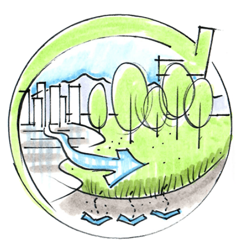
Increase Vancouver's resilience through sustainable water management

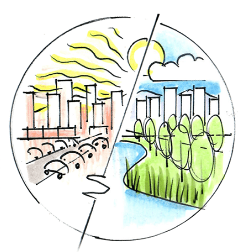
Enhance Vancouver's livability by improving natural and urban ecosystems

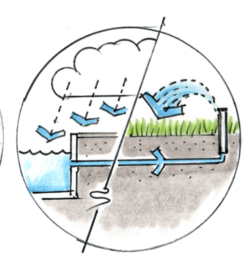












Objectives:

Remove pollutants from water and air

Reduce volume of rainwater entering pipe system

Increase managed impermeable area that treats urban rainwater runoff

Increase total green area that treats urban rainwater runoff

Mitigate urban heat island effect

Harvest and reuse water

Strategy snapshot

Vision

Vancouver's rainwater is embraced as a valued resource for our communities and natural ecosystems

Goals

1. Improve and protect Vancouver's water quality;
2. Increase Vancouver's resilience through sustainable water management; and
3. Enhance Vancouver's livability by improving natural and urban ecosystems.

Objectives

- Remove pollutants from water and air;
- Increase managed impermeable area;
- Reduce volume of rainwater entering the pipe system;
- Harvest and reuse water;
- Mitigate urban heat island effect; and
- Increase total green area.

Targets

- Capture (infiltrate, evapotranspirate, and/or reuse) and clean (treat) a minimum of 90% of Vancouver's average annual rainfall volume (long term); and
- Manage urban rainwater runoff from 40% of impervious areas in the city by 2050.

Rainwater management design standard for public property as of November 2019

Capture and clean 48 mm in:

- Streets and public spaces;
- Civic facilities; and
- Parks.

Rainwater management design standard for private property by 2022

- Capture and clean 48 mm.

Guiding principles to become a water sensitive city

- Design our city as a water supply catchment;
- Design our city and infrastructure to deliver ecosystem services;
- Design our city for water resilience, adaptability and flexibility;
- Design our city to encourage collaborative action and enable water wise behaviours; and
- Design our city to support an equitable water future.

Transformative directions

1. Strive to become a water sensitive city;
2. Respond with urgency to climate change;
3. Accelerate action to protect the health and vitality of surrounding waterbodies;
4. Revitalize watersheds and waterfronts to enable communities and natural systems to thrive;
5. Shape systems to integrate and value all forms of water;
6. Explore intersectionality, equity and reconciliation with Indigenous Peoples through urban water management;
7. Drive innovation and system effectiveness through data and analytics;
8. Enable a culture of collaboration; and
9. Invest in education, capacity-building and partnerships to mobilize action.

Action plans

- Streets and public spaces: 11 implementation and 5 enabling programs;
- Buildings and sites: 7 implementation, 5 enabling programs and 2 linked (complementary) programs; and
- Parks and beaches: 12 implementation and 4 enabling programs.

Executive summary

For some, water is a practicality. For others, water is a gift, even sacred. For all living species, water is life.

Transitioning to become a water sensitive city to address the water challenges Vancouver is facing has never been more urgent. Strong economic, environmental and social imperatives are driving the call for change. The Rain City Strategy is a step in this transition that builds upon past actions and leadership around green rainwater infrastructure over two decades. It is a cross-departmental initiative that seeks a paradigm shift in how we manage water and embraces rainwater as a valued resource for our communities and ecosystems, both in Vancouver and with our peers in the region and province.

Starting today, and with an outlook to 2050, the Rain City Strategy provides a long-term, yet pragmatic roadmap for advancing and evolving our rainwater management practices and services. The strategy builds on the City of Vancouver's provincially mandated Integrated Rainwater Management Plan (IRMP), adopted by City Council in 2016, and sets an ambitious vision for collective action around green rainwater infrastructure (GRI) implementation in Vancouver. GRI implementation and a more integrated approach to water resource management will lead to holistic integrated water utility services, protect water quality, support resilience and enhance livability and equity.

Achieving a paradigm shift in urban water management begins with a renewed focus on the health of receiving waterbodies, reducing flood risk, creating spaces for water in our city and advancing water harvest and reuse. It also means shared leadership and responsibility for rainwater management that extends beyond a single City department and beyond public sector and public infrastructure alone.

More holistic and cost-effective rainwater management calls for all lands in Vancouver to do their part to help manage rainwater close to where it lands. Today, private properties depend largely on public infrastructure to manage onsite rainwater. In the future, as part of more cost-effectively managing citywide rainfall, private properties and infrastructure will play an important role in reducing discharge to the pipe system through onsite actions.

The strategy articulates nine transformative directions that are meant to be implemented in the medium and long term, together with three GRI implementation actions plans that define the efforts needed in the near term. The GRI implementation action plans relate to (1) Streets and Public Spaces, (2) Building and Sites, and (3) Parks and Beaches. In all, the strategy is recommending 46 programs and enabling initiatives to be developed and implemented over the coming three decades.

The Strategy reaffirms the previously adopted performance target to manage 90% of Vancouver's average annual rainfall, increases the design standard for the volume of rainwater to be managed by sites and GRI assets to 48 mm per day and establishes an ambitious implementation target to manage rainwater volume and water quality for 40% of Vancouver's impervious areas by 2050 through new development, capital projects and strategic retrofits.

Moving forward, City staff will be exploring how multiple municipal tools including (1) regulation,

(2) advocacy and (3) investment can be used to advance implementation of the strategy. New regulatory requirements and advocacy efforts for private property will be developed through the Buildings and Sites Action Plan. In addition, it is expected that new street design standards that include rainwater management will become part of boulevard restoration requirements as new developments occur. Achieving desired outcomes will require a move beyond pilot projects and one-off demonstrations to making holistic rainwater management and GRI tools a new business-as-usual across sectors and through all urban planning, development and infrastructure decisions.

In terms of investments, the City has dedicated considerable effort and initial investments to advance GRI planning and implementation as part of the 2015-2018 Capital Plan. The 2019-2022 Capital Plan and operating budget has identified nearly $70 million from within existing budgets, to support the delivery of priority investments and program development associated with the Rain City Strategy implementation and GRI through the Streets and Public Spaces, Buildings and Sites, and Park and Beaches Action Plans.

A longer-term implementation and financial strategy will be developed to identify equitable and sustainable funding approaches and partnerships to guide the pace and magnitude of investments and funding needed beyond 2022. Advocacy, developing partnerships and working with other agencies and levels of government to identify potential for regulatory, program and grant program alignments has begun and will be essential moving forward.

The following sections define GRI, imperatives for a new approach, and provide an overview of the vision, goals and objectives, strategy development process, transformative directions, and the importance of adaptive management as we learn and develop our capacity to meet the goals and objectives of the Rain City Strategy.

Defining green rainwater infrastructure

GRI is an emerging field and approach to rainwater management that uses both engineered and ecosystem-based practices to protect, restore and mimic the natural water cycle. It uses soils, plants, trees and built structures such as blue-green roofs, swales, rainwater tree trenches and rain gardens to capture, store and clean rainwater before being absorbed in the ground or returning it to our waterways and atmosphere (see Figure 1 for examples). GRI can also include the harvest and reuse of rainwater.

GRI can be considered both a drainage infrastructure tool and an approach to water management and natural systems. GRI is gaining traction and widespread use globally. Its feasibility, value and cost-effectiveness have been demonstrated broadly in cities across North America, Europe, Australia and Asia.

Imperatives for a new approach

There are many imperatives for advancing a new approach to water management in Vancouver, including population growth, a chronic aquatic water quality crisis, the climate emergency, affordability, equity and reconciliation with Indigenous Peoples.

Rainwater management in a growing city

Vancouver is a city that continues to densify and changes form through development as we grow to meet our housing, community and economic needs. By 2041, the Metro Vancouver Regional Growth Strategy (2011) anticipates Vancouver is expected to have grown by more than 150,000 residents and close to 90,000 jobs,[1] putting ever more pressure on the existing water, sewer and drainage system, much of which is aging.

FIGURE 1: EXAMPLES OF GRI

BIORETENTION

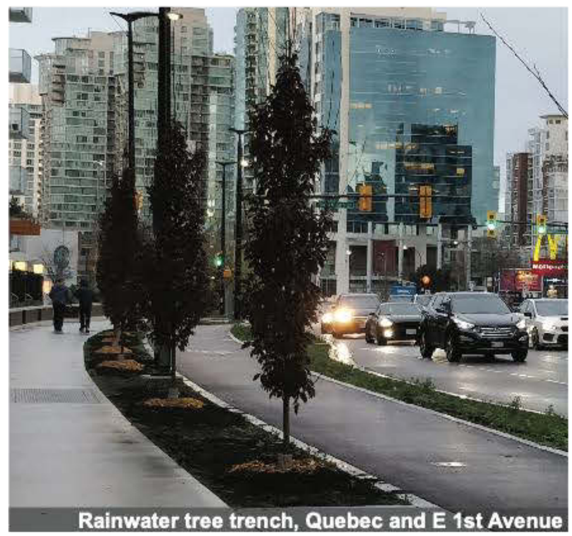
63rd Avenue at Yukon Rain Garden and Bioswale Vancouver

Bioretention Bulge, East Fraser Lands, Vancouver

RESILIENT ROOFS

Building 002 blue-green roof retrofit, Amsterdam

RAINWATER TREE TRENCHES

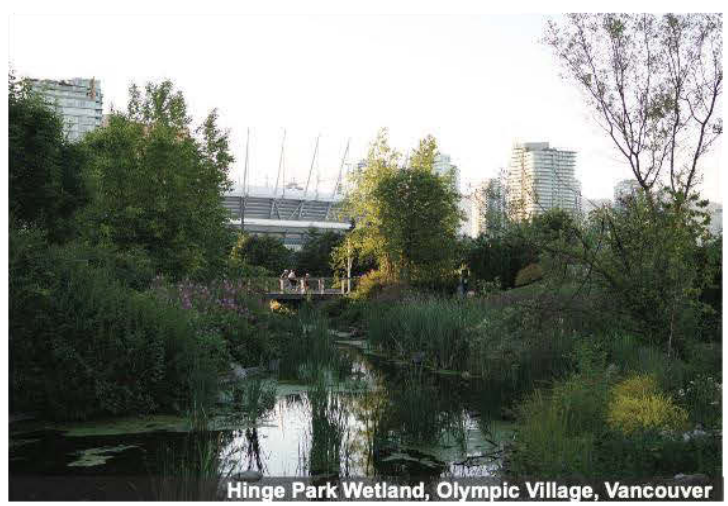


Rainwater tree trench, Quebec and E 1st Avenue

SUBSURFACE INFILTRATION

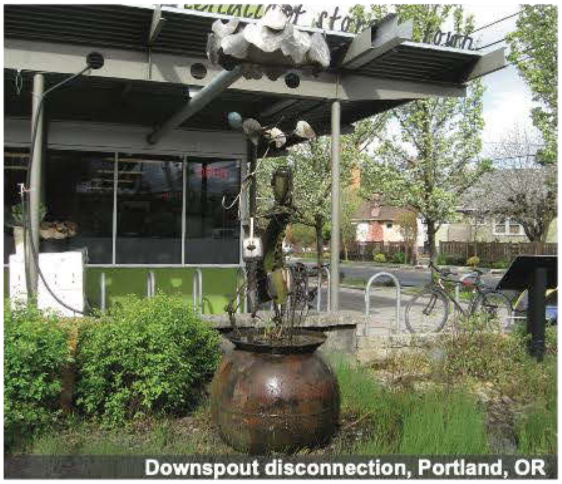
Infiltration trench under construction, Burrard at Cornwall

LARGE SCALE PRACTICES



Hinge Park Wetland, Olympic Village, Vancouver

DOWNSPOUT DISCONNECTION



Downspout disconnection, Portland, OR

NON-POTABLE SYSTEMS

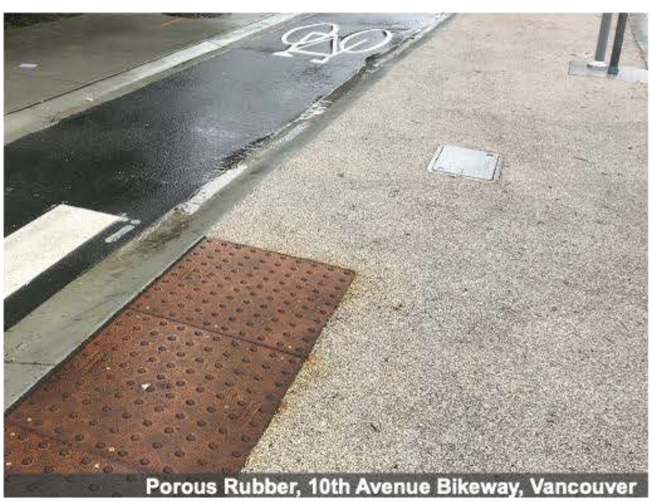
Hassalo and 8th District Blackwater Treatment, Portland, OR

ABSORBENT LANDSCAPES

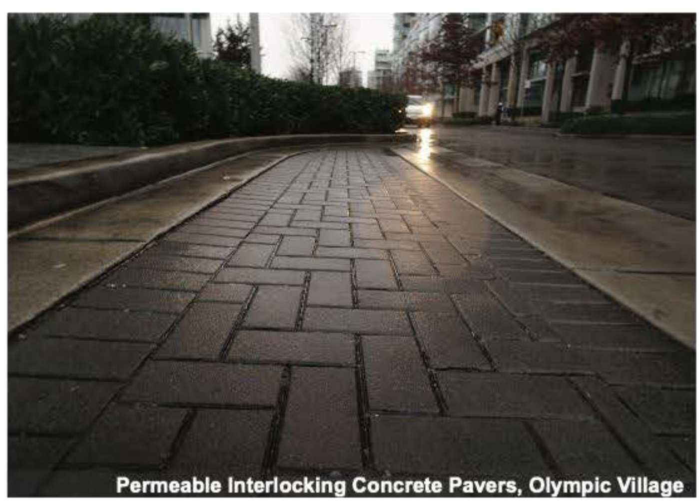
Grange Park Absorbent Landscaping, Toronto

Photo: PFS Studio

PERMEABLE PAVEMENT



Porous Rubber, 10th Avenue Bikeway, Vancouver



Permeable Interlocking Concrete Pavers, Olympic Village

These factors make it necessary for the City to be more strategic and intentional with its investments to optimize infrastructure servicing capacity.

Densification is critical to meeting future housing needs. Without purposeful intervention, however, development also means a loss in absorbent landscape areas; trees and natural systems that help manage water as well as an increase in impervious areas that generate urban rainwater runoff and pollutants. There is a need to expand water management capacity in our cities and relieve pressure on our systems. GRI provides an opportunity to consider how our built form and urban design better supports water management in order to expand our water service capacity and complement our existing grey infrastructure systems.

Clean water for a healthy city and ecosystems

Community values and expectations around clean waterbodies, environmental protection and healthy natural ecosystems are becoming more pronounced. Vancouver's sewer and drainage system contributes to water quality impacts in our local waters through both combined sewer overflows (CSO) and urban rainwater runoff pollution.

As with many older cities with combined sewer and drainage systems, Vancouver has a significant challenge with CSOs. In 2018, over 33 billion litres of combined sewage (wastewater diluted with polluted rainwater runoff) was discharged in to the waters surrounding Vancouver. While the City and Metro Vancouver have been working to address CSOs since the 1970s, population growth, increasing precipitation, fiscal limitations and the pace of implementation are challenging our progress.

Beyond CSOs, Vancouver is also contending with pollutants picked-up in rainwater runoff mostly from roads, rooftops and other high pollutant surfaces. Urban rainwater runoff discharged directly to our sewer and drainage system is contributing to pollutants in our receiving waters, many of which are known to be highly toxic to fish and other aquatic species.

Climate emergency and the need to mitigate and adapt for the future

Vancouver City Council has declared a climate emergency and is at a pivotal point in terms of the need to both mitigate and adapt to the effects of climate change. Most people will experience climate change as either too much or too little water or high heat, all of which contribute to community, infrastructure and ecosystem vulnerability.

Rising sea levels and more extreme rain events are to be expected, increasing the risk of coastal and overland flooding and triggering CSO events. Milder winters mean less snowpack in our drinking watershed and less recharge of our reservoirs in the spring and summer. More consecutive dry days during summertime and urban heat island effect have implications for human health, water consumption and the health of our natural systems. Heat is a stressor for many trees, plants, and wildlife, including fish and other species in our aquatic ecosystems.

GRI implementation has a role to play in helping Vancouver address the climate emergency and sequester carbon, cool our urban environment, help mitigate flooding, reduce drinking water use, and create new non-potable water supplies through distributed and resilient water management infrastructure, among other benefits.

Affordability and value-for-money

Water-related infrastructure makes-up one of the most costly building blocks of modern cities. With the pressures to upgrade our systems to serve growth, increase water quality treatment, adapt to changing rainfall patterns due to climate change and address the infrastructure renewal gap, the expected cost of integrated water infrastructure in Vancouver within the coming decades is in the billions of dollars. Water-related infrastructure will become an increasingly important affordability issue in Vancouver. Finding ways to deliver greater value-for-money, and better opportunities to avoid or defer costs of additional integrated water infrastructure is a critical opportunity for GRI implementation.

An integrated approach, combining traditional piped infrastructure with GRI solutions has been demonstrated to be economically preferred in terms of reducing overall system costs, sharing responsibility, costs and risks associated with water management between public and private realms, and delivering better water services and a range of other beneficial outcomes. Ambitious and sustained investments in GRI in other cities have been shown to have added benefits in terms of economic development, accessible employment opportunities, energy and cost savings for heating and cooling buildings and health care.

A livable and more equitable city that supports reconciliation with Indigenous Peoples

GRI implementation sits in a unique position as it can be found at the intersection of a variety of equity related topics. Concepts such as neighbourhood resiliency, public and community health and well-being, environmental justice, public participation, capacity building, sustainable transportation and place-making, can all be found within the sphere of influence of a GRI project. These factors, together with ensuring that people have access to clean and safe drinking water provision, wastewater treatment services, rainwater management services and flood protection, regardless of race, color, national origin, or income, call for a paradigm shift to plan for and manage our water resources more wisely and equitably.

GRI implementation is also an opportunity to support Vancouver's commitment as a City of Reconciliation and to connect with the values and interests of the Musqueam, Squamish, and Tsleil-Waututh Nations and urban Indigenous Peoples. GRI programs and initiatives have a great deal to learn from Indigenous perspectives, knowledge and ethics around environmental protection, stewardship, food harvesting, and the cultural and spiritual values around water and natural systems. GRI implementation may be an opportunity for learning, building understanding, strengthening relationships, sharing, new partnerships, and collaboration.

Vancouver's vision, goals and objectives for rainwater management

The Rain City Strategy articulates a new narrative for rainwater management in Vancouver. One that integrates infrastructure planning, land-use planning, and urban design approaches into the management of the urban water cycle. It reimagines how we plan, design, and construct our communities, streets, public spaces, parks, buildings and sites to include a holistic and integrated approach to rainwater management and leverage environmental, social and economic benefits. The strategy presents a vision to embrace rainwater as a valued resource for our communities and natural ecosystems (see Figure 2) and establishes goals around (1) water quality, (2) resilience and (3) livability (see Figure 3).

FIGURE 2: RAIN CITY STRATEGY VISION

FIGURE 3: RAIN CITY STRATEGY GOALS

Six measurable objectives were identified that intersect to reinforce the strategy goals include (1) remove pollutants from water and air, (2) increase managed impermeable area, (3) reduce the volume of rainwater entering the pipe system, (4) harvest and reuse water, (5) mitigate urban heat and (6) increase total green area (see Figure 4).

Targets and associated rainwater management design standards

The strategy reaffirms the City's aspirational target to capture and treat 90% of Vancouver's average annual rainfall, close to where it lands. The strategy amends the associated rainwater management design standard for GRI assets and site plans to capture (infiltrate, evapotranspirate or reuse) and clean (treat) 48 mm of rainfall per day. The design standard is applied at the project, site or district scale whenever rainwater management objectives are included as part of a project scope.

The amended design standard will apply immediately to streets and public spaces, parks and civic facilities and will be adopted for private sites by 2022. In addition, the strategy establishes an implementation target for capturing and cleaning rainwater from 40% of Vancouver's impervious areas by 2050. It is estimated that 30% of this total would be achieved by including rainwater management, where feasible, as a standard practice in new

FIGURE 4: RAIN CITY STRATEGY OBJECTIVES

capital projects in the public realm and through regulation for new developments in the private realm. The remaining 10% of the total would be achieved through targeted retrofits in the public and private realm.

The process and action while planning

The development of the Rain City Strategy employed a strategic design process, moving through cyclical phases of *Ask*, *Try* and *Do*. To gain far reaching and sustained support, the *Ask* phase included engagement opportunities and events for City staff, industry professionals, expert panelists and the public to define the scope of this initiative and unpack the values and assumptions around urban water management and rainwater management in particular. In all, there were over 10,000 contacts with the community and industry through an open house, workshops, events, surveys and more than thirty sessions across five departments involving hundreds of City staff at all levels of the organization.

Through the *Try* phase a shared understanding of the issues at large emerged. Work included engagement with internal and external partners, learning about innovative grey (pipe systems, smart controls and other storage tools) and green rainwater management solutions, and best practices. New GRI prototypes were tested in dozens of demonstration projects.

Since the initiation of this process in early 2017, and building on learnings from the IRMP and earlier efforts over the past two decades, the City has designed and constructed 38 new GRI practices in the public realm. These recent additions, which manage rainwater volume and water quality for an estimate 15.7 hectares of impervious areas on streets and lanes, bring the total number of assets in the public realm to 238. In the private realm, the City has introduced a new rainwater management policy for private developments. This has resulted in 170 sites developing rainwater management plans, and implementing GRI on private development sites. In 2018, the City introduced a new rainwater harvest permit program, which for streamlined program approach.

Our work has led to dozens of collaborations and partnerships to support research, education, training and capacity building with Musqueam, Squamish and Tsleil-Waututh Nations and organizations such as Earth Watch, HSBC, the Fraser Basin Council, the University of British Columbia, BC Institute of Technology, Simon Fraser, Langara and Kwantlen Universities, Museum of Vancouver and peer cities.

We are now in the *Do* phase of the strategy and are aiming to move beyond pilots and demonstration projects into mainstreaming GRI as a standard practice. The *Do* phase guides the implementation of rainwater management strategies and GRI implementation to 2050. It involves an agile approach to implementation of ambitious, multi-year transformative directions and actions as well as scoping the identified implementation and enabling programs in Streets and Public Spaces, Buildings and Sites, as well as Parks and Beaches.

Key Findings

Extensive research, analysis, engagement and learning-by-doing led to a number of key findings that have shaped the directions of the Rain City Strategy and the action plans:

1. Urban rainwater runoff is an impactful source of pollution discharged through the sewer and drainage system into receiving waters
2. Opportunistic implementation of GRI will not reach our regulatory obligations and policy goals
3. An integrated grey-green approach to sewer and drainage infrastructure is economically preferred
4. GRI is versatile and can be designed to manage all types of rain events
5. Urban water management is fundamental to all aspects of city building processes
6. Rainwater management solutions are most effective when planned at an urban watershed scale
7. Water harvest and reuse is a key approach to conserve pipe capacity, help mitigate CSOs and protect and preserve water resources
8. Strategically planned, operated and maintained GRI can support climate adaptation while also sequestering carbon
9. Operations and maintenance, rehabilitation and renewal are critical needs for long-term success and performance of a GRI program
10. GRI approaches will broaden responsibilities for rainwater management and shifts how funds will be spent over GRI asset life cycles
11. GRI implementation requires establishing a culture of collaboration and fostering partnerships
12. GRI requires deliberate education and capacity building to expand momentum and mature the state of practice

Transformative directions

As multi-year endeavors, the Rain City Strategy recommends that the City of Vancouver:

1. **Strives to become a water sensitive city** that integrates water, community, land use, urban design and infrastructure planning
2. **Responds with urgency to climate change** and use GRI to advance both mitigation, adaptation, and water resilience
3. **Accelerates action to protect the health and vitality of surrounding waterbodies** by developing a Clean Waters Plan to expedite the mitigation of pollutants discharged in local waters
4. **Revitalizes watersheds to enable communities and natural systems to thrive** and develop holistic plans for 19 urban watersheds
5. **Shapes systems to integrate and value all forms of water** by developing an integrated water utility planning framework
6. **Explores intersectionality, equity, and reconciliation with Indigenous Peoples through urban water management** by cultivating relationships and a shared understanding of histories and values
7. **Drives innovation and system effectiveness through data collection and analytics** for our community, land and water systems
8. **Enables a culture of collaboration** by facilitating a shift in governance structures, processes, practices, and culture to enable GRI implementation
9. **Invests in education, capacity-building, and partnerships to mobilize action** within the community, industry, academia, the not-for-profit sector and others.

Snapshot of the implementation action plans

While the Transformative Directions support medium and long-term outcomes, a number of action plans have been developed to support near term implementation programs related to Streets and Public Spaces (S&PS), Buildings and Sites (B&S), and Parks and Beaches (P&B). The proposed action plans were developed by the City and Vancouver Board of Parks and Recreation staff through research on best practices, analysis of existing capacities, gaps and opportunities and feedback and ideas from engagement with expert panelists, industry and the public. The action plans are intended to be complementary to the Transformative Directions and will promote Vancouver's transition to a water sensitive city.

Initial start-up funding of $70 million for several programs within the action plans has been identified within existing 2019-2022 Capital Plan and operating budgets. Funding will support resources to scope, evaluate and develop programs in the short term. Beyond 2022, program funding and business cases will be assessed as needed for each program and proposed through the City's financial planning process. A summary of the action plan programs is detailed in the next few pages.

Learning by doing, innovation and adaptive management

Recognizing that we live in a time of great change and uncertainty, we expect that an adaptive management approach to implementation will be needed. Expanding the sector around GRI and urban water management in Vancouver will require curiosity, innovation and the courage to embrace lessons from both successes and failures. Learning together and sharing lessons learned through demonstration projects and partnerships with other levels of government, business, industry, academia, non-profits and others will build collective capacity, allow us to understand barriers and opportunities, and learn and adjust programs as they are implemented.

Conclusion

To conclude, a holistic and integrated urban water management approach can do much more than serve the basic water needs of a community. It embraces all water as a valued resource and leverages cost-effective investments in water and rainwater management to support diverse ecosystems and community needs and aspirations.

Ultimately, the Rain City Strategy is about a paradigm shift in how we manage water, rainwater in particular, in the city. It moves the City beyond the opportunistic implementation of GRI, towards approaches that bring natural and engineered systems together with community and infrastructure planning. Widespread GRI implementation has the potential for profound impacts on the health and well-being of our communities and ecosystems, water quality, equity, reconciliation, intergenerational thinking and the future resilience of the city.

The City, however, cannot achieve this ambitious vision alone. The Rain City Strategy calls for intentional leadership by the City but also by individuals, community groups, not-for-profits, academia, industry and other agencies. A collective investment in education, capacity-building, partnerships and collaboration will catalyze action and help Vancouver progress on its path to become a water sensitive city.

TABLE 1: STREETS & PUBLIC SPACES ACTION PLAN

Street & Public Spaces Action Plan	
Implementation Programs	
S&PS-01	New Capital Projects Green Rainwater Infrastructure Integration Program
S&PS-02	Strategic Retrofits Green Rainwater Infrastructure Program
S&PS-03	Blue-Green Systems that Enable Water Management and Biodiversity Program
S&PS-04	Permeable Pavement Program
S&PS-05	Laneway Rehabilitation & Retrofit Program
S&PS-06	Green Rainwater Infrastructure Pilot and Demonstration Project Program
S&PS-07	Streets and Public Spaces Adjacent to Schools Green Rainwater Infrastructure Retrofit Program
S&PS-08	District Scale Non-potable Water Systems Program
S&PS-09	Green Rainwater Infrastructure Asset Management Program
S&PS-10	Green Rainwater Infrastructure Operation and Maintenance Program
S&PS-11	Sediment Management and Source Control Program
Enabling Programs	
S&PS-12	Citywide Green Rainwater Infrastructure Financial Planning and Sustainable Funding Program
S&PS-13	Research and Innovation Program
S&PS-14	Shift in City Process & Capacity Building
S&PS-15	Industry Capacity Building & Public Engagement
S&PS-16	Water Quality Monitoring Program

TABLE 2: BUILDINGS & SITES ACTION PLAN

Buildings & Sites Action Plan	
Implementation Programs	
B&S-01	Advance Rainwater Management Policies and Regulations— Supporting Implementation Through New and Existing Policies and Regulations
B&S-02	Improve Review and Compliance of Rainwater Management Plans — Bolstering the Internal Review Process to Ensure the Targets of Rain City are Being Achieved on Buildings & Sites
B&S-03	Single Family Dwellings, Laneway Homes, and Townhouses — Assessing New & Existing Building Opportunities
B&S-04	Mid- and High-Rise Structures — Assessing New & Existing Building Opportunities
B&S-05	Rainwater Harvesting Program — Building on Existing Policy
B&S-06	Resilient Roofs Program
B&S-07	Civic Facilities — Demonstrating Corporate Leadership
Enabling Programs	
Capacity Building and Engagement	
B&S-08	Public Engagement and Activation — Empowering Positive Community Action
B&S-09	Industry Capacity Building — Fostering Industry Excellence
Monitoring and Evaluation	
B&S-10	Monitoring, Data Analysis and Metrics -Assuring an Evidence-Based Approach
Research and Innovation	
B&S-11	Infiltration — Evaluating Geotechnical and Building Foundation Aspects
B&S-12	Resilient Roofs with Water Management Capabilities — Assessing Opportunities & Barriers
Linked (Complementary) Programs	
B&S-13	Non-Potable Water Systems — Assessing New Opportunities and Evaluating Public Health and Engineering Aspects
B&S-14	Reduce Sanitary Discharge to Sewer — Maximizing Existing Sewer Capacity Cost-Effectively

TABLE 3: PARKS & BEACHES ACTION PLAN

Parks & Beaches Action Plan	
Implementation Programs	
P&B-01	Green Rainwater Infrastructure Integration into Park Development Standards Programs
P&B-02	Protect and Enhance Park Service Levels through Green Rainwater Infrastructure Retrofits
P&B-03	Non-potable Water Systems and Water Conservation & Efficiency
P&B-04	Green Rainwater Infrastructure Integration into Playing Fields
P&B-05	Parks and Recreation Spaces Climate Change Adaptation Program
P&B-06	Create a Green Network that will Connect our Parks, Waterfront and Recreation Areas
P&B-07	Enhanced Urban Forest Program
P&B-08	Enhanced Park Biodiversity Program
P&B-09	Minimize Impervious Surfaces within Parks and Recreation Spaces
P&B-10	Multi-Stakeholder Land Acquisition for Rainwater Management and Park Use in Key Watershed Areas
P&B-11	Green Rainwater Infrastructure Operation and Maintenance and Asset Management
P&B-12	Protect and Enhance Beaches and Waterfront Program
Research and Innovation	
P&B-13	Citywide Green Rainwater Infrastructure Financial Planning and Sustainable Funding Program
P&B-14	Research and Innovation Program
P&B-15	Shift in Park Board Process & Capacity Building
P&B-16	Industry Capacity Building & Public Engagement

PHOTO CREDIT: WENDY DE HOOG

Chapter 1.

Water as a vital resource

No matter who we are, where we live, or what we do, water is an essential part of life and has the ability to connect us all.

The Rain City Strategy is a cross-departmental initiative led by Engineering Services that reframes how we manage rainwater in our city, today and over the long term. The strategy builds on the initial work of the citywide Integrated Rainwater Management Plan (IRMP) and provides a strategic roadmap to 2050 with action plans for green rainwater infrastructure (GRI) implementation that will enable our city to actively value rainwater as a resource.

Through the implementation of GRI, the City of Vancouver will improve its utility services and natural assets. GRI has also been demonstrated to be effective to reduce long-term costs, reduce pollution from urban rainwater runoff and combined sewer overflows (CSO), increase our climate resilience and contribute to improved livability. A new approach to water management involving GRI will help to restore and enhance the health of our urban watersheds, waterfronts and ecosystems and improve integrated water utility services.

While the strategy stems from regulatory obligations (see Figure 5) regarding water quality and CSO mitigation, it has evolved into an opportunity for the City to show leadership and move towards a more holistic, integrated urban water management approach that will help shift the water paradigm in Vancouver to support a more equitable water future.

1.1 Water paradigm shift

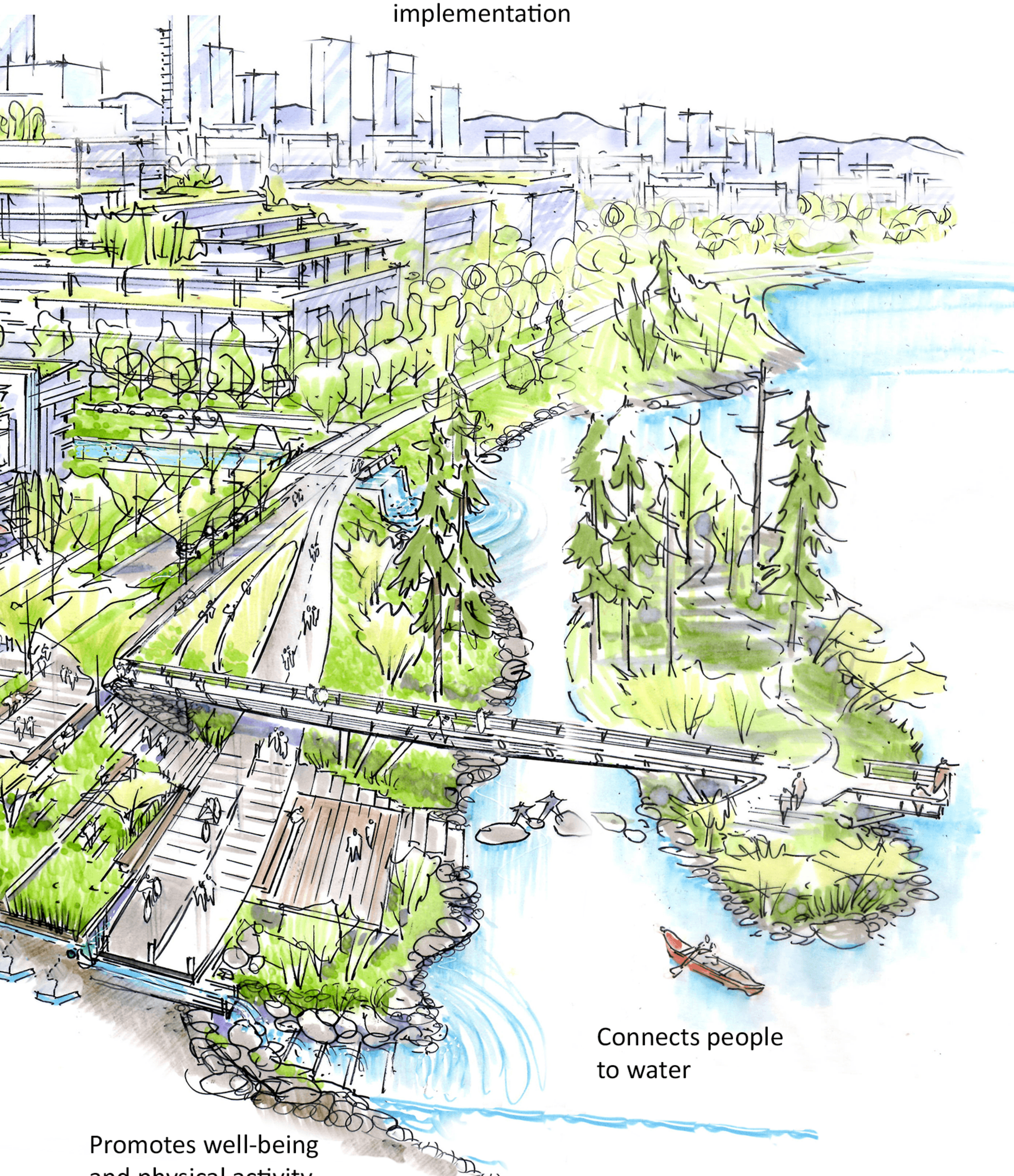
Over centuries, humans have created ways to ensure that clean, drinkable water is available when and where we need it, as well as ways to carry away wastewater and rainwater from where we live, work and play. The traditional approach to urban water management is based on principles of predictability and control. Water is typically managed by centralized systems of pipes that meet our utilitarian needs of supplying water, protecting public health, and mitigating the impact of overland flooding.

Our climate, however, is changing and so are our community values and expectations around clean waterbodies, increased water quality, environmental protection, and healthy ecosystems within and around Vancouver. In addition, our city continues to grow, putting ever more pressure on our existing water, sewer and drainage infrastructure, much of which is aging and nearing the end of its service life.

Emerging innovative approaches, together with an increase in challenging issues such as climate change, affordability and equity, call for a paradigm shift in how we plan, design and construct our communities, streets, public spaces, parks, buildings and sites. These innovative approaches include rainwater management that leverages environmental, social and economic benefits. Furthermore, the intentional inclusion of the equitable distribution of these benefits as a guiding principle for rainwater management allows the City and the Vancouver Board of Parks and Recreation to champion ecological justice in new ways.

As such, the water paradigm shift is about much more than how we provide holistic and integrated water utility services. It is about a more thoughtful approach to water resource management and finding synergies between integrated water utility servicing, resiliency planning, community planning and urban design. Fundamentally, it is about water as a valuable building block for urban living and water equity.

a water sensitive future


Reduces pollution and urban flooding through GRI implementation
Connects people to water
Promotes well-being and physical activity

1.2 A vision for a water sensitive future

By 2050, this paradigm shift has the potential to transform our city. We could not only be known for the frequency of our rain, but also for the exciting and unique ways that we celebrate and value our rainwater.

Public spaces and parks would have green spaces that capture and clean urban rainwater runoff, coupled with fountains, pavilions and public art pieces that come alive in the rain. On the streets, a network of newly created urban streams would wind their way beside bike paths, with tiny bridges where pedestrians stop to admire the butterflies among the flowers along the banks.

Across the rooftops, a meadow of blue-green roofs would stretch the length of the city, dotted with green spaces, water storage, food gardens, rooftop patios and solar panels. Rainwater would flow down from the eaves of houses and apartments into raingardens in the yard or into a rain cistern to be reused for irrigation and flushing toilets. Every project would do its part to reduce urban rainwater runoff pollution and thereby improving the water quality in our surrounding waterbodies, and protecting our valuable water resources.

We would build new parks, streets and public spaces that act as 'sponges', with restored creeks and wetlands, that provide public access to beautiful green spaces. The thriving urban forest would cool the city, reminding us of the rainforest this place once was. On its way into the Fraser River, English Bay, False Creek and Burrard Inlet, our rainwater would pass through filtering wetlands, ready to welcome the salmon back into healthy eel grass beds and spawning grounds supporting aquatic ecosystems and food harvesting. Our relationship with nature would deepen through our cultural connections with water and the many species that depend on a healthy environment

Underneath it all, rainwater would soak back into the ground, leaving our pipe networks better able to serve the many people who call Vancouver home.

1.3 Green rainwater infrastructure

An essential tool to bring about this water sensitive vision is GRI. The emergence of GRI as an approach to manage rainwater, improve water quality in our surrounding waterbodies and restore natural ecosystems that are degrading due to CSOs and toxic urban rainwater runoff presents a strategic opportunity for the City to take action. Besides, GRI is also a cost-effective way to deliver both water management and other community benefits. Implementation of GRI approaches are an opportunity for the City to lead the way as responsible water stewards, valuing rainwater as a resource instead of a product to be moved quickly to receiving waters, as is often done today. GRI is an urgent necessity to combat the impacts of urban living on our natural and urban ecosystems.

GRI helps to bring nature back to the city and uses plants, soils and engineered structures to mimic natural water systems in an urban environment. It focuses on capturing rainwater where it falls, using ecological processes to remove pollution from urban rainwater runoff, and allowing it to be absorbed back in to the ground and recharge aquifers, returned to the atmosphere or harvested for reuse, rather than moving it away as quickly as possible, into our underground sewer and drainage system and to our receiving waterbodies where it can be harmful for our aquatic environment. GRI also acts as a way to prevent rainwater from becoming runoff that becomes polluted when passing over contaminated impervious areas.

In addition to the essential water quality improvements GRI provides, it also expands the services of urban water infrastructure to include ecosystem services such as:

- Improved micro climate through shading and green spaces;
- Enhanced habitat and biodiversity;
- Reduced overland flooding;
- Improved air quality and carbon sequestration; and
- Replenished groundwater.

GRI can also provide the promotion of well-being and physical health, lower mental health distress and increased social cohesion through access to greenery. Implementing GRI tools across the city promotes additional economic benefits that allow for a healthier workforce deployment in cultivating local business and contracting opportunities.

1.4 Regulatory and policy context

There is growing recognition and a body of regulation that addresses water quality issues in urban rainwater runoff and our surrounding waterbodies. The City is subject to a number of federal, provincial, regional and local regulatory obligations and policy directives that have shaped the directions presented in the Rain City Strategy (see Figure 5).

On a regional level the Integrated Liquid Waste and Resource Management Plan (ILWRMP) was approved by the Provincial government in 2010 and is administered by Metro Vancouver. Among other requirements, the ILWRMP requires that the City:

- Protect public health and the environment (ILWRMP Goal 1);
- Use liquid waste as a resource (ILWRMP Goal 2);
- Employ effective, affordable and collaborative management (ILWRMP Goal 3);
- Reduce environmental impacts from liquid waste management to a minimum (ILWRMP 1.3);
- Implement plans to prevent combined sewer overflows by 2050 (ILWRMP 1.2.6);
- Evaluate opportunities to expand alternatives to potable water for non-drinking purposes, such as rainwater harvesting, greywater reuse and reclaimed treated wastewater (ILWRMP 2.1.1);
- Develop and implement an IRMP at the watershed scale that integrates with land use planning to manage urban rainwater runoff (ILWRMP 3.4.7); and
- Separate combined sewers in the Vancouver Sewerage Area [and make] strategic use of existing combined sewers as part of a strategy to reduce combined sewer overflows and manage urban rainwater runoff quality (ILWRMP 1.2.1, 1.2.2, 1.2.6).

The City of Vancouver strategies and policies that have shaped the Rain City Strategy include:

- Climate Emergency Response (2019);
- Resilient Vancouver Strategy (2019);
- Climate Change Adaptation Strategy (developed in 2012 and updated in 2018);
- Cambie Corridor Utility Servicing Plan (2018);
- Water conservation action plan (2017);
- Sea Level Rise Strategy and Coastal Flood Risk Assessment Phase III (2017);
- Healthy City Strategy (2015);
- Renewable City Strategy (2015);
- Transportation 2040 (2012); and
- Greenest City Action Plan (2011).

Strategies and policies from the Vancouver Board of Parks and Recreation that have influenced the Rain City Strategy include:

- VanPlay Parks and Recreation Services Master Plan (2019);
- Biodiversity Strategy (2016); and
- Urban Forest Strategy (2014).

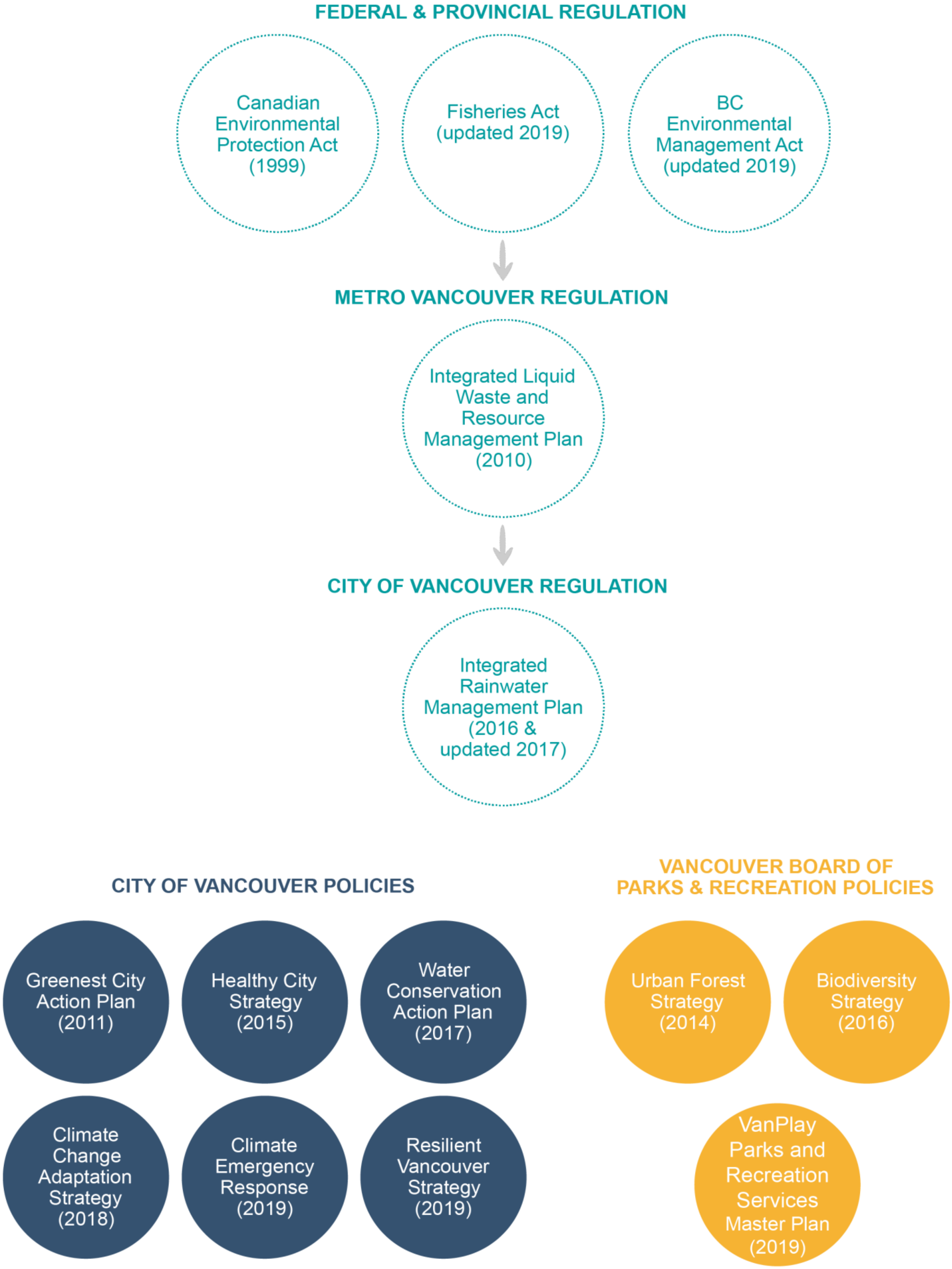


FIGURE 5: REGULATORY AND POLICY CONTEXT

In addition to these core regulatory and policy drivers, there are a significant number of other policies and programs from the City and the Vancouver Board of Parks and Recreation that align with and can be reinforced through the Rain City Strategy. For example, City Council recently passed a number of motions related to watershed revival (2019), greenways (2019), blueways (2019), green roofs (2018) and safe and accessible waterfronts (2017) that have influenced the Rain City Strategy. Both government agencies also passed motions to accelerate efforts to address CSOs (2019). The transformative directions and action plans within the Rain City Strategy respond to these directions (see chapter 5 for transformative directions and chapter 7 for the action plans).

1.5 Strategy development, engagement and timeline

Urban water management is multifaceted, involves many stakeholders and needs to respond to many growing pressures such as rapid densification, declining water quality and aging infrastructure, which are all compounded by climate change. In preparing this strategy document, critical thinking, co-creating, collaboration and innovative problem solving were needed to gain an understanding of systemic urban water challenges.

While traditionally rainwater management would be an utilities initiative, the Rain City Strategy is a joint effort between the City of Vancouver's Engineering Services department; Planning, Urban Design, and Sustainability Department; Development, Buildings, and Licensing Department; Real Estate and Facilities Management and the Vancouver Board of Parks and Recreation; with indispensable support from Business Planning and Project Support, and Finance, Risk and Supply Chain Management Department.

The development of the Rain City Strategy followed a strategic design process of "Ask, Try, Do^2" (see Figure 6).

The "Ask" phase was focused on research, problem identification, engaging in dialogue with internal and external partners, defining the scope of this initiative and unpacking values and assumptions around urban water management and rainwater management in particular.

In the "Try" phase, a shared understanding of the issues at large emerged, engagement with internal and external partners continued to develop innovative water solutions, best practices were identified, and new GRI prototypes were tested in demonstration projects.

The "Do" phase was all about developing the guiding principles, transformative directions, action plans, and identifying the programs needed to successfully implement urban water management solutions and GRI. The "Do" phase is not over yet. Another important aspect is the actual implementation of the strategy and accompanying evaluation of actions taken, progress made and lessons learned to innovate and improve results, bringing us back to the next version of the "Ask" phase.

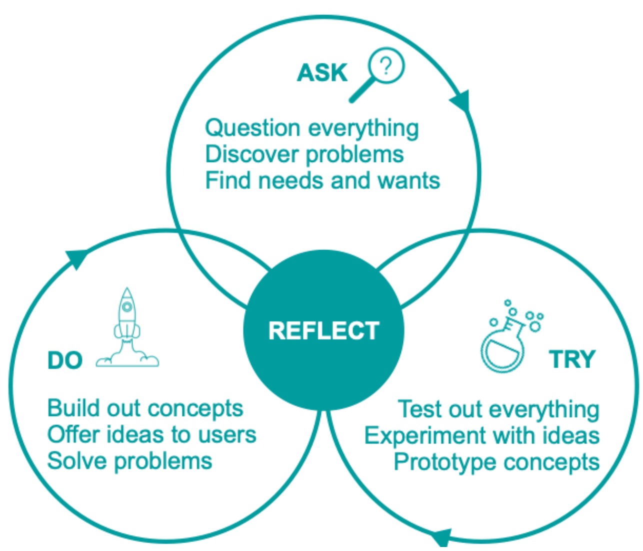


FIGURE 6: STRATEGIC DESIGN PROCESS

Since 2013, as work on the IRMP and the Rain City Strategy has progressed through these phases, we have achieved the following milestones shown in Figure 7.

In addition, the development of the Rain City Strategy was accompanied by many engagement opportunities and events for City staff, industry professionals, expert panelists and members of the public. A summary of the engagement activities conducted and the outcomes of the engagement process can be found in Appendix E.

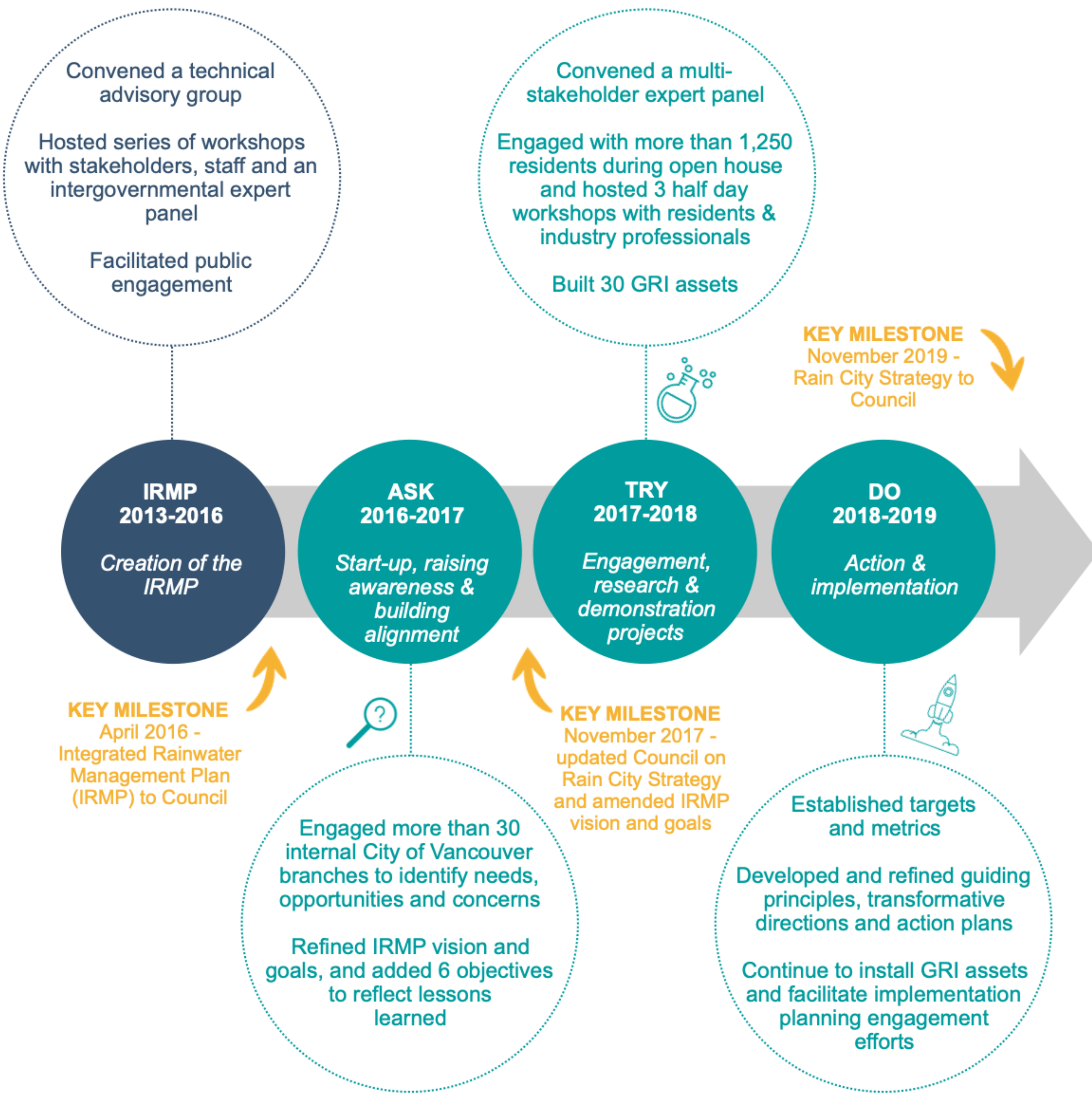


FIGURE 7: STRATEGY DEVELOPMENT PHASES & KEY MILESTONES

1.6 Report structure

The Rain City Strategy articulates a long-term roadmap for advancing and evolving our rainwater management practices and services over the coming decades. An overview of the report structure is given in Figure 8.

In Chapters 2 to 4 of this report, the context and a deeper look at the driving forces behind the development of this strategy and implementation of GRI are provided, along with the key findings that have shaped our work. Chapter 5 presents the actual strategy, including water sensitive guiding principles, and the vision, goals and objectives of the Rain City Strategy. It also introduces the Transformative Directions and related Action Plans needed to pivot and transition to become a water sensitive city.

Chapter 6 presents the targets and design standards developed for GRI implementation. The Streets and Public Spaces, Buildings and Sites, and Parks and Beaches Action Plans are introduced in Chapter 7 followed by Chapter 8, which highlights the next steps.

Included in the back of the report is a glossary intended to guide readers through terminology and concepts presented in this report.

The strategy is applied through four Action Plans for GRI implementation:

1. Transformative Directions Action Plan
2. Streets & Public Spaces Action Plan
3. Buildings & Sites Action Plan
4. Parks & Beaches Action Plan

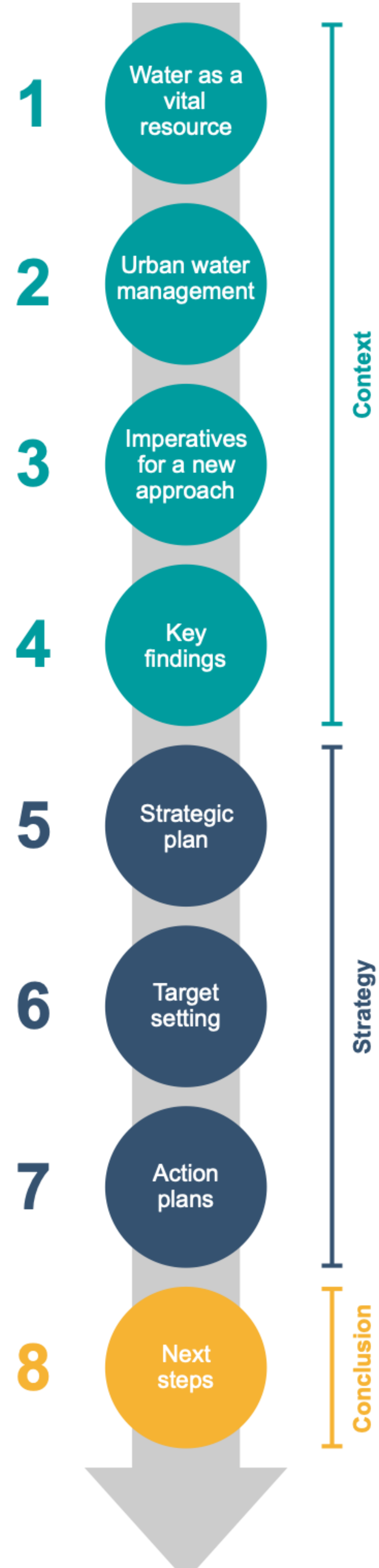


FIGURE 8: REPORT STRUCTURE

PHOTO CREDIT: WENDY DE HOOG

Chapter 2.

Urban water management

To begin addressing the urban water challenges that Vancouver is facing and to create new water management opportunities and solutions, it is useful to understand how the urban water cycle functions, and which water resources can be found in Vancouver. This chapter will cover the basics of the City of Vancouver's sewer and drainage system and what kind of tools, including green rainwater infrastructure (GRI) are available to us, and the current state of the City's urban rainwater management systems. The chapter concludes with a discussion on the progress made to date on implementing GRI actions in streets and public spaces, buildings and sites, and parks and beaches.

2.1 Water cycle, resources and systems

2.1.1 Natural and urban water cycles

The natural water cycle is the continuous movement of water above and below the earth's surface. When it rains, some rainwater is absorbed by plants and trees, some infiltrates through the soil becoming groundwater and some flows along the surface and joins streams, rivers, lakes and oceans. The next stage of the water cycle is evapotranspiration, releasing water vapour into the air from plants and trees or directly from water held within soil and waterbodies. That water vapour gathers into clouds, which brings rain, and begins the cycle again.

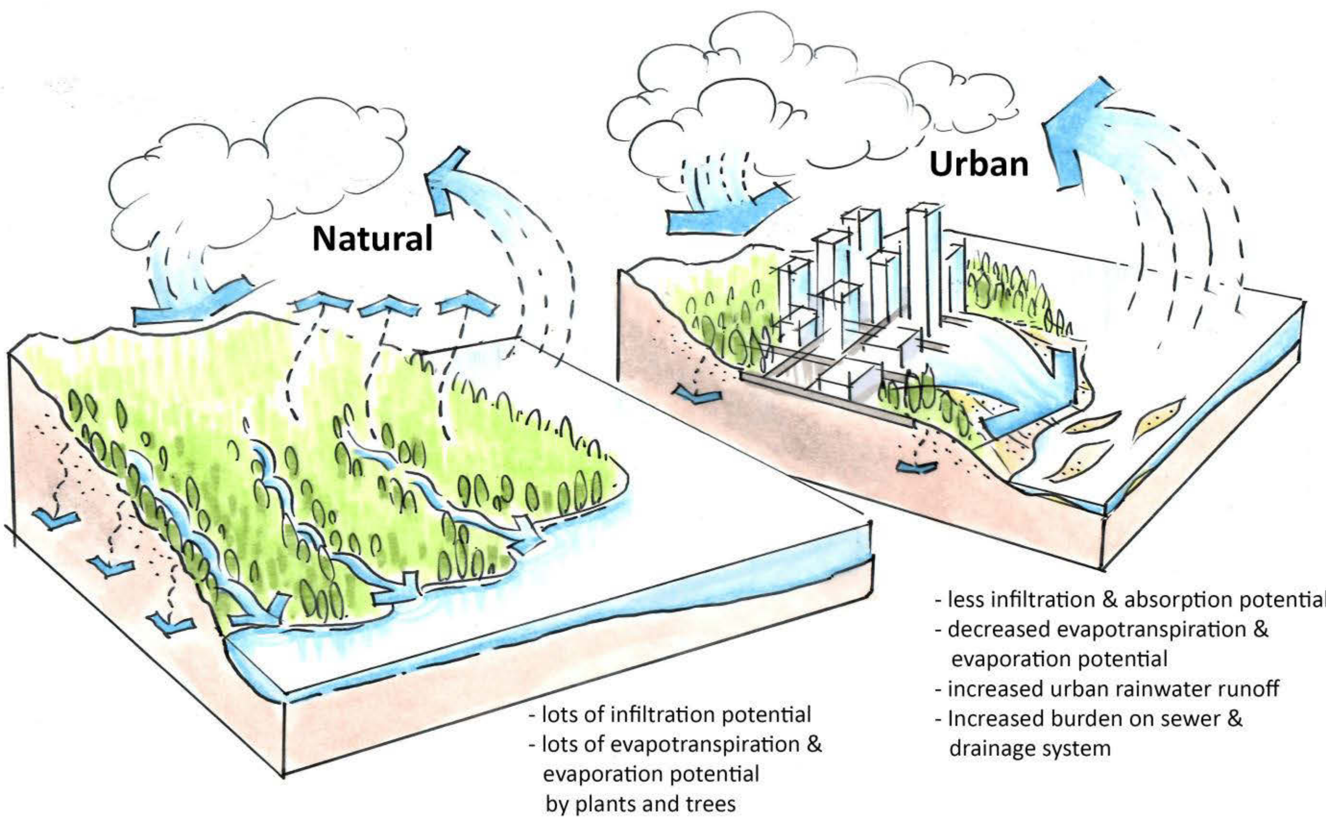


FIGURE 9: NATURAL AND URBAN WATER CYCLES

In urban areas, like Vancouver, the natural water cycle is disrupted by impermeable surfaces, such as buildings and streets. There are fewer green spaces to absorb and infiltrate rainwater and so it flows along roofs and paved surfaces into catch basins or drains, instead of streams. From the catch basins, the rainwater falling in Vancouver is then carried underground into a vast network of over 2100 kilometers of sewer pipes that conveys both wastewater and rainwater to the Iona Island Wastewater Treatment Plant and to our surrounding waterbodies; the Fraser River, False Creek, English Bay, Burrard Inlet and the Salish Sea. This new route for urban water can cause many problems in the urban ecosystem, described in more detail in Chapter 3 (Imperatives for a new approach).The natural and urban water cycles are shown in Figure 9.

2.1.2 Water resources

The water resources found in urban areas, such as Vancouver, include groundwater, surface water, drinking water, rainwater and wastewater. These water resources are inter-related and all contribute to or were derived from some part of the natural water cycle.

Groundwater

Groundwater is found underground in cracks and spaces in soil, sand and rocks. Large bodies of water can be found underground, called aquifers. An aquifer is a layer of permeable material below ground where groundwater can be transmitted and stored. Aquifers can be unconfined, where groundwater can move freely both horizontally and vertically, or they can be confined (called artesian aquifers), which contain groundwater under pressure. If the confining layer of an artesian aquifer area is pierced, the groundwater can emerge at or below the surface like a spring. Aquifers are recharged by precipitation, when rainwater is able to soak into the ground unimpeded by paved surfaces and buildings.

The largest aquifer in Vancouver is called Quadra Sands, which extends across much of Vancouver, south of Broadway and into Burnaby (see Figure 10). Artesian conditions exist in some areas of south Vancouver along the Fraser River (see Figure 10).

Groundwater is not used as a source of drinking water in Vancouver, but it is used for some other needs, such as irrigation. Groundwater also has the potential to be an emergency water supply if the centralized water supply system is offline. Of course, groundwater in its most fundamental role is part of the natural water cycle, storing water and conveying water underground, absorbing and discharging rainwater from overland flow and within streams. Our natural systems depend on groundwater for health.

Surface water

Surface water is water on the surface of the earth, such as streams, rivers, lakes, wetlands and oceans. Historically, many creeks and streams flowed freely across the peninsula (see Figure 11). Over the 19th and early 20th centuries, most streams were culverted and integrated into the sewer and drainage system, and ravines were filled for development. Two exceptions are Musqueam Creek and Still Creek, which are Vancouver's last two remaining salmon-bearing streams. The larger bodies of surface water around Vancouver (Fraser River, False Creek, English Bay, Burrard Inlet and the Salish Sea) have played significant roles in shaping the history and peoples of this place, and remain a central part of the identity of Vancouver. Urban development and modern human activity has, however, led to the severe degradation of these waterbodies due to pollution and poor stewardship.

Drinking water

Drinking water, also known as potable water, generally comes from two main sources: surface water or groundwater. In Vancouver, our drinking water comes from surface water collected in three reservoirs: the Capilano and

Seymour reservoirs on the North Shore, and the Coquitlam reservoir, located just north of the City of Coquitlam. The three reservoirs are managed by Metro Vancouver. The water in the reservoirs originates primarily from rainfall and snowmelt, which is collected by various rivers and streams into the reservoir lakes. The water is treated, and then delivered through a pipe network to 2.5 million residents and water users in the Metro Vancouver area. This water is used for drinking, washing, cooking and irrigation, and for other purposes. We rely on rainfall and snowmelt for recharging our drinking water supply. Due to climate change, warmer winters with less snow, and hotter summers with dry spells and less rainfall are predicted and will affect our water security and availability.[3]

Rainwater

Vancouver is famous for its rain, which has become an intrinsic part of the city's culture and identity. Rain is deeply embedded in many of our daily experiences. On average, it rains over 160 days and between 1200 – 1600 millimetres a year.[4] Around 70% of our rainfall volume arrives as light showers (less than 24 mm per day), and another 20% as rain storms (between 24-48 mm per day). The last 10% of our annual rainfall volume arrives as extreme rainstorms (greater than 48 mm per day). These large rain storms are predicted to increase in intensity and frequency due to climate change.[5] Not only are we expecting more extreme events, but we are also expecting an increase in the volume of rainfall received annually, especially in fall and winter. In the summer, we have a different situation. Our summers are warm and dry, and are predicted to become even more so as the climate changes.[6]

Urban rainwater runoff is a major cause of water pollution in urban areas.[7] [8] When rain falls on our roofs, streets, parking lots and other hard surfaces, the rainwater flowing over these surfaces - also known as urban rainwater runoff - picks up pollutants and the untreated rainwater is conveyed through our pipes, either to the treatment plant or directly into our local waterbodies. Common pollutants found in urban rainwater runoff include:

- Litter (e.g. cigarette butts);
- Bacteria (e.g. E. coli from animal waste);
- Heavy metals (e.g. copper released from brake pads and zinc and other metals from tire wear and rooftops);
- Chemical compounds in tire dust;
- Hydrocarbons (e.g. oils and gasoline);
- Nutrients (e.g. fertilizers and animal waste);
- Micro-plastics (e.g. vehicle and building material wear), and
- Sediment (e.g. dust and other particles and soil disturbance from construction activity).

Wastewater

Wastewater is the by-product of many uses of water by humans, and can be split into two categories, blackwater and greywater.

Blackwater refers to wastewater from intensive uses, like flushing toilets, and is also referred to as sanitary sewage. Greywater refers to wastewater from less intensive uses, including showering, hand and dish washing and laundry. Greywater requires less intensive treatment before it can be discharged or reused. However, the current collection and treatment system in Vancouver does not differentiate between the two categories.

What is non-potable water?

For drinking, cooking and bathing, water must be potable, or safe for human consumption. Non-potable water is water that is not safe to drink, but can still be used for other purposes.

Non-potable water can come from many sources, including rainwater, surface water, groundwater and wastewater (which includes both greywater and blackwater). Even though non-potable water is not used for drinking, some treatment may be required to make sure it is safe to use. Current water quality requirements for non-potable water use are specified in the City of Vancouver Plumbing By-law.

As of 2019 in the city, non-potable rainwater harvested from rooftops is only permitted by the City of Vancouver Building By-law to be used for watering non-food plants, cooling towers and boilers, and flushing toilets and urinals.

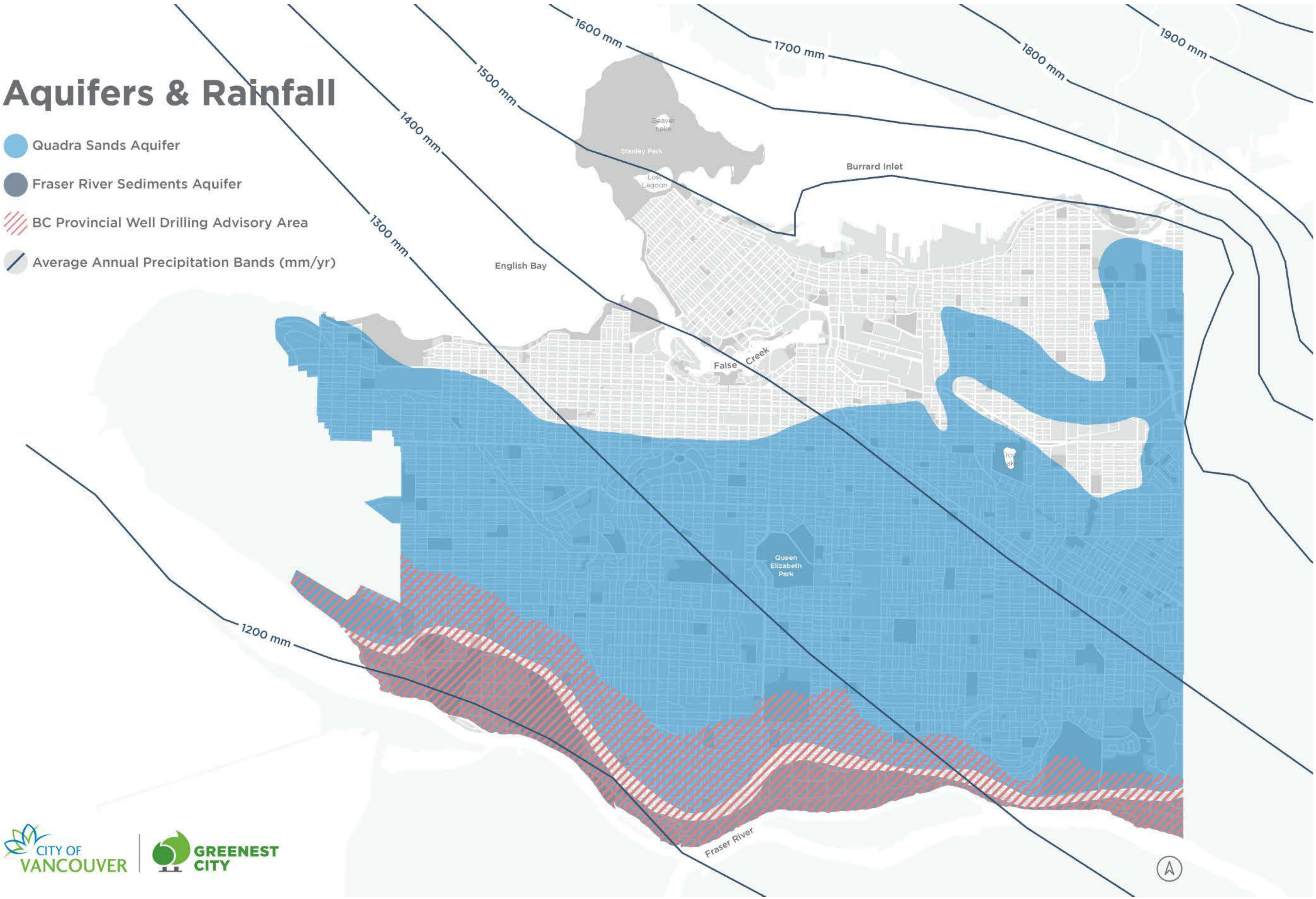


FIGURE 10: VANCOUVER AQUIFERS AND RAINFALL

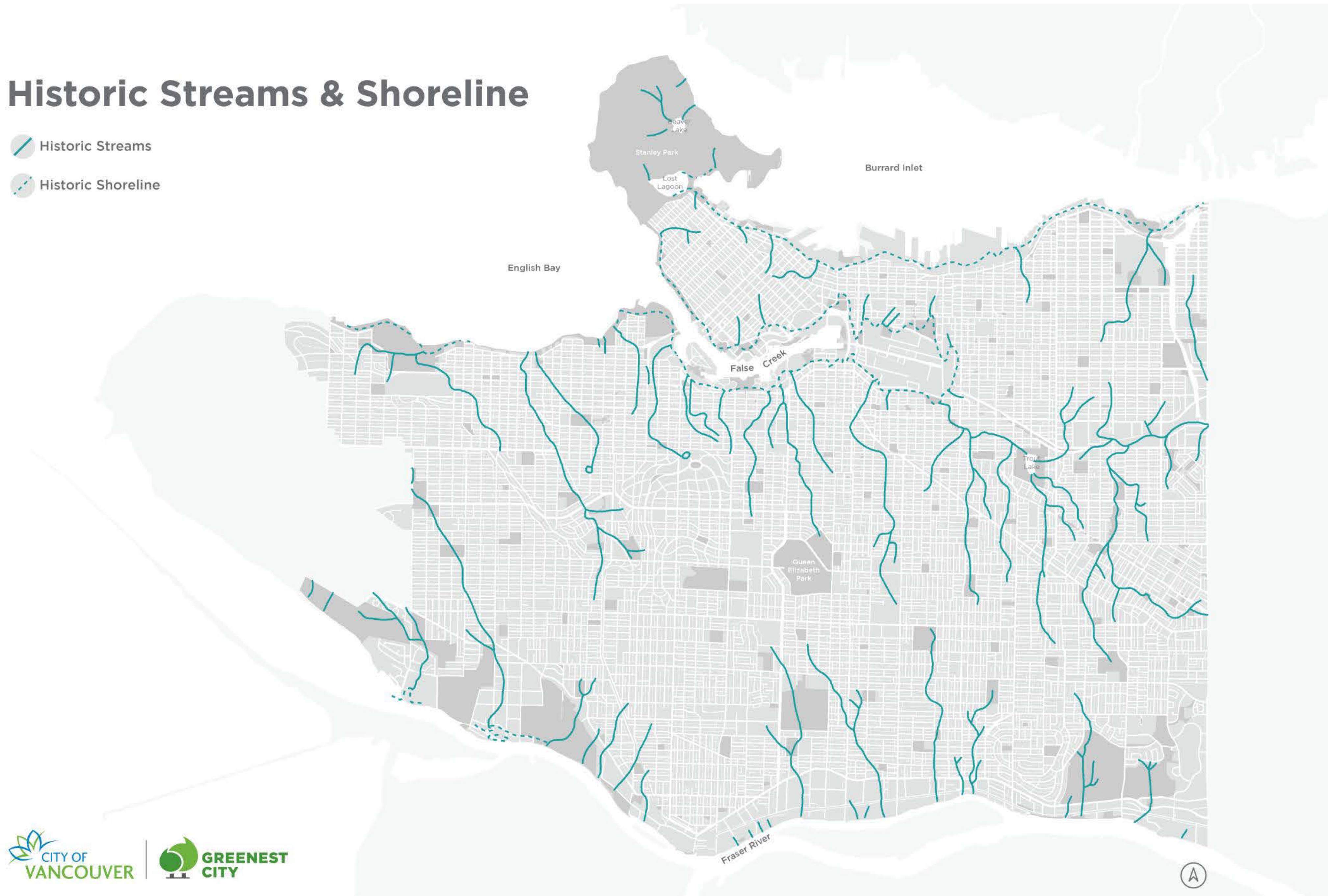


FIGURE 11: VANCOUVER HISTORIC STREAMS AND SHORELINE

What about pollutant accumulation in green rainwater infrastructure assets?

GRI is designed to protect rainwater from becoming polluted by capturing and cleaning urban rainwater runoff, but what happens to the plants and soil which provide this cleaning function? The answer depends on the type of pollutant.

Hydrocarbons and petroleum pollutants: Studies conducted in the field and laboratory find that GRI is effective in capturing hydrocarbons, and that the chemicals are largely eliminated by bacteria in the soil.

Harmful bacteria and viruses: Exposure to sunlight and soil microorganisms can destroy pathogens associated with urban rainwater runoff.

Heavy metals: Soils and mulch in GRI contain particles that will adsorb and hold metals including copper, cadmium, lead, and zinc. Only a small fraction of the metals accumulate in plant roots and vegetation. While metals are not degraded in rain gardens, they are typically present at very low levels. The objective is to remove contaminants from urban rainwater runoff at the source, before they spread to groundwater or other waterbodies. Research has shown that metals are mainly captured in the top 10 cm of bioretention soil, and are not expected to reach concentrations that would cause concern for at least a few decades, at which point testing and remediation may be necessary. However, in some cases cleaning urban rainwater runoff through infiltration may not always be preferable as it may mobilize existing contaminants in the soil. Other types of GRI might be more appropriate in those cases.

2.1.3 Watersheds and sewersheds

A watershed, also called a drainage basin or a catchment area, is a distinct hydrologically-defined geographic unit, within which all land and waterways such as creeks, streams and rivers drain to a common outlet point. A watershed includes all rain, snow and groundwater in the area, and is often characterized by its topography and land form.

Depending on the size of the watershed or variations in geography within the larger watershed unit, the watershed may be broken down into smaller planning units, or sub-catchments. Sub-catchments connect in a hierarchical pattern to form a watershed.

A sewershed is an area of land where all underground sewers are constructed to flow to a common outlet point. Sewersheds can also be comprised of smaller sub-sewershed units that drain into larger trunk sewers. Currently, the 19 urban watersheds of Vancouver could be referred to as sewersheds, as the majority of our natural drainage systems have been entirely replaced by sewers and other grey infrastructure (see Figure 12).

Through the Rain City Strategy, however, we will expand the urban water management toolkit to include more natural systems, and restore some of the features more traditionally part of a watershed.

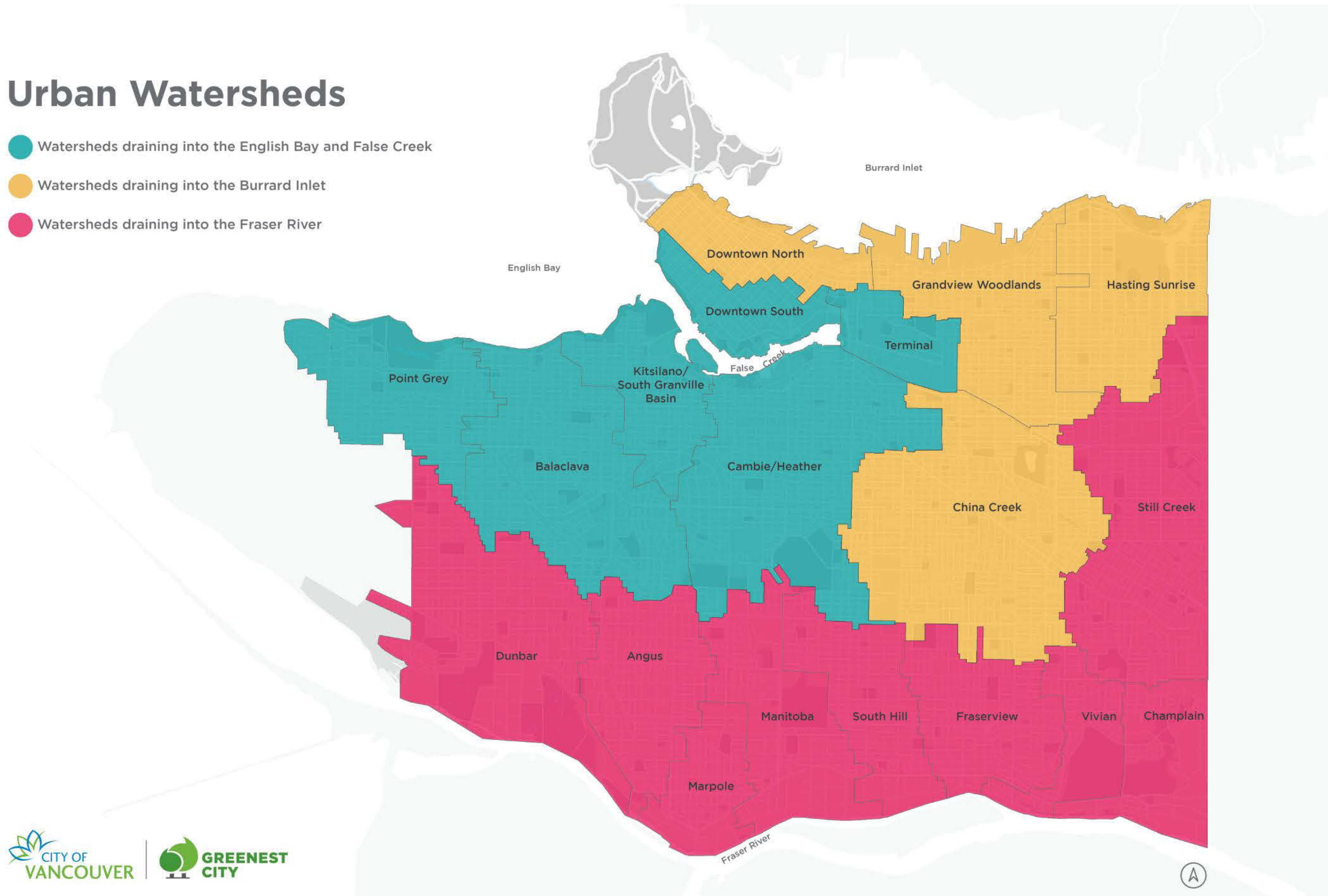


FIGURE 12: VANCOUVER WATERSHEDS

What is grey infrastructure?

In the context of rainwater management, grey infrastructure refers to purely engineered rainwater management practices, such as pipes, detention tanks, water quality devices, treatment plants and pump stations. Grey infrastructure is the rainwater management method that has traditionally been used by the City, and is primarily focused on protecting public health by collecting urban rainwater runoff and wastewater, and conveying it to the treatment plant or receiving waterbodies as quickly as possible.

Over time, additional grey infrastructure tools have been developed that complement and support GRI, primarily through storage of rainwater. They can be built on their own, or combined with GRI tools that provide green space on the surface. These storage tools include detention systems, and ways to store water on the surface, such as water squares and other floodable spaces, and when deployed together with GRI they can be particularly effective.

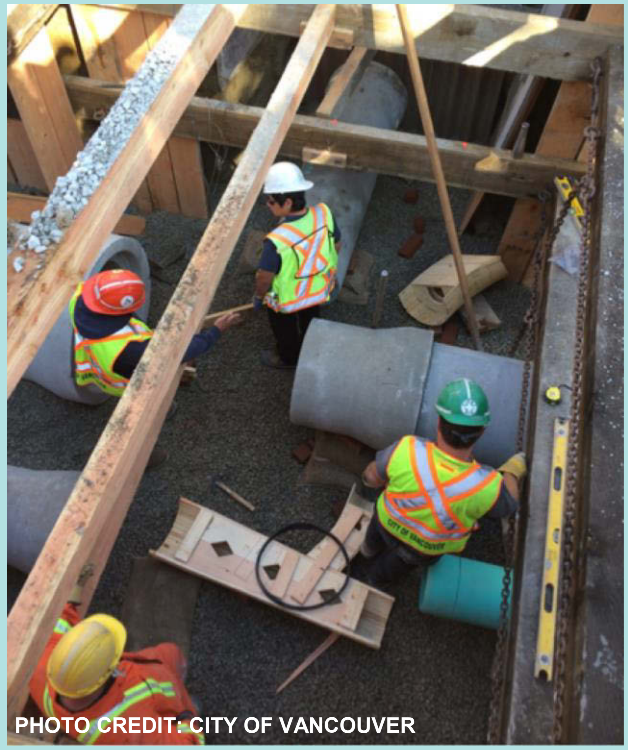


PHOTO CREDIT: CITY OF VANCOUVER

An example of this integrated approach is the water square at the Benthemplein in Rotterdam that captures, stores and cleans rainwater. Some water is infiltrated through GRI while some is pumped back in to the combined sewer system once capacity in the system is available.

PHOTO CREDIT: JEROEN MUSCH

2.1.4 Combined and separated sewer systems

The City's sewer and drainage system provides essential public health, safety and utility services. As with many other cities, the system began as natural creek channels were re-routed into buried sewer pipes that collected both wastewater and rainwater, commonly called combined sewers. The pipe system was designed to then bring the wastewater to the treatment plant.

Vancouver's wastewater is predominantly treated at Metro Vancouver's Iona Wastewater Treatment Plant on the shores of the Fraser River. A small portion of Vancouver's wastewater from the south-east catchments is directed to Metro Vancouver's Annacis Island Wastewater Treatment Plant. The Iona facility currently provides primary treatment levels, which mostly removes material that will either float or readily settle out by gravity. Plans are underway to upgrade the Iona facility by 2030 to secondary treatment levels, which typically also include biological processes to more effectively remove organic matter from the wastewater.

The design of our combined sewer system also includes overflows (also called outfalls), so that when the system is over capacity, rather than flooding the treatment plant or homes and businesses, the combined sewage (sanitary sewage diluted with rainwater) flows into the receiving waterbodies around the city. These overflow events are called combined sewer overflows (CSOs).

Figure 13 shows the location of outfalls. The volume of CSO discharge from these outfalls in 2018 was nearly 33 billion litres. It is important to note that these CSO volumes include CSOs from the Vancouver Sewerage Area (VSA), which includes wastewater from most of Vancouver and some of the City of Burnaby's highest density neighbourhoods, including Brentwood and Metrotown. CSOs are also known to occur at up to 12 additional City owned outfalls. A monitoring program for these outfalls was established in 2019 and, as such, volume data is not yet available. CSO volume is high relative to other major cities and has been increasing over time. Figure 14 shows the volumes from these outfalls over the past decade. Through Transformative Direction 3, extensive CSO flow monitoring and water quality testing programs will be implemented.

As part of a program to eliminate CSOs, the City has been working since the 1970s to convert our combined sewer system to a separated sewer system, where two separate pipes are used - one for rainwater and one for wastewater. The new separated sanitary pipes take wastewater (blackwater and greywater) from buildings to the treatment plant, and upon full separation of an area, the new rainwater pipes carry urban rainwater runoff to be discharged into local waterbodies.

To date, the City has separated approximately 54% of its mainline sewer pipes in the city. Of the 19 urban watersheds, only one is fully separated (Champlain in Southeast Vancouver) and several others, including Downtown North and South, Terminal and Vivian are nearly fully separated.

The City's system of combined and separated pipes, however, is highly complex and the percent separation for the mainline sewer pipes is not necessarily the best indicator of the system's performance outcomes in terms of discharge of wastewater pollutants to our receiving waters. Many of Vancouver's separated areas subsequently flow in to combined trunks downstream that may continue to overflow. As well, across the city, we have significant challenges with cross-connections within our system that result in combined sewage connections from private properties being connected to our separated storm pipe system and eventually our receiving waters.

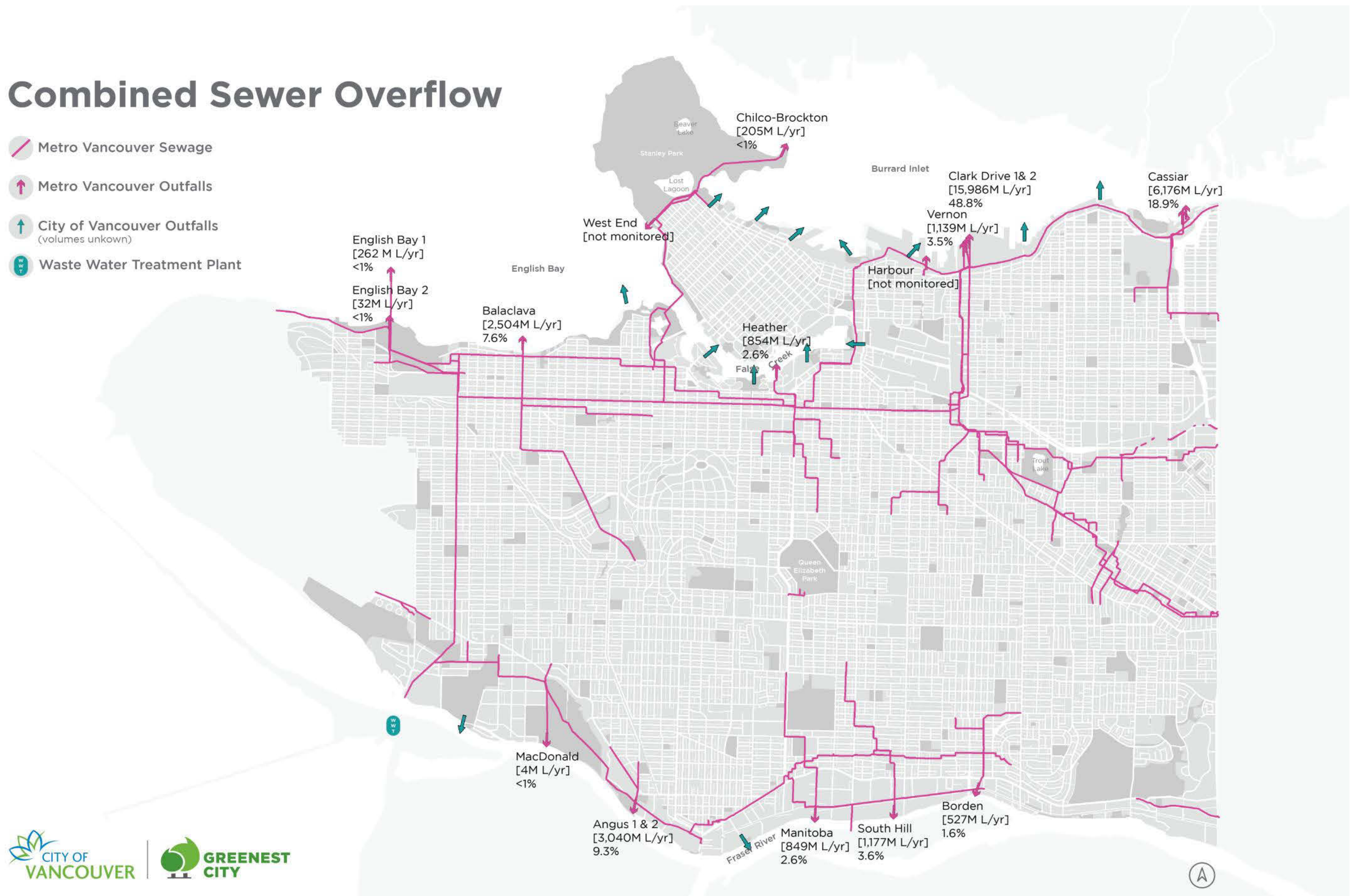


FIGURE 13: COMBINED SEWER OVERFLOW

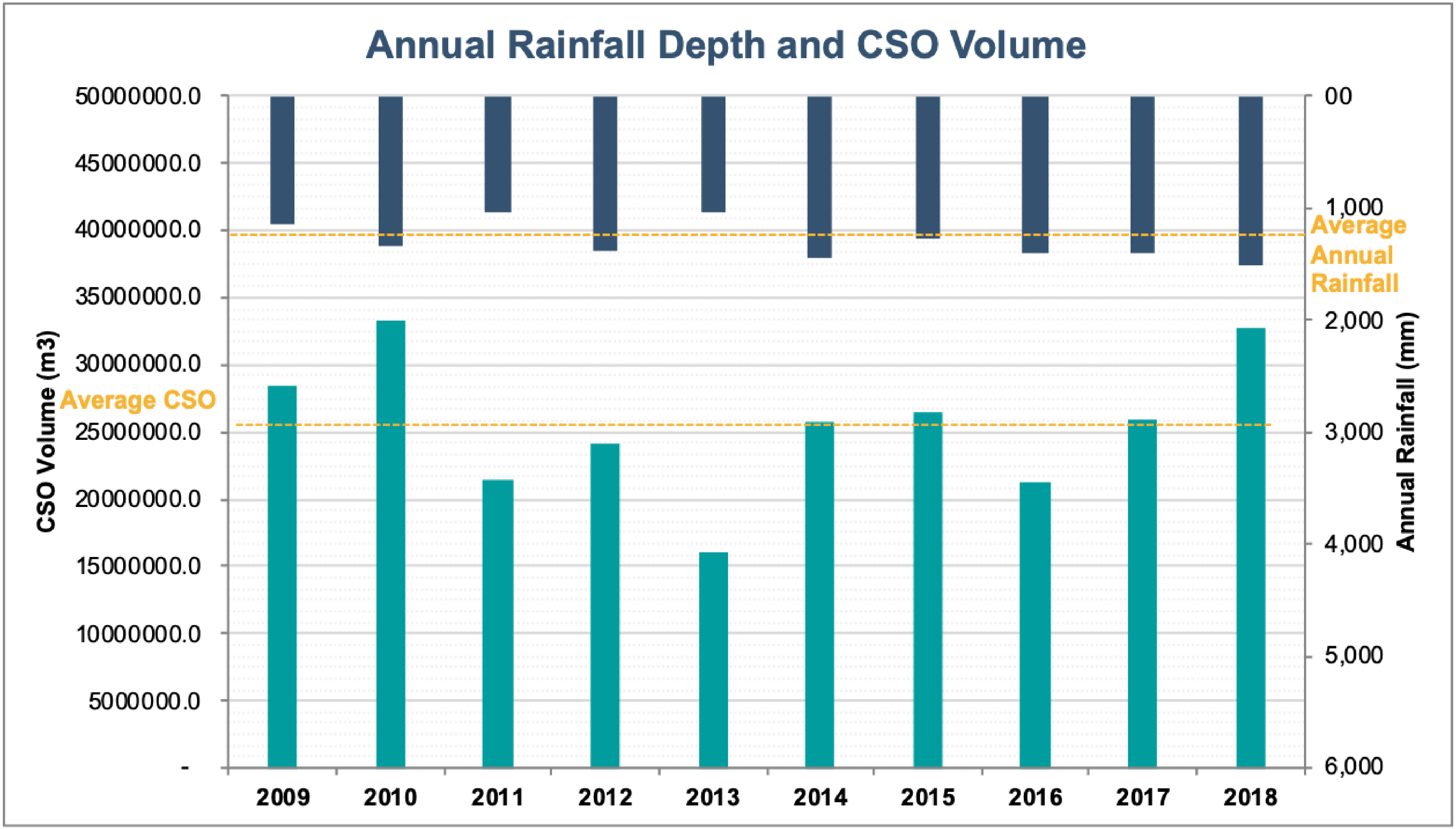


FIGURE 14: VANCOUVER ANNUAL RAINFALL DEPTH AND CSO VOLUME

Some of these connections are due to unauthorized connections, while others are due to inadvertent mis-connections during construction or legacy system designs that connected combined private rainwater and wastewater connections to the storm system to reduce surcharges within the lower capacity sanitary pipes.

In addition to undertaking mainline sewer separation, the City has an ongoing sewer cross-connection rectification program to address these aforementioned issues, though the scale of the program is not currently adequate to address the extent of cross-connections in a timely manner. It is estimated that of the approximately 92,000 private property wastewater service connections, about 37,000 or 40 percent remain combined. In addition, it is estimated that about 17,000 of the 92,000 private wastewater connections link to drainage pipes rather than combined or sanitary pipes. As such, the level of separation of sewer mainlines at 54% presents only part of the picture of how our system currently functions and the water quality issues from our system discharges that need to be addressed moving forward.

Moreover, from a water quality impacts perspective, even in our fully or substantially separated areas, water pollution remains a concern. Rainwater picks up many pollutants. As such, it is important to supplement a separated sewer system with tools which clean the rainwater before it is discharged, such as rain gardens and other GRI practices. GRI is an ideal tool to perform this cleaning function. Furthermore, GRI can help reduce CSOs in watersheds that are not fully separated, by reducing the amount of rainfall that enters the pipe system.

Figure 15 depicts our current sewer and drainage system showing both a combined and separated system together.

2.2 Rainwater management

Rainwater management (also referred to by some as stormwater management) focuses on how we manage urban rainwater runoff in the environment through a combination of land use, surface and sub-surface GRI and traditional pipe and other grey infrastructure solutions. It is one part of the larger umbrella term of integrated water management, which can also include sewer and drinking water systems, and the services provided by natural areas such as forested parks, tidal flats, vegetated buffers and floodplain areas.

In many communities, rainwater management systems have historically focused on the goals of public health, efficient drainage away from private lands and public spaces to prevent flooding and protect properties, and sediment management. Other environmental and social considerations were not integral to the system. For many cities, including Vancouver, protecting local waterbodies and aquatic ecosystems as well as long-term climate resilience and water equity have grown in importance, prompting the exploration of new approaches to managing rainwater in the urban environment.

An approach that manages rainwater in a way that is integrated with other water sources and City systems can bring us beyond the traditional view of rainwater as a waste product and advance a broader set of goals. Rainwater can shape and serve city-building processes by reinforcing water sensitive values and behaviours that deliver livability and equity outcomes. These include:

- Greater water security;
- Workforce development opportunities;
- Biodiversity and habitat creation;
- Enhanced public green spaces;
- Increased climate resilience and carbon sequestration;
- Safely connected neighbourhoods through blue-green networks; and

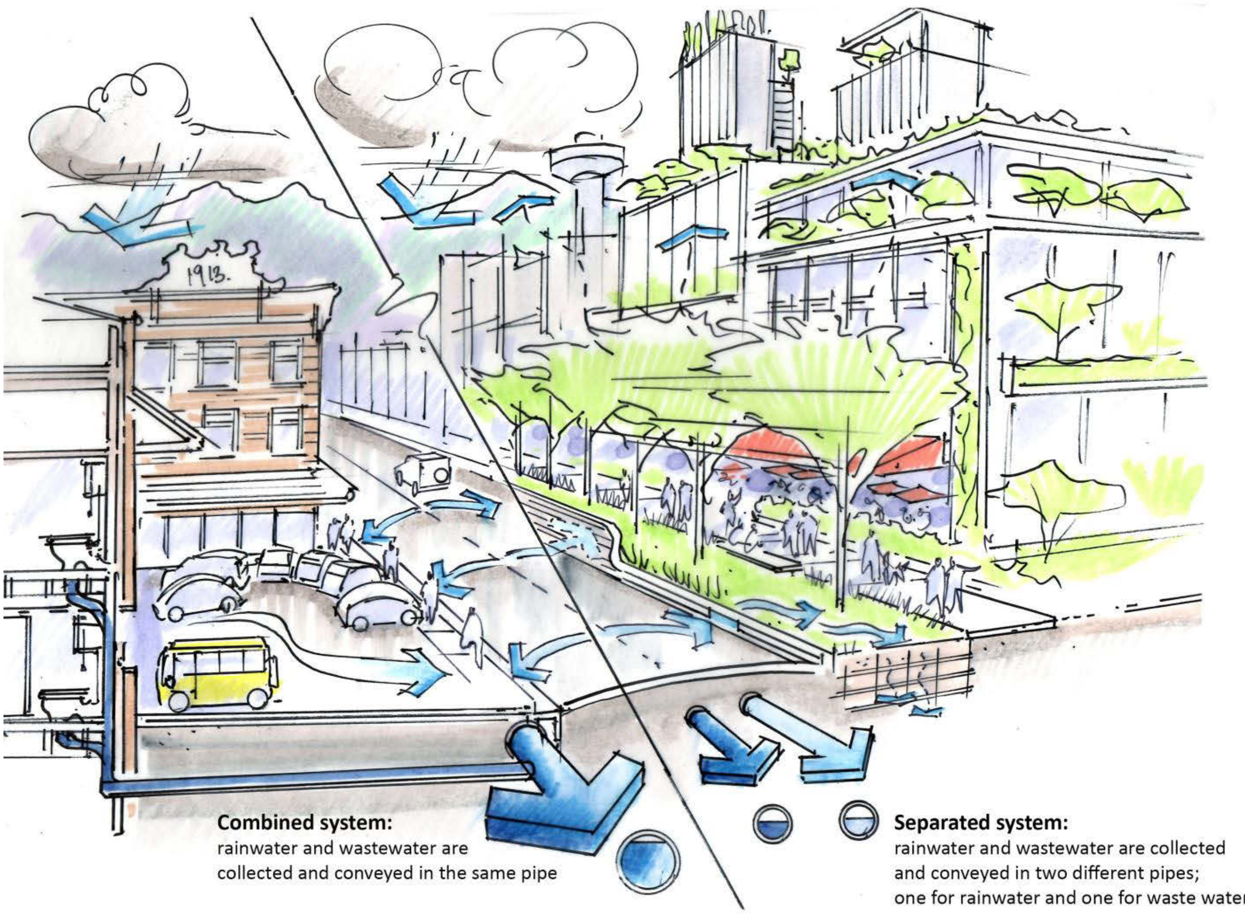


FIGURE 15: VANCOUVER'S CURRENT SEWER AND DRAINAGE SYSTEM

- Access to nature that supports social connection, enhances a sense of belonging, promotes well-being and stimulates our cognitive development and learning aptitudes.

GRI is an emerging field and approach to rainwater management that uses both nature-based solutions, land use and engineered systems to protect, restore and mimic the natural water cycle in a way that supports healthier, more equitable and resilient natural and urban environments. Cities around the world are embracing GRI to meet water quality objectives and other city priorities.

GRI projects can take many forms and use vegetation, soils and engineered elements to slow down, absorb, infiltrate, evaporate and remove pollutants from urban rainwater runoff. They can be designed to manage all types of rain events from a small drizzle to large storms and can be designed to meet many different goals. Examples of GRI include raingardens, absorbent landscaping, wetlands, trees, soil cells, bioretention swales, permeable pavement, underground infiltration trenches or drywells, rainwater tree trenches, blue-green roofs and water harvest and reuse systems. More information on GRI tools and best management practices can be found in Appendix B (GRI Typology) and the City of Vancouver's Integrated Rainwater Management Plan Volume II - Best Management Practice Toolkit (2016).

At a local scale, GRI is designed to reduce pollutant loads in urban rainwater runoff at the source and mimics the natural hydrological cycle flows, creating alternate pathways for rainwater to go.

Grey infrastructure remains a valuable modern tool that carries urban rainwater runoff flows that cannot be readily accommodated through infiltration, evapotranspiration, harvest and reuse. GRI does not eliminate the need for grey infrastructure. Pipes are still needed to convey any excess rainwater that would exceed the capacity of GRI assets.

At a city scale, GRI is a distributed network of natural areas and engineered practices that contribute to cleaner water and air, habitat, flood protection, carbon sequestration and cooler urban environments.

From a citywide perspective, a core principle of GRI is a decentralized approach; small, widely applied GRI across the city collectively will have significant impacts by keeping rainfall close to where it falls. A concept that fits well into citywide GRI is that of blue-green systems. Blue-green systems have the ability to connect the Vancouver Board of Parks and Recreation's major parks and ecological areas with green linkages that work with the natural flow of rainwater across the city. These blue-green connections aim to co-locate habitat, hydrology, rainwater management, pedestrian walkways and cycling routes to provide a connection to nature within the urban environment. For more information on blue-green systems see the B.4-False Creek to Fraser River Blueway council motion (2019).

What is integrated water management?

Integrated water management takes into consideration the entire urban water cycle, with the mindset that all water has value. An integrated approach is required to ensure that the management, construction and utilization of our water resources, water infrastructure and treatment plants are beneficial for the community, economy and environment. GRI has linkages to all of these different types of water.

FIGURE 16: INTEGRATED WATER MANAGEMENT

Case study:

Bioretention installation at Yukon Street and 63rd Avenue, Vancouver

PHOTO CREDIT: WENDY DE HOOG

The enhanced public space at 63rd Ave. and Yukon St. uses green rainwater infrastructure (GRI) to manage urban rainwater runoff from adjacent streets. The location was highlighted in the Marpole Community Plan as a new neighbourhood plaza.

A historic stream runs underground in the vicinity of this project, which inspired the use of the space for rainwater management and informed the design of the plaza, which evokes the image of fallen trees across a typical British Columbia creek. The project was led and designed by the City of Vancouver's Green Infrastructure Implementation Branch, and built in 2018 by City crews.

The plaza includes seating areas, a drinking water fountain, interpretive signage and a bioretention system to capture and remove pollutants from urban rainwater runoff. Soon, the site will also include public art installations created by Indigenous youth.

The design pilots innovative inlets, developed together with operations and maintenance staff for ease of cleaning and onsite soil amendment and reuse. Plantings are predominantly native species, supplemented with targeted non-native species to improve GRI practice performance and resiliency.

There will be ongoing monitoring of inlet function, groundwater levels and plant health to evaluate design performance and inform future design standards.

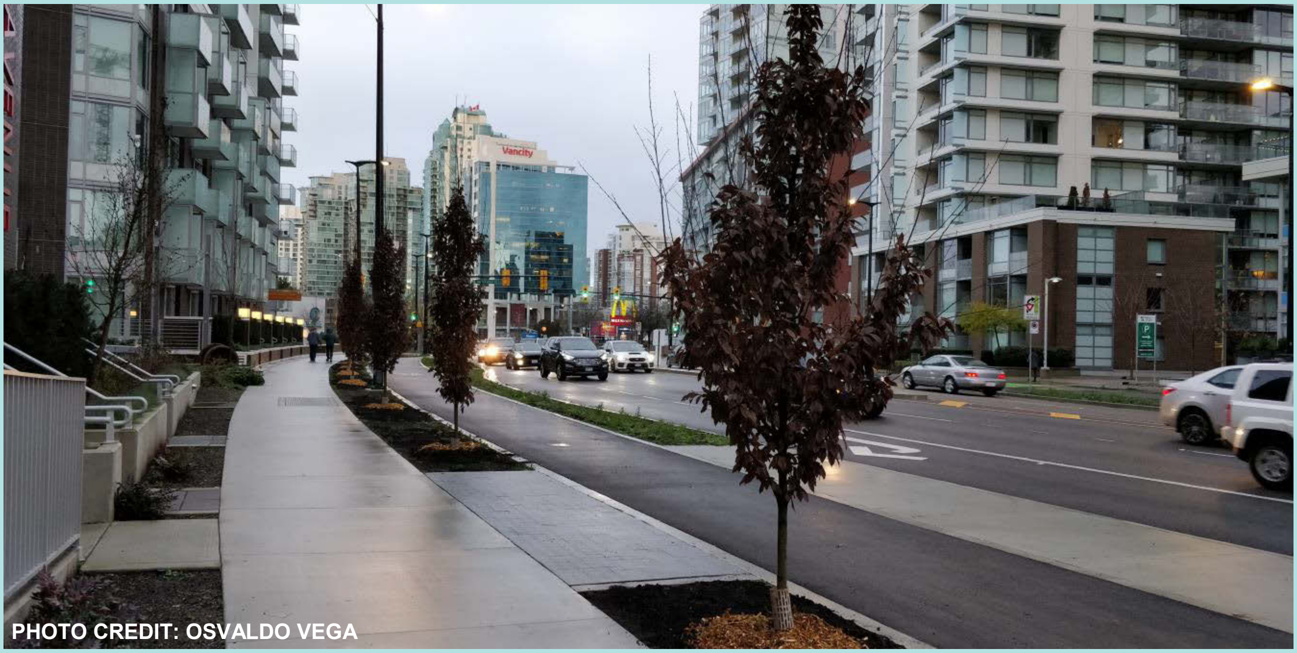
Performance statistics

The project includes 102 m^2 of dedicated bioretention systems. The practices incorporate fail safes should rainwater flows exceed design capacity.

The project manages urban rainwater runoff from more than 1,170 m^2 of adjacent impermeable area, largely roads and sidewalks.

Case study:

Rainwater tree trenches at Quebec Street and 1st Avenue, Vancouver



Rainwater Tree Trenches (RTTs) are versatile green rainwater infrastructure (GRI) assets that show a promising application potential in Vancouver's highly dense urban environment (see Appendix B GRI typology for more details).

On the surface, an RTT looks the same as a traditional street tree, boulevard or bike path. Underground, trenches of soil cells or structural soils provide structural support for the pavement above while creating uncompacted soil volume for tree roots below paved surfaces. This allows the tree to grow to its full mature canopy and live longer.

Additionally, urban rainwater runoff is directed into the structural soil and soil cell trenches. Through filtering, infiltration and tree uptake, the urban rainwater runoff is treated and kept from entering the sewer and drainage system. The RTT system can accept urban rainwater runoff from adjacent impervious areas such as streets, parking lots, sidewalks, plazas and rooftops. Excess flow from extreme rain events is directed to the sewer and drainage through a bypass system.

An RTT was installed as part of the Quebec St. and 1st Ave. precinct upgrades, underneath the new separated bike lane. This project was a collaborative effort between the City of Vancouver's Green Infrastructure Implementation, Transportation, Streets and Development, and Development and Major Projects Branches and the Vancouver Board of Parks and Recreation. Performance facts about this practice are discussed below.

Performance statistics

The Quebec St. and 1st Ave. RTT has been continuously monitored since September of 2018 on a water quantity and a water quality performance basis. The results discussed in this case study correspond to the collection period that ended in February of 2019.

In Vancouver, the majority (about 70%) of the rainfall happens in events of 24mm or less which are referred to as light showers. Roughly 20% falls in volumes between 24 mm to 48 mm storms and are referred to as rainstorms. Anything larger than 48 mm is considered an extreme rainstorm (see Figure 36 for rainfall intensity patterns). This RTT was designed to handle a rainstorm storm of 48 mm which accounts for 90% of storms in a typical year. During the monitoring period, 59 rain events were recorded: 38 as light showers, 13 as rainstorms and 8 as extreme rainstorms.

Water quantity performance

One pivotal goal of RTT is to infiltrate urban rainwater runoff into the soil, imitating what would happen in a non-urbanized watershed. RTTs, as any other GRI, can be used to delay the rainwater from entering the sewer and drainage system to reduce combined sewer overflows and overland flooding. As rainwater is infiltrated and delayed within RTT, the amount of rainwater entering the sewer and drainage sewer system is far less. Therefore the peak flow of a rain event is not only delayed but also reduced. Measuring how well these practices perform in terms of volume reduction, flow delay and peak flow reduction is necessary to inform planners, designers and engineers on how well the GRI works in Vancouver's climate and incorporate lessons learned to improve the city's watershed health. The table below summarizes the RTT's performance for this monitoring period.

Water quality performance

The pollutants collected during the runoff process are treated through filtration of the rainwater through the RTT. The soil traps the pollutants where they are retained or processed and taken up by the tree roots. RTTs are particularly effective in removing heavy metals, suspended solids, and phosphorus. The reported removal efficiencies are:

- Heavy metals - 57% to 100% removal
- Suspended solids - ≥ 68% removal
- Phosphorus - ≥ 74%

The reported efficiencies are expected to increase as the monitoring period was performed during the establishment of the vegetation in the RTT practice.

Performance attribute	Analysis	Results
Total rainwater volume captured	Focused on the total rainwater volume that was captured in the RTT and did not enter to the sewer and drainage system	Light shower events captured an average of 87% of total volume. Rainstorm events captured an average of 72% of total volume.
Total rainwater volume delayed to sewer and drainage system	Time of rainwater entering the RTT against the time of rainwater entering the sewer and drainage system through the bypass	Rainstorm event flows delayed by an average of 3.8 hours
Peak flow reduction	Reducing the inflow of rainwater to the sewer and drainage system during the peak of a rain event	Peak flow of rainstorm events reduced by an average of 60%

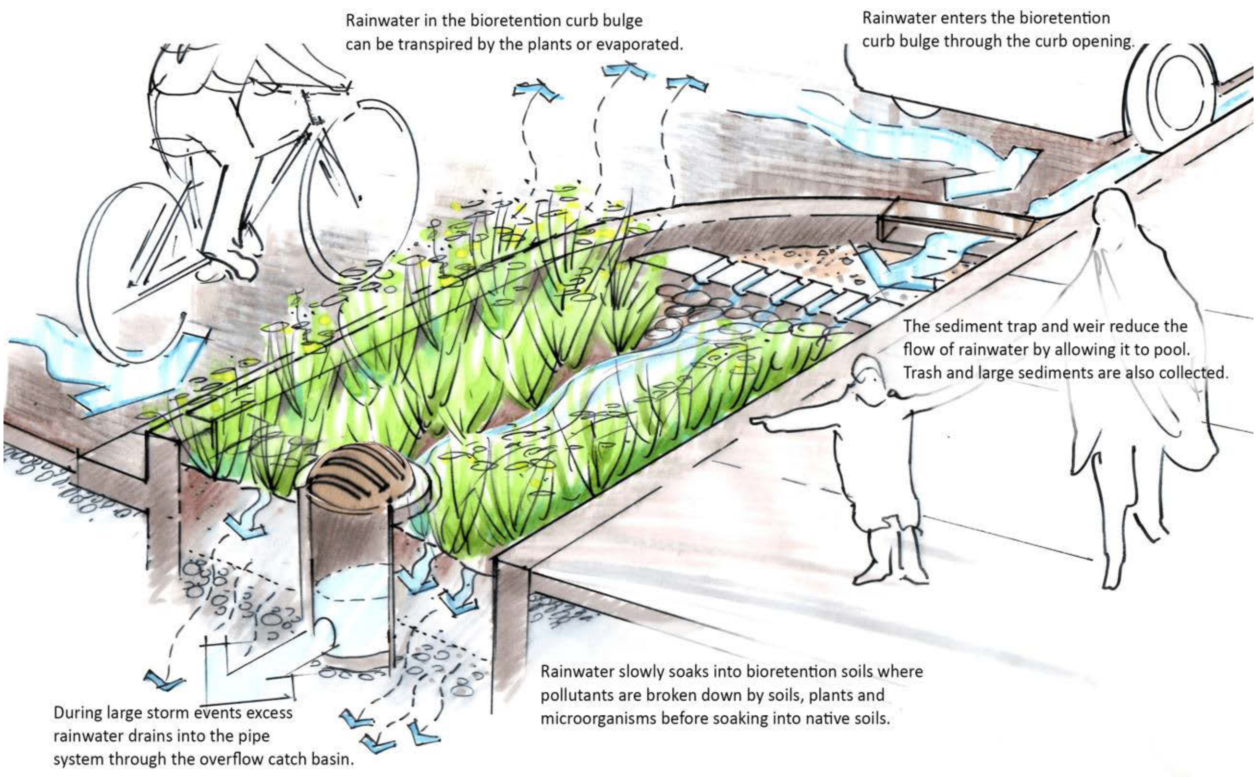


FIGURE 17: BIORETENTION

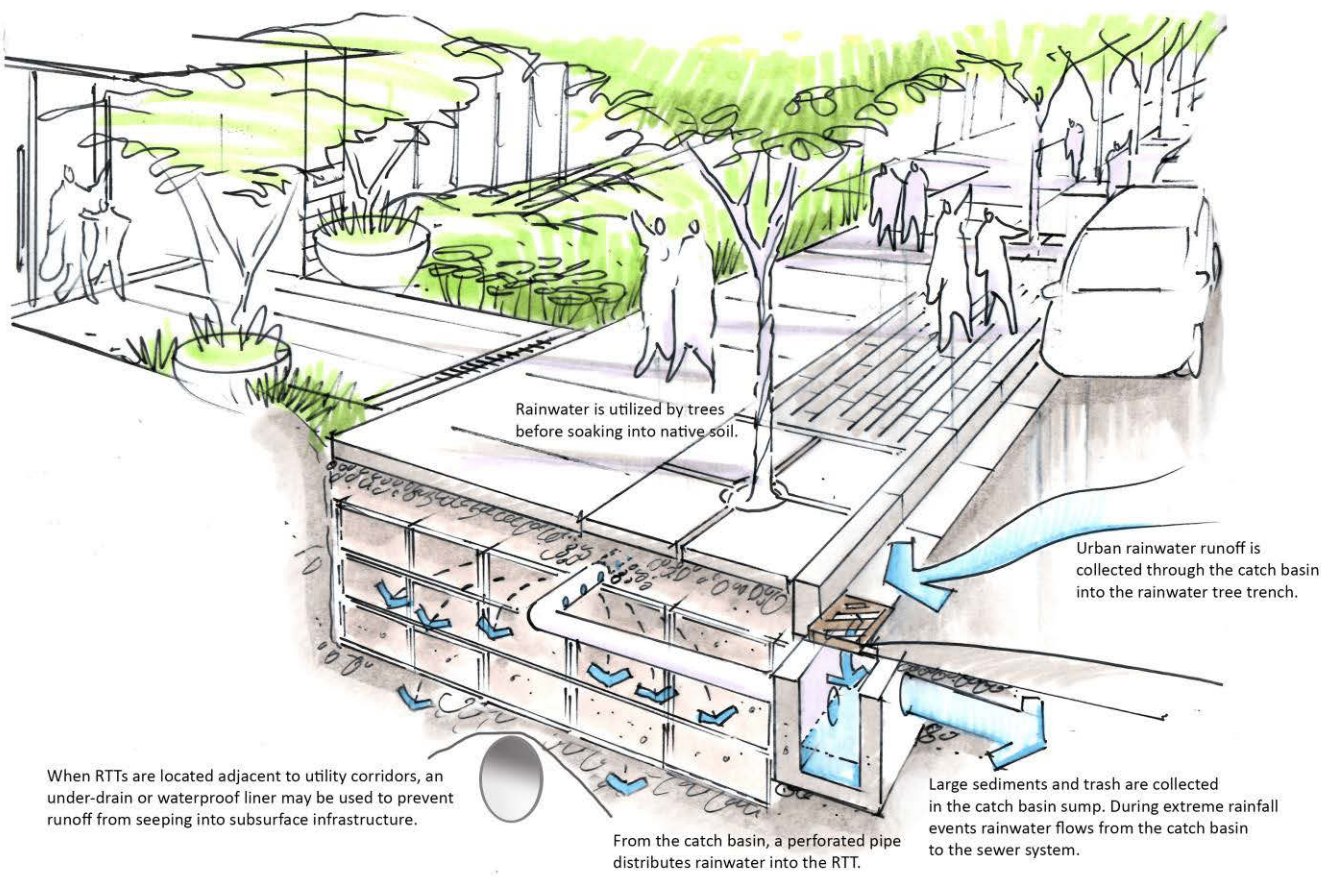


FIGURE 18: RAINWATER TREE TRENCH

2.3 Progress to date

The City and Vancouver Board of Parks and Recreation have been constructing GRI across the city, piloting new designs and demonstrating what is possible. The following sections describe the progress on the IRMP and what kind of GRI has been built to date and where they can be found.

2.3.1 Progress on citywide Integrated Rainwater Management Plan

The 2016 citywide Integrated Rainwater Management Plan (IRMP) outlines a phasing structure to implement a mix of GRI on public, private and park land, gradually working towards making GRI not only a standard but also a prioritized option for managing urban rainwater runoff.

The IRMP suggested a five year period to ramp up the implementation of GRI. With each step, the City will develop its approach and expand the reach of the programs. The work of the Rain City Strategy and the accompanying action plans have built upon the strong foundation of the IRMP phasing and scheduling strategy.

The report card presented in Appendix C shows our progress against this phasing and scheduling strategy:

- Phase A: Immediate and ongoing (2016);
- Phase B: Remove barriers, build capacity (2017);
- Phase C: Expand GRI into new non-single family projects (2018);
- Phase D: Expand GRI to new one/two family and lane housing (2019);
- Phase E: Expand GRI to retrofits (2020); and
- Phase F: Long term aspirations (beyond 2020).

2.3.2 Progress on streets and in public spaces

The City to date has implemented 238 GRI assets in streets and public spaces (public realm) in the form of:

- Bioretention practices;
- Permeable pavement areas;
- Subsurface infiltration trenches and soak ways;
- Rainwater tree trenches; and
- Engineered wetland.

By far, the biggest asset category is bioretention, which makes up 59% of all GRI assets in Vancouver. The category of bioretention, which is an engineered landscape that captures and cleans urban rainwater runoff, includes rain gardens, bioswales, bioretention cells, bioretention planters and bioretention corner bulges. A breakdown of what has been constructed in each category as of 2019 is shown in Figure 19, and Figure 20 shows a map of the City's assets. For more information on GRI typologies see Appendix B.

The City is developing an inspection program for all GRI assets that will ensure they are performing up to our standards. In 2017, a comprehensive field evaluation found that over half of the City's bioretention practices were underperforming due to a lack of regular maintenance and outdated design standards. An asset renewal program, starting in 2019, aims to rehabilitate approximately 10-15 of these underperforming practices each year. The rehabilitation program will update the designs to improve rainwater management performance, reduce maintenance needs, beautify our neighbourhoods and ultimately improve water quality in our aquatic ecosystems.

FIGURE 19: GRI ASSETS IN STREETS AND PUBLIC SPACES

2.3.3 Progress on buildings and sites

Through the City's development requirements, there are a number of GRI assets located on buildings and private sites. The City's Sustainable Large Sites Rezoning Policy, which was updated in 2018, requires rainwater management, with an emphasis on water infiltration and on-site treatment. The City's Green Buildings Rezoning Policy, also updated in 2018, similarly requires the submission of a Rainwater Management Plan to achieve the 2016 IRMP design standards. Additionally, development within the Cambie Corridor is also subject to rainwater management requirements, primarily to avoid further overloading the sewer and drainage system in that area.

Since the Rainwater Management Plan requirements came into effect, City staff have reviewed approximately 264 rezoning and development permit applications pertaining to rainwater management across the city. These applications represent approximately 170 unique sites at various stages of the permitting process. Proposals put forward by developers have included a variety of GRI tools including bioretention, absorbent landscapes and green roofs, though many are continuing to rely heavily on non-GRI strategies including detention tanks and water treatment systems to achieve the required targets. This highlights the need to work with industry to develop strategies, technical guidelines and reduce barriers for greater application of GRI tools.

In addition to rainwater management requirements, City Council recently approved updates to the Vancouver Building By-law (VBBL) which includes some of North America's strongest water efficiency requirements for all new construction. The City now requires all toilets to have a maximum flush volume of 4.8 litres per flush, regardless of whether it is dual-flush. From an integrated water management perspective, this complementary action helps to reduce pressure on the sewer and drainage system from sanitary loads (blackwater). In addition, the VBBL also includes standards for non-potable water systems, facilitating the adoption of rainwater harvest and reuse. These reuse systems are currently being registered citywide (as required through the new operating permits) and, with funding, inspections will commence to ensure they are operating as intended.

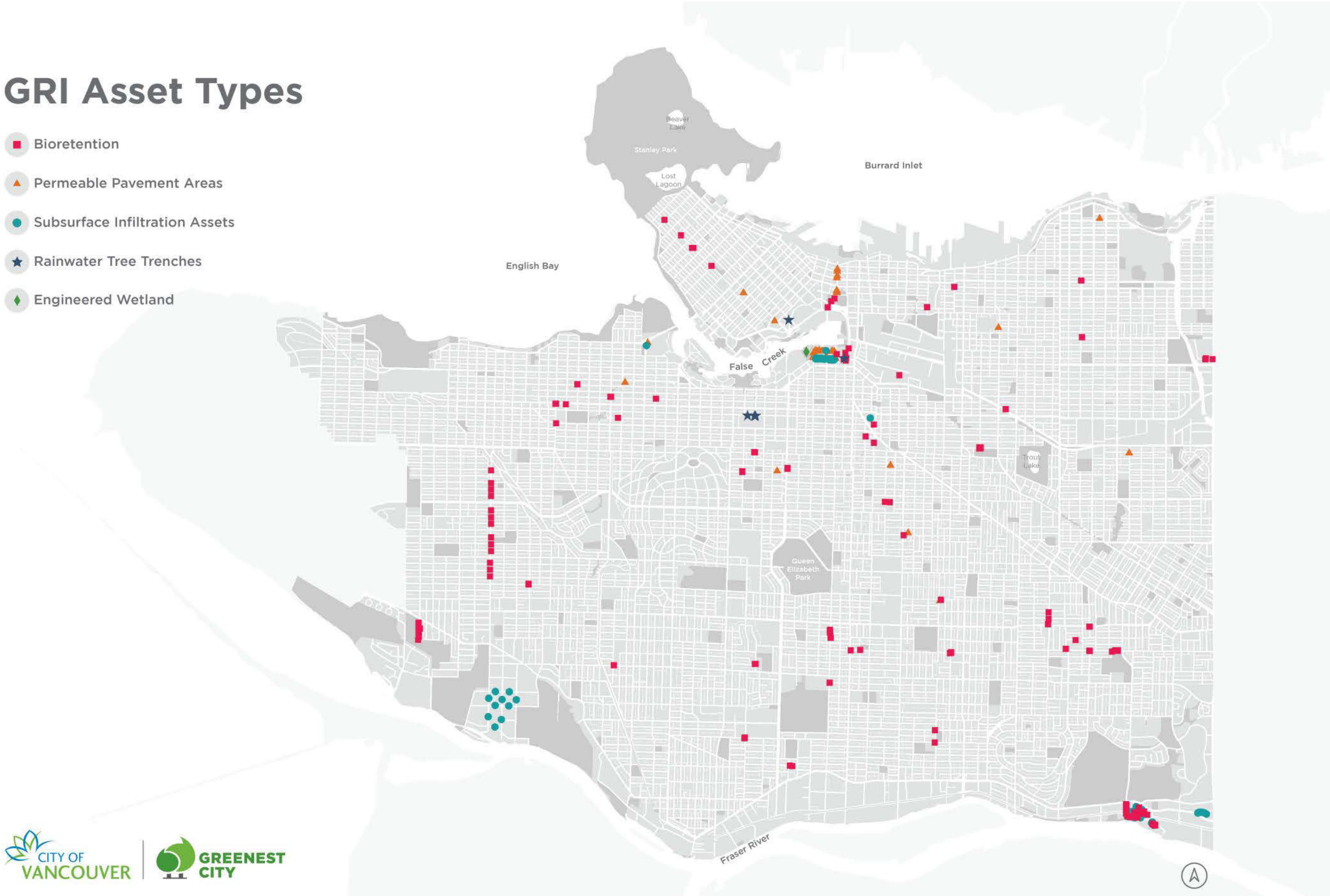


FIGURE 20: GRI ASSETS IN VANCOUVER STREETS AND PUBLIC SPACES

While there is still a lot of work to be done in terms of advancing rainwater management on private sites, there are significantly more GRI assets being created now than there were just a few years ago. Some of the challenges that have been encountered to date are around the impact of site design, building form and basements. Operation and maintenance on these private assets is needed to ensure the most GRI tools are functioning effectively. Actions to address these challenges are included in the Buildings & Sites Action Plan described in Chapter 7 and Appendix F.

2.3.4 Progress in parks

Vancouver's roughly 240 parks play an important role in terms of rainwater management through absorbent landscapes, urban forest, habitat, daylighted creeks, wetlands and other features. Many parks also depend on our sewer and drainage pipe system, particularly to manage water and wastewater related to impervious areas in parks including community centres, roadways, parking lots, sports playing surfaces and other extensive hardscape areas. Many natural and artificial playing fields also depend on the sewer and drainage system.

Throughout our parks, there are a variety of GRI assets that support water management. The planted and lawn areas within parks, while not deliberately designed as GRI, have an inherent ability to capture rainwater and slow overland flow to allow time for infiltration and evapotranspiration. The effectiveness of these processes, however, varies depending on levels of soil compaction, soil composition and types of vegetation in individual park areas. In addition, many catch basins or drains in parks are designed to allow some rainwater to infiltrate into the ground through the bottom of the catch basin. Once the ground becomes saturated, the remaining rainwater discharges into the sewer and drainage system.

Given the wide variety of park configurations across the city and the secondary ability of most green areas within parks to manage rainwater, Table 4 is intended as an overview of several prominent GRI assets rather than an exhaustive inventory.

TABLE 4: GRI ASSETS IN VANCOUVER PARKS

Park	GRI Asset
Riley Park	Rain garden and bioswale that collects urban rainwater runoff from parking plot area
New Brighton Park/Creekway Park	Constructed saltwater marsh fed by day lighted streams
Tatlow and Volunteer Park	Stream restoration
17^{th} Ave. & Yukon St.	Bioswale
6^{th} Ave. & Fir St.	Bioswale
Sun Hop Park	Permeable concrete
Emery Barnes Park	Permeable pavers over structural soil at SW plaza
Stanley Park	Permeable pavers
Stanley Park Horse & Carriage Station	Bioswales between rows of parking; bioretention area to north of parking lot
Hinge Park	Engineered wetland
Grandview Park	Rain gardens (1 in the NW Corner and 1 in the NE corner)
Sunset Park	Stream and rain garden (East of new parking area)
Hastings Park Sanctuary Park	Rainwater from city drainage system directed to pond – more planned as part of master plan (stream daylighting)
Falaise Park	Bioretention areas
5^{th} Ave. and Pine St.	Rooftop rainwater runoff captured into cistern for on-site irrigation
Memorial South	Wetland area and pond

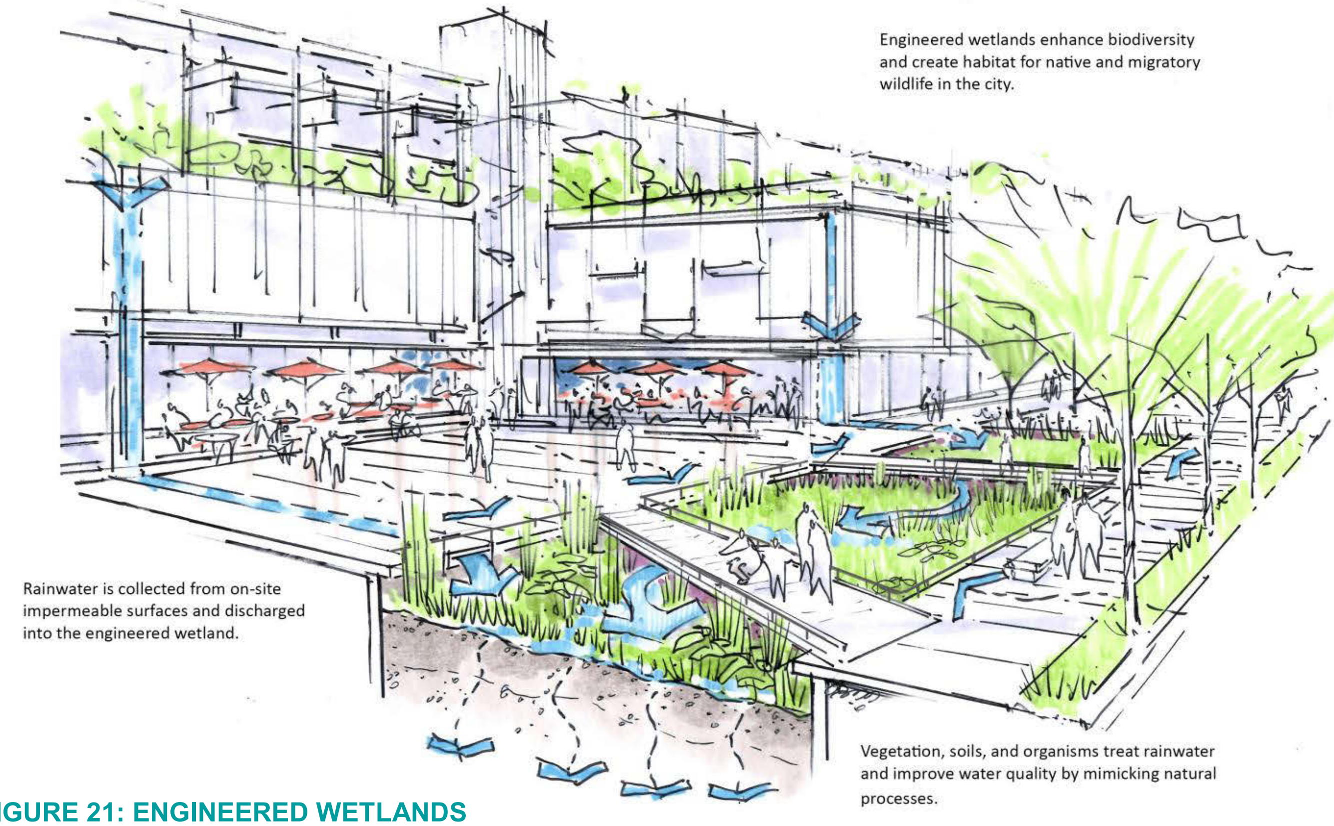


FIGURE 21: ENGINEERED WETLANDS

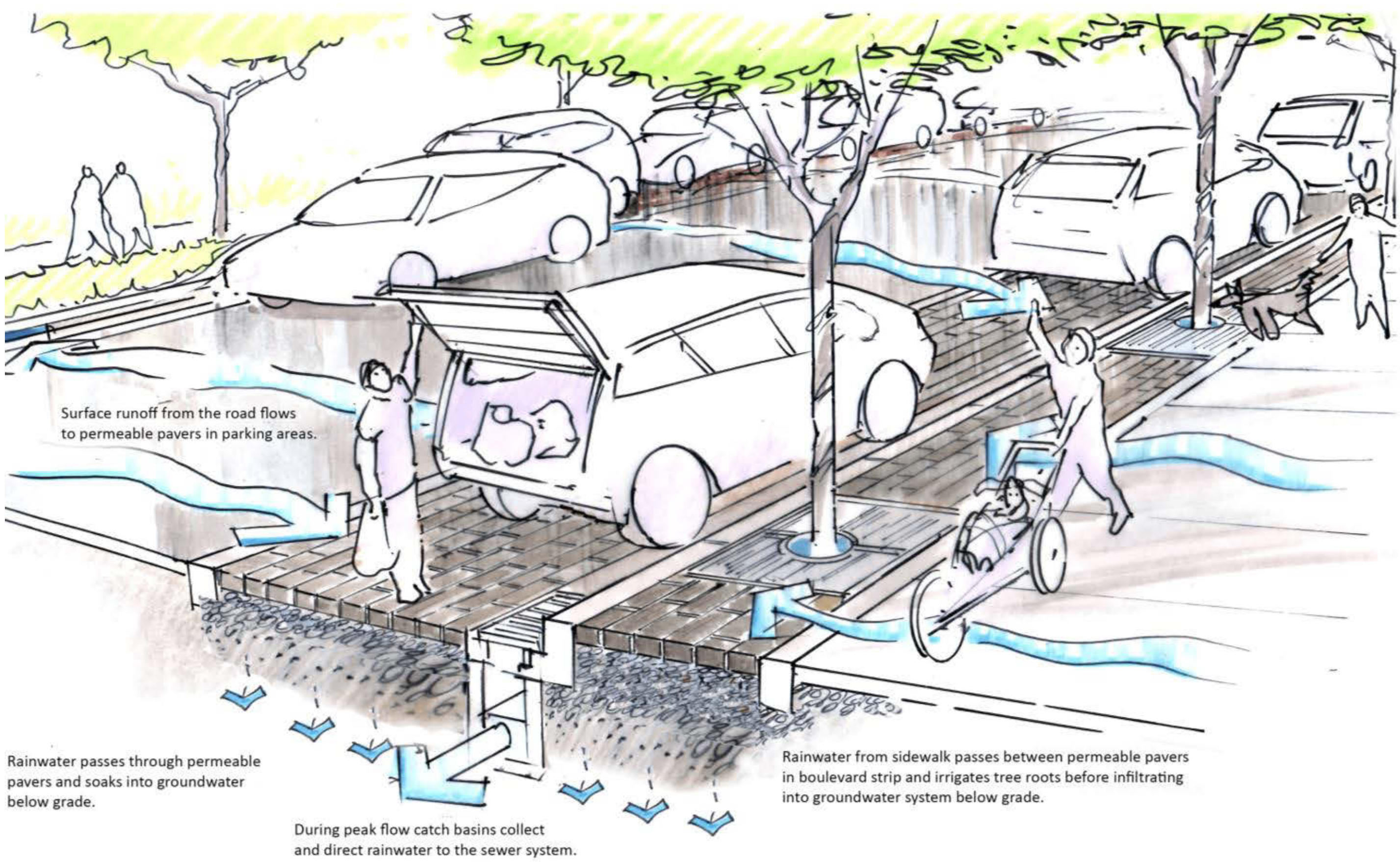


FIGURE 22: PERMEABLE PAVERS

PHOTO CREDIT: ALEXANDRA COUILLARD

Chapter 3.

Imperatives for a new approach

The urban water system in Vancouver is facing many emerging and long-standing challenges that together drive the need to re-examine existing systems and find innovative ways to change our rainwater management practices. Our climate is changing, leading to shifts in precipitation and temperature patterns for our growing city. In addition to climate change, increasing urban development will create more impermeable surfaces in the built environment and reduce the presence of mature trees and other plants, leading to increased urban rainwater runoff. This combination of factors requires purposeful interventions around rainwater management.

Connecting rainwater management and climate adaptation planning with land use and infrastructure planning, Vancouver can become a more resilient and water sensitive city. As a result, we can restore hydrological pathways and protect our valued local waterbodies, while building resilience to climate change impacts. Green rainwater infrastructure (GRI) plays a major role in alleviating water management challenges and creating new synergies and benefits for the city.

In addition to regulations, the five key imperatives for action on rainwater management include:

- Climate emergency and resilience;
- Water quality;
- Integrated water utility servicing;
- Water utility cost and value-for-money investments; and
- Livability and water equity.

3.1 Climate emergency and resilience

A leading challenge in the water sector is climate change. Climate change impacts are already being felt in our communities today, particularly more extreme and volatile weather patterns and rising sea levels. The effects of climate change also have a significant impact on our water quality and sewer and drainage system. How to effectively reduce vulnerability and increase resilience to the impacts of climate change are critical considerations. However, exposure to these risks is not uniform across the city. As a result, identifying how to invest in our communities to build resilience and protect those who are vulnerable in an equitable way is a priority. In 2016, the Pacific Climate Impacts Consortium, in partnership with the University of Victoria and the City of Vancouver, updated the climate projections for the city. The results have significant implications for Vancouver by 2050[9] including:

- Changes to rainfall patterns;
- Prolonged dry periods in summer;
- Increased heat;
- Rising level rise.

Climate change today

The Earth's climate has been changing over millions of years but the atmosphere has been warming at an accelerated rate over the past century due to human activities that release heat-trapping greenhouse gases (GHGs). The accelerated changes in our climate are already noticeable in Vancouver. For example, in October 2017 we experienced two brief and unexpectedly intense rainfall events, both of which immediately overwhelmed our sewer and drainage system and flooded the intersection of Broadway and Cambie St (see photo on the left).

3.1.1 Changes to rainfall patterns

More extreme rainfall events in fall, winter and spring are to be expected by 2050. Specifically, there is an expected increase of 12% in fall, 5% in winter and 7% in spring precipitation.[10] The amount of rain from each of these events is also predicted to increase, with 33% more precipitation on very wet days and 63% more on extremely wet days. Less frequent events, such as 1-in-20 year events are projected to increase in intensity by 36%, indicating a potential for increased flooding (see Figure 23).

3.1.2 Prolonged dry periods in summer

Consecutive dry days in the summer are expected to increase from 23 to 29 days per year, an increase of 23%. In addition, a decrease of summer precipitation by 19% is also projected. These prolonged days of summer drought have implications for the health of our natural assets and water consumption needs. The changing climate also means new threats to ecological system health in terms of making trees, plants, soils, waterways and a range of wildlife more vulnerable to drought and extreme rain and flooding events. Climate change is also likely to bring new pests and a greater susceptibility to diseases, resulting in greater impact to tree, plant and ecosystem health, habitat and the well-being of wildlife on land and in local waters.

Long dry periods also increase the likelihood and severity of forest fires. The worst fire seasons recorded in B.C. were 2017 and 2018, with severe air quality advisories in place in Vancouver due to smoke. Furthermore, in 2017 over 65,000 people across the province were displaced, many of whom came to Vancouver. As the climate continues to change, the number of climate refugees will increase, air quality will continue to worsen and the risk of localized fires will increase[11] (see Figure 23).

3.1.3 Increased heat

More frequent heat waves are predicted, with the number of days above 25°C increasing 139%, from 18 to 43 days per year. A study done by the British Columbia Ministry of Environment and Climate Change Strategy assessing climate risks in B.C. reported that heat waves were ranked 3rd in terms of highest risk score rating, just below severe wildfire seasons, and seasonal water shortage risks.[12] Heat waves can contribute to a range of medical conditions beyond fatalities when people are unable to maintain suitable body temperatures. Impacts range from heavy sweating and dehydration to heat stroke and chronic cardiac disease. Particularly acute negative health outcomes could occur for vulnerable populations, including the elderly, infants, socioeconomically disadvantaged, pregnant women and people experiencing homelessness. Given that heat waves can occur over large areas, it is likely that many people could be affected by some type of heat-related illness. However, pre-existing conditions and location will influence the severity of impact[13] (see Figure 23).

In addition to the threat urban heat poses for human health, it is also a well-known threat to the health of the natural environment. Heat is a stressor for many trees, plants and wildlife, including fish and other species in aquatic ecosystems, impacting their ability to provide ecosystem services. Increased heat also has the potential to exacerbate toxic algae blooms and the proliferation harmful bacteria from discharges in our waterways.

Furthermore, the occurrence of hot summer days above 30°C is expected to increase from an average of one day per year to 12 times a year, with the temperatures of very hot days intensifying from 32°C today to 37°C in 2050.[14]

These heat impacts are amplified by the urban heat island effect, which causes urban areas to be significantly warmer than areas with greater canopy cover and green spaces. Figure 24 describes the urban heat island effect in Vancouver.

3.1.4 Impacts on drinking water supply

Warmer winters are predicted to result in a 58% decline in snowpack by 2050. This decline, when combined with hotter and drier summers, has implications for our water security and availability. Vancouver relies on rainfall and snowmelt for recharging our drinking water supply in springtime. Population growth and our high rates of drinking water consumption amplify the need for enhanced water efficiency. There are growing opportunities to develop a broader portfolio of water resources, such as rainwater, greywater, blackwater or groundwater for non-potable water needs, such as flushing toilets. This will reduce pressures on our drinking water supply (see Figure 23).

3.1.5 Rising sea levels

Models predict a 0.5 meter increase in sea levels by 2050 and 1 meter by 2100 (see Figure 23). Our low-lying coastal areas are already vulnerable to sea level rise and storm surges. They receive rainwater from the upstream watersheds, either overland or via our sewer and drainage system, compounding the risk of urban flooding or sewer and water back-ups. Sea level rise can also contaminate our groundwater through saltwater intrusion.

In 2005, Vancouver was ranked 11th out of 136 port cities in the world, in terms of average annual economic losses based on the vulnerability of our exposed coastal assets.[15] Considering climate change impacts, a growing population and aging infrastructure, adaptation to climate change is critical for Vancouver. This is recognized in the 2019 Climate Emergency Response (see Figure 23).

What is the difference between climate mitigation and climate adaptation?

The City of Vancouver's Climate Change Adaptation Strategy (developed in 2012 and updated in 2018) defines **climate mitigation** as "the ongoing attempts to prevent significant climate change through the reductions of greenhouse gases in the atmosphere."

Climate adaptation "refers to actions taken to respond to the impacts of climate change by taking advantage of opportunities or reducing the associated risks. Examples of adaptation actions include modifications of coastal development to account for sea level rise, provision of heat refuges during heat waves, planting hardy or suitable plants and dealing with increases in beach erosion."[16]

GRI can be used in both climate mitigation and adaptation measures.

What is urban heat island effect?

Urban heat island effect is the increased temperature found in urban areas due to human activity and modification of land surfaces. The high concentration of rooftops, asphalt, and concrete absorbs and traps heat from the sun, warming the air. Urban areas are further warmed by the energy emitted from the many people, cars, buses and trucks found in a city.

Changes in rainfall patterns

extreme rain events will be **36%** more intense

33% more rain on very wet days

increased risk of coastal flooding because of king tide and stormy weather

Prolonged dry periods in summer

19% less rain during the summer

23% increase of consecutive dry days

increased risk of summer drought and wildfires

Increased heat

more frequent heat waves

twice as many days above 25℃ from 18 to 43 days

increased health risks for vulnerable people

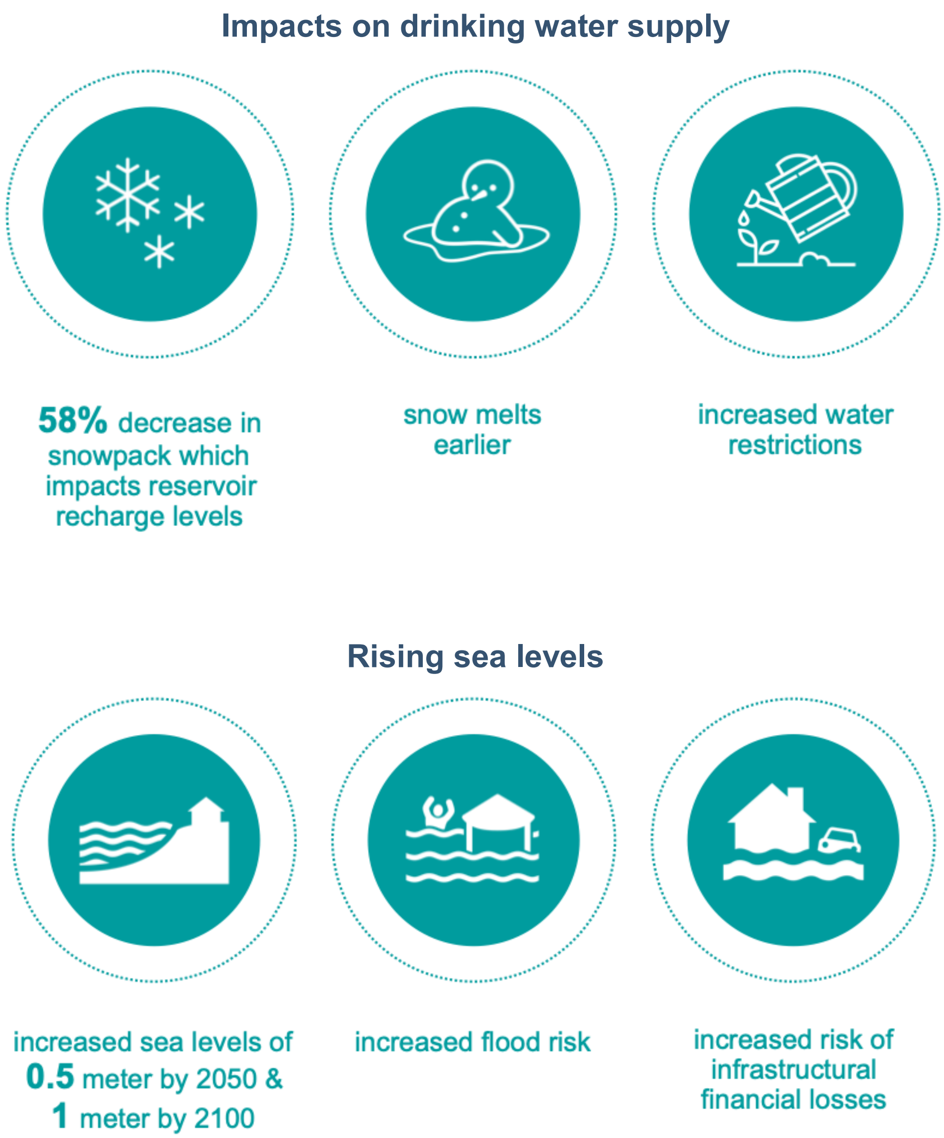


FIGURE 23: PROJECTED CLIMATE CHANGE IMPACTS IN VANCOUVER BY 2050

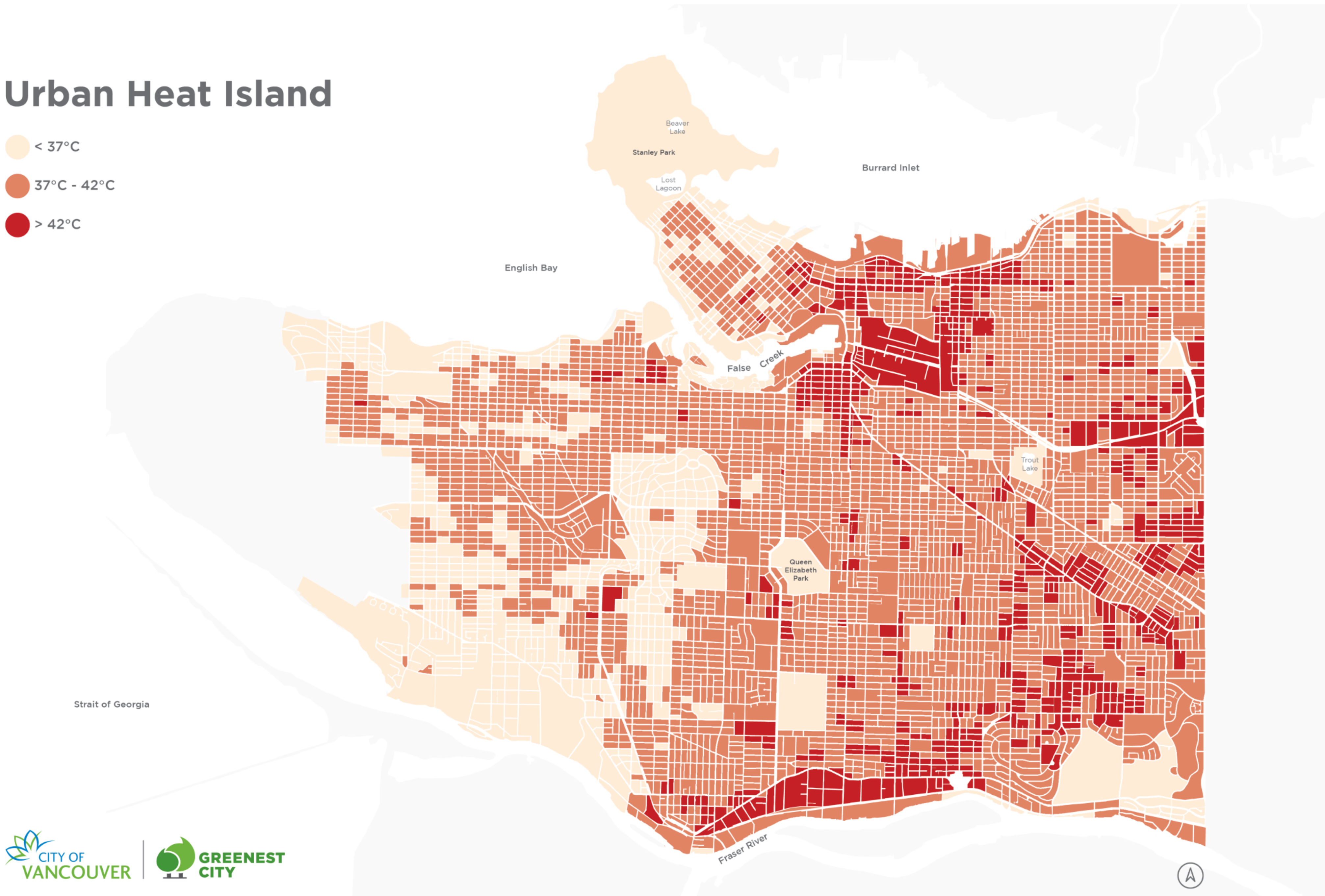


FIGURE 24: URBAN HEAT ISLAND EFFECT IN VANCOUVER (2016)

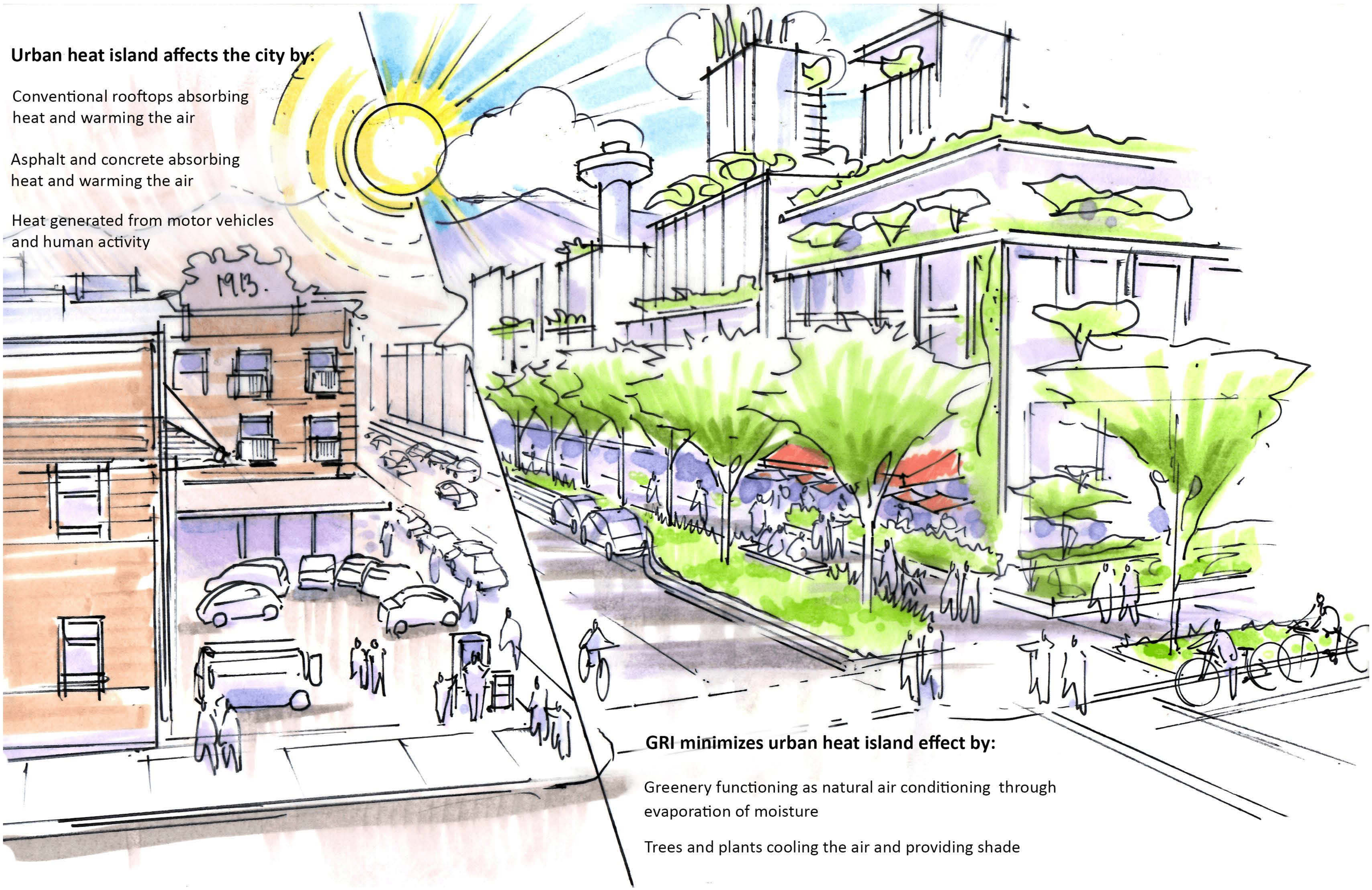


FIGURE 25: URBAN HEAT ISLAND EFFECT IN THE CITY

How can green rainwater infrastructure be used to mitigate and adapt to climate change?

From a climate mitigation perspective, green rainwater infrastructure (GRI) can help reduce the greenhouse gas emissions of cities. Elements of GRI practices, like trees, plants and in particular soil, can play a critical role in absorbing and sequestering carbon dioxide[17] – which is a significant greenhouse gas produced by burning fossil fuels like gasoline, diesel and natural gas. Through the Climate Emergency Response, the City of Vancouver has committed to sequestering one million tonnes of CO2 per year by 2060[18] to help mitigate global and local climate change. GRI can help contribute to this goal. Practices like blue-green roofs also provide insulation to buildings,[19] reducing their energy use for heating and cooling[20] and the associated greenhouse gas emissions.

From a climate adaptation perspective, GRI can help us adapt to changing rainfall patterns and help manage extreme rain events through its capacity to manage large quantities of rainwater. This also provides opportunities to help control flooding and detain water temporarily.

The cooling qualities of trees and other green spaces can help reduce the urban heat island effect. While higher levels of moisture in the ground evaporate in to the atmosphere serving as a natural air conditioning system for the city. A combination of these natural functions helps us adapt to hotter summer temperatures, increase public health and reduce cooling needs in buildings.

In addition, harvest and reuse systems can both divert rainwater from our sewer and drainage systems and reduce the use of potable water for non-drinking purposes. By not using drinking water for toilet flushing, laundry use, garden watering and irrigation, helps us adapt to a future in which drinking water is likely to be less plentiful and more costly than it is today.

How can green rainwater infrastructure be used to improve water quality?

For water quality related to combined sewer overflows (CSOs), green rainwater infrastructure (GRI) cost-effectively captures rainwater at the source which reduces the volume of rainwater entering the sewer and drainage system, lowering the likelihood of CSO events and their overall volume.

In terms of pollutants in urban rainwater runoff, improvements are achieved through GRI designs that use soils, microbes, plants and sediment traps to retain and metabolize pollutants. Research from the Washington Stormwater Centre at the University of Washington has shown that GRI is very effective in treating a wide range of pollutants picked up from typical road and roof runoff. Their studies found that bioretention is effective and sufficient to counter the toxicity of urban rainwater runoff for salmon.[21]

3.2 Water quality

Reducing the polluting impacts of urban activities on the waters in and around Vancouver is fundamental to preserve and enhance our natural aquatic ecosystems for future generations. Discharging clean water into areas such as False Creek, Burrard Inlet and English Bay can also improve our ability to harvest food, swim and recreate at our beaches all year round. Water quality concerns in Vancouver are twofold:

3.2.1 Combined sewer overflows

Originally, the sewer and drainage system was designed for a certain population size and modest rain events. Currently, population growth and increased density have had a profound impact on the demands placed on our sewer and drainage infrastructure. In addition, increased rainfall volumes due to climate change, is leading to capacity constraints in the sewer and drainage system and causing combined sewer overflows (CSOs) into our local waterbodies.

CSOs occur when the volume of combined wastewater and rainwater exceeds the capacity in the pipe system and/or treatment plant. In 2018, the Vancouver Sewerage Area generated nearly 33 billion litres of CSO. Additional CSOs occurred at the City of Vancouver owned and operated outfalls (see Figure 13 & Figure 14).

The sewer and drainage systems in Vancouver are made of a complex network of pipes, built gradually over the past hundred years. To fully address the water quality impacts of our sewer and drainage system in Vancouver requires considering the current rate of separation enforced through regulation and the extent of combined sewer and rainwater connections from older private properties. For many combined sewer cities such as Edmonton, Toronto, Montreal, Seattle and Portland, fully addressing CSOs is a multi-decade and multi-billion dollar endeavor.

Since the 1970's, the primary strategy used by the City to eliminate CSOs is sewer separation. However, in a completely separated sewer system, a major source of water quality concern remains: urban rainwater runoff.

3.2.2 Polluted urban rainwater runoff

Urban rainwater runoff is a major cause of water pollution in urban areas. When rain falls on our paved roofs, streets and parking lots, it cannot soak into the ground as it would have in a natural area. Instead, rainwater flows over land and picks up pollutants before entering a catch basin or drain. In a separated sewer system the rainwater is ultimately discharged, untreated directly into surrounding waterbodies. There are a variety of pollutants that can be found in urban rainwater runoff that can be severely toxic and adversely impact aquatic environments. Research has shown that polluted urban rainwater runoff is highly toxic to salmon and other fish,[22] and has far reaching impacts throughout the coastal and marine food chain[23] (see section 2.1.2 for more information on urban rainwater runoff).

3.3 Integrated water utility services

The ability to deliver integrated water utility services is complicated by changes in population, density and built form. All of which are compounded by the state of the existing sewer and drainage system and climate change.

3.3.1 Aging sewer and drainage system

Aging and deteriorating water infrastructure compounds the water challenges faced by the city. Sewer and drainage pipes are usually designed to last for 80 to 100 years before they must be replaced. While the City of Vancouver has been renewing the sewer and drainage system with the intent of 1% on an annual basis, the system was not built at the same pace. As a result, renewal needs are often not linear and put pressure on repair and maintenance efforts.

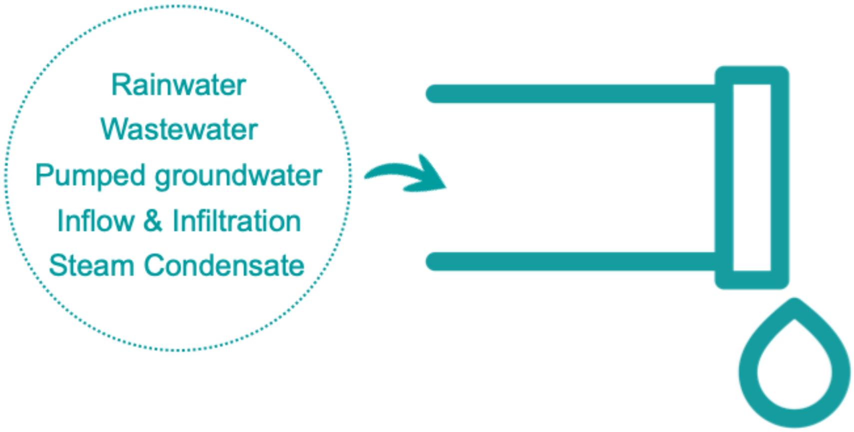


FIGURE 26: COMBINED SEWER AND DRAINAGE PIPE

Like many other older cities, much of Vancouver's underground sewer and drainage system were built in the early to mid-1900s, following the Second World War and during major city densification in the 1960s. Many of these pipes are reaching the end of their life cycle and need to be replaced, requiring significant investments to maintain a state of good repair in our system. In addition to renewing our infrastructure, there is also a need and opportunity to look at how we adapt our system to better prepare for changing climatic conditions, population growth and densification.

Sewer and drainage renewal is further strained by the uncertainty of climate change, changing land use patterns and built form. For instance, with climate change, future weather patterns are much less predictable, and the storm projections used to inform design standards become challenging to predict as global climate change projections continue to evolve. Furthermore, our population and employment growth patterns tend to focus on 20 year time horizons. This makes it more difficult to accurately predict the appropriate servicing needs for the roughly 100 year service lifespan of a sewer pipe.

To address this uncertainty, there is a need to build resilience and flexibility into the system, including our design choices and types of infrastructure we use to replace our current aging system. Hence, underground pipes are difficult and costly to change once installed, making them a less flexible option. A combination of grey infrastructure and green rainwater infrastructure (GRI) allows for a more adaptable and resilient system in the future.

3.3.2 Redevelopment and capacity constraints in the sewer and drainage system

Population growth and changes in density, coupled with a legacy combined sewer and drainage system, exacerbate existing water challenges and create new ones (see Figure 27). Vancouver is experiencing population growth and increased density as significant new development moves forward to help address housing needs.

By 2041, the Metro Vancouver Regional Growth Strategy (2011) anticipates Vancouver is expected to have grown by more than 150,000 residents and close to 90,000 jobs.[24] This increase in the number of people relying on our sewer and drainage system increases the amount of wastewater in our pipes. In addition, the tradeoff of denser communities is the decrease in permeable areas, like yards and unpaved laneways, which can increase the amount of urban rainwater runoff generated in a neighbourhood.

Together, this increase in urban rainwater runoff and wastewater means that not only are our pipes often old and in need of replacement or repair, they are also quickly becoming too small to serve these new communities (see Figure 26). When the sewer and drainage system is at or over capacity, there is an increase in the frequency of CSOs and the potential for flooding.

Furthermore, if the sewer and drainage system that serves a proposed new development is already at capacity, the system must be upgraded to facilitate the development project. Often, grey infrastructure, especially, trunks are very costly. Using a combination of green and grey infrastructure and greater onsite management of rainwater can reduce the flow of water in to the pipe system, providing cost-effective servicing.

3.3.3 Drinking water availability

The desire to have a resilient drinking water system is spurred by considerations of water security and a reliable year-round supply of drinking water. The British Columbia Ministry of Environment and Climate Change Strategy assessment of climate risks in B.C. reported that seasonal water shortages are ranked 2nd in terms of highest risk score rating, just below severe wildfire risks.[25] The impacts of an extreme summer water shortage can be wide-ranging and affect drinking water quality, ecosystem health, community water supply and water-dependent industries.[26]

Reducing drinking water consumption and identifying new sources of water for non-potable uses will be important to align with water supply planning and water infrastructure investments. The current pressures on the water supply system, combined with the impacts of climate change, highlight the need for the City to demonstrate leadership and new thinking related to fit-for-purpose water usage. This will include viewing rainwater as a valuable resource that can be harvested and reused or allowing it to return to naturalized pathways in support of urban ecosystems.

FIGURE 27: PRESSURE ON EXISTING SEWER AND DRAINAGE SYSTEM AS DENSITY INCREASES

How can green rainwater infrastructure be used to transition our integrated water utility services through asset renewal and growth servicing upgrades?

Reducing the volume entering the sewer and drainage system can help address our pipe capacity constraints and enhance resiliency to climate change. By keeping rainwater out of the pipes entirely, we help alleviate pressure and preserve capacity on existing pipes. Diverting water from the pipe system provides an opportunity to make targeted and strategic investments in upgrading and renewing grey infrastructure at the time of life cycle replacement, rather than delivering whole system upgrades early. It also reduces the load on our wastewater treatment plants, preserving capacity and the overall cost of treating wastewater. This approach is resourceful and a cost-efficient way to deliver essential integrated water utility services well into the future.

3.4 Integrated water utilities cost and value-for-money

The City of Vancouver faces increasing cost pressures associated with maintaining, renewing and expanding our sewer and drainage system. It is vital to manage services and optimize capital assets and investments in a financially sustainable way. Cost pressures will directly impact tax and utility rate payers in Vancouver.

3.4.1 The City of Vancouver's current integrated water utilities

For the City, the current approach used in managing drinking water, wastewater and rainwater is based on primarily grey infrastructure systems. These systems are comprised of the following components (using 2018 replacement value):

- $2.4 B in potable water infrastructure;
- $6.1 B in sewer and drainage infrastructure;
- $0.02 B in green rainwater infrastructure.

As with many other major cities, asset renewal needs are a significant expenditure in the coming decades. Recent assessments of sewer mains indicated that 23% are in poor or very poor condition and in need of renewal. In the next 10 years, the condition of our assets is expected to continue to deteriorate with a projected 27% being in poor or very poor condition. By 2039, this is expected to increase further to 29%, or nearly one third of our overall system. The poor condition of aging infrastructure is both a challenge and an opportunity as it provides us with the chance to renew our infrastructure in a way that will be responsive to future needs and servicing outcomes around climate adaptation, growth, accessing co-benefits and equity.

3.4.2 The City of Vancouver's future integrated water utilities costs

The City of Vancouver's integrated water utility services include City owned infrastructure and regional infrastructure owned and operated by Metro Vancouver. Metro Vancouver provides drinking water reservoirs and distribution trunks, major conveyance trunks and outfalls for CSO as well as wastewater treatment plants. Altogether, the City and Metro Vancouver's water-related infrastructure that serves the city's residents, businesses and visitors represent tens of billions of dollars of investments in today's costs.

Considering the extent of integrated water utilities nearing the end of their service life in the coming decades, includes analyzing the need to accommodate growth, adapt to climate change and address CSOs and urban rainwater runoff pollutant issues. It is expected that water-related infrastructure will require significant investment from now through to 2050, in the range of billions to tens of billions of dollars.

Consequently, there is a significant financial, social and environmental imperative to strategically examine how to deliver our services efficiently and to deliver the greatest value for investment. It also means there is a need to broaden responsibility for urban water management and rainwater management beyond municipal and regional government jurisdiction. Private land owners can also be encouraged to manage rainwater on their own property.

3.4.3 Sharing responsibilities for managing rainwater to optimize outcomes

Today, wastewater and rainwater is collected in the City's sewer and drainage system and is then conveyed to Metro Vancouver's trunks and wastewater treatment facility. The water either receives primary-level treatment at the Iona Island Wastewater Treatment Plant, or it becomes a CSO. The majority of rainwater falling in Vancouver is not managed on site; private site urban rainwater runoff is generally managed by the City's sewer and drainage system.

There is an imperative that everyone in Vancouver, particularly all land owners and property managers, contribute to a collective effort to manage rainwater more effectively. This shift in approach could be compared to that of solid waste management seen over the last decades. There was a time when residents and businesses could generate near unlimited waste for collection and management by local governments. As landfills filled up, costs and delivery of waste management services rose, and dealing with the environmental aftermath of all that waste became unsustainable. The waste sector identified a need to divert, reuse and reduce the amount of waste generated, and as much as possible manage it locally. Rainwater management parallels this transition towards reducing waste generation and using water resources more wisely.

The pollutants carried by wastewater and rainwater are generally discharged at little to no cost into our local waters. However, the acceptability of CSOs and urban rainwater runoff discharged from sewer and drainage systems is a growing concern. In the future, expanding environmental regulations, potential for fines, and the social and financial costs related to discharge of water in our low lying, flood prone areas, requires new approaches to managing urban water and spending our financial resources wisely.

3.4.4 Using green rainwater infrastructure to leverage cost-effective water services and value-for-investments that reduce financial risk

An investment in GRI serves many other functions. Grey infrastructure typically only serves very specific and limited functions related to rainwater and wastewater conveyance, focusing on protecting public health and properties from flooding. While GRI is multi-functional as it manages and filters rainwater, and provides landscaping features, along with other social, environmental and economic benefits. GRI tools are estimated to be 3-6 times more cost-effective in managing rainwater per $1000 invested than grey infrastructure.[27] It is also estimated that every fully vegetated acre of GRI provides approximately $8,000 in reduced energy demand, $160 in reduced CO_2 emissions, $1,000 in improved air quality and $4,725 in increased property value annually.[28] Through the benefits described above, GRI also leads to savings in health care costs,[29] disaster recovery,[30] climate adaptation[31] and energy use in buildings.[32]

The following case studies demonstrate how several cities choose a combination of grey-green infrastructure investments to meet their water servicing needs, and manage financial and environmental risk related to their water systems.

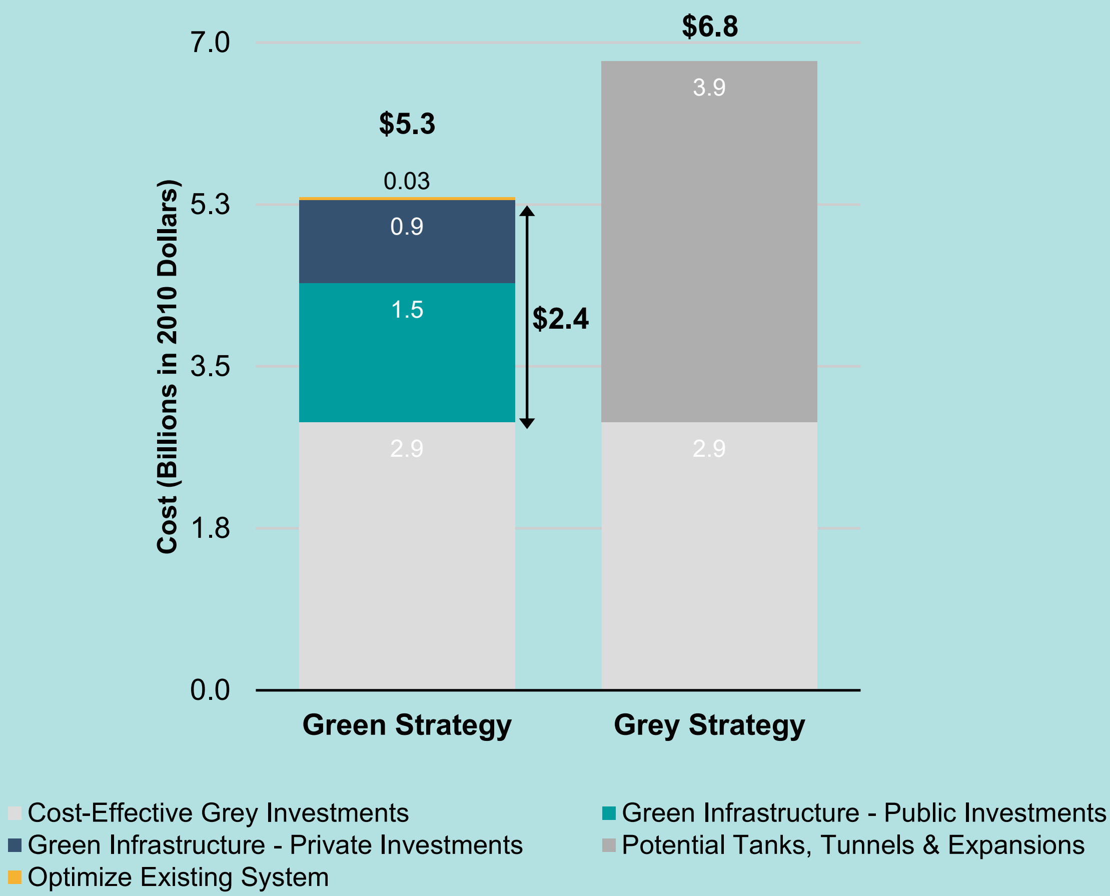
Case Study:

New York City Green Infrastructure Plan, a sustainable strategy for clean waterways

The New York City Green Infrastructure Plan recognized the cost effectiveness of a combined grey-green solution for rainwater management in their combined sewer watersheds. The total costs were derived from the cost of demonstration projects and an evaluation of green rainwater infrastructure (GRI) interventions that would meet the goal of capturing one inch (24 mm) of urban rainwater runoff from 10% of the impervious surface in a combined sewer watershed.

The NYC Department of Environmental Protection (DEP), who conducted the study, assumed that 15% of the impervious area within the watershed would be required to meet this goal.

The study determined the Green Strategy - which includes cost-effective grey strategies - would cost roughly $5.3 billion USD ($4.4 billion in public investment and $0.9 billion in private), while the Grey Strategy - which includes the use of tanks, tunnels, and expansion of existing infrastructure - would cost roughly $6.8 billion USD. On a unit cost basis the Green Strategy will cost $0.45 per gallon of combined sewer overflow (CSO) reduction, while the Grey Strategy will cost $0.62 USD per gallon.



The cost-effective grey infrastructure solutions that were considered to reduce CSO volume include sewer system improvements, pump station upgrades, diverting low lying sewers and regulator improvements. The difference in cost between the Green and Grey Strategies is the result of utilizing GRI interventions –rooftop detention, rain gardens, swales, and permeable surfaces – instead of tanks, tunnels and expansions.

The Green Strategy is expected to reduce CSO volumes from roughly 30 billion gallons a year to approximately 17.9 billion over 20 years. Although operations and maintenance costs of the Green Strategy were identified to be higher in the initial stages, the Grey Strategy costs surpass those in the long run. The cost effectiveness of the Green Strategy was identified as variable across watersheds, where in some cases costs are closely comparable to those of the Grey Strategy, and in other cases providing complementary CSO reductions to grey interventions.

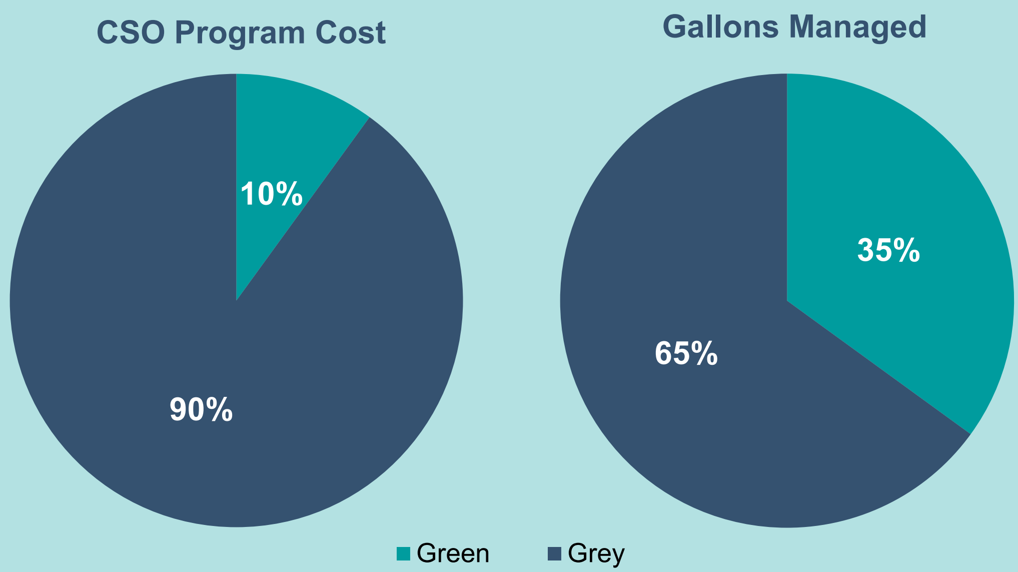
The DEP determined that spending on GRI should be targeted to the most cost effective areas and coupled with grey infrastructure interventions where feasible. Establishing an appropriate cost evaluation of the other sustainable benefits of the Green Strategy is difficult; however it is assumed that there are very few, if any sustainability benefits to the grey options.[33]

Case Study: City of Portland's CSO Mitigation and Green Streets program

In 1991, the City of Portland began an ambitious program to address nearly 23 billion liters of CSO discharge per year. As of 2011, the volume of CSOs in the city is negligible. The City of Portland is a leader in North America for integrated grey-green approaches. They were an early adopter of intensive and widespread green rainwater infrastructure (GRI) practices as part of their combined sewer overflow (CSO) mitigation efforts as a cost effective means of achieving water quality goals. Ten percent of the program investments were on GRI, which yielded 35% of the CSO mitigation outcomes for their program, among other benefits for their city.

The City of Portland's Green Streets program is designed to integrate best practices in GRI and grey infrastructure to maintain and improve the City's sewer capacity. This cost-effective measure has been identified as capable of reducing peak flows from drainage areas by 80%-85%, and retains roughly 60% of rainfall volume. GRI programs on both public and private lands in the city focus on capturing, retaining and diverting rainwater out of combined sewer systems.

For example in the Brooklyn Creek Basin – an area that covers approximately 2.3 square miles – the cost of constructing a new rainwater system using traditional grey infrastructure was $144 million (2009 USD). The alternative plan, which included an integrated grey-green infrastructure approach, was estimated to cost roughly $81 million. The stated objectives for this integrated approach were to improve surface and groundwater quality, improve community livability and prolong the life span of sewer infrastructure.



The grey infrastructure requirements for this project were to replace 81,000 feet of combined sewer pipes. The green interventions include installing green roofs, planting 4,000 street trees, adding 500 green street features and creating sustainable rainwater controls in parking lots.

Additionally, The City of Portland's Downspout Disconnection Program, which ran from 1993 to 2011, offered rebates for residents to redirect rooftop runoff to gardens and lawns resulting in 1.3 billion gallons of rainwater per year to be redirected from the combined sewer systems. The program disconnected 56,000 downspouts across the city in targeted areas.[34] The City has identified the avoided cost of treating and pumping rainwater through an existing combined sewer as $0.0002 per gallon representing a significant cost saving across its combined sewer network of $260,000 per year.[35]


PHOTO CREDIT: ROBB LUKES

Case Study:

The City of Philadelphia: Philadelphia Water Department CSO mitigation

The Philadelphia Water Department (PWD) is responsible for a combined sewer network that covers four watersheds over an area of 63 square miles. The PWD has identified four approaches to combined sewer overflow (CSO) mitigation: (1) low-impact development (LID); (2) tunneling; (3) transmission, plant expansion and treatment; and (4) transmission and satellite treatment. The goals identified in implementing a low-impact development practice, i.e. green rainwater infrastructure (GRI), include restoring natural balance between urban rainwater runoff and infiltration and reducing pollutants and urban rainwater runoff rates, with the overall goal to remove the CSO streams from the state's list of impaired waters.

GRI opportunities used by the PWD include increasing permeable surfaces, storage practices, green roofs, swales and increasing tree canopy. The PWD calculates the net benefit values of LID options by subtracting the external costs by the benefits of the intervention.

For example, the City estimates the economic value of applying a citywide, 50% increase in LID interventions that enhance the natural features of creeks and streams to result in roughly $520 million over the 40-year period (all values in 2009 USD). Additionally, the same increase in LID interventions could result in a $575 million present value benefits to the residential property market.

The identified external costs of LID interventions are the costs of disruption caused by construction and maintenance over 40 years. For example, using the Intergovernmental Panel on Climate Change estimates, the PWD values the social cost of carbon as $48 per ton. The net benefits of grey infrastructure interventions were calculated by considering the benefits to water quality and aquatic habitat enhancement, minus the associated energy usage, damages caused by CO_2, SO_2, NOx, and the costs of disruption caused by construction and maintenance over 40 years.

Benefits	> 50% Low Impact Development (Green Rainwater Infrastructure)		30' Tunnel (Grey Infrastructure)	
Increased recreational opportunities	✓	*$ 524.50*		
Improved aesthetics / property value	✓	*$ 574.70*		
Reduction in heat stress mortality	✓	*$ 1,057.60*		
Water quality / aquatic habitat enhancement	✓	*$ 336.40*	✓	*$ 189.00*
Wetland services	✓	*$ 1.60*		
Social costs avoided by green collar jobs	✓	*$ 124.90*		
Air quality improvements from trees	✓	*$ 131.00*		
Energy savings / usage	✓	*$ 33.70*	✗	*$ (2.50)*
Reduced (increased) damage from SO2 and NOx emissions	✓	*$ 46.30*	✗	*$ (45.20)*
Reduced (increased) damage from CO2 emissions	✓	*$ 21.20*	✗	*$ (5.90)*
Disruption costs from construction and maintenance	✗	*$ (5.60)*	✗	*$ (13.40)*
TOTAL		**$ 2,846.30**		**$ 122.00**
** Parentheses indicate negative values*				

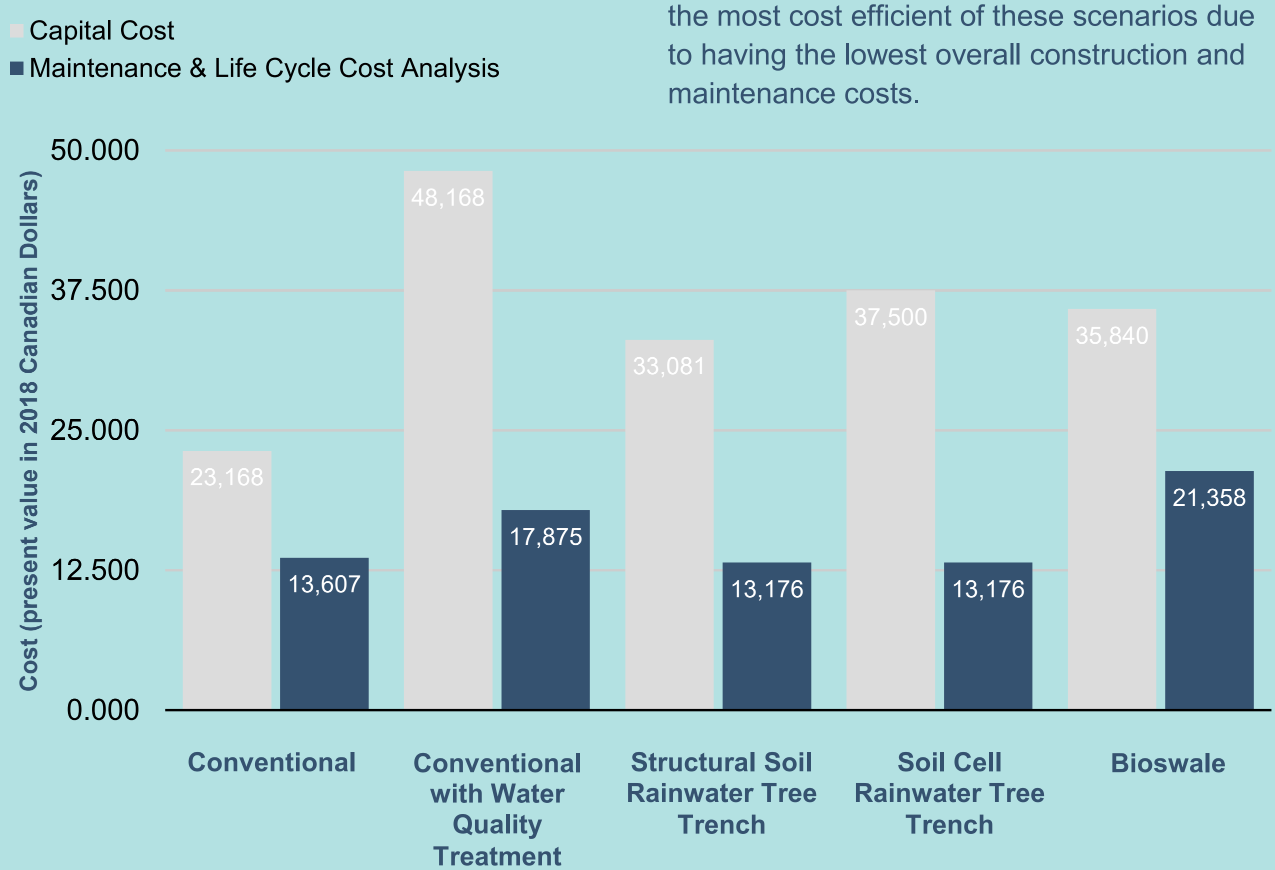
As a result, a citywide increase in LID by 50% would result in roughly $2.85 billion net benefit whereas a 30' tunnel option – representing the grey infrastructure intervention –would result in a $0.12 billion net benefit.[36]

Case Study: City of Vancouver Rainwater Tree Trenches

Life cycle cost analysis evaluates projects on the basis of short and long term costs and benefits. Rainwater Tree Trench (RTT) benefits include watershed protection, urban heat island effect reduction, groundwater recharge, reduced urban rainwater runoff flows to sewers, adjacent building energy savings and tree replacement savings. Not all long term benefits were estimated in this analysis as they are difficult to quantify. The Quebec St. and 1st Ave. project was evaluated to determine which green rainwater infrastructure (GRI) treatment would deliver the most benefits with the lowest cost. The analysis includes the construction estimation of a new sidewalk, an off street bicycle lane, a tree boulevard and a pad for a bike share station. Five scenarios were evaluated, each with a different GRI method:

1. Base case: Typical street reconstruction method (tree pit surrounded by compacted soils).
2. Identical to Scenario 1 with the addition of a generic water quality treatment device in the catch basin.
3. Structural soil RTT underneath the bicycle lane.
4. Soil cell RTT underneath the bicycle lane.
5. Bioswale adjacent to street and tree pit.

The life cycle cost analysis determined that from a cost perspective solely, the base case scenario was the most cost efficient method. This scenario however does not achieve any long term benefit or address the strategic plans adopted by the City of Vancouver. The addition of a water quality treatment device (evaluated under Scenario 2), is the most expensive option while yielding only a water quality benefit. Whereas, the three GRI methods (Scenario 3 to 5) address the City's long term strategic plans. Overall, the RTT is the most cost efficient of these scenarios due to having the lowest overall construction and maintenance costs.



3.5 Livability, water equity and reconciliation with Indigenous Peoples

Beyond responding to the major water and climate-related challenges faced by the city, when planned strategically, green rainwater infrastructure (GRI) can deliver a range of other benefits. By considering how quality of life, vulnerability to climate change and resilience varies across the city, we are better able to evaluate community investment. In addition, developing a more holistic understanding of water, natural systems and environmental stewardship through principles of reconciliation we can grow our ability to provide the highest level of service across the city.

3.5.1 Livability

There are many people today who spend their entire lives in the city. How a city is designed in terms of housing, affordable and accessible integrated water utility services, and built infrastructure, influences the safety and level of enjoyment of life in urban areas. As Vancouver becomes denser, pressures on services and amenities increase. Increasing pressure on City services and amenities requires greater consideration of who benefits from, who has access to and who is burdened by changing conditions. While the fundamental purpose of GRI is water management, its implementation presents opportunities to invest in the livability and well-being of communities.

When GRI includes a landscaped, green feature on the surface, it enhances our experience of a space and improves its aesthetic appeal. GRI can make public spaces, sidewalks, cycling routes and outdoor roof areas more pleasant, by for example mitigating urban heat island effect through the shading and the cooling influences of plants[37] and also improving air quality.[38] Engaging with the community in the design, implementation and maintenance of GRI can also strengthen the sense of place within a neighbourhood. Enjoyable public spaces encourage people to get out and experience those spaces, helping to foster a sense of connectedness to their community. There is extensive research showing that exposure to nature increases social values around community, intimacy, personal growth and generosity, all of which enhance social bonding[39] and resilience following disasters.[40] As well, most urbanized environments are home to more and more children and youth. Being thoughtful of nature-deficiency faced by many children and youth is of growing interest to many young people, parents, educators and health practitioners.

These greened rainwater management spaces also have significant advantages for residents' physical and mental health. Mental health benefits associated with experiencing green and natural urban spaces include improvements to:

- Anxiety
- Depression
- ADHD
- Memory
- Stress[41] [42] [43] [44] [45]

Physical health improvements associated with proximity to green urban space include:

- Increased longevity for seniors;
- Healthier birth weights of babies;
- Improved self-regulation and well-being among children and youth;
- Faster recovery time for surgery patients; and
- Reductions in heart disease, blood pressure, and cardiovascular disease mortality. [46] [47] [48] [49] [50] [51]

In addition, increasing green spaces can enhance urban biodiversity, which creates ecosystems that are more resilient to the impacts of climate change[52] and provides greater habitat connectivity for pollinators[53] and other urban wildlife increasing their chances of survival.[54]

nature in the city


Increases biodiversity and habitat connectivity
Decreases water pollution and reduces urban flooding
Improves children's learning ability

Case Study:
Life Between Umbrellas – Design Ideas Competition

In spring 2019, the City of Vancouver, through its VIVA Vancouver public space program, partnered with the Vancouver Public Space Network (VPSN) on Life Between Umbrellas, a design, ideas, and pop-up activation competition. This competition was held to improve public space and public life during Vancouver's rainy months, responding to the many challenges and opportunities associated with the wet-weather months.

The competition had three streams:

1. The Place: An idea to make a new or existing public space rain-friendly
2. The Intervention: A rain-friendly design feature or element, or seasonal structure
3. The Celebration: A rain-friendly pop-up public space activation

VIVA and VPSN hosted design jams, ideation workshops, and rain-friendly celebrations, attracting over 3,500 attendees and generated ideas from residents of all ages and backgrounds. Subsequently, a jury comprised of both design professionals and community representatives shortlisted winners for each of the streams while 12 'People's Choice' voting pop-ups were held across the city. Prizes were awarded for the winning and 'runner-up' designs in each of the categories.

Under The Celebration stream, VPSN selected the top three entries in which VIVA is currently working with to deliver the winning rain-friendly public space activations this fall and winter 2019. For the other two streams, City staff are working with the winning entries to support further development of the designs for 2020.

For more information:

- Project website: lifebetweenumbrellas.ca
- VPSN website: vancouver.ca/viva
- VIVA webpage: vancouverpublicspace.ca

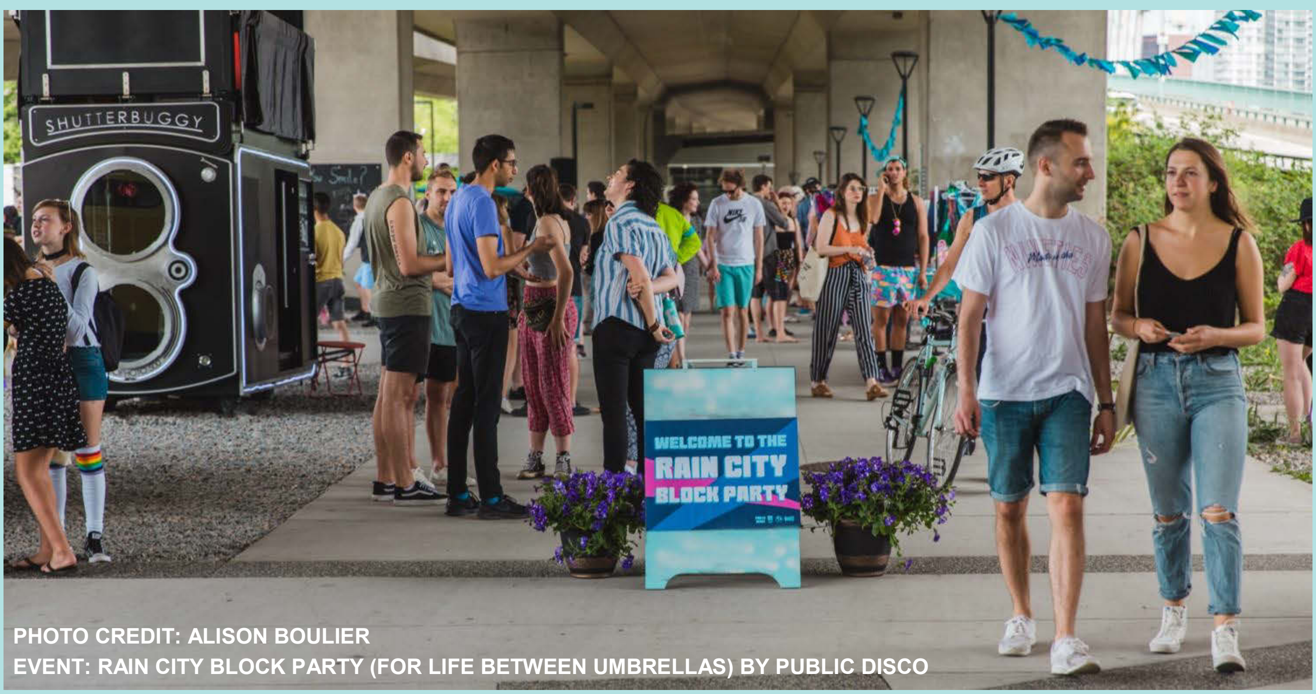


PHOTO CREDIT: ALISON BOULIER
EVENT: RAIN CITY BLOCK PARTY (FOR LIFE BETWEEN UMBRELLAS) BY PUBLIC DISCO

GRI provides larger soil volume and a more reliable source of water leading to bigger and healthier trees. Allowing water to soak back into the soil also keeps groundwater level in aquifers high. In urban environments, recharging groundwater is often disrupted by paving over green spaces and designing piped water systems. Allowing aquifers to recharge maintains them as potential future sources of water for people and ecosystems, and also keeps soil from settling and sinking when aquifers are drawn down. Healthier trees and greenery in the city will contribute to biodiversity, healthier people and ecosystems, cooler public spaces and a more livable community.

3.5.2 Water equity and reconciliation

As described in the previous sections, GRI can bring a broad range of livability, water quality, climate resilience and cost efficiency benefits to Vancouver. It can also support and reinforce equity across the city and promote reconciliation with Indigenous Peoples. To do so, investments are needed to support an inclusive dialogue with a broad range of voices and to explore how reconciliation and intersectionality can guide GRI policies, programs and integrated water utility investments.

Inequities in a city may include the distribution of benefits and access to services associated with green space, water services and economic development opportunities. Inequities more specifically related to urban rainwater management can relate to disproportionate impacts from structural vulnerabilities associated with environmental degradation, food harvesting potential, access to culturally significant elements of water and natural systems and climate change impacts.

As part of the 2014 Framework for City of Reconciliation, the City of Vancouver adopted three foundational components to guide reconciliation. The framework's goals are to grow cultural competencies, strengthen partnerships and develop effective decision-making processes. Working with the Musqueam, Squamish and Tsleil-Waututh Nations and urban Indigenous communities is a starting point for learning and reflecting on matters of cultural significance and values related to rainwater management and stewardship. Strong relationships and a shared understanding of values and priorities will help frame GRI policies, programs and implementation to effectively support meaningful reconciliation.

What is intersectionality?

The understanding that the impacts of inequity are compounded by all forms of discrimination related to gender, race, disability, language, immigration status, income, age, ability, sexual orientation and more.

In addition, it is important to recognize that there is a broad cross-section of the community who may experience barriers to participating in or influencing City processes. Considering equity and reconciliation as lenses applied to rainwater management, and water more generally, will help achieve better outcomes and reduce social, environmental and economic vulnerability for all. A number of key questions can help guide policies, programs and implementation of GRI, including:

- How do existing City structures and processes act as barriers to relationship-building, engagement and partnership?
- How can we support those facing barriers overcome them and develop an inclusive approach to the planning, implementing and caring for GRI?
- Who benefits from GRI policies, programs and investments and how accessible are the benefits?
- Who may become unknowingly burdened by GRI policies, programs and investments, including costs and other impacts?

Key terms from the US Water Alliance[55]

Water equity: Equity refers to just and fair inclusion - a condition in which everyone has an opportunity to participate and prosper. Water equity occurs when all communities have access to safe, clean, affordable drinking water and wastewater services; are resilient in the face of floods, drought and other climate risks; have a role in decision-making processes related to water management in their communities; and share in the economic, social and environmental benefits of water systems.

Water stress: Water stress occurs when individuals and communities face difficulty in accessing water services. It can include inadequate access to drinking water, wastewater, and rainwater services for everyday needs, whether due to lack of infrastructure, difficulty paying for services, or poor water quality. Water stress encompasses water-related climate impacts such as floods, droughts and rising sea levels.

Vulnerable communities: Vulnerable communities face historic or contemporary barriers to economic and social opportunities and a healthy environment. The principal factors in community vulnerability are income, race or ethnicity, age, language ability and geographic location. This may include low-income people, certain communities of color, immigrants, seniors, children, people with disabilities, people with limited English-speaking ability, rural communities, people living in social housing and currently or formerly incarcerated people.

- How can we reduce vulnerability and systemic inequality related to rainwater management and integrated water utility services?
- What are the potential unintended consequences of GRI implementation and how are they mitigated?
- How can GRI policies and programs lead to capacity building, economic opportunity and green jobs for local communities?
- How can the framework for the City of Vancouver as a City of Reconciliation guide GRI policies, programs and investments?
- How can Indigenous knowledge, values and expertise around water, land, natural systems stewardship, environmental protection, food harvesting and inter-generational relationships better influence the planning, design, construction, operation and maintenance of GRI implementation?

Incorporating equity and reconciliation in the Rain City Strategy aligns with broader City of Vancouver and Vancouver Board of Parks and Recreation goals. For example, one of the Big Moves of the VanPlay Parks and Recreation Services Master Plan is to create Equity Initiative Zones.[56] Future revisions of the Rain City Strategy and any supporting projects will also build upon the upcoming citywide Equity Framework, currently in development by the Arts, Culture and Community Services Department.

As a first step in exploring how to incorporate equity into integrated water utility services, staff will be learning from ongoing City and Park Board initiatives and will initiate research with thought-leaders in the community and peer cities specifically related to water. This work will compile examples of how equity objectives have been integrated into similar initiatives. The second step is to listen, learn and co-create a shared understanding of equity, particularly as it relates to rainwater management and GRI, with a variety of communities and knowledge holders. Relationship-building and learning will help shape the Rain City Strategy programs outlined in the Action Plans. We have much more to learn, and our plans to continue this journey are outlined in Transformative Direction 6.

3.5.3 Seismic resilience and water security

Vancouver is at risk of a catastrophic earthquake, it is likely that a magnitude 7 or higher earthquake will impact Vancouver within the lifetime of the infrastructure we are constructing today. Disasters like this have the potential to damage our centralized piped infrastructure, drinking water system and wastewater treatment plant, and the delivery of potable water is inefficient and may be limited by damaged roadways. Currently residents are advised to store 4 L per person per day in case of an emergency – this falls short of normal daily water use by more than 300 L per day, and provides the bare minimum for drinking and hygiene.

Without access to water residents may not be able to stay in their homes, and many businesses and critical services, like hospitals, will not be able to operate. Recovery of water systems is among the most critical tasks post-disaster, both for life safety and for the recovery of communities. Developing infrastructure that can withstand earthquakes and provide redundant sources of potable and non-potable water is the most effective way to prevent catastrophic impacts and accelerate recovery. Harvest and reuse of rainwater, among other water resources, can support seismic resilience and help reduce community vulnerability.
GRI decentralizes our drainage system, so a breakage in one spot would not cause the entire system to stop functioning, which contributes to resilience. It is also less likely to be damaged and become non-functional after an earthquake than a pipe, which will minimize the work needed to get our system up and running after a disaster.

A major opportunity to explore further is district scale harvest and reuse systems that typically function as non-potable water resource for toilet flushing or irrigation, which could, with some additional treatment, potentially become a source of drinking water during a critical disruption to conventional water services. Water stored on private property is highly valuable as often the connections between people’s homes and the main water lines are the most vulnerable to damage during seismic events.

An equitable water future for all

We are learning that an equitable water future means providing all residents of a city, regardless race, religion, national origin, or income, with cost-effective access to water that is clean and safe. This includes all water utility services, such as drinking water delivery, wastewater treatment, rainwater management services and flood protection. As well as increasing public access to drinking water fountains and supporting freely accessible and healthy waterbodies for recreational, cultural, spiritual and food harvesting use.

An intersectional understanding of interconnected vulnerabilities affecting communities is essential to applying an effective equity lens in our work. Developing a greater understanding of community needs must align with rainwater management and GRI solutions. This will better support programs that are designed for mitigating and adapting to climate-related risks and ensure they are equitably distributed (see Transformative Direction 6). To achieve this, meaningful collaboration and co-investment by all levels of government, water providers, private sector, non-profit sector, knowledge holders, residents and others is critical.

What could an equity lens look like while implementing green rainwater infrastructure?

What we build
By combining infrastructure investments, such as pipe upgrades and street renewals with green rainwater infrastructure (GRI), we can deliver water management in a cost-effective way and work to address affordability and the needs of vulnerable populations or underserved areas.

Where we build GRI
We can prioritize the placement and type of GRI to yield greater benefits for vulnerable and underserved populations,[56] who are disproportionately exposed to environmental hazards and stressors[57] or service deficits. Spatial factors we can consider include:

- Green deficient areas;
- Urban heat island effects;
- Flood prone areas;
- Highly polluted areas;
- Areas with low access to amenities; and
- Areas with low resilience to climate change.

How we build GRI
The implementation process can intentionally enhance the equitable distribution of GRI benefits, for example:

- Provide economic opportunities, green jobs, capacity building and training in design, construction, maintenance and operations of GRI[58]
- Plan public engagement activities to be inclusive and accessible; and
- Allow designs of GRI to be meaningfully shaped by the concerns, needs and desires of the community to help enhance community involvement and reduce displacement.[59] [60] [61] [62]

How we use GRI
GRI assets can also be designed and programmed to enhance opportunities for environmental education and capacity building, which can help communities, industry, students and others, become more knowledgeable about natural systems. Beyond learning about nature, for students between the age of five and 17, environmental education has been found to:

- Combat Nature Deficit Disorder;
- Enhance science, technology, engineering and math (STEM) programs;
- Promote place making and community involvement;
- Improve academic performance and critical thinking skills; and
- Enhancing confidence, autonomy and leadership in students.[63]

Case Study:

Reconciled Futures at Yukon St. and 63rd Ave, Vancouver

In 2019, the Museum of Vancouver and the City of Vancouver's Green Infrastructure Implementation Branch partnered on a reconciliation initiative by offering a Spring Break opportunity for a one week art mentorship camp for Indigenous youth. Core objectives of the program were capacity building and exploring art and culture. As part of the camp activities, the youth worked together to produce designs for a public art installation to accompany the green rainwater infrastructure (GRI) asset at 63rd Ave. and Yukon St.

Nine youth, age 12-17, participated in the camp. Two Musqueam and two Squamish youth participated, while the Tsleil-Waututh Nation waived their spots due to other commitments within their community. This allowed for Tsawwassen youth to participate in their place. The camp also hosted youth with Haida and Nlaka'pamux ancestry.

Host Nation artists Aaron Nelson Moody, Ocean Hyland, Kelsey Sparrow, and Atheana Picha delivered workshops on copper arrowhead pendants, Coast Salish formline painting on wooden pendants, and cedar bark basketry. Haida artist Marcel Russ also spent a day supporting the students as they created their public art designs. Youth met with City of Vancouver staff to learn about the function and design of GRI and careers related to GRI. The group also visited MOV Collections Storage twice during the week providing a unique opportunity to see and learn about the extensive collection of Coast Salish art and cultural artifacts at the museum. They also took the *Care and Handling Workshop* in the Conservation Lab; went on a tour of the *Haida Now* exhibition with Haida educator, Lia Hart; and had a presentation from the YVR Art Foundation about upcoming opportunities for youth.

Each student in the program received an honorarium for the use of their design in the public art piece. They were also all provided with art supplies, transit day passes and lunches.

Five art pieces were designed by the youth: A raven; a hummingbird; two sets of salmon; and a heron. The City of Vancouver fabrication shop will produce the pieces in metal, to be installed at 63rd Ave. and Yukon S.

museum of vancouver

KEY FINDINGS

1

Urban rainwater runoff is an impactful source of pollution discharged through the sewer and drainage system into receiving waters

2

Opportunistic implementation of green rainwater infrastructure will not reach our regulatory obligations and policy goals

3

An integrated grey-green infrastructure approach to sewer and drainage infrastructure is economically preferred

4

Green rainwater infrastructure is versatile and can be designed to manage all types of rain events

5

Urban water management is fundamental to all aspects of city building processes

6

Rainwater management solutions are most effective when planned at an urban watershed scale

7

Water harvest and reuse is a key approach to conserve pipe capacity, help mitigate combined sewer overflows, and protect and preserve water resources

8

Strategically planned, operated and maintained GRI can support climate adaptation while also sequestering carbon

9

Operations and maintenance, rehabilitation and renewal are critical needs for long-term success and performance of a green rainwater infrastructure program

10

Green rainwater infrastructure approaches will broaden responsibilities for rainwater management and shifts how funds will be spent over the green rainwater infrastructure's asset lifecycles

11

Green rainwater infrastructure implementation requires establishing a culture of collaboration and fostering partnerships

12

Green rainwater infrastructure requires deliberate education and capacity building to expand momentum and mature the state of practice

Chapter 4.

Key findings

Through extensive research, analysis, engagement and learning-by-doing, there are a number of key findings that have shaped the directions of the Rain City Strategy and the action plan recommendations (see left page):

1

Urban rainwater runoff is an impactful source of pollution discharged through the sewer and drainage system into receiving waters

Scientific research on the quantity and severity of contaminants picked up by rainwater in urban environments continues to identify rainwater pollution as a critical environmental concern. Recent research in Vancouver, B.C. and Seattle, Washington, found that rainwater carries toxic pollutants from roadways[64] and pesticides[65] and fertilizers[66] from yards or gardens, leading to degradation of aquatic ecosystem. Preventing rainwater from becoming polluted should be prioritized. Treating polluted urban rainwater runoff is needed before it is discharged into our local waterbodies to protect and improve water resources and natural environments.

2

Opportunistic implementation of green rainwater infrastructure will not reach our regulatory obligations and policy goals

Opportunistic implementation means integrating green rainwater infrastructure (GRI) in new capital infrastructure projects built by the City of Vancouver for purposes such as street, sewer and drainage, water infrastructure renewal or street modification for transportation purposes. The placement of GRI in these situations is based on the opportunity provided by the other capital projects, rather than a strategic analysis of where GRI is needed or most effective from a water management, climate adaptation or ecosystem services perspective.

Meeting the citywide Integrated Rainwater Management Plan (IRMP) long-term targets for managing rainwater from 100% of impervious areas, requires expanding efforts beyond opportunistic implementation to include strategic GRI retrofits of existing buildings, streets and urban spaces. The strategic application of GRI includes adding blue-green roofs, raingardens or harvest and reuse systems to new and existing buildings and sites. The targeted redesign of streets, public spaces and parks will help meet rainwater management needs related to water quality, greening, urban heat or flood management.

3

An integrated grey-green approach to sewer and drainage infrastructure is economically preferred

Numerous studies[67 68] have compared the economics of grey infrastructure and GRI through a triple bottom line analysis or life cycle assessment. These studies have demonstrated that an integrated grey-green infrastructure approach is economically preferred, given water quality improvements, incremental climate change impacts and reduced combined sewer overflows (CSO). An integrated approach has proven environmental, social and economic benefits that a grey-only approach is unable to provide.[69] [70] Beyond cost-effectiveness, GRI is also found to positively stimulate the local economy, providing accessible employment opportunities[71] and providing savings in heating and cooling buildings,[72] health benefits and reductions in intensity of energy use.[73]

In addition, when considering climate change and the need for more resilient and adaptable services, GRI in the public realm is more readily accessible at the surface and more easily expanded if needed than deeply buried grey infrastructure requiring a more complex and costly construction process.

How polluted are our local waterbodies?

Ocean Wise, in collaboration with coastal partners, launched the PollutionTracker: The first coastal, integrated marine pollution monitoring program in British Columbia. The program helps to answer an important question: How polluted is our ocean?

The PollutionTracker uses high resolution analysis to report the levels and trends of hundreds of contaminants of concern in mussels and nearshore subtidal sediment along the entire coast of B.C. This long-term dataset will help inform source identification, pollution priorities, best practices and natural resource management in B.C.

Testing occurred at 14 locations around Vancouver. All 14 locations were in the top 20 most contaminated of the 60 locations tested province-wide. The results show that legacy and the current application of pesticides as well as personal care and prescription products (likely conveyed through combined sewage overflows) remain problematic in the waters around Vancouver.[74] For more information check out http://pollutiontracker.org/

4

Green rainwater infrastructure is versatile and can be designed to manage all types of rain events

At the outset of this initiative, there was a widely held perception that GRI is predominantly a small scale solution, usually heavily landscaped, such as rain gardens or swales, and can only handle very modest rain events. As we have learned, however, there are many examples of small, mid, large and district scale GRI projects in cities around the world that are handling significant volumes of water, and providing an alternative servicing approach to traditional grey infrastructure. In leading GRI cities such as New York, Washington, Rotterdam, and Copenhagen, GRI is a core part of their 'cloudburst' strategies to handle extreme precipitation events and to manage overland flow, flooding and coastal flood protection for climate resilience.

From an urban design perspective, GRI is highly versatile. GRI can come in the form of small local-serving raingardens or extensive and heavily landscaped swales. It can also be integrated seamlessly into heavily urbanized areas through practices such as sub-surface infiltration, permeable pavement and rainwater tree trenches. The applications of these GRI tools look and function as any sidewalk, bike lane, paved area, plaza or street would, but have an engineered ecosystem service function below the surface that helps our urban forests thrive. On densely built sites with limited infiltration potential, rainwater management is also possible. Rainwater harvest and reuse, blue-green roofs and other evaporationdominant strategies are effective. From an aesthetic perspective, landscaped GRI can vary widely to suit many contexts and design aspirations.

5

Urban water management is fundamental to all aspects of city building processes

Cost-effective and strategic rainwater management requires the integration of urban planning, land use and urban design with the management, protection and conservation of the entire urban water cycle. To date, water management has often not been addressed early in the planning and development processes. To build urban environments that value water as a resource, replenish and protect natural ecosystems, and are adaptable to future growth and climate change impacts, it is critical to plan for integrated water utility services in conjunction with land-use decisions, community plans and urban design from the outset. This principle applies equally to the development of new area plans, transportation projects, streets and public space design or park spaces. Early consideration of rainwater, water resources and services is key to maximizing investments and yielding multiple economic, social, cultural, equity, reconciliation and livability benefits.

6

Rainwater management solutions are most effective when planned at an urban watershed scale

A widespread practice among leading cities that implement GRI is to plan for water in combination with urban development and natural systems on an urban watershed scale[75] (see Section 2.1.3 for more on urban watersheds). Urban watershed planning enables a systems approach that characterizes local and network conditions related to urban water management, urban development patterns, rainfall patterns, ecosystem services, built infrastructure and sensitivity to climate change impacts. Information derived from the watershed planning process can then be used to inform projects and interventions that address local challenges and the needs of the urban watershed as a whole.

Case Study: large scale green rainwater infrastructure projects

Green rainwater infrastructure (GRI) can take on many forms and scales and many major cities around the world are making significant investments in large scale projects.

Sherbourne Common in Toronto is the first park in Canada to integrate a UV treatment facility into its design and represents major innovation in the way natural systems and civic infrastructures are integrated into cities. The process of cleaning urban rainwater runoff binds all of the elements of the park together. GRI turns the entire park into an aesthetic and experiential rainwater management system that educates the public about water quality issues through its interactive and engaging spaces.

Front Street, both a green street and a linear park, stretching four city blocks in the West Don Land Neighbourhood in Toronto, is relying on the concept of urban forest and tree roots' rainwater uptake to manage the urban rainwater runoff in the right of way and the development.

7

Water harvest and reuse is a key approach to conserve pipe capacity, help mitigate combined sewer overflows and protect and preserve water resources

Rainwater harvest and reuse systems divert rainwater from the sewer and drainage system. In so doing, there is a reduction in CSOs, preserved capacity in the sewer and drainage system for growth, flood mitigation and reduced potable water demand. However, peak potable water demand is during the long, dry periods of summer, but rainfall in Vancouver is largely concentrated outside of summer. As a result, a greater diversity of water sources and non-potable water uses should be considered.

Harvesting rainwater and re-using other alternative water sources can enable a more consistent supply of non-potable water. District-scale systems may be preferable when contemplating water harvest and reuse beyond rainwater, as treatment can be complex and ongoing operations and maintenance require an experienced operator. On the demand side, additional uses of non-potable water during the fall, winter and spring seasons can reduce burdens on the sewer and drainage system.

As water shortages and stressors are becoming commonplace globally, many jurisdictions are adopting expansive water harvest and reuse policies and practices. Expanding water harvest and reuse beyond rainwater represents a significant opportunity for the City of Vancouver to develop a diverse, reliable and fit-for-use water system. Exploring similar, expansive water harvest and reuse policies will entail research, gaining technical knowledge and engagement with health authorities, regulators, industry building and system operators and more in order to proceed.

8

Strategically planned, operated and maintained green rainwater infrastructure can support climate adaptation while also sequestering carbon

Calculating, accounting and reporting the carbon sequestration capacity of GRI is a complex process.[76] There is a general acceptance that vegetation-based rainwater management have carbon sequestration capabilities, as this is a natural function of plants, trees and soils. The extent to which a system can sequester carbon depends on many factors: Size, location, types of species planted, maintenance and end-of-life cycle processes.[77] Studies have shown that GRI interventions such as bioswales, rain gardens and tree trenches, if planned, operated and maintained strategically, can have significant carbon sequestration capacity. Therefore mitigating the impacts caused by climate change.[78] For example, planting perennial species, leaving grass clippings, maintaining multi-age structures and promoting the deep rooting of vegetation will enhance the long-term carbon sequestration capacity of GRI.[79]

GRI is different from grey infrastructure in that GRI has the potential to mitigate the emissions associated with its own construction, operation and maintenance. These emissions come from operating machinery, trucking materials long distances, grass cutting and end-of-life cycle removal.[80] To meet city and global emissions reduction targets and increase carbon sequestration capacity in urban environments considering the entire life cycle of a GRI asset can reduce emissions in the construction process and build resilience through strategic planning.[81]

9

Operations and maintenance, rehabilitation and renewal are critical needs for the long-term success and performance of a green rainwater infrastructure program

GRI provides an important drainage function and therefore must be treated and maintained as a critical water management infrastructure asset. In the past, GRI has been treated as a decorative landscaping feature, for which the impact of neglectful care may have fewer consequences. Downstream pipe infrastructure and receiving waterbodies are relying on the performance of the GRI assets in managing both the volume and quality of water, and so robust operations and maintenance plans and identifying funding streams for these functions are essential.

In addition, operation and maintenance, rehabilitation and renewal programs for GRI must take into account how GRI performance and care needs differ from other infrastructure asset types. For example, vegetated GRI typically improves in performance with age, subject to appropriate sediment management and plant and soil ecosystem health. As plants mature and their root structure develops, they provide more effective filtration and evapotranspiration functions, incorporate sediment into the soil structure and prevent erosion. Worms, fungi and other aspects of the GRI ecosystem also help improve the system performance over time by aerating the soil. As such, maintenance of vegetated GRI should prioritize sediment management and nurturing and maintaining the health of existing plants, to avoid having to replace them before the end of their natural life. Action Plan Programs S&PS-09 and P&B-11 include the directive to develop asset management systems that recognize these unique asset needs, and clearly define the operations, maintenance, replacement norms and funding streams for GRI.

10

Green rainwater infrastructure approaches will broaden responsibility for rainwater management and shift how funds will be spent over the assets life cycle

Many studies[82] have reinforced that GRI provides economic rainwater management services delivery, often at a lower overall life cycle cost than traditional methods. Adopting a holistic and integrated approach to rainwater management, however, requires breaking down financing and delivery barriers between upfront capital cost, ongoing operations and maintenance costs, renewal costs and identifying who is responsible for what work. Moving to a greater reliance on GRI over traditional approaches will often mean a shift in expenditures at different stages of a GRI asset's life cycle and to different groups who perform the work. Compared to grey infrastructure, GRI has lower upfront capital and renewal costs, but increased ongoing operations and maintenance costs.

For the City of Vancouver's internal work processes, this means securing resources for groups beyond the sewer and drainage utilities to ensure that delivery, maintenance and operations, and renewal are adequately funded to provide cost-effective and high value-for-money investments in rainwater management through GRI.

11

Green rainwater infrastructure implementation requires establishing a culture of collaboration and fostering partnerships

The integrated nature of GRI means that the role of water management extends beyond sewer and drainage specialists. Planning, design, implementation and care of GRI, requires cooperation between a variety of groups, including both public and private property owners. It requires deliberate coordination between various specialists in engineering, landscape architecture, urban design, urban planning, ecology, horticulture, construction, maintenance, and public and industry engagement and education. In recognition of the level of cooperation required, paying attention to the culture shift and what it means for individuals and groups is essential. Developing partnerships with industry, community, and academia and breaking through silos between professions, departments and agencies is essential for long-term success.

Practically, this requires updating existing internal governance structures and processes, such as decision-making and collaboration systems. This update can foster and facilitate effective cross-disciplinary, cross-departmental, cross-agency and cross-sectoral collaboration, decision-making and partnerships. It also requires alignment of resources to achieve the lasting environmental, social and economic benefits of GRI implementation.

12

Green rainwater infrastructure requires deliberate education and capacity building to expand momentum and mature the state of practice

The City of Vancouver is seeking widespread adoption of GRI and a paradigm shift in rainwater management. This includes a dedicated effort to support, catalyze and enable those beyond our own agency. By doing so, we can help develop expertise, share knowledge, learn best practices and integrate innovative water solutions across sectors to reach the full potential and overall maturity of the water sector. Strong policy and leadership commitments as well as investing in capacity building related to integrative thinking, innovation and collaboration are critical.

In addition, continued public engagement, educational and training programs, and demonstration projects are essential to build capacity, develop acceptance for water design solutions, and enable water wise behaviours. Creating networks and ecosystems of communities, industry professionals and municipal practices can play an important role in developing the overall maturity and effectiveness of GRI implementation within Vancouver and the region.

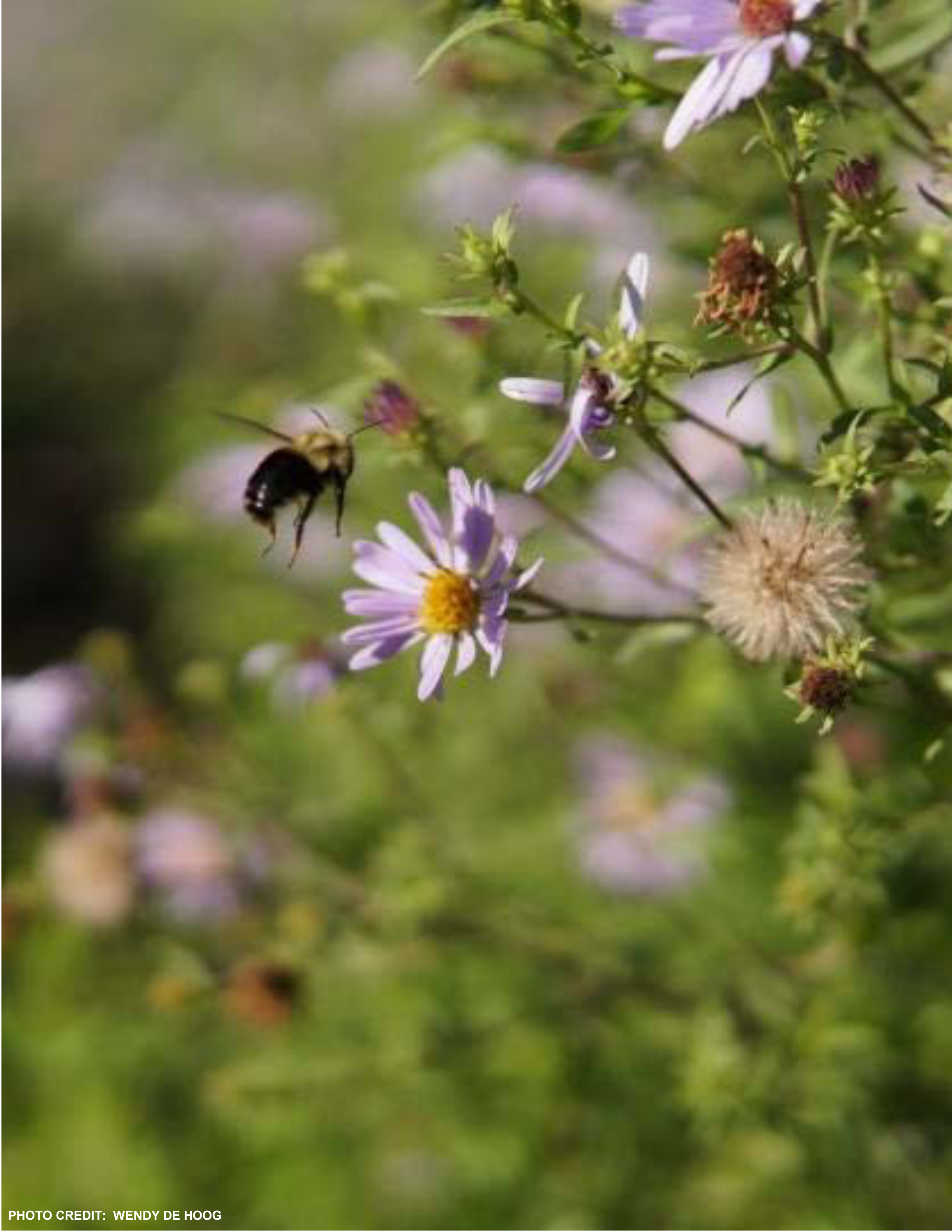


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PHOTO CREDIT: KRISTEN HUDSON

Chapter 5.

Strategic plan

Urban water management is a basic necessity for any community and has significant potential to enhance our urban environment and the daily experiences of life in the city. Historically, rainwater management has meant quickly moving rainwater out of our public spaces and into a network of underground pipes. This leaves water unseen, undervalued and disconnects our relationship with water and natural systems in many ways. It has also led to impacts on local receiving waterbodies and aquatic ecosystems that are difficult to perceive or experience.

Through the Rain City Strategy process of exploring our relationship with rainwater and water more broadly, we see a need to reframe our thinking about the role and value of water in our city and over a longer time horizon. Holistic and integrated urban water management approaches can do more than serve the rainwater and wastewater needs of a community.

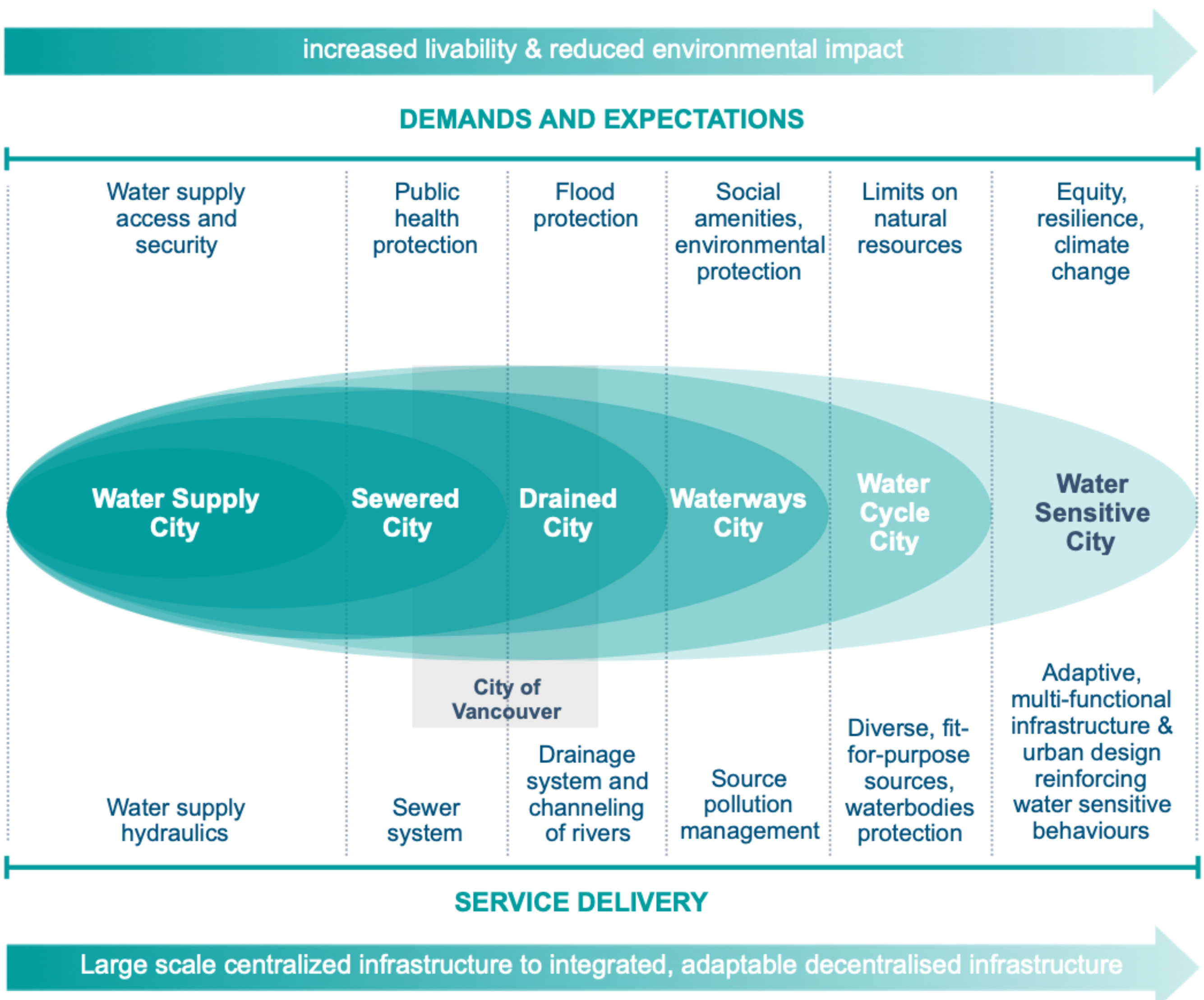


***FIGURE 28*: URBAN WATER TRANSITION FRAMEWORK.** Adapted from "Urban Water Management in Cities: historical current and future Regimes," by T.H. Wong et al, 2009, *Water Science and Technology*, 59(5), page 850

Guiding principles to transition towards increased water sensitivity

Embedding water sensitive values, behaviors and design principles into citywide systems planning is critical. Citywide systems and networks, such as our sewer and drainage system, transportation network, park system, natural assets and community plans must consider the full urban water cycle in their planning processes. Becoming a water sensitive city requires alignment between urban water management and the built environment.

Design our city as a water supply catchment
When we design the city as a water supply catchment, we no longer see water of any kind as a waste product. By celebrating and valuing all water resources, we are able to close the loop, restoring the circular nature of the water cycle. This approach means managing rainwater where it lands, rather than prioritizing conveying it away. This approach supports a decentralized and resilient infrastructure system, and prevents rainwater from reaching low-lying areas that are the most vulnerable to impacts from sea level rise, storm surge and overland flooding from upstream watersheds. As such, implementation of green rainwater infrastructure (GRI) should strive to manage rainwater, at a minimum, to the design standard outlined in chapter 6, or more if conditions are particularly favourable for managing a greater volume of rainfall.

Design our city and infrastructure to deliver ecosystem services and biodiversity
Often when we think of urban development and infrastructure delivery, we think about how to limit impacts on the environment. How would our city be different if our built environment and service systems were designed to deliver, restore and enhance ecosystem services instead of simply reducing impacts on ecosystems? Integrating GRI into integrated water utility planning and all facets of urban planning and design delivers multiple ecosystem services, including rainwater management, microclimate regulation, flood protection, habitat and other livability benefits.

Design our city for water resilience, adaptability and flexibility
Water sewer and drainage infrastructure makes up one of the largest components of most cities' budgets. This vital infrastructure is very costly and is typically challenging to readily modify or adapt to changing needs over time. Looking ahead, in the context of climate change and a growing city, there is increasing uncertainty about future needs and conditions. A transition towards a water sensitive city calls for deliberate consideration of how we can build more flexible systems that can adapt in function and service levels over much shorter time frames than traditional water infrastructure enables.

Design our city to encourage collaborative action and enable water wise behaviours

Achieving lasting benefits through GRI implementation means a lot of change, new skills, and new practices in how organizations do their business. This means intentionally designing, supporting, and enabling opportunities and avenues to create, develop and share knowledge and best practices. Engagement with government agencies, industry, academia, non-profits, strata organizations and residents will help fully understand the dependencies and synergies of urban water management and reach overall maturity of the sector. It is also about recognizing that all of us have a role to play to make a difference. Continued public engagement, educational and training programs and demonstration projects are essential in building capacity, developing acceptance for new kinds of water design solutions and enabling water wise behaviours.

Design our city to support an equitable water future

Water and climate related challenges affect all communities, and those that are already overburdened with economic, social, and health challenges are especially vulnerable. An equitable water future can ensure that water sewer and drainage services are accessible to all and that co-benefits of GRI implementation are maximized and distributed equitably, such that they address the needs of all people regardless of gender, race, income, age, ability, immigration status, sexual orientation and more. Leveraging water, transportation, parks and public space investments can support underserved neighbourhoods that are green deficient, and physically prepare these neighbourhoods for a changing climate in terms of flood management, urban heat and rain. GRI implementation can also help create and cultivate opportunities in local employment and career pathways, business development and contracting, and stewardship and educational programs.

An integrated approach can augment economic growth through workforce development and green jobs, help protect and restore the environment through healthy watershed and ecosystems planning, and enhance public health, community connections, climate resilience and quality of life in cities. How we manage our water resources and services also has a significant effect on affordability and equity in our city.

5.1 Guiding principles of a water sensitive city

As an overarching and transformative direction, the Rain City Strategy recommends that the City of Vancouver strives to become a water sensitive city and that this aspiration shapes input into community, land use, infrastructure and natural system plans and programs in the coming decades.

The concept of a water sensitive city[83] recognizes how human influences and land use decisions impact the environment. A water sensitive city is one that seeks to embed holistic, integrated and inter-generational water thinking in the planning, design and delivery of water services. It seeks to protect and enhance the health of receiving waterbodies and natural systems, reduce flood risk, and develop buildings, public spaces and infrastructure that can harvest, clean and reuse water. It advocates fit-for-purpose water use and delivery of water through both centralised and decentralised infrastructure in order to deal with shocks and stressors. It achieves these outcomes using the tool of green spaces and systems that enhance biodiversity, mitigate pollution, reduce flooding and promote well-being and physical activity.

The concept of a water sensitive city was developed by researchers from the Monash University and the Cooperative Research Centre for Water Sensitive Cities in Australia while exploring critical water resource management needs in cities globally experiencing water challenges. These institutions have defined the concept through a framework that identifies six distinct developmental stages a city can occupy while on its path to increased water sensitivity (see *Figure 28*).[84]

Today, Vancouver could be considered to be somewhere between the sewered and the drained city on the spectrum, recognizing, of course, that some parts of our sewer and drainage system may be further along.

The framework is founded on the idea that urban water management approaches and drivers are not static; they transition over time as the needs of a city evolve. This transition is not, however, a process over which we have complete control. It evolves either unconsciously or more purposefully as a city works to achieve a broader set of outcomes for their community.

The following guiding principles are developed to guide and support Vancouver's evolution towards becoming a water sensitive city.

5.2 Vision, goals and objectives

In November 2017,[85] Vancouver City Council adopted the Rain City Strategy vision, goals and objectives, which have guided the development of the strategy and action plans over the past two years.

FIGURE 29: RAIN CITY STRATEGY GOALS

FIGURE 30: RAIN CITY STRATEGY OBJECTIVES

The underlying idea of the vision is to appreciate water as a valued resource with enormous potential to build healthy watersheds and ecosystems where people and wildlife can thrive. It also recognizes the importance of building inclusive communities that all have equitable access to safe, clean, affordable drinking water, wastewater and rainwater services. In addition, rainwater management is a means by which we can become more resilient in terms of sea level rise, flooding, drought, urban heat and other water-related shocks and stressors.

To reach this vision, three supporting goals have been established to guide decisions and actions in relation to rainwater management and implementation of green rainwater infrastructure (GRI) (see Figure 29).

The goals intersect and are intended to reinforce one another. In order to measure progress towards these goals, the following six objectives have been identified to guide GRI implementation and explained in the text below on the next page (see Figure 30).

Remove pollutants from water and air

GRI can contribute to the reduction of water and air pollutants such as combined sewer overflows (CSOs), heavy metals, hydrocarbons, litter, organic material, greenhouse gases (including carbon dioxide), dust and other sediments, improving water quality and livability. Preventing pollution in runoff at the outset is critical.

Increase managed impermeable area

Using GRI to manage urban rainwater runoff from more impermeable areas in the city will increase the effectiveness and the reach of the GRI implementation program and supports all three goals.

Reduce volume of rainwater entering the pipe system

GRI designed to capture rainwater (infiltrate, evaporate or reuse) will reduce the volume of rainwater entering the sewer and drainage system. This will reduce the likelihood of CSO occurrences, and improve water quality and climate resilience in Vancouver.

Harvest and reuse water

Systems that harvest and reuse all types of water, whether in a single building, or at a district or neighbourhood scale, allow us to conserve potable water for the uses that require it, and minimizes waste of our valuable water resources. These systems increase resilience and can help improve water quality.

Mitigate urban heat island effect

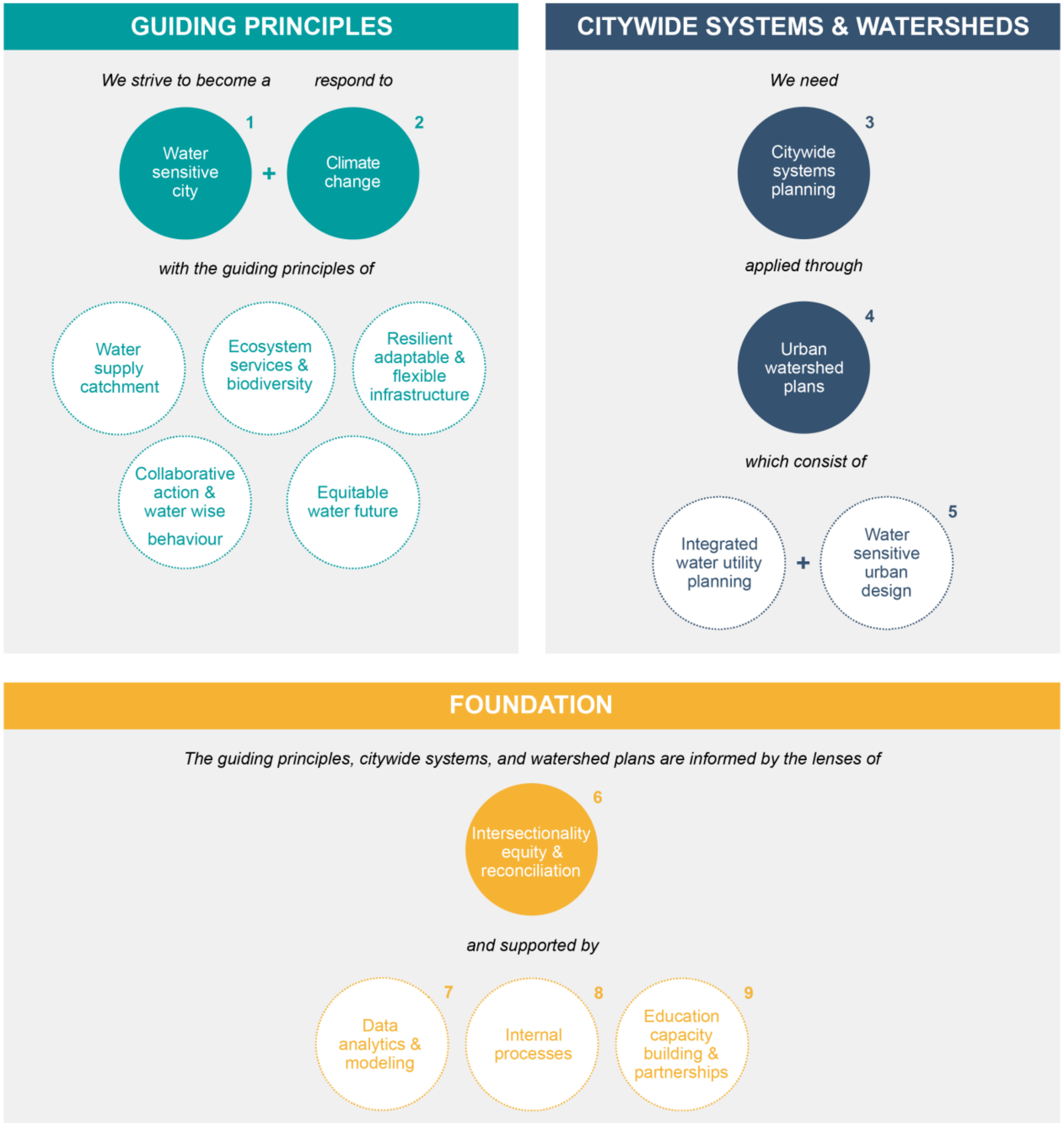
GRI features that include vegetation or surface water will cool the air around them, mitigating urban heat island effect and enhancing the livability and climate resiliency of dense, urban neighbourhoods.

Increase total green area

Increasing the total amount of green area in Vancouver, and ensuring that those areas are designed to treat urban rainwater runoff will improve livability, water quality and resilience.

5.3 Transformative directions

The following section describes a number of transformative directions that will support Vancouver's rainwater management paradigm shift and its trajectory towards water sensitivity. Each transformative direction represents a significant work program that will need to be scoped, resourced and developed over many years. There are inter-dependencies between the transformative directions and each focuses on a different scale and element of rainwater management. A more detailed action plan with sample actions for the Transformative Directions can be found in Appendix F. Figure 31 describes the nine transformative directions and how they relate to one another.



TRANSFORMATIVE DIRECTIONS

1 STRIVE TO BECOME A WATER SENSITIVE CITY
Pursue water sensitive city aspirations in the City-wide Plan through redefining what water means and demonstrate leadership in how we manage urban water in harmony with community planning, natural systems and infrastructure.

2 RESPOND WITH URGENCY TO CLIMATE CHANGE
Apply a climate adaptation lens to GRI planning and implementation, including undertaking an assessment of risks, vulnerabilities, and opportunities to water-related threats.

3 ACCELERATE ACTION TO PROTECT THE HEALTH AND VITALITY OF SURROUNDING WATERBODIES
Develop a Clean Waters Plan to expedite the mitigation of pollutants discharges from our sewer and drainage system in local waters.

4 REVITALIZE WATERSHEDS AND WATERFRONTS TO ENABLE COMMUNITIES AND NATURAL SYSTEMS TO THRIVE
Develop watershed plans that bring together all the elements of the urban water cycle in the built environment, while addressing flooding, pollution, and water security through integrated water utility planning and water sensitive urban design.

5 SHAPE SYSTEMS TO INTEGRATE AND VALUE ALL FORMS OF WATER
Develop an integrated water utility planning framework that integrates and values all forms of water including surface water, rainwater, wastewater, groundwater, drinking water, and non-potable water.

6 EXPLORE INTERSECTIONALITY, EQUITY, AND RECONCILIATION WITH INDIGENOUS PEOPLES THROUGH URBAN WATER MANAGEMENT
Cultivate relationships and a shared understanding of histories, cultures, and values and explore how these concepts can be embedded in our City processes and actions in relation to urban water management.

7 DRIVE INNOVATION AND SYSTEM EFFECTIVENESS THROUGH DATA ANALYTICS
Invest in data collection, data analytics, monitoring, and hydrologic and hydraulic modelling to inform planning, design, and capital delivery of GRI and our sewer and drainage system.

8 ENABLE A CULTURE OF COLLABORATION
Facilitate greater cross-departmental collaboration and update internal structures, processes, practices, and culture to improve coordination and alignment while planning, designing, and implementing GRI.

9 INVEST IN EDUCATION, CAPACITY BUILDING, AND PARTNERSHIPS TO MOBILISE ACTION
Facilitate the continued development of local industry capacity and engage the public, empowering them to take positive actions in their communities.

FIGURE 31: RAIN CITY STRATEGY TRANSFORMATIVE DIRECTIONS

1

Strive to become a water sensitive city

In July 2019, the City of Vancouver initiated a strategic and long-range visioning process to develop a new City-wide Plan. This will be the first comprehensive plan of its kind since the 1990s. The City-wide Plan intends to be strategic and address broad policy areas including land use, transportation, social, economic, environmental and cultural aspects of daily life in Vancouver. The plan will be guided by cross-cutting themes related to reconciliation, equity and resiliency. It will focus on people, making investments for the future, and look to improve the quality of life of residents by creating a long-term plan that takes into account the needs of all residents—current and future.

Given the climate emergency, the opportunity to strengthen environmental protections and equity through the City-wide Plan initiative is a unique and timely chance to pursue water sensitive city aspirations. Through redefining what water means for Vancouver, we can promote the use of best management practices in many ways. In addition, by joining the global movement of water sensitive cities we are presented with a great opportunity to demonstrate leadership in how we manage urban water in harmony with community planning, natural systems and a range of infrastructure on a citywide scale.

For more information and sample actions related to this Transformative Direction see Appendix F.

2

Respond with urgency to climate change

Decisions and actions associated with urban water management and implementation of GRI are all informed by the lens of climate change and resiliency. In April 2019, Vancouver City Council declared a climate emergency in recognition of the urgent need to increase the City's efforts to reduce our carbon emissions and address the impacts of climate change. The application of a climate adaptation lens to integrated water utility planning and water sensitive urban planning and design will bring us closer to becoming a water sensitive city, and provide significant progress towards a robust response to the climate emergency.

While GRI can contribute to carbon sequestration and help reduce overall energy consumption through urban cooling, one of the most significant benefits is in its ability to support our adaptive capacity—particularly in the areas of flooding, extreme heat and drought.

In a changing climate, a fundamental component of urban water management and GRI implementation is identifying risks, vulnerabilities and opportunities to water-related threats. A vulnerability and risk assessment might include sewer and drainage system, overland flood, economic and lifeline infrastructure risks, all while identifying priority areas to undertake GRI and other climate adaptive measures.

For more information and sample actions related to this Transformative Direction see Appendix F.

3

Accelerate action to protect the health and vitality of surrounding waterbodies

CSOs represent a significant environmental and public health challenge for Vancouver and many other major cities across North America, including Edmonton, Toronto, Montreal, Seattle and San Francisco. The City of Vancouver has been vigorously working to address CSOs since the 1970s through its long-standing Sewer Separation Program. Fully addressing this challenge continues to be costly and requires multi-decade strategic planning. In addition, separated pipe systems present substantial environmental challenges in that, without treatment, urban rainwater runoff discharged to local waterbodies can be highly toxic to aquatic ecosystems.

Over the past decade, the state of practice around CSO mitigation has developed and evolved significantly. Many cities now rely heavily on intensive GRI applications to divert water from the sewer and drainage system, which is complementary to the range of cost-effective grey infrastructure solutions. By including system optimization, smart-flow controls, storage and detention, as well as strategically applied sewer separation, water conservation efforts, and water harvest and reuse schemes we can reduce the volume of water entering the sewer and drainage system. Many cities are also sharing greater responsibility with private properties to capture and clean rainwater onsite from rooftops and foundations.

It is abundantly clear there is an urgent need to update plans for CSO and rainwater pollution mitigation. These updated plans will inform how we transform our sewer and drainage system for the future in order to build resilience, while addressing the increasing water quality challenges to protecting our local aquatic environments.

For more information and sample actions related to this Transformative Direction see Appendix F.

4

Revitalize watersheds to enable communities and natural systems to thrive

Urban watershed plans are essential in characterizing opportunities to promote water sensitive urban planning and design. Planning at the watershed scale requires a systems approach in a way that considers the characteristics and interactions between each of the city's unique urban watersheds. We may not be able to see it, but the watersheds where we live, work and play shape how we interact with the urban environment. Not only do watersheds influence human communities, their function is vital to all species who call it home.

Urban water management characteristics to consider when planning integrated water utilities include:

- How rainfall relates to the geography, geology and ecology;
- How rainfall interacts with the sewer and drainage system;
- The age and renewal status of the grey infrastructure;
- Soil type and infiltration rates;
- Urban development patterns;
- Sensitivity to climate change;
- Urban heat island effect;
- Cultural and ecosystem influence;
- Impervious and pervious areas; and more.

Bringing all elements of the urban water cycle together in the built environment, while working with integrated water utility planning to address flooding, pollution and water security issues is another element of watershed planning. This process changes water from being perceived as a potential nuisance into a valuable resource to enhance urban life. Water sensitive urban planning and design can be applied on many scales, from the design of our homes and streets to community, park and citywide plans. At its root, watershed planning enhances livability, connects people with their surrounding environment and efficiently integrates grey and green rainwater infrastructure into the built environment.

Ultimately, through public consultation and technical analysis, urban watershed plans will propose a suite of capital projects, programs, operational improvements and policy recommendations. All of which, will collectively meet the specific urban water management and city building needs and aspirations in each of the unique watersheds.

A first step in the watershed planning process was to identify the characteristics of each watershed shown in Appendix D. Development and implementation of watershed plans are prioritized based on system needs, growth plans, environmental impacts, climate adaptation needs and water equity. For more information and sample actions related to this Transformative Direction see Appendix F.

5

Shape systems to integrate and value all forms of water

Integrated water utility planning takes into consideration the entire urban water cycle with the mindset that all water is connected and has value. An integrated water utility framework ensures that the management, construction and utilization of our water resources and infrastructure are conducted holistically. This requires water in all forms to be leveraged in order to access the wide range of social, environmental and economic benefits. Integrated water utility planning is a major component of watershed planning, and a step towards becoming a water sensitive city. Development of a framework for integrated water management will guide planning and decisions related to policy, utility service plans, capital investments and system operations. Through thoughtful communication and an exploration of how water networks are connected, we can begin to see how our actions on land influence the health of surrounding waters. The health of the ocean and subsequently the species it supports are greatly influenced by actions we take in our streets, parks and private properties.

For more information and sample actions related to this Transformative Direction see Appendix F.

6

Explore intersectionality, equity and Indigenous reconciliation through urban water management

The City and Park Board have undertaken a variety of initiatives to incorporate the foundational components of reconciliation into plans and actions. Meaningful reconciliation, however, is an ongoing process that requires cultivating relationships and a shared understanding of histories, cultures and shared values. Urban water management represents a unique opportunity to explore Indigenous reconciliation in the urban context through water.

Furthermore, the concepts of intersectionality and equity are becoming accepted as an essential part of service delivery for communities. The City and Park Board are beginning to discover how these concepts can be reflected in their respective processes and actions. GRI implementation sits in a distinct position as it can be found at the intersection of a variety of equity related topics. Concepts such as neighbourhood resiliency, public health, environmental justice, public participation, capacity-building and place-making can all be found within the sphere of influence of a GRI project.

One of the ways the City is working to address questions of intersectional equity is through the upcoming citywide Equity Framework, currently in development by the Arts, Culture and Community Services Department. Participation in this initiative will support our exploration of how integrated water utility services could support equity.

We acknowledge that we are in the early stages of understanding how GRI can embrace concepts associated with reconciliation, intersectionality and equity and have much more to learn. Some initial plans and sample actions to continue the journey related to this Transformative Direction are outlined in Appendix F.

7

Drive innovation and system effectiveness through data and analytics

Urban watershed and water sensitive planning and design, must be informed by data, analytics, monitoring and modeling processes. To provide this important foundation, we must invest in developing a comprehensive understanding of rainfall patterns, sewer and drainage system performance, and the many other related systems and characteristics of the urban watersheds of Vancouver.

Data, analytics and hydrologic and hydraulic models are essential tools to inform and enable decisions that are defensible, measured and fiscally responsible. As rainfall patterns continue to change and urban water systems are put under growing pressure, they must be able to respond quickly and effectively in order to deliver a consistent high level of service.

For more information and sample actions related to this Transformative Direction see Appendix F.

8

Enable a culture of collaboration

The Rain City Strategy outlines a new and innovative approach to urban water management and GRI implementation. There is an inherent impact on internal structures, processes and culture concerning the planning, design and construction of capital infrastructure projects when pursuing transformative new directions. As a result, the City and Park Board will need to work collaboratively in the design, implementation, operation and maintenance of new GRI assets.

This shift is encouraged through enabling greater cross-departmental collaboration and updating internal structures, processes and practices to improve coordination and alignment. Staff knowledge and capacity to support the implementation of the actions outlined in the Action Plans will be strengthened through training, the development of clear policies, standards, guidelines and other applicable approaches and tools.

Beyond the City, partnerships and collaboration between community, industry, academia, not-for-profits, other municipalities and the region, as well as other levels of government are vital to mobilize collective action and to mainstream GRI implementation.

For more information and sample actions related to this Transformative Direction see Appendix F.

9

Invest in education, capacity-building and partnerships to mobilise action

GRI is an emerging field, and will require a major paradigm shift in business practices for those involved across many sectors. It will entail a considerable ongoing effort and sustained investment to develop a more robust ecosystem of practice and build capacity amongst GRI champions and practitioners. In addition, the most cost-effective and better overall value for grey and green rainwater infrastructure investments are achieved when all actors - all levels of government, academia, industry, non-profits and residents – are included early in the process.

To support this inclusion, continued facilitation, support, and development with local industry professionals, other levels of government, not-for-profits, tradespeople and academia is necessary to co-develop the City of Vancouver's approach to rainwater management and transition to a water sensitive city.

We can use this engagement to share knowledge and build capacity with industry, government, not-for-profits, trades people, and academia. These relationships will support the implementation of integrated approaches to water management, including GRI, across the city. With practitioners and the public, we can raise awareness of rainwater management, climate change and GRI, while empowering all actors to take positive actions in their community.

For more information and sample actions related to this Transformative Direction see Appendix F.

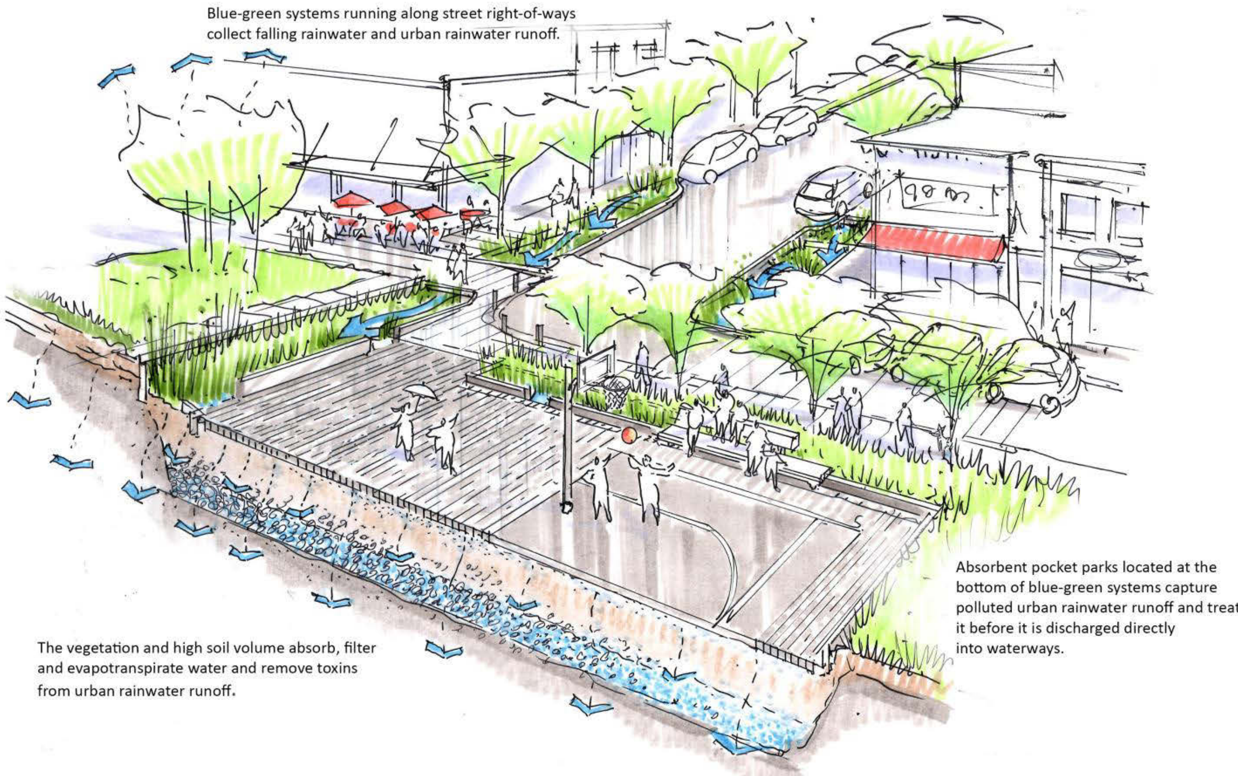


FIGURE 32: ABSORBENT LANDSCAPE

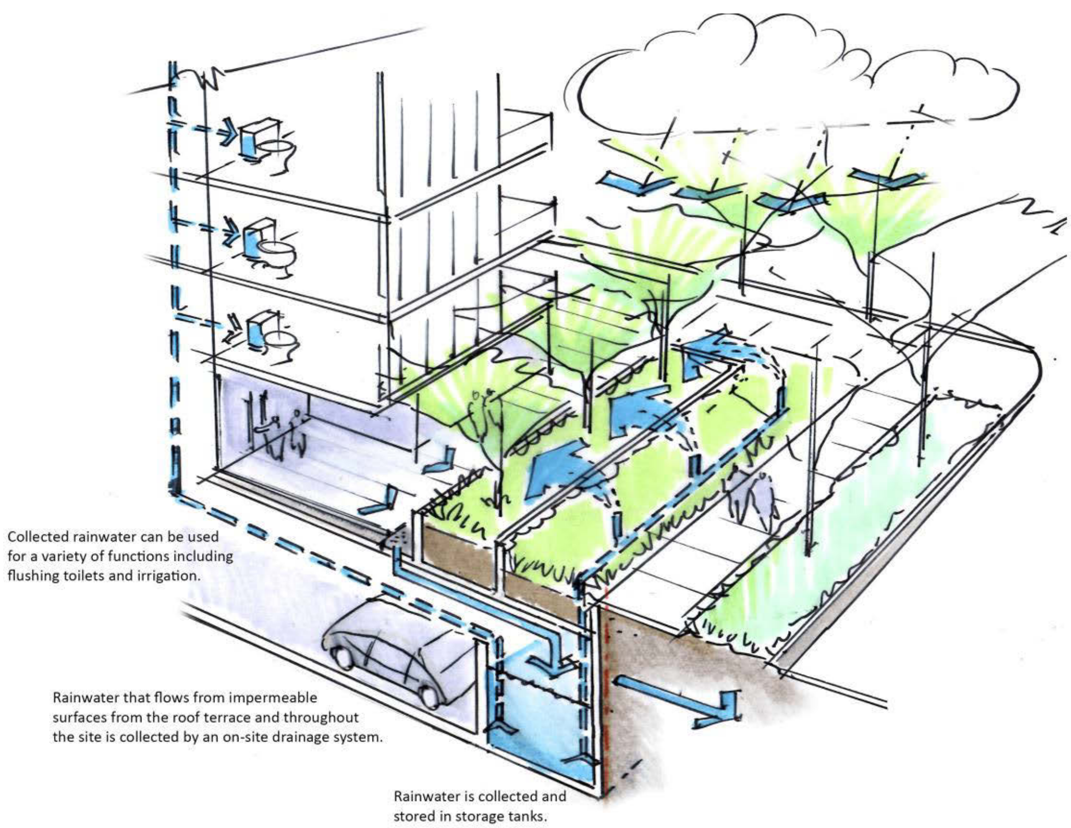


FIGURE 33: RAINWATER HARVEST AND REUSE

PHOTO CREDIT: WENDY DE HOOG

Chapter 6.

Target setting

The citywide Integrated Rainwater Management Plan (IRMP), adopted by Vancouver City Council in April 2016, outlines the City of Vancouver's current commitments to the Province of British Columbia to meet our regulatory obligations under the regional Integrated Liquid Waste Resource Management Plan (ILWRMP). The regulatory obligations set out in the IRMP apply to all private and public property in Vancouver, excluding the Still Creek and Musqueam Creek watersheds, which will have their own regulatory rainwater management plans.

The IRMP established a citywide aspirational implementation target and green rainwater infrastructure (GRI) design standard. The citywide aspirational implementation target sets a long-term goal for the amount of impervious area in the city that will be managed by GRI. This target serves to inform policies and capital projects of the City of Vancouver and Vancouver Board of Parks and Recreation to ensure that early and continued progress is made on implementing GRI across the city. However, it does not set a specific deadline or expected pace of delivery. The GRI design standard specifies how much rainfall must be captured and cleaned by GRI practices in a 24 hour period for impervious surfaces to be considered as 'managed by GRI'.

To demonstrate leadership and act in response to Council's declared climate emergency, the Rain City Strategy includes updates to the IRMP design standard and sets a pace for citywide GRI delivery through a 2050 implementation target. The updated design standard and citywide implementation target for GRI will be reported to the Provincial Government as a proposed amendment to our regulatory obligations through our IRMP. Further details and a rationale for these changes are provided in the following sections.

6.1 Process to update the 2016 Integrated Rainwater Management Plan performance targets and associated design standards

A number of resources were utilized to inform the updated GRI design standard including a review of Vancouver's rainfall patterns, policy and technical standards benchmarking, engagement with water resource professionals, and the City's experience with designing, constructing, and monitoring its own GRI practices in streets and public spaces. This process is highlighted in Figure 34 below.

6.1.1 Integrated Rainwater Management Plan 2016 performance targets and associated design standards

The IRMP's design standard specifies the amount of rainwater that a site or GRI practices must manage from impervious surfaces that generate urban rainwater runoff. The design standard can be applied at a project, site or district scale.

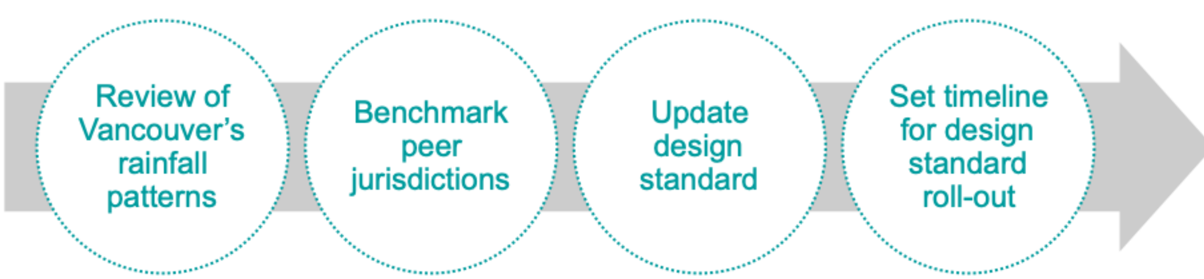


FIGURE 34: IMPLEMENTATION TARGET SETTING PROCESS

The volume of rainwater that should be designed for is expressed as a depth of rainfall, in millimetres, managed over a 24 hour period.

The 2016 IRMP design standard consists of two rainfall depths – one aimed at capturing (through infiltration, evapotranspiration and/or reuse) an initial portion of rainfall landing on impervious surfaces, and the second to ensure that additional rainfall is cleaned (treated) before being discharged to a sewer or receiving waterbody. The 2016 IRMP performance targets and design standard is illustrated in Figure 35 below.

As illustrated in Figure 35, managing this first portion of rainfall, 24 mm, ensures that roughly 70% of annual rainfall is captured onsite. Whereas the second component of the standard, 48 mm, equates to rainfall from approximately 90% of all storms being cleaned prior to discharge. Further details regarding how the 70% and 90% rainfall management performance targets were established is presented in the following section.

An issue with the current IRMP design standard identified through the update process is that its two-part structure with separate targets for 'capture' and 'clean' is cumbersome due to its two design volumes with different performance targets. This structure makes it complex to communicate to consultants and contractors designing GRI practices. Feedback received from stakeholders has indicated that there is a desire for a more simplified and streamlined design standard.

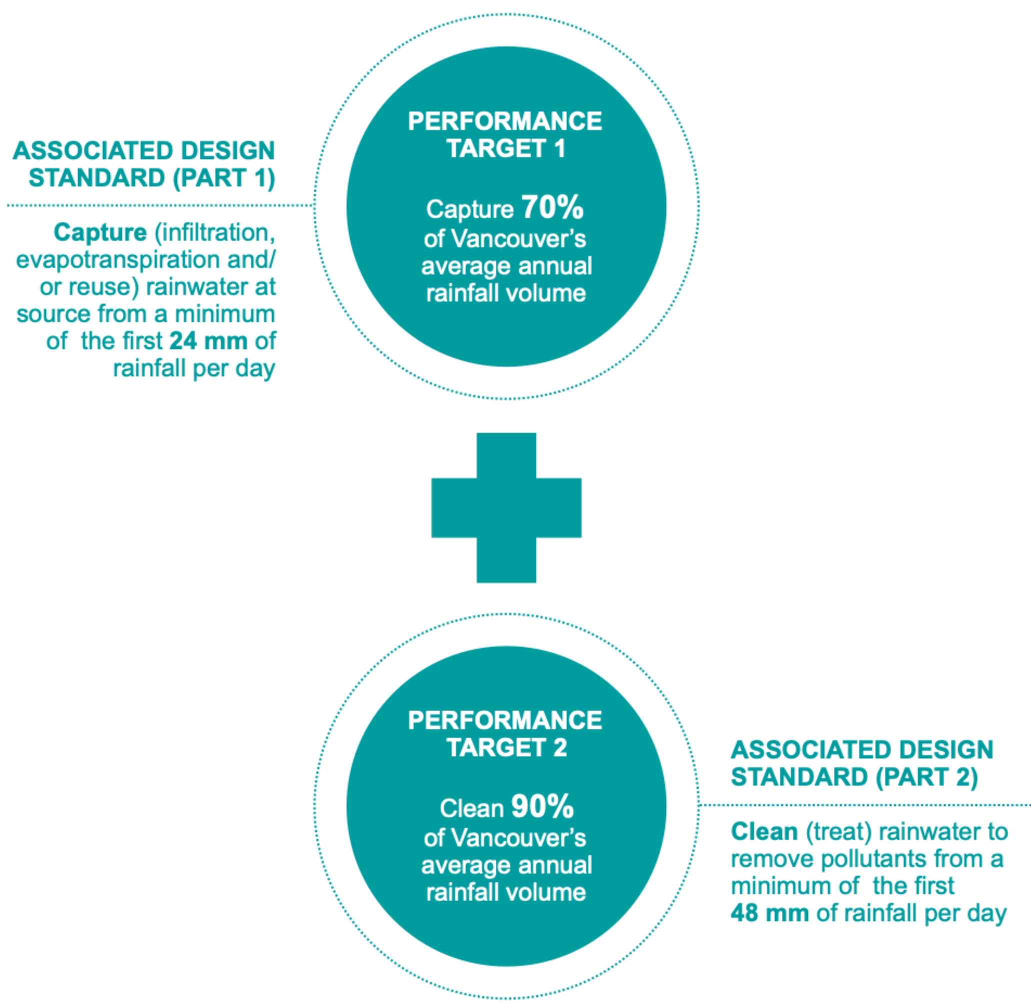


FIGURE 35: IRMP PERFORMANCE TARGETS AND DESIGN STANDARDS

6.1.2 Vancouver rainfall

A quantitative assessment of historical rainfall patterns was undertaken for the City of Vancouver as part of the 2016 IRMP. As illustrated in Figure 36 this assessment found that light showers make up about 70% of the annual rainfall volume in the city, which is equivalent to the first 24 mm of rainfall in a 24 hour period. Light showers and rainstorms together make up about 90% of the annual rainfall volume in Vancouver. These are represented by the first 48 mm of rainfall in 24 hours. Extreme rainstorms represent only 10% of annual rainfall volume and are represented by events exceeding 48 mm in 24 hours.

The 2016 IRMP based its design standard, in part, on this historical analysis of rainfall patterns. As discussed in Chapter 3.1 climate change projections for the Metro Vancouver region are predicting wetter fall and winters and potentially more intense rainfall events due to climate change. As such there is a risk that GRI practices designed to the 2016 IRMP's design standard may not perform as well as rainfall patterns shift due to climate change. This in turn will have implications for the City's sewer and drainage systems. For example, limiting the benefits GRI will have in reducing urban rainwater runoff contributions to the sewer, mitigating combined sewer overflows (CSOs) and preserving capacity in the system for growth. This risk was an important factor that informed the update to the design standard as part of the Rain City Strategy.

6.1.3 Benchmarking

Benchmarking of policies and technical standards amongst a number of North American jurisdictions was also undertaken as part of updating the design standard. Figure 37 provides a summary of rainwater management criteria, including the rainfall depth and percentage of annual rainfall for jurisdictions in the Pacific Northwest and across North America.

The review found that design standards vary widely depending on the unique rainwater management goals and rainfall patterns of each jurisdiction making it difficult to make direct

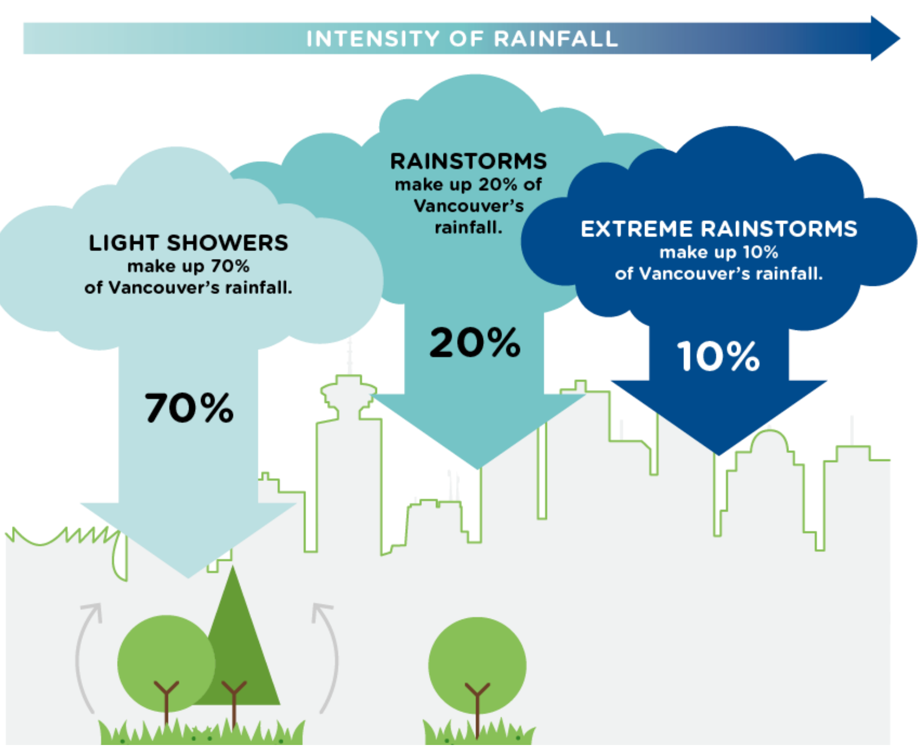


FIGURE 36: VANCOUVER'S RAINFALL PATTERNS

FIGURE 37: SUMMARY OF RAINWATER MANAGEMENT CRITERIA

comparisons across jurisdictions. Many jurisdictions, however, aim to capture and clean 90% of the average annual rainfall within their geographic region. Many North American peers specifying a higher rainfall target than the City of Vancouver's 24mm capture design standard, further strengthening the case for updating the design standard.

6.2 Amended Integrated Rainwater Management Plan performance target and associated design standard

As discussed in the previous sections the review process undertaken as part of the Rain City Strategy identified a number of risks and factors supporting the need for an updated design standard. As such, in order to mitigate risks, build resilience to climate change, enhance performance related to CSO mitigation and capacity in the pipe system, the Rain City Strategy recommends that the 2016 IRMP design standard be strengthened and streamlined as in Figure 38.

This shift in the design standard from the 2016 IRMP to the Rain City Strategy is illustrated in Figure 39. The standard should be applied to the maximum extent practicable and there may be instances in which there is a strong technical rationale for deviating from this standard. Examples could include areas where infiltration is not viable due to slope stability issues, high groundwater or bedrock conditions, significant soil contamination or unacceptable risks of harm to other sub-surface infrastructure. The design standard would only be applied to projects for which rainwater management is part of the scope.

6.2.1 Implications of updated design standard

Adoption of the new design standard is expected to provide a number of immediate benefits. Firstly, strengthening the capture and cleaning performance target to 90% of annual rainfall will improve the City of Vancouver's compliance with regional criteria specified by Metro Vancouver and Fisheries and Oceans Canada. The design standard also ensures that the City of Vancouver is in line with the criteria

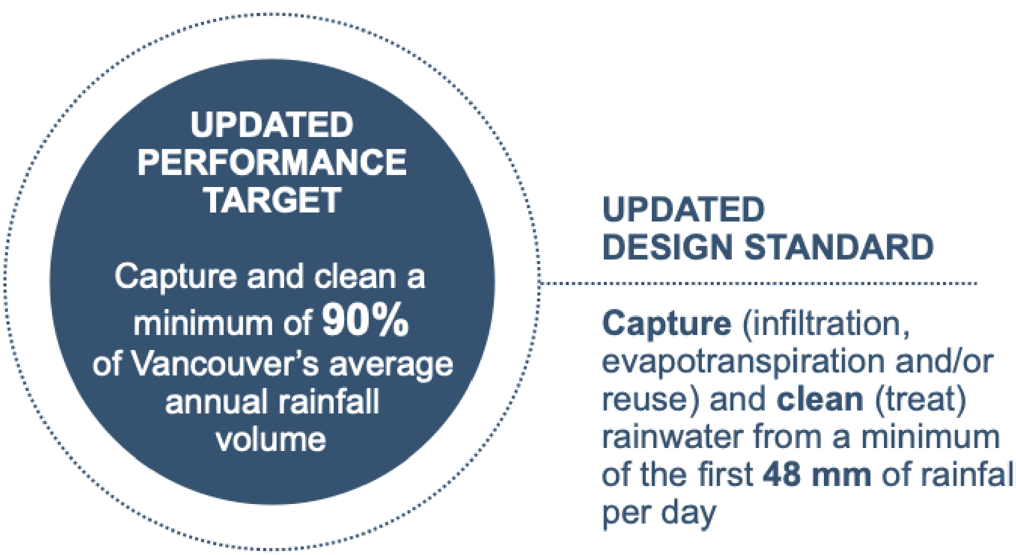


FIGURE 38: UPDATED DESIGN STANDARDS

specified by many jurisdictions across the Pacific Northwest and other cities across North America.

Secondly, by streamlining the design standard to reference one unified rainwater management target, we can greatly reduce the complexity of communicating the standard to others and ensuring compliance. This simplified approach is visualized in Figure 40.

As part of the City's efforts at demonstrating leadership on the implementation of GRI, it has designed and constructed many of its existing GRI practices to meet this updated 48mm capture design standard. Through ongoing performance monitoring we have confirmed that many of these GRI practices are meeting or even exceeding this standard. This shift will, however, require some changes in how GRI practices are designed in order to meet this new design standard.

6.2.2 Implementation timeline for updated performance target and design standard

The majority of the City's capital projects implemented with GRI in streets and public spaces are already being designed and constructed to achieve the 48 mm capture design standard. The City of Vancouver will

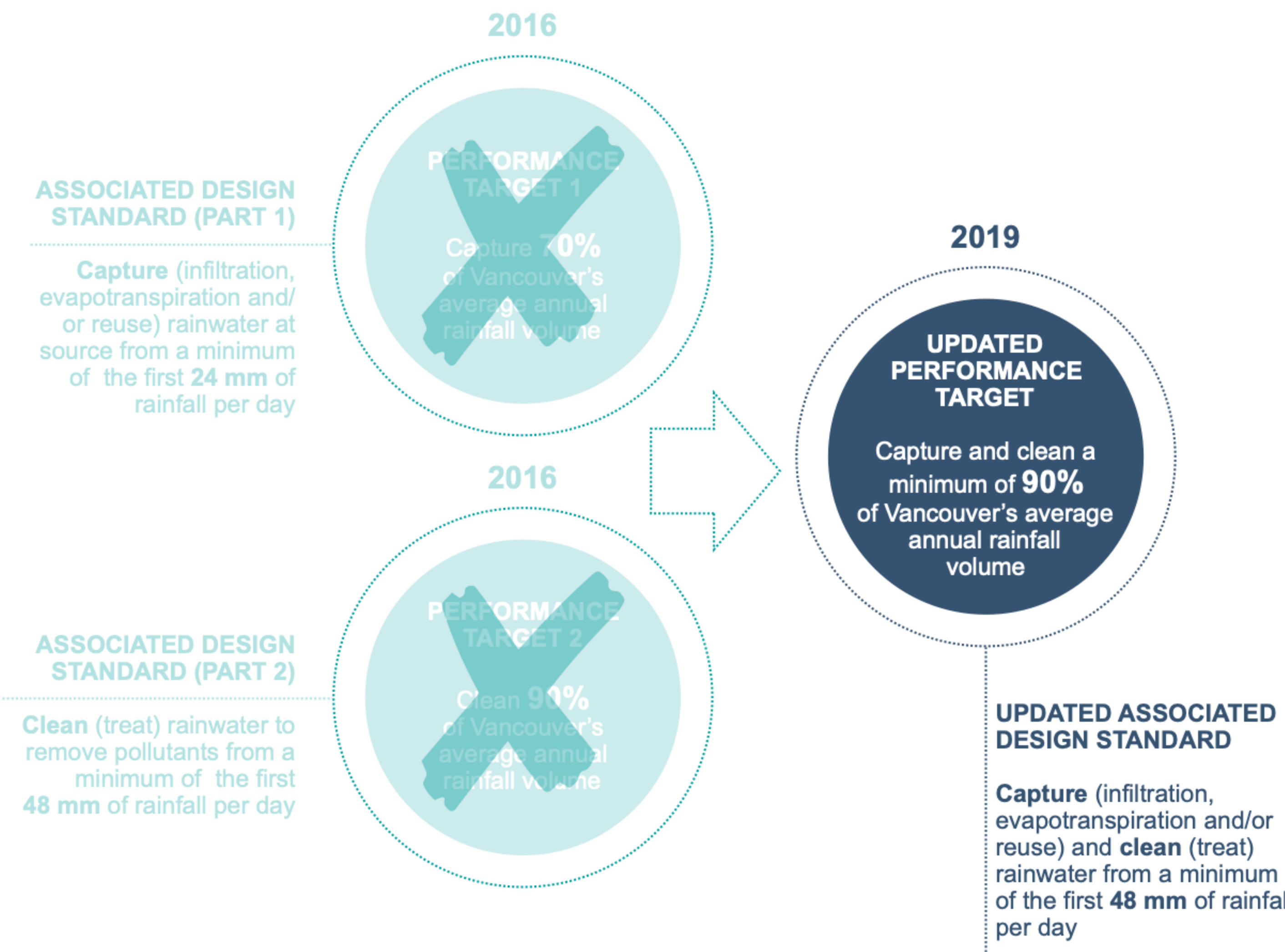


FIGURE 39: SHIFT IN THE DESIGN STANDARD FROM THE IRMP TO THE RAIN CITY STRATEGY

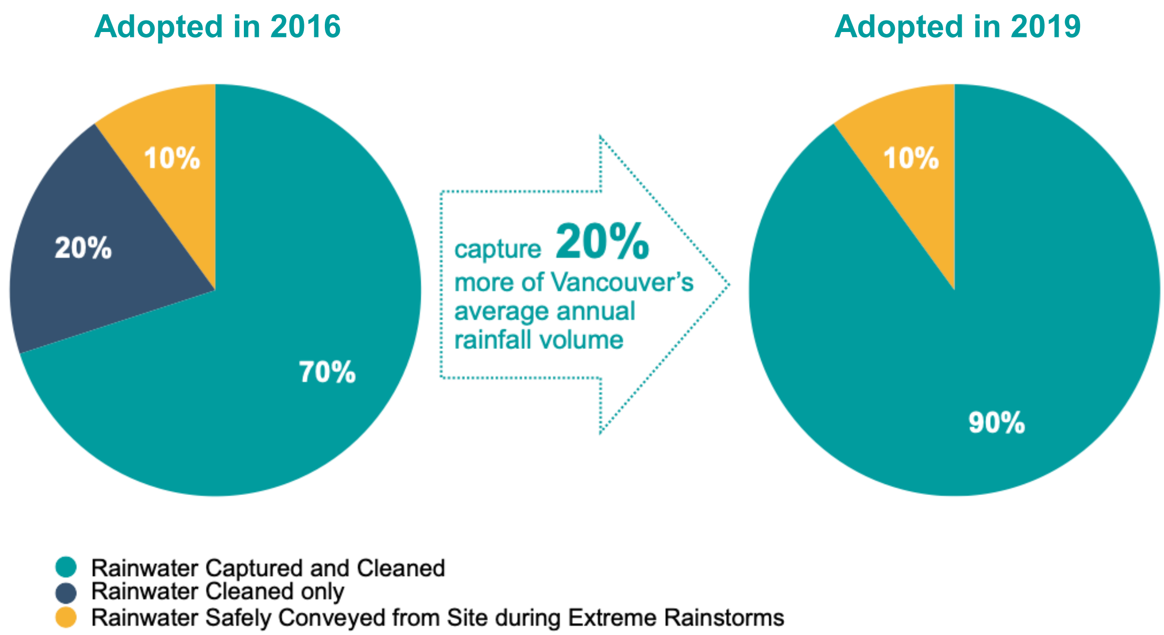


FIGURE 40: ONE UNIFIED RAINWATER MANAGEMENT TARGET DESIGN STANDARD

continue to act as an early adopter of this standard and will design new capital projects in: Streets and Public Spaces; Parks and Beaches; and Civic Facilities to capture and clean 48mm from 2019 onwards.

While the City has implemented GRI in streets and public spaces for several years, GRI design to a 48 mm capture standard will likely be new for most buildings and sites. As such, GRI in these areas will aim to gradually adopt the 48 mm design standard with a goal of being fully adopted by 2022. By 2025, the updated design standard will be reviewed for effectiveness, ease of implementation and also alignment with emerging water quality and rainwater volume performance outcomes identified through watershed and clean water planning initiatives. The process is illustrated in Figure 41.

A phased approach will provide time for engagement with industry practitioners and

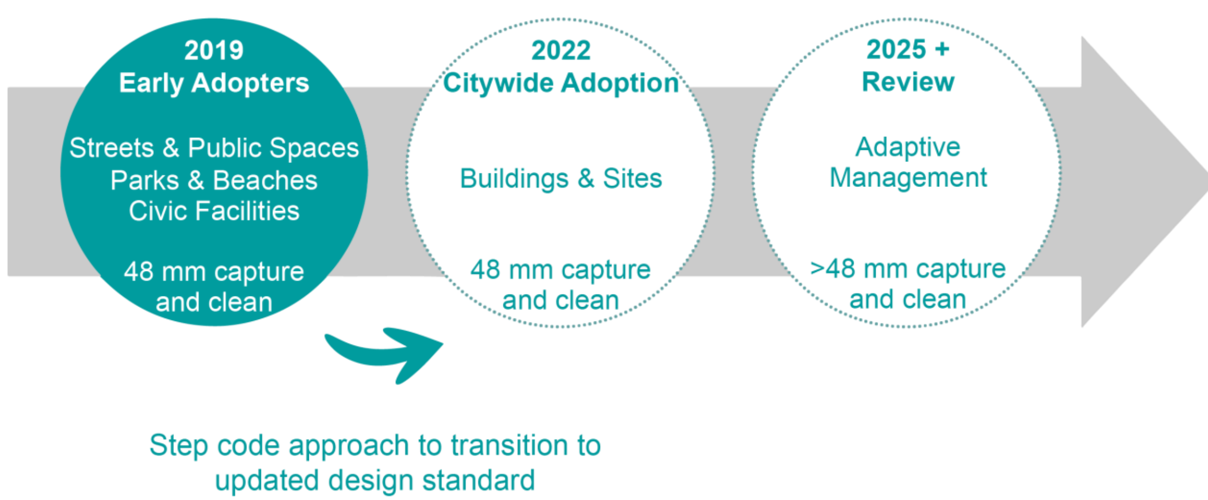


FIGURE 41: PROCESS TO TRANSITION TO THE UPDATED DESIGN STANDARD

project planners as well as the development of guidance materials, training, education and capacity building in the GRI field. To ensure that this transition takes place successfully, the Rain City Strategy has outlined dedicated programs as part of Transformative Directions and Action Plan programs to develop and implement the necessary actions to support the adoption of this new design standard.

6.3 Process to update the 2016 Integrated Rainwater Management Plan citywide green rainwater infrastructure implementation target for impervious area managed

Whereas the design standard specifies requirements for managing rainfall on an individual site or project, the citywide implementation target takes a wider view and looks at the amount of impervious area being managed by GRI across the city. This section provides an overview of the aspirational citywide implementation target specified in the 2016 IRMP. The steps taken as part of the Rain City Strategy are to refine and develop a detailed 2050 citywide implementation target. This process is highlighted in Figure 43.

6.3.1 Integrated Rainwater Management Plan citywide green rainwater infrastructure implementation target for impervious area managed

The 2016 IRMP set an implementation target to manage urban rainwater runoff from 100% of impervious areas in the city. The IRMP, however, did not specify a date for when this target would be achieved. As such, this target is considered to be an 'aspirational' implementation target in the Rain City Strategy, as follows:

FIGURE 42: ASPIRATIONAL IMPLEMENTATION TARGET

The Rain City Strategy reaffirms the IRMP aspirational target. To provide greater clarity and direction on how to work towards this target, further work was undertaken to develop a more

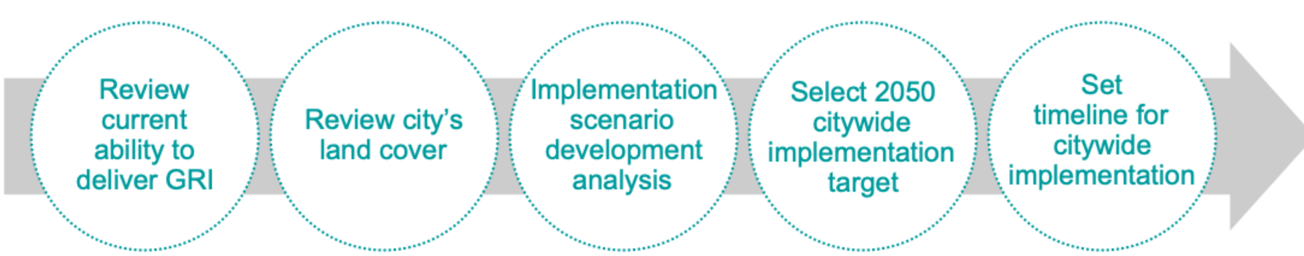


FIGURE 43: IMPLEMENTATION TARGET SETTING PROCESS

detailed 2050 citywide implementation target. Details regarding how the target was selected and its implications are discussed in section 6.3.2.

6.3.2 Developing the 2050 citywide green rainwater infrastructure implementation target

To help develop the 2050 citywide implementation target, a total of four GRI implementation scenarios were developed and analyzed to look at how, and by what date, the city could achieve the aspirational target of 100% of impervious areas managed. The city's current land cover and the pace at which GRI is delivered at scale by both the City and industry formed the basis of the scenarios.

The City of Vancouver is approximately 11,670 ha in area, of which 49% of the land area is currently impervious (see Figure 44). Of that 49%, 19% falls within streets and public spaces, 29% is within buildings and sites, and 1% is within parks. While not all impervious areas are connected to our sewer and drainage system, most are. Improving data about which impervious areas in the city are not connected to the sewer and drainage system will be considered as part of future GRI implementation planning.

With the distribution of impervious surfaces across the city established, the next task was to examine at what pace GRI could be implemented to manage urban rainwater runoff. Each sector was considered based on their contributing impervious surfaces through opportunistic renewal and redevelopment and also strategically through retrofits.

The first step was to characterize the rate of infrastructure renewal within each sector. Research found that streets and public spaces as well as buildings and sites tend to be redeveloped or renewed at a rate of roughly 1% per year. Impervious infrastructure related to parks and beaches were found to renew at a slightly slower rate of 0.5% per year.

Rates of renewal and redevelopment were considered to be a prime mechanism for implementing GRI citywide. In addition to renewal and redevelopment rates, targeted retrofits of existing impervious surfaces represent an opportunity for GRI implementation.

Using the collected data, four implementation scenarios were developed, based on a different rate of GRI delivery. These scenarios are described in Figure 45.

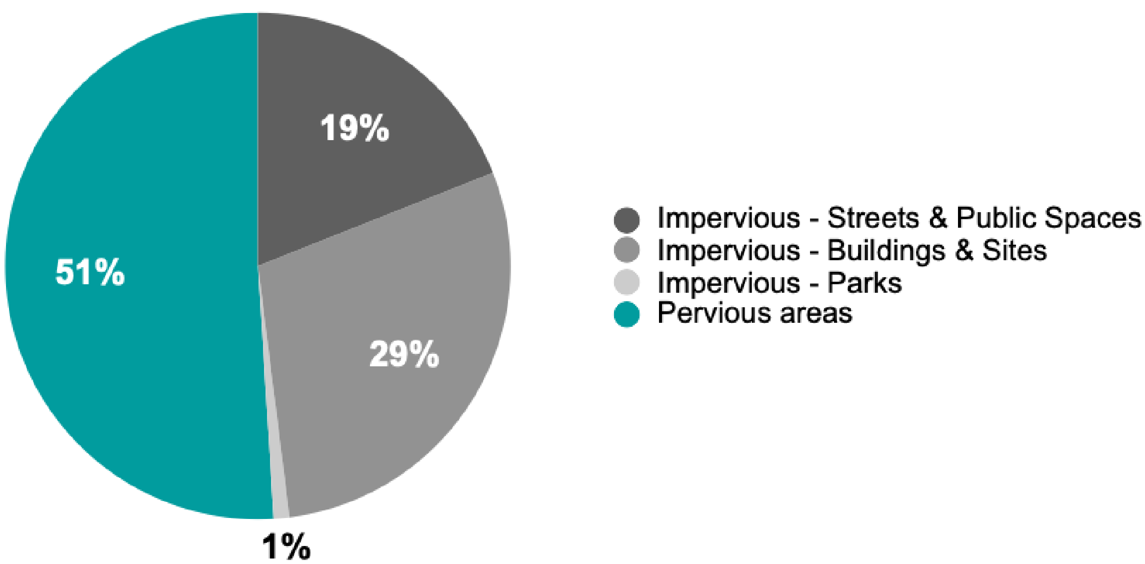


FIGURE 44: LAND COVER DISTRIBUTION IN VANCOUVER

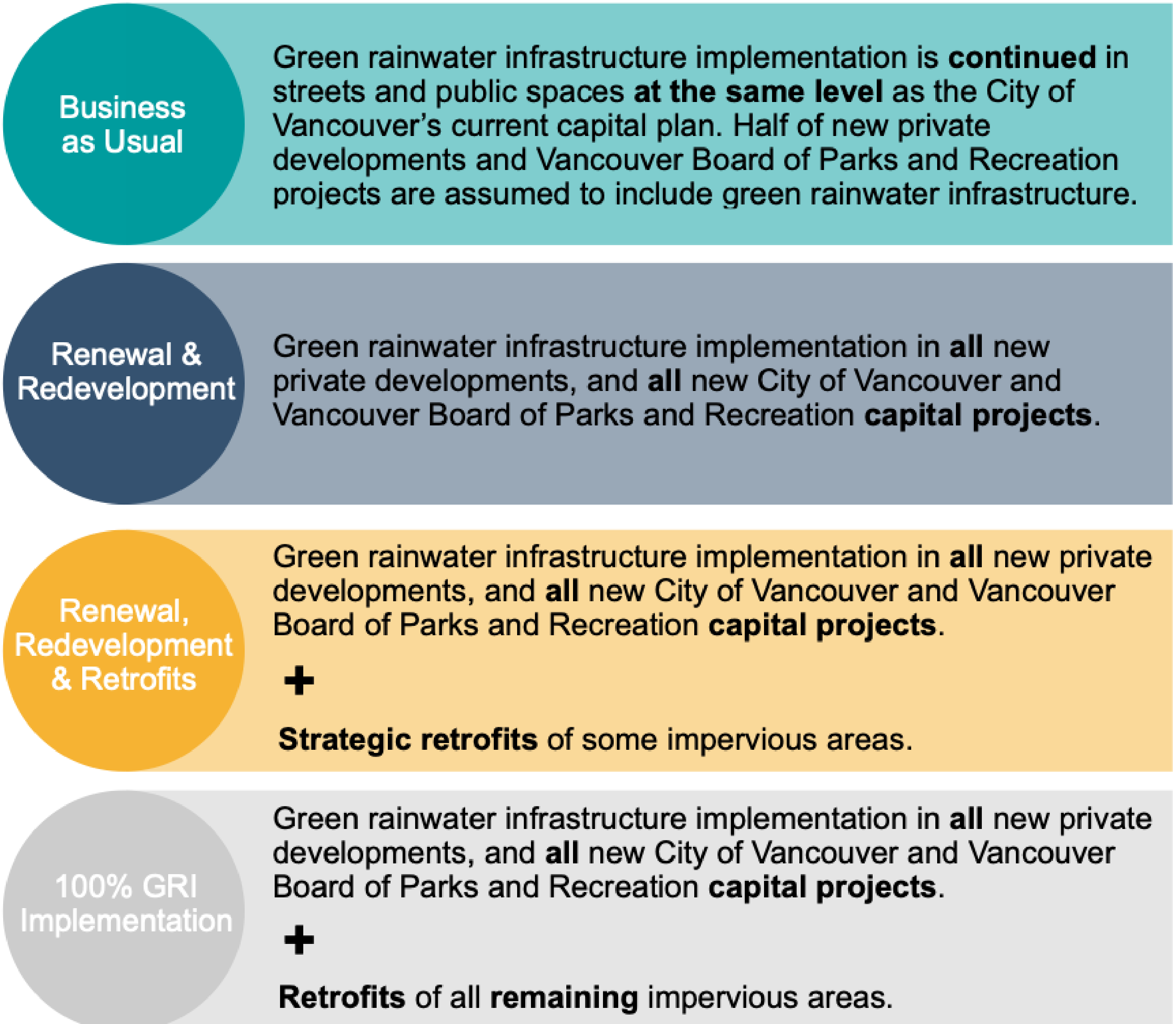


FIGURE 45: IMPLEMENTATION SCENARIOS

The annual rate of GRI delivery for each of the four implementation scenarios was extrapolated to provide an estimate of how much impervious area each scenario could manage with GRI by 2050. The results from this analysis are presented in Figure 46.

A final step in analyzing these implementation scenarios was to assess quantitative and qualitative outcomes associated with each of the different rates of GRI implementation. The estimated outcomes include:

- The volume of rainfall captured and diverted from the sewer and drainage system;
- The volume urban rainwater runoff cleaned; and
- An estimate of CSO volume reduction.

In addition, each scenario was rated based on its ease of implementation, how well it addressed City Council's declared climate emergency and regulations in a timely manner. The outcomes and rating matrix used to compare the scenarios is presented in Table 5.

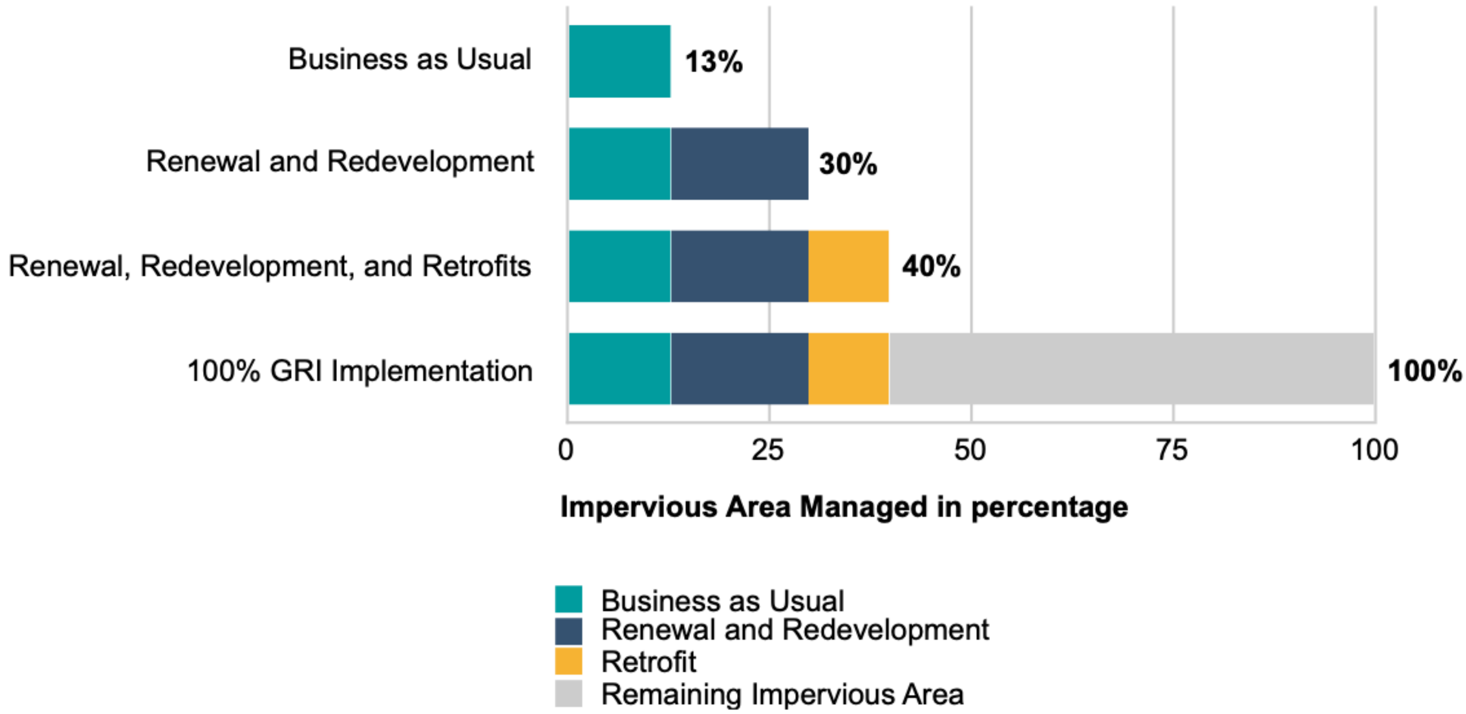


FIGURE 46: DELIVERY OF POTENTIAL GRI IN 2050

Table 5 shows that the 'business as usual' scenario scored highest on ease of implementation, due to the small amount of impervious area it manages. However, due to the limited scale of GRI implementation in the business as usual scenario, this option scored low in all other beneficial outcomes.

The 'renewal and redevelopment' scenario scored fair across the majority of outcomes and good on ease of implementation due to its focus on managing urban rainwater runoff from all renewal and redevelopment citywide. This approach however means that managing the urban rainwater runoff from impervious surfaces is tied solely to renewal and redevelopment, overlooking the significant opportunities for strategic GRI retrofits across the city.

The 'renewal, redevelopment and retrofits' scenario scored well across all categories and requires a reasonably ambitious amount of effort over the business as usual and renewal and redevelopment scenarios.

The 'complete by 2050' scenario is highly ambitious and receives top scores in all beneficial outcome categories. However, it would be challenging to implement by 2050 due to the sheer extent and feasibility of retrofits to all public and private sites.

TABLE 5: IMPLEMENTATION SCENARIO RATING MATRIX

	Impervious Area Managed		Water Quality Improvement		Climate Resilience		CSO Reduction		Adresses Regulation in a Timely Manner		Ease of Implementation	
Scenarios	*Impervious Area Managed (%)*	*Rating*	*Annual Rainfall Treated (%)*	*Rating*	*Volume diverted from sewer system (IBillion liters)*	*Rating*	*Estimated Annual CSO reduction (%)*	*Rating*	*Date to reach 100% impervious area managed*	*Rating*	*Effort above business as usual*	*Rating*
Business as Usual	13%		12%		8,8		11%		2274		1x	
Renewal and Redevelopment	30%		27%		20,4		25%		2119		2x	
Renewal, Redevelopment and Retrofits	40%		36%		27,7		34%		2092		3x	
100% GRI Implementation	100%		90%		69,2		85%		2050		8x	

6.4 Desired 2050 citywide green rainwater infrastructure implementation target

From the benefits analysis and rating matrix (Table 5) presented in the previous section, the 'renewal, redevelopment and retrofits' scenario was selected as the preferred scenario, providing the best balance between maximizing benefits and addressing regulations in a timely manner. As such the Rain City Strategy recommends that the aspirational citywide implementation target stated in the 2016 IRMP be supplemented by the following target: (see Figure 47).

FIGURE 47: 2050 IMPLEMENTATION TARGET

This implementation target means that the performance target of managing 90% of average annual rainfall, to a design standard of 48 mm, will be applied to 40% of Vancouver's impervious areas by 2050. Managing rainwater for 40% of Vancouver's impervious areas by 2050 is ambitious yet attainable, considering the current extent of GRI implementation in the city. This target will require ongoing leadership, purposeful efforts towards building capacity building within our organizations, academia, industry and community as well as dedicated resources to support GRI implementation, establishment, operations, maintenance and renewal.

6.4.1 Green rainwater infrastructure implementation timeline

The 2050 citywide implementation timeline will provide direction and interim milestones for the City and Park Board to track progress in managing urban rainwater runoff from impervious surfaces across the city. These interim milestones, as well as targets for the percent of impervious surfaces being managed by GRI by 2019, 2030, and 2050 are presented in Figure 48.

6.4.2 Implications of updated 2050 citywide implementation target and amended rainwater management design standard

Achieving the citywide implementation target of 40% of impervious surfaces managed by 2050 will require that all redeveloping and renewing infrastructure in streets and public spaces, parks and beaches and buildings and sites utilize GRI to manage the rainwater runoff from their impervious surfaces. The current renewal and redevelopment rate of roughly 1% per year will mean that the majority of the 2050 implementation target, 30%, will come from these sources. The remaining 10% will be achieved through the implementation of strategic retrofits of impervious surfaces across the city.

Taking on this ambitious approach to managing urban rainwater runoff will have a number of implications. Implications include GRI's role and relationship with other infrastructure, City finances in terms of cost implications to capital and renewal projects, developing and expanding strategic retrofit programs and adapting the City's asset management practices. These elements are discussed further below.

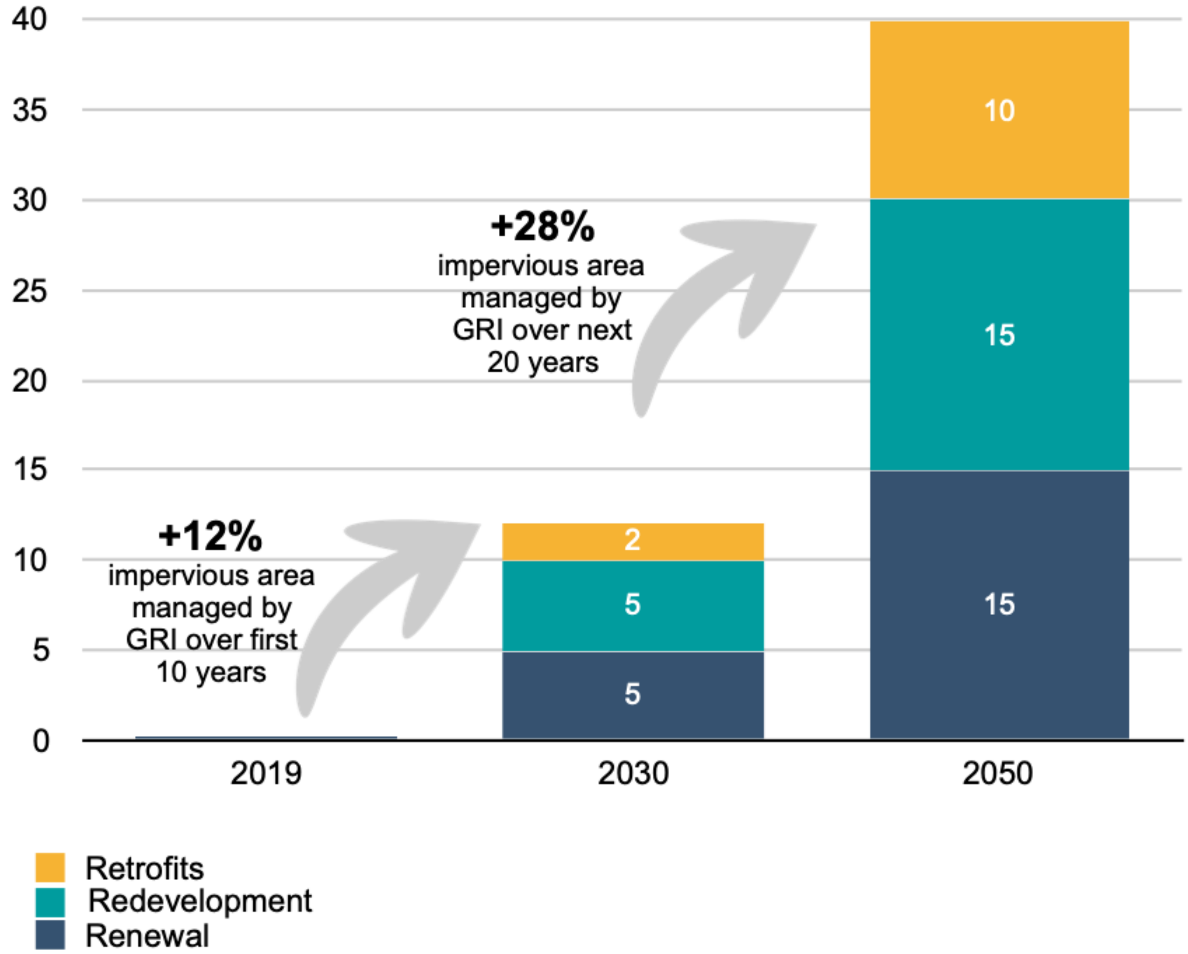


FIGURE 48: CITYWIDE GRI IMPLEMENTATION TARGET WITH INTERIM MILESTONES

Implications of green rainwater relative to major infrastructure serving Vancouver

Achieving the 2050 citywide implementation target will influence affordability of integrated water utility infrastructure and has financial implications for tax payers, utility rate payers, development, and the City, which delivers capital and renewal projects (see Figure 49).

Based on the 2018 replacement value, the City currently owns and manages over $8.5 billion worth of water-related infrastructure, of which $6 billion is sewer and drainage infrastructure. Examples of sewer and drainage infrastructure includes sewer mains, pump stations, service connections, catch basins and a modest inventory of green infrastructure. Additionally, sewer and drainage infrastructure represents a significant portion of the City's overall capital assets, which amount to roughly $26B across all service groups. The City's utilities infrastructure is also integrated as part of the regional infrastructure with Metro Vancouver, including its trunk sewers and the Iona Wastewater Treatment Plant.

Between the City of Vancouver and Metro Vancouver, the total value of assets that serve the city is likely in the tens of billions of dollars. Business-as-usual investments for both governments will be in the billions of dollars or even tens of billions of dollars over the next thirty years. Significant investment will be required as renewal pressures grow, new services for population and employment growth are implemented, as a response to climate change, expanding wastewater treatment services and measures to address CSOs and rainwater run-off pollutants.

The City will not be able to meet future rainwater management, climate adaptation and water quality objectives on its own. Regulation will be vital to private properties playing their part in managing water and sharing the costs and responsibilities while helping to mitigate overall citywide risks related to rainwater management. Advocacy, education, partnerships, collaborations and other initiatives will be vital to catalyze actions and have all sectors contribute to outcomes.

Implications for overall utility servicing costs and potential for cost-efficiencies

Numerous studies have found that GRI brings higher value over its entire life cycle compared to traditional grey infrastructure.

Typically, GRI has lower initial capital cost, more flexibility and lower renewal cost relative to grey infrastructure. GRI also provides greater environmental and social benefits, and can be excellent at leveraging a single investment to offset other investments and services. Environmental and social benefits are often associated with the public realm and are

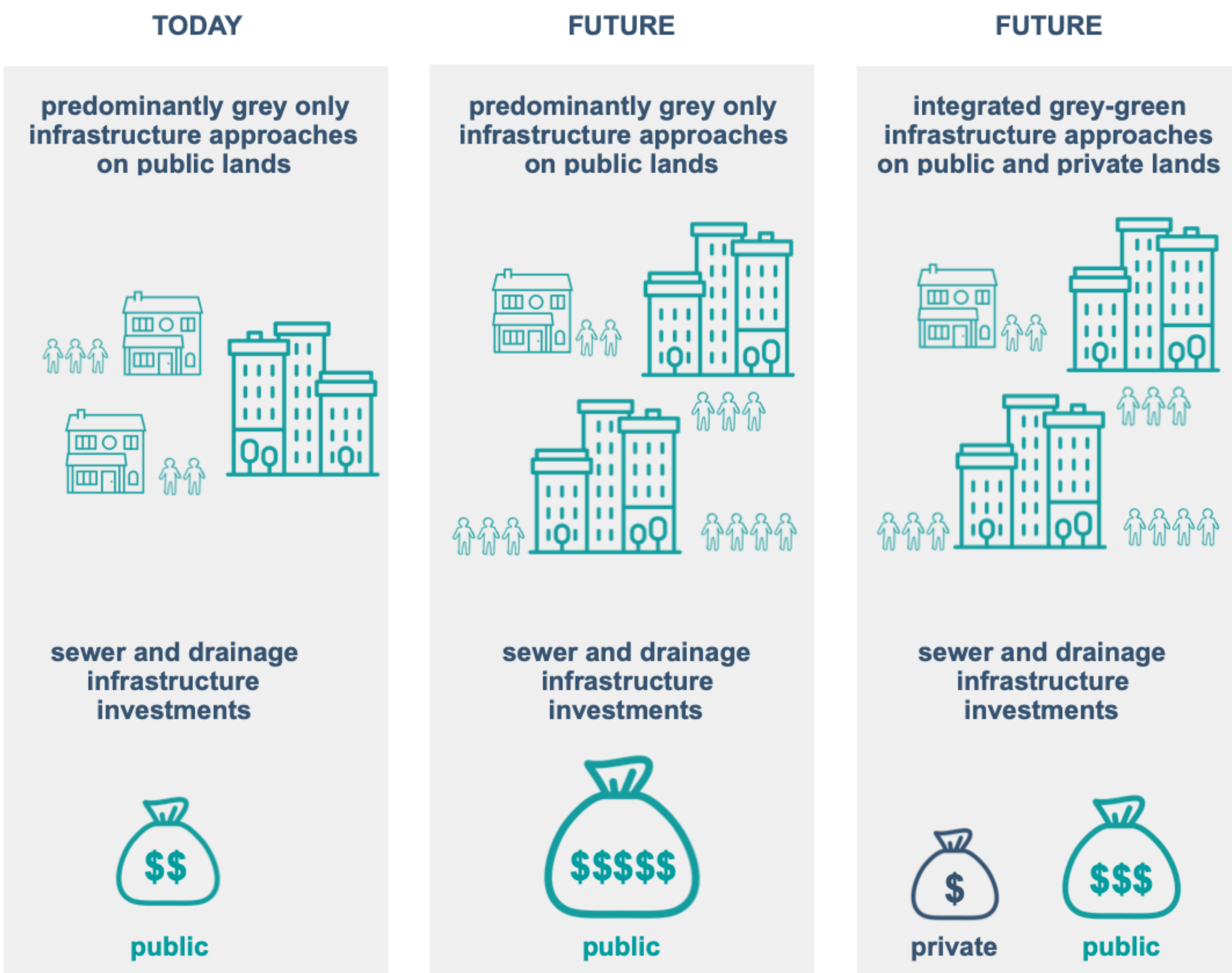


FIGURE 49: FINANCIAL IMPLICATIONS OF GRI IMPLEMENTATION

typically borne by multiple departments, agencies and sectors within the city.

Some GRI assets typically require higher operating and maintenance costs, and therefore higher ongoing asset maintenance expenditures relative to grey infrastructure. Others require minimal ongoing care and effort, and are on par with piped infrastructure in terms of operations and maintenance costs.

Undertaking a comprehensive and detailed analysis of the full life cycle costs, benefits, potential for cost-avoidance or risk mitigation and regulatory compliance potential will be an important part of the work moving forward. There is a diverse array of GRI solutions and the optimal combination with grey infrastructure investments to meet servicing, CSO, water quality and climate adaptation needs is a complex endeavour beyond the scope of this strategy. The established body of knowledge, business cases, and research undertaken over the past decade by reputed institutions around the world have established without a doubt the suitability of GRI as a compelling complement or alternative to grey infrastructure, and its superior value relative to cost in many contexts.

The Rain City Strategy is premised on the established body of research, and the multiple pilot projects deployed and monitored locally and across peer cities. Detailed in the implementation action plans, this strategy recommends further analysis and evaluation over the next three years and beyond. Research will identify the desirable mix of grey and green infrastructure, to optimize system performance, achieve desired policy and co-benefit outcomes and to maximize the value of the investments made.

Although difficult to measure, co-benefits such as improved air quality, energy savings, reduced urban heat island effect, community health and amenity benefits, amongst others need to be examined and quantified where possible. The financial analysis shall be undertaken as part of part of the Streets & Public Spaces Action Plan (S&PS) (see S&PS-12).

Implications of amended rainwater management design standard

Updating design standards to capture and clean 48 mm and the 2050 citywide implementation target of managing 40% of impervious areas by 2050 will have cost implications for both public spaces and buildings and sites. Not all of these costs will be net new costs, but rather result in a shift of costs. For instance, many new developments in Vancouver may require that the City undertakes significant water, sewer and drainage infrastructure upgrades to provide sufficient capacity to service the increased density. In some cases, this can trigger upgrades costing millions or hundreds of millions of dollars.

Greater onsite management of rainwater through GRI practices and appropriately designed utilities to handle excess flow and extreme events will be a cost-effective approach to reduce the scale and cost of major sewer and drainage system upgrades. An integrated grey-green infrastructure approach is expected to shift or potentially reduce the overall utility costs for new development compared to a grey infrastructure-only approach.

As GRI design and implementation practices mature in Vancouver and, as the development community becomes accustomed to the design, implementation, and life cycle management of these measures will become increasingly cost-effective and standard practice. A parallel to such an approach has already been achieved with green building practices. LEED Silver certification for example, was considered excessively onerous by many developers, but as maturity was achieved in the market across the value chain, LEED Silver has become commonplace.

By deploying this strategy, the City of Vancouver will engage and work closely with developers, consultants, contractors, manufacturers and academia. The City's collaboration with a range of groups will build capacity, incentivize early adoption, undertake pilots, build communities of practice, extract lessons learned and disseminate knowledge. All of which will streamline GRI implementation to support cost-effective GRI and rainwater management performance outcomes on private sites as part the Buildings & Sites Action Plan (B&S). These actions are outlined in Action Plan B&S-07, and 09.

Implications of strategic retrofit approach

Strategic retrofits make up a significant proportion of the citywide implementation target. By 2050, the Rain City Strategy is targeting 10% of all impervious surfaces citywide to be retrofitted in order for rainwater runoff to be managed by GRI. To ensure that this target is achieved, the City plans to initiate a pilot retrofit program in the latter half of the 2019-2022 capital plan, which will also include a monitoring program. Retrofit projects will then be evaluated to assess effectiveness, ease of implementation, value-for-money, and potential for partnerships to support expanded deployment.

Over the next several years, the city will transition effective pilot programs into established and ongoing programs to be in full effect by 2027. These retrofit programs will be strategic in nature, targeting priority areas, needs and value-for-money. To help identify and continuously improve this process programs have been established as part of the Rain City Strategy's Transformative Directions. Retrofit programs are expected to include projects across streets and public spaces, buildings and sites and parks and beaches. It is also expected that strategic retrofits and servicing approaches will be implemented in support of major growth areas, such as the Cambie Corridor, Broadway Area Plan and areas that may emerge through the City-wide Plan.

Implications for asset management

GRI implementation as part of new capital projects and retrofit programs will also require an in-depth evaluation and modification of the City's existing asset management and operations and maintenance protocols. An important component of this process will be the review of service delivery models for asset management, operations and maintenance. The review will also investigate funding options, resources and innovative opportunities for partnership and stewardship that may be available. See Streets & Public Spaces Action Plan (including S&PS-01 and S&PS-10). GRI implementation on buildings and sites is likely to serve as a catalyst for the development of new service sectors and green jobs that provide ongoing operation and maintenance of GRI on private property.

PHOTO CREDIT: WENDY DE HOOG

Chapter 7.

Action plans

Through extensive research, experience and engagement with City of Vancouver and Vancouver Board of Parks and Recreation staff, expert panelists, industry and the public, we developed three action plans; Streets and Public Spaces (S&PS); Buildings and Sites (B&S); and Parks and Beaches (P&B). These actions are intended to be complementary to the Transformative Directions in Chapter 5 and will promote the City of Vancouver's transition to a water sensitive city.

The three action plans are briefly described below, while a set of potential sample actions for the S&PS and B&S action plans can be found in Appendix F. The detailed action plans in the appendices describe a suite of implementation and enabling programs associated with each action area. The lists of sample actions were gathered through Rain City Strategy engagement activities to inform the scoping and development of each program.

Initial start-up funding for several programs within the action plans will be allocated through the existing 2019-2022 Capital Plan and operating budgets. Funding will support resources to scope, evaluate and develop programs in the short term. Beyond 2022, funding will be assessed based on each program with the development of sustainable funding models and financial planning for long-term implementation.

In the sections below are overviews of the programs in each Action Plan.

7.1 Streets and Public Spaces Action Plan

The Streets and Public Spaces (S&PS) Action Plan will to be led by the Engineering Services Department in collaboration with other departments. A collaborative effort will advance the implementation of green rainwater infrastructure (GRI) on streets and public spaces to achieve the targets set in Chapter 6.

Streets and public spaces make up approximately 30% of the city's total area, and they represent over 37% of the city's total impervious area. Vehicles on our streets release heavy metal pollutants, such as copper and zinc that can get picked-up in urban rainwater runoff and conveyed into our receiving waters. In addition, streets themselves have an important drainage function for overland rainwater flow in the city. As such, managing rainfall on streets and public spaces is critical to achieving the rainwater management targets.

The Implementation Programs in the S&PS action plan are aimed at embedding GRI into the planning, design and delivery of all new capital projects across the city – making GRI the new 'business as usual'. In addition, the action plan aims to foster implementation of GRI retrofits in new and innovative ways. This will result in a wide range of benefits in terms of water quality, flood and CSO mitigation, and enhanced experiences within our streets and public spaces. The action plan is also focused on developing tools and streamlining internal processes to manage GRI assets. These efforts will include life cycle asset management and how these practices are operated and maintained over their lifetimes.

The S&PS Action Plan will be supported by eleven implementation and five enabling programs (see Table 6). These programs will identify sustainable long-term funding sources for capital delivery and asset management, support research to better understand emerging rainwater management issues and GRI solutions, and facilitate capacity building and education amongst the public.

TABLE 6: STREETS & PUBLIC SPACES ACTION PLAN

Streets & Public Spaces		
Implementation Programs		
S&PS-01	**New Capital Projects Green Rainwater Infrastructure Integration Program**	Expand the implementation of green rainwater infrastructure beyond the existing opportunistic approach by making its implementation standard practice by developing and adopting design standards, targets, guidelines, capital and lifecycle financial plans and internal processes. These tools shall be used to facilitate the implementation of green rainwater infrastructure in new capital projects in streets and public spaces.
S&PS-02	**Strategic Retrofits Green Rainwater Infrastructure Program**	Expand the implementation of green rainwater infrastructure beyond the existing opportunistic approach by developing and adopting design standards, targets, guidelines, capital and lifecycle financial plans and internal processes to facilitate retrofitting existing streets and public spaces with green rainwater infrastructure.
S&PS-03	**Blue-Green Systems Program that Enable Water Management and Biodiversity Program**	Implement green rainwater infrastructure along streets and public spaces as an integral part of blue-green systems. These systems optimize rainwater management from adjacent streets, increase urban forest cover and provide corridors for enhanced biodiversity and wildlife connectivity. Pilot and demonstration projects will be implemented to determine how to best integrate and align these with the city's active transportation routes. The findings from these pilot and demonstration projects shall be applied to streamline the delivery of blue-green systems across the city.
S&PS-04	**Permeable Pavement Program**	Undertake research to assess the opportunities, barriers, lessons learned and business case for the use of permeable pavement on the city's streets and public spaces. Use research findings to develop and implement a program to facilitate the effective design, construction and maintenance of permeable pavement.

S&PS-05	**Laneway Rehabilitation & Retrofit Program**	Undertake research to assess the opportunities, barriers, lessons learned and financial tools and mechanisms for retrofitting laneways to enable them to manage rainwater runoff and potentially adjacent private properties. Use research findings to develop and implement a retrofit program with new laneway typologies and integrate green rainwater infrastructure into existing city rehabilitation programs.
S&PS-06	**Green Rainwater Infrastructure Pilot and Demonstration Project Program**	Implement innovative green rainwater infrastructure practices at select locations in streets and public spaces. Document lessons learned during the design and construction of the practices as well as performance monitoring data and incorporate learnings as part of an adaptive management process to enhance the ongoing delivery of green rainwater infrastructure.
S&PS-07	**Streets and Public Spaces Adjacent to Schools Green Rainwater Infrastructure Retrofit Program**	Work with school district and schools to explore potential opportunities for engaging students to learn and be part of the water cycle by implementing and maintaining green rainwater infrastructure on streets and public spaces adjacent to school grounds.
S&PS-08	**District Scale Non-potable Water Systems Program**	Undertake research to assess the business case, opportunities and barriers for district scale non-potable water systems in Vancouver. Develop and modify policies to enable the development of safe and well-regulated district scale non-potable water systems.
S&PS-09	**Green Rainwater Infrastructure Asset Management Program**	Clarify green rainwater infrastructure asset management roles and responsibilities with partners, including asset stewardship and maintenance responsibilities. Identify sustainable funding mechanisms and develop plans to finance the management of assets over their life cycle. Streamline internal processes and adopt standards to facilitate the management of green rainwater infrastructure assets to preserve and optimize their service life.
S&PS-10	**Green Rainwater Infrastructure Operation and Maintenance Program**	Work with partners to investigate service delivery models for green rainwater infrastructure operation and maintenance, including the potential for a stewardship-based model. Identify sustainable funding mechanisms and develop plans to finance operation and maintenance activities. Select the preferred service delivery model and streamline internal processes to enable the effective operation and maintenance of green rainwater infrastructure that preserves and extends their level of service.

S&PS-11	**Sediment Management and Source Control Program**	Work with partners to develop and adopt a holistic program for limiting and managing sediment deposited on streets and public spaces and captured by green rainwater infrastructure practices, drains, catchbasins and sewers. Identify potential sources and 'hot spots' for sediment and how to better manage these to protect sediment accumulation on streets and public spaces and to ensure that green rainwater infrastructure practices are protected from heavy sediment loads.
Streets & Public Spaces		
Enabling Programs		
S&PS-12	**Citywide Green Rainwater Infrastructure Financial Planning and Sustainable Funding Program**	Identify sustainable sources of long-term funding for green rainwater infrastructure, including funding sources associated with pollutant generation. Use funding source(s) to develop and implement a holistic financial plan that encompasses capital costs, asset management and operation and maintenance to enable green rainwater infrastructure implementation in capital projects and retrofits in streets and public spaces. Undertake research to develop a business case to identify funding requirements to manage these assets to preserve and extend their service life and level of service.
S&PS-13	**Research and Innovation Program**	Continuously improve ways of managing rainwater by undertaking research and keeping up-to-date on innovations in the green rainwater infrastructure sector. Contribute to industry best practice and innovations in the sector by reporting monitoring data and analysis and lessons learned at conferences and workshops.
S&PS-14	**Shift in City Process & Capacity Building**	Facilitate a shift in city culture and process to enable the successful implementation of green rainwater infrastructure. Encourage this shift through greater cross-departmental collaboration and updating internal processes to improve coordination and alignment. Staff knowledge and capacity to support the implementation of green rainwater infrastructure will be strengthened through training, standards, guidelines and other approaches and tools.

S&PS-15	**Industry Capacity Building & Public Engagement**	Facilitate capacity building amongst developers, designers and contractors to share knowledge regarding the City's design standards, guidelines and industry best practices for implementing green rainwater infrastructure in the City's new capital projects. Engage with practitioners and the public to raise awareness of rainwater management, climate change and green rainwater infrastructure, empowering them to take positive actions and be environmental stewards in their community.
S&PS-16	**Water Quality Monitoring Program**	Work with partners to continue and enhance stormwater and combined sewer overflow monitoring for quantity and quality across the city and use the data to prioritize and inform green rainwater infrastructure implementation and other water quality initiatives.

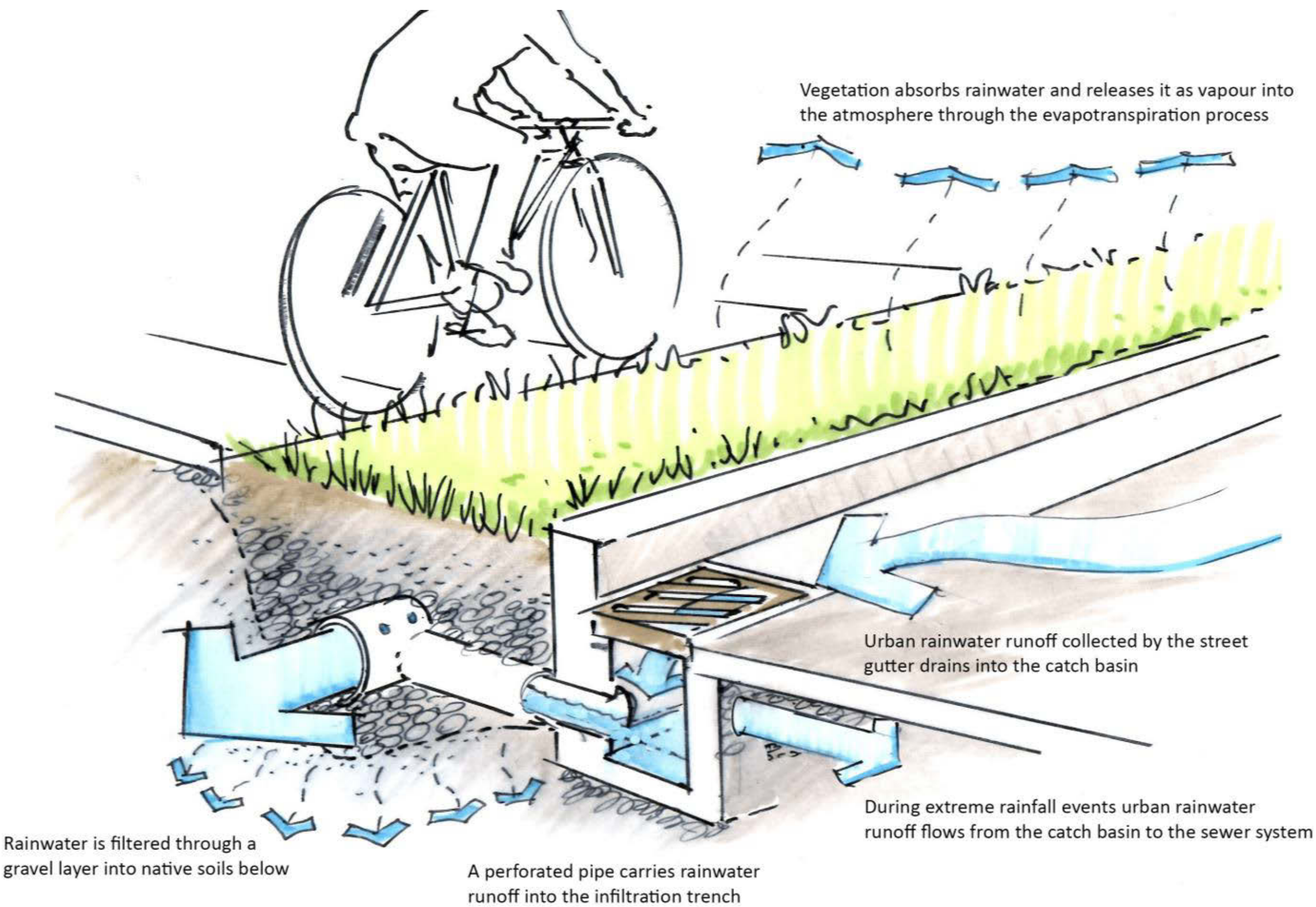


FIGURE 50: STREET SUBSURFACE INFILTRATION

7.2 Buildings and Sites Action Plan

The Building and Sites (B&S) Action Plan will be led by the Planning, Urban Design and Sustainability Department (PDS) and the Development, Buildings and Licensing Department (DBL). The two departments will work with other City departments, the Vancouver Board of Parks and Recreation and other provincial and municipal entities to advance the implementation of GRI on publicly owned buildings and sites, and will work collaboratively with the community and industry to advance the implementation of GRI on privately owned buildings and sites. In addition, this work will be performed in close collaboration with the City's Engineering Services Department as actions in the private realm have critical implications for public infrastructure and servicing.

Private properties make up 62% of the city's impervious areas mostly through roof tops, hardscapes and parking areas. Some types of properties have high infiltration potential such as single family lots, while others with underground structures such as parkades must rely on other rainwater management strategies. Fortunately, there are GRI and integrated grey-green solutions for all types of densities and building forms. Given the high percentage of impervious areas in the private realm, pairing GRI on buildings and sites with efforts in streets and public spaces and parks and beaches, is critical to achieving the targets set out in the Rain City Strategy.

It is becoming standard practice in many cities across North America to have GRI programs and set requirements for new developments and sites, as well as for existing buildings. Ensuring that private properties share responsibility for managing water on site to limit discharge into the public sewer and drainage system is a key part of a cities' ability to deliver cost-effective public drainage services. The benefits of GRI are manifold: less urban rainwater runoff, cleaner water leaving a site, cooler and more comfortable buildings, enhanced gardens and green space and support for biodiversity.

The overall approach proposed for advancing GRI on buildings and sites is similar to programs used to successfully advance energy efficiency in buildings. The approach is as follows:

1. Providing clear and consistent regulations that are balanced appropriately with other City objectives;

2. Encouraging and enabling early adopters to "do the right thing" and share their learnings with others;

3. Supporting residents, businesses and developers with the tools, information and resources needed to implement GRI based on sound engineering principles and best practices;

4. Demonstrating corporate leadership by integrating GRI as part of all new and existing City-owned facilities; and

5. Apply a step code approach to implement the updated rainwater management targets of all private property.

This approach will enable GRI to be implemented in a progressive manner, building on research, lessons learned and measured results over time. In order to advance priority areas, such as blue-green roofs and rainwater harvesting and reuse, the City of Vancouver will work collaboratively internally and externally with a range of partners. The B&S Action Plan will be supported by seven Implementation and five Enabling Programs and two Linked (Complementary) Programs.

A list of the programs is shown in Table 7.

TABLE 7: BUILDINGS & SITES ACTION PLAN

Buildings & Sites		
Implementation Programs		
B&S-01	**Advance Rainwater Management Policies and Regulations — Supporting Implementation Through New and Existing Policies and Regulations**	Facilitate the integration of green rainwater infrastructure through the refinement of existing policies and regulations such as the Green Buildings Policy for Rezonings and the Sustainable Large Developments Policy for Rezonings and through the development of additional policies and regulations.
B&S-02	**Improve Review and Compliance of Rainwater Management Plans — Bolstering the Internal Review Process to Ensure the Targets of Rain City are Being Achieved on Buildings & Sites**	Strengthen the review processes within the rezoning, development and building permit stages to ensure efficiency, validate compliance, and improve outcomes. Ensure continuity between design, construction and occupancy stages.
B&S-03	**Single Family Dwellings, Laneway Homes, and Townhouses — Assessing New & Existing Building Opportunities**	Engage key stakeholders, including home builders, designers and public, to evaluate opportunities and develop incentive programs and regulations, as appropriate, to implement green rainwater infrastructure in new and existing Part 9 buildings (simple structures).
B&S-04	**Mid- and High-Rise Structures — Assessing New & Existing Building Opportunities**	Engage industry to evaluate opportunities and develop incentive programs and regulations to integrate green rainwater infrastructure in new and existing Part 3 buildings (complex structures) not already captured through existing policies.
B&S-05	**Rainwater Harvesting Program — Building on Existing Policy**	Implement inspections of new and existing rainwater harvesting systems under the Council-approved Operating Permit program to protect public health and verify compliance.
B&S-06	**Resilient Roofs Program**	Examine policy and program options for resilient, blue-green roofs (and variations therein) for new and existing buildings, integrating learnings from "Research and Innovation." Ensure roofs are used most effectively, based on building form, use, and characteristics of the area.
B&S-07	**Civic Facilities — Demonstrating Corporate Leadership**	Continue to implement innovative practices in city-owned buildings. Document lessons learned from the design, construction and operations of innovative green rainwater infrastructure already installed at civic facilities. Study performance through monitoring and incorporate learnings to enhance delivery and inform potential green rainwater infrastructure policies and programs.

Buildings & Sites		
Enabling Programs		
Capacity Building and Engagement		
B&S-08	**Public Engagement and Activation — Empowering Positive Community Action**	Engage with the public to raise awareness of rainwater management, climate change and green rainwater infrastructure, empowering positive action in the community.
B&S-09	**Industry Capacity Building — Fostering Industry Excellence**	Facilitate capacity building amongst developers, designers and contractors to share knowledge regarding design standards, guidelines and industry best practices for implementing green rainwater infrastructure.
Monitoring and Evaluation		
B&S-10	**Monitoring, Data Analysis and Metrics — Assuring an Evidence-Based Approach**	Monitor, measure and analyze data to facilitate a robust, evidence-based approach to policy and program development. Use reliable data to prioritize efforts and highlight areas for improvement. Consider neighbourhood and watershed-level metrics such as impermeable area, extent of sewer separation and degree of effective connectivity. Evaluate metrics quantifying the relative flows from Streets & Public Spaces, Buildings & Sites and Parks & Beaches to focus efforts effectively.
Research and Innovation		
B&S-11	**Infiltration — Evaluating Geotechnical and Building Foundation Aspects**	Assess infiltration opportunities and barriers within the Vancouver context.
B&S-12	**Resilient Roofs with Water Management Capabilities — Assessing Opportunities and Barriers**	Evaluate the engineering implications, business case, opportunities, barriers and lessons learned (including actual outcomes) for resilient, blue-green roofs (and variations therein) for new and existing buildings. Consider the context of potentially competing roof-top demands such as building mechanical equipment.
Linked (Complementary) Programs		
B&S-13	**Non-Potable Water Systems — Evaluating Public Health and Engineering Aspects**	Develop policies to facilitate the implementation of safe and well-maintained non-potable water systems in Vancouver.
B&S-14	**Reduce Sanitary Discharge to Sewer — Maximizing Existing Sewer Capacity Cost-Effectively**	Continue to implement water conservation and efficiency efforts to drive down sanitary loads from building and sites. Create capacity to manage rainwater within the existing combined sewer infrastructure by reducing sanitary discharges (including groundwater, condensate, etc.).

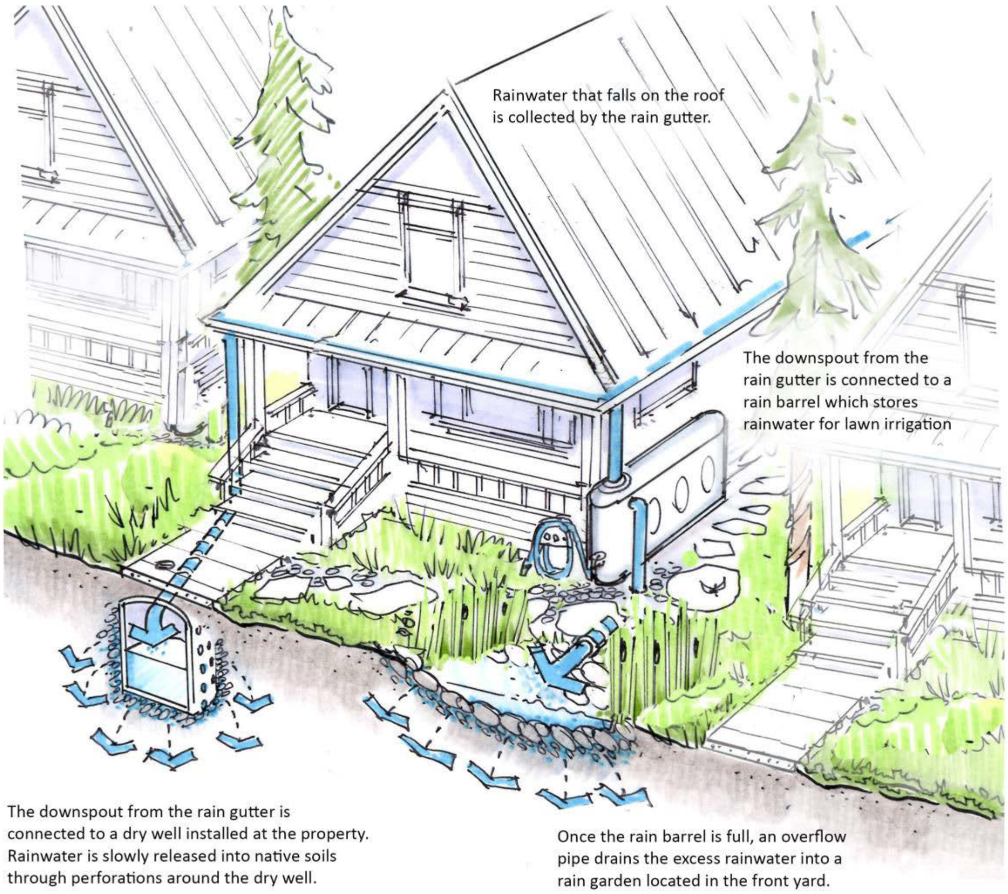


FIGURE 51: RESIDENTIAL DOWNSPOUT DISCONNECTION

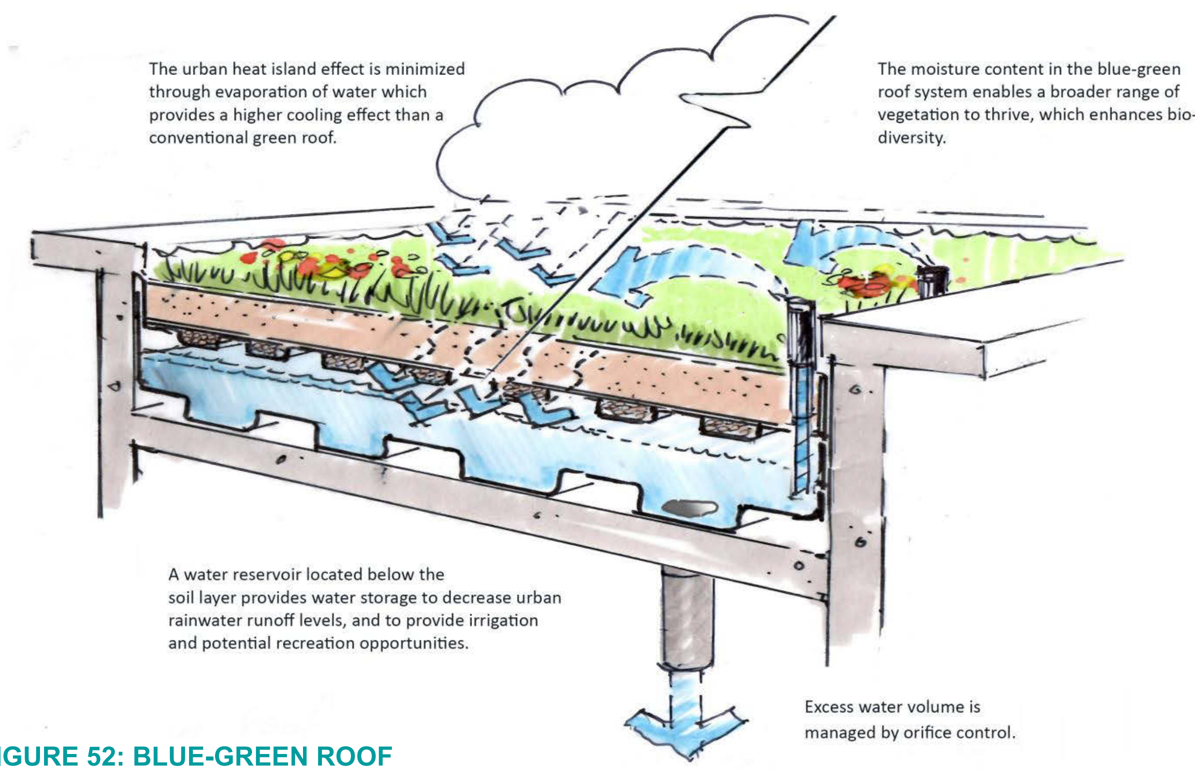


FIGURE 52: BLUE-GREEN ROOF

7.3 Parks and Beaches Action Plan

The Parks and Beaches (P&B) Action Plan will be led by the Vancouver Board of Parks and Recreation. In addition to providing cooler public spaces and clean and healthy waterbodies, their experience is crucial to implement GRI on park land, and achieve the targets set in the Rain City Strategy and other key policy directives. The programs listed here promote opportunities for new parks, natural areas, wetlands, enhanced urban forests and sustainably drained sports fields.

Climate change and what it means in terms of dealing with either too much or too little water in the future means rainwater management will need to align closely with the Park Board's priorities and core park-provision mandate.

Increased intensity and duration of rainfall events pose an immense challenge that without purposeful planning, will likely affect the Park Board's core mandate which is to "provide, preserve, and advocate for parks and recreation services" in Vancouver. These events can damage park assets, limit their use and can be costly to restore, repair and rehabilitate. During extended heat and drought periods, water availability for Park Board operations and adequate supply for plants, trees and natural systems is paramount. Replenishing groundwater sources and supporting opportunities for harvest and reuse will increase water security and resilience within park systems.

These citywide objectives are achieved at the site level through best practices in park design and construction. In Vancouver, these best practices have already begun to be implemented. For example, the protection and enhancement of natural areas in Everett Crawley Park, green rainwater infrastructure in park design in Riley Park, water-efficient and drought tolerant landscape design and the maximizing pervious surfaces. The P&B Action Plan will be supported by twelve implementation and four enabling programs.

A list of the programs is shown in Table 8.

TABLE 8: PARKS & BEACHES ACTION PLAN

Parks & Beaches		
Implementation Programs		
P&B-01	**Green Rainwater Infrastructure Integration into Park Development Standards**	Develop new and/or modify existing Park Development Standards, Standard Technical Specifications and Best Management Practices to facilitate the integration of green rainwater infrastructure in parks, beaches and recreational spaces. Ensure that new and modified standards, specifications and best management practices adopt the provincially-mandated Citywide Integrated Rainwater Management Plan, including the IRMP's rainwater management design standard and performance target. This initiative will be guided by high-level principles, which shall be developed and adopted to inform an integrated water management approach across all parks, beaches and recreational spaces.
P&B-02	**Protect and Enhance Park Service Levels through Green Rainwater Infrastructure Retrofits**	Explore opportunities to integrate green rainwater infrastructure retrofits in parks, beaches and recreation spaces to address drainage issues and manage areas prone to surface water ponding and flooding and to enhance park biodiversity and visual amenities. Ensure that green rainwater retrofits on parks, beaches and recreation spaces protect, and ideally enhance, service levels.
P&B-03	**Non-potable Water Systems and Water Conservation & Efficiency**	Explore opportunities for the use of non-potable water systems, and water conservation & efficiency to reduce potable water use and reduce park discharges to the city's sewer and drainage system. Retrofit and new capital project opportunities to pursue include the use of non-potable water systems for irrigating parks and recreation areas, implementing re-circulating systems on splash pads and water features, and the use of smart controls to minimize discharges to the sewer system from non-critical water features during combined sewer overflows. This work shall include developing policies, design, operation and maintenance standards to ensure the safe and well-regulated use of these measures to ensure the health and wellbeing of park and recreation area users.
P&B-04	**Green Rainwater Infrastructure Integration into Playing Fields**	Undertake research to identify opportunities to update playing field design standards to incorporate green rainwater infrastructure as part of enhancing playing field drainage and improving field service levels. Retrofit an existing playing field or identify a playing field under development for a pilot / demonstration project that incorporates green rainwater infrastructure. Monitor the performance of pilot/demonstration project(s) and incorporate lessons learned to inform future playing field projects.
P&B-05	**Parks and Recreation Spaces Climate Change Adaptation Program**	Undertake research to identify risks to parks and recreation areas associated with drainage, flooding and drought and how these will be impacted by climate change. Develop and adopt more holistic way of planning, delivering and managing water resources, utilities and green rainwater infrastructure as part of achieving VanPlay's Goal #5 - adapt parks and recreation spaces to a changing climate.

P&B-06	**Create a Green Network that will Connect our Parks, Waterfront and Recreation Areas**	Work citywide to implement a layered GRI, human and ecological network to help achieve VanPlay Goal #6 to create a green network to connect parks, waterfronts and recreation spaces. Utilize pilot and demonstration green network projects to determine how to best integrate green rainwater infrastructure and deliver benefits through these networks and apply findings to enhance their delivery across the city.
P&B-07	**Enhanced Urban Forest Program**	Undertake research to understand how green rainwater infrastructure can help protect, grow, and manage trees to create a diverse, resilient, and beautiful urban forest across the city. Use findings to guide the implementation of green rainwater infrastructure capital and retrofit programs that enhance the city's urban forest cover.
P&B-08	**Enhanced Park Biodiversity Program**	Undertake research to understand the biodiversity benefits associated with green rainwater infrastructure and use findings to enhance the delivery of the Park Board's Biodiversity Strategy. Green rainwater infrastructure practices shall be used as part of improving the quality of Vancouver's natural areas and to support biodiversity and increase access to nature.
P&B-09	**Minimize Impervious Surfaces within Parks and Recreation Spaces**	In new and existing parks, implement Park Board design best practices, such as permeable pavement and other green rainwater infrastructure practices to minimize impervious surfaces and drain impervious surfaces to green rainwater infrastructure practices to enhance how rainwater is managed.
P&B-10	**Multi-stakeholder Land Acquisition for Rainwater Management and Park Use in Key Watershed Areas**	Contribute to a reduction in paved surfaces and associated rainwater runoff as well as provide a location for the management of rainwater and park amenity space through land acquisition across the city. Work with partners to find synergies for the acquisition of new land in areas with critical drainage or flooding issues, urban heat island issues and other concerns, and use this land for rainwater management and recreational use.
P&B-11	**Green Rainwater Infrastructure Operation and Maintenance and Asset Management**	Identify sustainable funding mechanisms and develop plans to finance the management of green rainwater infrastructure assets in parks, beaches and recreation areas including operation and maintenance over their life cycle. Implement an effective operation and maintenance program for green rainwater infrastructure assets that preserves and extends their level of service and their service life.
P&B 12	**Protect and Enhance Beaches and Waterfront Program**	Work in partnership with Indigenous Peoples, other levels of government and stakeholders to protect and enhance the city's beaches and waterfront through improvements to rainwater quality and reduction of combined sewer overflows into waterways. Seek opportunities to implement green rainwater infrastructure to enhance recreational uses of beaches and the waterfront, improve aquatic habitat for fish and wildlife and help mitigate and adapt to impacts associated with climate change.

Parks & Beaches		
Enabling Programs		
P&B-13	**Citywide Green Rainwater Infrastructure Financial Planning and Sustainable Funding Program**	Identify equitable sources of long-term funding for green rainwater infrastructure, including funding sources associated with pollutant generation. Use funding source(s) to develop and implement a holistic financial plan that encompasses capital costs, asset management and operation and maintenance to enable green rainwater infrastructure implementation in capital projects and retrofits in parks, beaches and recreation spaces. Undertake research to develop a business case to identify funding requirements to manage these assets to preserve and extend their service life and level of service.
P&B-14	**Research and Innovation Program**	Continuously improve ways of managing rainwater in parks, beaches and recreation spaces by undertaking research and keeping up-to-date on innovations in the green rainwater infrastructure sector. Contribute to industry best practice and innovations in the sector by reporting monitoring data and analysis and lessons learned at conferences and workshops.
P&B-15	**Shift in Park Board Process & Capacity Building**	Facilitate adaptation of Park Board processes to enable the successful implementation of green rainwater infrastructure. Encourage this shift through greater collaboration and updating internal processes to adapt to a changing environment. Staff knowledge and capacity to support the implementation of green rainwater infrastructure will be strengthened through training, standards, guidelines and other approaches and tools.
P&B-16	**Industry Capacity Building & Public Engagement**	Facilitate building capacity amongst designers and contractors by communicating Park Development Standards, Standard Technical Specifications and Best Management Practices applicable to implementing green rainwater infrastructure in new parks capital projects. Achieve the Park Board's VanPlay Goal #7 to engage with industry professionals, designers, and contractors through environmental stewardship and educational programs to build awareness on how green rainwater infrastructure integrates with wild spaces and vital biodiversity across the city's parks, beaches and recreational spaces.

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Chapter 8.

Next steps

Sustainable, resilient and equitable urban water solutions are no longer a choice. Developing new approaches to rainwater management is necessary to create a Vancouver that is attractive, inclusive, swimmable, fishable, healthy, connected, resilient and in essence a place where people and wildlife can thrive.

8.1 Adaptive management

We live in a time of great change and uncertainty around climate change, its effects and appropriate responses. Yet, there is a tremendous opportunity to connect water resource management with climate adaptation solutions so we can manage our water a resource to be valued and protected. As a result, we require solutions that are thoughtful, sustainable and equitable to continue improving the quality of life and wellbeing for all.

Transitioning to become a water sensitive city involves working hard to find synergies between water utility servicing, community planning and urban design. Reaching our goals will require the willingness to breakdown silos, build partnerships, explore new technologies and approaches, and link learning with policy development and green rainwater infrastructure (GRI) implementation. Inherently, the transition to a water sensitive city also calls for curiosity, innovation and courage to admit uncertainty and embrace lessons from successes and failures.

Learning together, through demonstration projects and partnerships with other levels of government, business, industry, academia, non-profits and others, is essential to advance the field of urban water management and GRI implementation. We must find a balance between taking time to gain knowledge to improve our urban water management policy directions and GRI implementation approaches, while achieving beneficial short-term results based on current data and knowledge.

Therefore, progress towards achieving the targets set out in this strategy will be reported annually through the Greenest City Action Plan Update reporting structure.

Tracking progress however, is not enough. As the field of rainwater management through GRI is a relatively new and emerging field of practice, continuous learning and evaluation is essential. To this end, the Rain City Strategy encourages the City of Vancouver and others actively helping to meet the goals and objectives of the strategy, to develop and adopt innovative and adaptive management approaches.

Adaptive management is an iterative process, driven by flexibility and adaptability. Incorporating this approach in planning, design and implementation of urban water management and GRI must change over time. These changes will result from learning and evaluating experiences, and adapting to political, economic, social and environmental changes. Thus, policy development and implementation becomes an ongoing process, designed to be nimble and agile. In addition, allowing for shifts in plans, programs, processes, design approaches, as needed, through our learning and maturation of practices in Vancouver, the region, and elsewhere.

Establishing learning and evaluation structures to pivot our policy development and decision-making process takes time, commitment and further exploration. It requires thoughtful consideration of how to measure the effects of implementation, beyond reporting out on progress of installation of GRI. It requires strong metrics and indicators that help us better understand how our efforts are helping to achieve desired outcomes. For example evaluating how GRI is reducing the risk of flooding, improving water quality, enhancing micro-climates and social values. This is not always easy to measure, and may require additional efforts to identify how our actions have contributed to improvements of natural and urban environments.

The first steps of an adaptive management practice involve developing systems for data collection, analytics, modeling and performance monitoring of GRI. In addition, management practices require updating existing governance structures and process in place to allow for proactive learning, fostering partnerships and building capacity. These first steps have been addressed in the Transformative Directions Action Plan, T-06, T-07 and T-08.

8.2 Conclusion

The Rain City Strategy is calling for a shift in our urban water management strategies to include a more holistic and integrated approach in the context of a changing climate, aging infrastructure, and challenges around water quality, livability, equity and cost efficiency.

GRI has a critical role to play, not only managing our urban water challenges, but also in making water-related investments that increase value-for-money and yield a range of social, environmental and economic benefits including:

- Mitigating flooding;
- Improving water quality;
- Reducing pollution;
- Improving air quality;
- Enhancing biodiversity and habitat;
- Sequestering carbon;
- Reducing urban heat island effects;
- Enhancing the experience of the public realm;
- Reducing mental health issues; and
- Offering workforce development opportunities.

Business-as-usual and even an incremental, opportunistic approach to GRI implementation is not enough to meet the needs of the future. Scaling up our GRI implementation is needed to meet our rainwater management and climate adaptation needs in a more cost-effective and equitable way. Investments made in GRI have a profound impact on public health, well-being, intergenerational equity and the future resilience of the city and region.

Shifting the city's water management paradigm towards one that respects and values water as a valuable resource for people and ecosystems represents a unique opportunity to advance the foundational concepts of reconciliation. Through thoughtful, holistic and meaningful consideration of the cultural implications of water management, the Rain City Strategy can contribute to the on-going process of reconciliation with the Musqueam, Squamish and Tsleil-Waututh Nations and urban Indigenous communities.

Striving to become a water sensitive city means we will need to transition our community planning, urban design, sewer and drainage infrastructure, streets, public spaces, buildings and parks to consider and value our water resources. We need to reframe our understanding of the benefits GRI brings in terms of realizing funding streams, removing legal and regulatory barriers, building partnerships, and creating internal, industry and community capacity to maximize the skill sets of everyone involved.

The work ahead will continue our transition towards a water sensitive city. The next years are focused on scoping the implementation and enabling programs outlined in the Streets & Public Spaces, Buildings & Sites, and Parks & Beaches Action Plans, while continuing to implement GRI projects across the city.

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Glossary

Aquifer: a layer of permeable material below ground where groundwater can be transmitted and stored

Artesian aquifer: a layer of pressurized water captured between layers of underground rock *(For technical definition, see the Vancouver Building Bylaw)*

Bioretention: a type of green rainwater infrastructure that captures and cleans urban rainwater runoff. It typically consists of a shallow depression or basin that features layers of rock, engineered soils, and resilient vegetation that can tolerate periods of inundation and drought

Bioswale: a type of green rainwater infrastructurethat is a linear form of bioretention practice

Blackwater: wastewater which includes human waste and requires the highest level of treatment to return to a clean or usable state *(For technical definition, see the Vancouver Building Bylaw)*

Blue-green systems: Networks of park-like corridors that manage water, contribute to the urban forest, and provide active transportation routes. Blue-green systems seek to protect the ecological, hydrological, and social values of the urban landscape and water cycle, and to provide resilient measures to address climate change and flood management, increase connectivity, and enhance access to nature.

Carbon sequestration: absorbing and holding carbon dioxide, usually in plants and soils, to prevent its contribution to climate change

Catch basin: a drain or storm sewer that drains excess rainwater from impervious surfaces such as roads, parking lots, sidewalks, and roofs into the sewer and drainage system *(For technical definition, see the Vancouver Building Bylaw)*

Catchment area: is the area from which rainwater flows into or through a green rainwater infrastructure asset.

Climate adaptation: actions taken to respond to the impacts of climate change by taking advantage of opportunities or reducing the associated risks.

Climate mitigation: ongoing efforts to limit climate change through the reductions of greenhouse gases emissions into the atmosphere.

Climate resilience: the ability to absorb stresses and maintain function, and to adapt and evolve in the face of impacts from climate change.

Combined sewer overflows (CSOs): events when a combined sewer is over capacity and releases a mixture of rainwater and sewage into receiving waterbodies.

Combined sewers: a type of sewer system in which one set of pipes carries both sanitary sewage and urban rainwater runoff. *(For technical definition, see the Sewer and Watercourse By-law).*

Detention: the temporary holding of rainwater, before controlled release into the sewer and drainage system.

Drainage system: a system of gutters, pipes, drains or catch basins, and green rainwater infrastructure that together manages urban rainwater runoff. *(For technical definition, see the Vancouver Building By-law).*

Ecological justice: a fair and equitable distribution of environmental benefits and burdens. Meaningful involvement of all people regardless of race, color, national origin, or income with respect to the management of natural resources and the development, implementation, and enforcement of environmental laws, regulations, and policies.

Ecosystem services: Ecosystem services are the many and varied benefits that humans, as well as other living organisms depend upon that are provided by the natural environment and properly-functioning ecosystems.

Equity: providing everyone with what they need to be successful, acknowledging the variation in needs and barriers faced by different people or groups.

Evapotranspiration: the process by which water is transferred from the land to the atmosphere by evaporation from the soil, tree canopy interception and other surfaces and by transpiration from plants.

Fit-for-purpose water use: water whose quality meets, but does not exceed, the required cleanliness levels for a given use.

Green rainwater infrastructure (GRI): a suite of rainwater management tools that use both engineered and nature based solutions to protect, restore, and mimic the natural water cycle.
(For technical definition, see the Rainwater Management Bulletin).

Green roof: is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane.
(For technical definition, see the Vancouver Building By-law).

Blue-green roof: combines blue and green roof technologies. A blue-green roof is a green roof designed to increase both the volume of water stored underneath the green roof and controls the amount of water released.

Grey-green infrastructure: a rainwater management approach that uses both green rainwater infrastructure and grey infrastructure tools together as a system.

Greenhouse gases: gases which cause the greenhouse effect, which trap heat inside the Earth's atmosphere and accelerate climate change.
(For technical definition, see the Vancouver Building By-law).

Grey infrastructure: human engineered infrastructure for water resources such as water and wastewater treatment plants, pipes, pump stations, and detention tanks.

Greywater: wastewater from sources such as sinks, washing machines, and baths, which has been used, but does not contain human waste.
(For technical definition, see the Vancouver Building By-law).

Groundwater: the water found under the ground in aquifers.
(For technical definition, see the Vancouver Building By-law).

Harvest and reuse: the practice of collecting water previously seen as a waste product (rainwater, greywater, blackwater or groundwater), and finding appropriate uses for it. On-site treatment systems are sometimes included in harvest and reuse systems.

Heavy metals: a group of naturally occurring metals, such as lead and mercury, with relatively high density which are released naturally and through human activities and, depending on concentrations, can be toxic to all forms of life

Hydrocarbons: a chemical compound of hydrogen and carbon, which are the chief components of petroleum and natural gas.

Impermeable surfaces: surfaces that water and other liquids cannot pass through.

Impervious surfaces: see impermeable surfaces.

Infiltration: the permeation of rainwater into the soil.

Integrated water management: an integrated water utility planning approach that takes into consideration the entire urban water cycle, with the mindset that all water has value.

Integrated water utilities: water related services (drinking water provision, wastewater and rainwater management) provided to residents and businesses.

Integrated water utility servicing: See *Water Utilities.*

Intersectionality: the understanding that the impacts of inequity are compounded by all forms of discrimination related to gender, race, disability, language, immigration status, income, age, ability, sexual orientation and more.

Life cycle assessment: a technique to assess the capital, maintenance and operation costs and environmental impacts associated with all the stages of a products life.

Livability: the sum of the factors that add up to a community's quality of life -including the built and natural environments (including functioning infrastructure and utility services), economic prosperity, social stability and equity, public health, educational opportunity, and cultural, entertainment and recreation possibilities.

Natural water cycle: the way in which water continuously moves above and below the earth's surface through the stages of the water cycle in a natural setting.

Nature-based design solutions: design solutions that are inspired and supported by nature, which are cost-effective and simultaneously provide environmental, social, economic benefits and help build resilience.

Non-potable water: is water that is not safe to drink, but can still be used for other purposes, such as to wash a car, flush a toilet or water plants.
(For technical definition, see the Vancouver Building By-law).

Overland flooding: when excessive rainwater flows over land (as opposed to in pipes) and causes flooding.

Peak flow: the volume of rainwater flowing off a site per second during the most intense part of a rain event.

Physical water quality: measures of water quality including temperature, acidity or alkalinity (pH), and turbidity.

Pipe capacity: how much water a pipe is able to safely hold.

Polyaromatic hydrocarbons (PAHs): a chemical compound made up of hydrogen and carbon, which is released by combustion and fossil fuel use and is persistent and toxic.

Potable water: water that is appropriate for drinking, cooking and bathing.
(For technical definition, see the Vancouver Building By-law).

Practice: (noun) used to refer to green rainwater infrastructure projects and assets.

Public space: all places that are publicly owned or of public use, accessible, and enjoyable by all without a profit motive.

Public realm: the parts of a city that can be seen and experienced at eye level, including public spaces, building facades, storefronts, patios, street furniture, public art, roadways and sidewalks.

Rain garden: a form of bioretention green rainwater infrastructure practice.

Rainwater: water which arrives in the form of rain.
(For technical definition, see the Vancouver Building By-law).

Rainwater tree trench: a form of green rainwater infrastructure where space taken up by street trees is used for rainwater management.

Receiving waters: larger bodies of water at the bottom of a watershed into which smaller waterbodies flow. Local receiving waters include Burrard Inlet, the Fraser River, False Creek, English Bay and the Salish Sea.

Reservoir: a large natural or artificial lake used as a source of drinking water.

Resiliency: the capacity to recover quickly from difficulties.

Retention: the capture of rainwater that is returned to the natural water cycle through infiltration, or reused, without entering the sewer and drainage system.

Sanitary sewage: See *Wastewater.*

Sea level rise: the phenomenon by which the level of the oceans in relation to land masses rises due to climate change.

Sediment: particulate matter that is carried by water or wind and deposited on the surface of the land or the bottom of a body of water.

Sediment trap: a device used to remove sediment from urban rainwater runoff.

Separated sewers: a sewer system in which there is two sets of pipes: one for sanitary sewage, and one for urban rainwater runoff.

Sewage: See Wastewater.

Sewer connection: the pipes that connect a building or drain to the sewer.

Sewer system: the system of drains, pipes, pumps, and treatment plants that manage wastewater.
(For technical definition, see the Sewer and Watercourse By-law).

Sewer trunk: a major sewer pipe, usually the largest in a system. In Vancouver, the trunks are mostly owned and operated by Metro Vancouver.

Sewershed: an area of land where all underground sewers are constructed to flow to a common outlet point.

Soil cells: plastic modules that bear the loadings from the surface. Soil fills voids left in the plastic module, and the volume of soil contained in the plastic matrix varies between soil cell manufacturers. Up to 92% void space can be achieved.

Storm drain: See *Catch basin.*
(For technical definition, see the Sewer and Watercourse By-law).

Stormwater: See Urban rainwater runoff.
(For technical definition, see the Sewer and Watercourse By-law).

Structural soil: uses open grade crushed stone to bear the loadings of the surface. Depending on the design, structural soil can be mixed with soil and a stabilizer or consist solely of crushed stone. Up to 30% void space is available.

Surface expression: when elements of green rainwater management are visible above-ground. Usually gardens or specially designed inlets and drains.

Surface water: water bodies such as rivers, lakes, streams, and oceans which sit on the surface of the planet.

Triple bottom line analysis: a cost-benefit analysis tool that takes into account economic, environmental, and social costs and benefits.

Urban design: the process of designing and shaping physical features of cities.

Urban form: the physical characteristics that make up built areas, such as shape, size, density and configuration of settlements.

Urban heat island effect: the increased temperature found in urban areas due to human activity and modification of land surfaces.

Urban planning: is a technical and political process concerned with the development and design of land use and the built environment, including air, water, and infrastructure.

Urban rainwater runoff: rainwater which has landed in an urban area and begun to flow across hard surface, usually quite polluted.

Urban water cycle: the way in which water continuously moves through the stages of the water cycle in cities.

Urban water management: the systems, processes, and tools used to manage all types of water in cities.

Utilities: See *Integrated water utilities.*

Vulnerable communities: Vulnerable communities face historic or contemporary barriers to economic and social opportunities and a healthy environment. The principal factors in community vulnerability are income, race or ethnicity, age, language ability, and geographic location.

Wastewater: the by-product of water use, including water from toilets, showers, hand and dish washing, laundry, and industrial uses. *(For technical definition, see the Sewer and Watercourse By-law).*

Water cycle: the continuous movement of water above and below the earth.

Water equity: when all communities have access to safe, clean, affordable drinking water and wastewater services; are resilient in the face of floods, drought, and other climate risks; have a role in decision-making processes related to water management in their communities; and share in the economic, social, and environmental benefits of water systems.

Water quality: the physical characteristics and cleanliness of water.

Water security: the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks.

Water stress: when individuals and communities face difficulty in accessing water services. It can include inadequate access to drinking water, wastewater, and rainwater services.

Water sensitive cities: a planning concept based on holistic management of the water cycle. It seeks to protect and enhance the health of receiving waterbodies, reduce flood risk, and create spaces that harvest and reuse water. It integrates water management and urban planning in order to facilitate livability and equity outcomes more broadly.

Watershed: a distinct hydrologically-defined geographic unit, within which all waterways such as creeks, streams and rivers drain to a common outlet point.

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