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DESIGNING A LIVING ROOF WEBPAGE

Prepared For: Gord Tycho, Senior Sustainability Planner – City of Vancouver

Prepared By: Michael Peterson, UBC Sustainability Scholar, 2022

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"If we steal the ground for a building,

we can give it back to nature on the roof"

– Wolfgang Ansel

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Vancouver is situated in the middle of a temperate rainforest, which is characterized by high amounts of rainfall and a relatively mild climate. In Vancouver, the average annual rainfall is about 2,351 mm (93 inches) (Climate Data, 2022). A high amount of rain and the proximity to the Pacific coast means that Vancouver has an intimate relationship with the rainwater cycle. Rainwater management plays an important role in maintaining the city's infrastructure and activities, limiting pollution, mitigating the urban heat island effect, and preserving natural habitats.

Project Background

The City of Vancouver developed the Rain City Strategy (RCS) to achieve the goals of improved water quality, increased resilience, and enhanced livability. This ambitious approach treats rainwater as a valuable resource and mimics the natural hydrologic cycle by capturing and treating rainwater where it lands using green rainwater infrastructure (GRI). GRI includes green and blue/green roof systems, rainwater reuse systems, and ground infiltration systems. The RCS also introduced specific rainwater management performance targets. It is anticipated that green and blue-green roofs will play an important role on some private sites in achieving these targets.

Implementation of the RCS is divided into three city 'realms': Parks and Beaches (P&B), Streets and Public Spaces (S&PS), and Buildings and Sites (B&S). Of the many Implementation and Enabling Programs within the B&S Action Plan, three, in particular, have provided a rationale for this research project:

- B&S 06/12: Resilient Roofs Program;
- B&S 08: Public Engagement and Activation; and
- B&S 09: Industry Capacity Building (e.g. create industry expertise through knowledge sharing for best practices).

The City intends to develop, at a future date, a Living Roof Information Portal to help promote green roof utilization, address common implementation barriers/requirements, minimize roof failures, and enhance co-benefits, thereby resulting in the construction and ongoing maintenance of higher quality green and blue-green roofs in the City. The Portal is envisioned to include a dedicated webpage, guidelines document, and other supporting tools.

This project intends to support Portal development by researching best practices of living roof webpages and living roof design guidelines from other exemplary jurisdictions to achieve the following goals:

- Brief background summary overview of green and blue-green roof systems (summarized with profile graphics and a table) with reference to:
    - Roof Categories (extensive, semi-intensive, intensive, other),
    - Roof System components and functions (e.g. roof deck, insulation, moisture barrier, root barrier, growing medium/soil type and depth, plants, other) that contribute to performance,

    - Roof Ecosystem services/co-benefits (rainwater management, biodiversity enhancement, carbon sequestration, provision of amenity space, property value uplift, etc.),
    - Indicators used to measure and assess green and blue-green roof performance,
    - Common implementation barriers/challenges (i.e. issues to consider when wanting to avoid installation and maintenance failures);
- Review of current green roof-related COV Bylaws, Policies, Bulletins, Guidelines, and Standards to identify gaps and opportunities for a potential future COV resource Portal;
- Confirmation of staff-proposed Search Criteria to guide selection and review of information sources;
- Best practices jurisdictional review of approximately four to six jurisdictions with applicable information sources on green and/or blue-green roof webpage content, guidelines (design, installation, maintenance), and standards.
    - The review shall reflect Search Criteria requirements. One information source must include Guidelines for the Planning, Construction, and Maintenance of Green Roofs (FLL, 2018),
    - Time permitting, this review may include interviews with knowledge holders;
- Recommendations (and, where applicable, brief supporting rationale) on topics and the actual content of particular websites, guidelines, and standards most suitable for the City to consider or include when developing our own Portal, including specific references to:
    - COV Webpage (suggested Topic List, suggested content from other jurisdictions to be considered for inclusion under each topic, brief commentary on suggested layout/graphic design characteristics (the organization, look, and feel of the webpage, etc.)),
    - COV Guidelines (suggested Topic List, suggested content from other jurisdictions to be considered for inclusion under each topic – should address issues applicable to the four roof types), and,
    - COV Design Standards (what drawing types should populate the drawing package, and suggestions for any particular drawings from other jurisdictions to be considered for inclusion);
- Time permitting, develop a conceptual organization and actual write-up of the proposed COV webpage content;
- Provide any recommendations for further studies (research, best practices, or in situ) to support the development of a COV Portal (Webpage, Guidelines (design, installation, maintenance), and Standards).

Introduction to Living Roofs

Living roofs (otherwise known as green roofs, blue roofs, blue-green roofs, and eco-roofs are defined as the roof of a building that is partially or completely covered with vegetation, a growing medium and installed over a waterproofing membrane (Droguett, 2011).

Living roofs fall into three major categories (extensive, semi-intensive, intensive). Each of these systems contains the following layers (in general):

- Plants/vegetation
- Engineered growing media
- Irrigation system (optional)
- Filter fabric
- Drainage layer/water retention layer
- Root barrier
- Waterproofing membrane
- Insulation
- Vapour barrier
- Roof structure

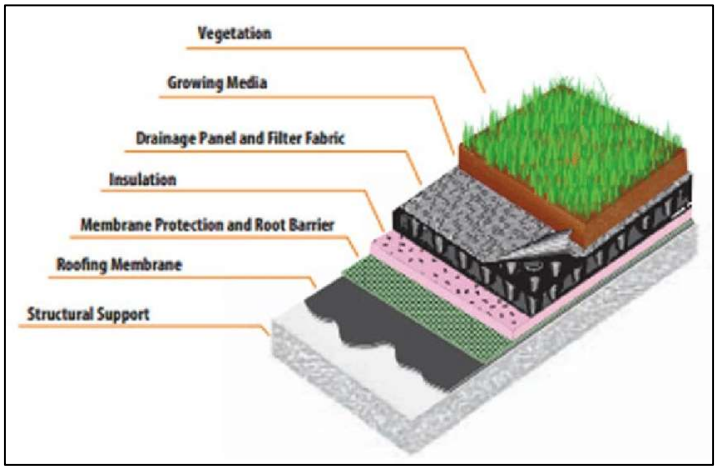


Figure 1: Typical Inverted Living Roof Section (Office of the Chief Building Official, City of Toronto, 2010).

The report also discusses the various ways in which technologies can be combined on living roofs, such as with solar panels and rainwater harvesting techniques.

Co-benefits of living roofs are a major discussion point in the overview of living roofs. Most property owners will not be solely convinced to install living roof systems based on cost or water management benefits alone. It is important to highlight all the co-benefits to promote the positive effects of green roofs and to show that building owners need to look beyond the direct installation costs of the system. A summary of the co-benefits is included below:

Co-Benefits of Living Roofs	
Private Benefits (Direct)	**Public Benefits (Indirect)**
1. Improved insulation 2. Energy savings 3. Health and well-being 4. Roof longevity 5. Sound attenuation 6. Temperature control for solar panels 7. Fire protection 8. LEED credits 9. Community resistance to development 10. Improved health and horticultural therapy 11. Increased property value	1. On-site stormwater management 2. Biodiversity 3. Reduce urban heat island effect 4. Policy/planning compliance 5. Air quality 6. Food production 7. Biophilia 8. New jobs/economic growth 9. Education 10. Water Equity 11. Carbon sequestration

The report also touches on barriers to living roof systems that may make a design or installation difficult or unfeasible. Barriers include cost of installation, space limitations, structural load restrictions, site location, legal/policy limitations, insurance restrictions, and lack of knowledgeable/skilled trades and designers.

Website Review and Recommendations

The review of relevant websites included several jurisdictions, such as the City of Portland, the City of San Francisco, the City of Toronto, the City of North Vancouver, and the Capital Regional District.

In general, it was noted that while each website's layout varied, the majority followed a relatively similar pattern that includes an overview of the living roof technology with some simple explanatory diagrams and text. Based on the research, a list of recommendations for the webpage layout has been developed:

1. Tiles on main B&S Site
2. Expandable menus on the Living Roofs webpage
3. Navigation Menu
4. Relevant Information Sidebar

From the review of both the website content and the design guidelines, the following topics are recommended to be included as various sections within the Living Roof Webpage:

1. Living Roof Banner and Overview of Living Roof Technologies
2. Breakdown of Living Roof Components
3. Overview of Living Roof Categories
4. Overview of Roof Functionalities
5. Co-benefits of Living Roofs
6. FAQ Section
7. Synergies with Existing City of Vancouver Strategies
8. Recommended Links/Documents
9. Recommended Tools

The layout and content provided aim to make the information easy to access, well organized, and prevent a user from being overwhelmed when navigating the webpage. Additionally, the content chosen was selected to provide adequate information to users of all experience levels, without overwhelming the user with unnecessary or overly complicated information.

A full breakdown of the recommendations as well as further details on recommended layouts and content are included in Appendix A.

Design Guidelines Review and Recommendations

Currently, there is no requirement to install living roofs on new or existing buildings in Vancouver. Additionally, there is no formal design guideline document for living roofs. A formal design guideline would also allow for customization of the guidelines to suit requirements that are specific to Vancouver (climate, local by-laws, etc.).

The Vancouver Building By-Law (VBBL) is based on the BC Building Code and serves as one of the major guiding documents for building design and construction within the City. The by-law contains two major sections that discuss living roof systems, Section 3.1.14.4 and Section A-5.6.1.2.(2). These clauses

provide a general basic overview of how living roofs should be installed (such as the inclusion of a root barrier) and that the roof assembly is designed to accommodate rainwater harvesting.

A gap analysis of the existing bylaws and standards was completed. The analysis found there are areas which can be improved upon. For example, the VBBL mentions that a living roof must include a root barrier. However, there are no specifications around materials options for the root barrier, no guidance on installation, and no language explaining the significance of the root barrier. A summary of the gap analysis can be found in Appendix D.

In addition to the referenced standards, the VBBL also references the German Landscape Research, Development and Construction Society's (FLL) "Guidelines for the Planning, Construction and Maintenance of Green Roofing". However, the language in the VBBL does not require that the FLL is used in the design of living roofs. Instead, it references the FLL as a resource that can be used for additional design guidance.

While useful in the right context, the FLL provides a level of detail that goes beyond the understanding of the average citizen, such as a building owner or operator. A design guideline for the City of Vancouver should be aimed to reach a wider audience to make living roof information more accessible and widely understood by readers with a wide range of expertise. A design guideline for the City of Vancouver could compliment the existing references in the VBBL and provide guidance that is more regionally focused and builds upon the existing design guidelines.

Review of other jurisdictions' design guidelines is a major component of this project as the intent is to develop a foundation upon which to build the City of Vancouver's best practices guidelines. A total of eight guidelines were reviewed:

1. City of Portland
2. City of Toronto
3. FLL (Germany)
4. City of San Francisco
5. GRO (United Kingdom)
6. CVC (Credit Valley Conservation Authority - Peel Region)
7. CMHC (Canada Mortgage and Housing Corporation)
8. City of Denver

Each design guideline was analyzed based on its overall layout and the information contained within each section. The majority of the design guidelines followed the same general layout, which includes three major sections:

1. Introduction to Living Roofs
2. Design Guidelines for Living Roofs
    a. Design
    b. Installation
    c. Maintenance
3. Miscellaneous Additional Information

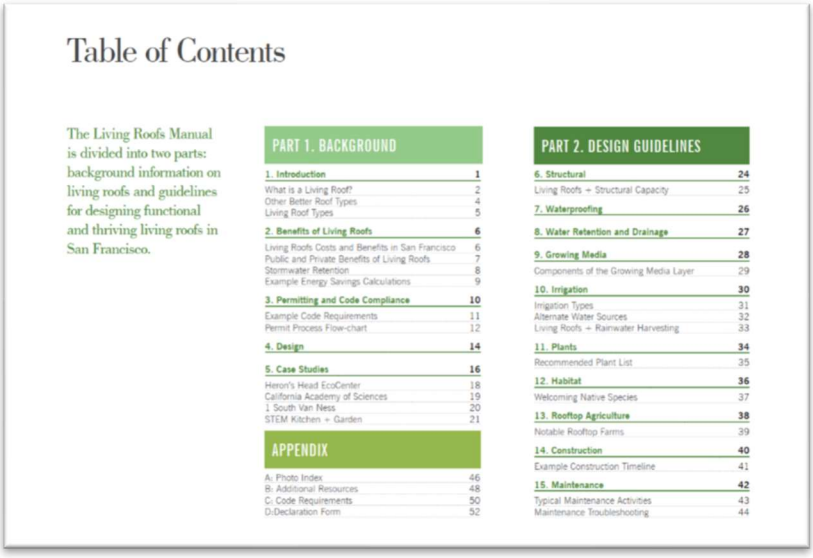


Table of Contents

The Living Roofs Manual is divided into two parts: background information on living roofs and guidelines for designing functional and thriving living roofs in San Francisco.

PART 1. BACKGROUND

APPENDIX

PART 2. DESIGN GUIDELINES

Figure 2: Typical table of contents - San Francisco design guidelines.

While the specific content included in each section of the guidelines varies, this general layout persisted throughout. This is an ideal organization of the guidelines, as it provides background information on living roof systems for anyone unfamiliar with the systems. Separate from this, the design guidelines section provides more technical requirements and standard processes that would be useful for more experienced living roof designers and installers. This report layout allows for easy navigation based on the individual user experience with living roofs. Section 3 varied between each guideline, but generally included components such as case studies, relevant design standards, or external industry contacts/companies.

When developing a design guideline, the complexity and detail of the information provided needs to strike a balance. If the content is too complex, it cannot be easily understood by the users and will likely be abandoned. If the content is too simple, the guidelines do not serve their purpose of informing users, so it will similarly be discarded. Some of the guidelines, such as the FLL, exemplify the concept of being overly complicated. While they are very useful, it cannot be easily understood. The design guidelines reviewed from both the City of Portland and the City of San Francisco provide ideal examples of the overall content of a guideline. Four important aspects that were identified were:

1. Use of colour in the text, headers and footers, and image backgrounds;
2. Low text-to-image ratio;
3. Use of summary tables to highlight important information; and,
4. Include inset boxes with additional links to more info for each chapter (where applicable).

These aspects allow for guidelines to provide a useful level of content that is not overly complicated and makes the content engaging and easier to digest. The final recommendations for the design guidelines include a breakdown of the recommended table of contents for each of the sections listed above. A general overview of the recommended table of contents is included below. The full detailed breakdown of the recommended content with explanations can be found in Appendix C.

PART A – INTRODUCTION TO LIVING ROOFS

1. Definition and History of Living Roofs
2. Rain City Strategy and Green Rainwater Infrastructure
3. Overview of Living Roof Components
4. Living Roof Categories
5. Living Roof Functions
6. Combining Living Roof Technologies
7. Co-benefits of Living Roofs
8. Designer Roles

PART B – DESIGN GUIDELINES

1. DESIGN
   - 1.1. Building Structure
   - 1.2. Waterproofing
   - 1.3. Root Barrier
   - 1.4. Drainage Layer
   - 1.5. Filter Fabric
   - 1.6. Growing Media
   - 1.7. Irrigation
   - 1.8. Vegetation/Plants
   - 1.9. Habitat Design/ Rooftop Agriculture
   - 1.10. Wind Design
   - 1.11. Fire Safety Considerations
   - 1.12. Rainwater Retention
   - 1.13. Area Drains & Scuppers
   - 1.14. Roof Slope
   - 1.15. Roof Access
   - 1.16. Permitting & Submission Requirements
2. INSTALLATION
   - 2.1. Site Preparation/Planning
   - 2.2. Waterproofing Membrane
   - 2.3. Growing Media Installation
   - 2.4. Vegetation Installation
   - 2.5. Fall Protection/Construction Safety
3. MAINTENANCE
   - 3.1. Maintenance plan
   - 3.2. Fertilization
   - 3.3. Irrigation
   - 3.4. Weeding
   - 3.5. Removal of Biomass

PART C – ADDITIONAL INFORMATION

1. Case Studies
2. Links to Relevant Related Documents (VBBL, FLL, RCS, etc.)
3. Glossary of Terms

Design Drawing Standards Review and Recommendations

The third portion of research for this report includes a review of available standardized drawing sets from relevant jurisdictions that have living roof policies or design guidelines in place. In most cases, living roof standardized drawings that can be downloaded and used by the general public were not available. The City of Portland provided one of the few occasions where some standardized drawings and details were made available. However, the drawings were still relatively sparse.

This serves as an opportunity for the City of Vancouver to take a position of leadership within the living roof industry by providing standardized drawings that can be used as examples or templates for designers and contractors. A list of the recommended drawings is included below. This list of drawings should not be considered exhaustive but can serve as a starting point to build upon.

1. Typical roof plan;
2. Typical detail showing structural connections and any modifications (existing building only);
3. Typical section details for roof drains;
4. Section showing the breakdown of living roof layers;
5. Typical section for parapet details at roof perimeter;
6. Section for border zones @ roof edge and surrounding drains;

7. Detail showing membrane termination;
8. Upturned roof barrier at transition from living roof area to conventional roof;
9. Fire separation details;
10. Footings for solar panels or other roof attachments;
11. Typical layout for calculations on drawings (like tables);
12. Schedule of materials; and,
13. Typical planting list

This report is intended to serve as a starting point for development of a living roof webpage, design guidelines and standard drawings. While the report provides several recommendations, additional work is needed to build upon this research. Further development of the webpage and design guidelines should include research into living roof costing, developing case studies around the city, and further consultation with industry experts to develop the webpage and guidelines further. This will realize the goals of the RCS by creating a central, useful, user-friendly webpage for living roof information.

INTRODUCTION

As climate change continues to impact the Lower Mainland, extreme weather events, such as heat waves and heavy rainfall events, are becoming increasingly frequent. Average rainfall in the Georgia Depression has increased by 14% over the last century (23% increase in the spring season) and is projected to increase up to an additional 17% over the next 60 years. (White, Wolf, Anslow, Werner, & Creative, 2016). This increase will require Vancouver to implement preventative strategies to ensure climate preparedness to meet these challenges.

Background

The Rain City Strategy (RCS), which builds upon the Integrated Rainwater Management Plan (IRMP), was developed and adopted by the City of Vancouver in 2019 to revise and improve upon the City's existing rainwater management goals. The RCS sets more ambitious goals relative to previous frameworks and creates a guiding vision for managing rainwater in Vancouver between today and 2050, with the ultimate objectives of:

- Removing pollutants from water and air;
- Increasing managed impermeable area;
- Reducing the volume of rainwater entering the pipe system;
- Increasing rainwater harvesting and reuse;
- Mitigating the urban heat island effect; and,
- Increasing the total green area in the city (Conger, et al., 2019).

To meet these objectives, the RCS had set ambitious, yet necessary, rainwater management targets for improving green rainwater infrastructure (GRI) such as:

1. Capturing (infiltrating, evapotranspiration and/or reusing) and cleaning (treating) rainwater from a minimum of the first 48mm of rainfall per day, which correlates to approximately 90% of Vancouver's average annual rainfall volume; and,
2. Managing urban rainwater runoff from 40% of impervious areas in the city by 2050 (Conger, et al., 2019)

Shifting rainwater management tactics from Vancouver's public infrastructure to controlling and treating stormwater at or near its source will require a multi-faceted approach that incorporates a wide range of GRI tools such as swales, rainwater tree trenches, rain gardens, living roofs, permeable pavements, and rainwater harvesting. Implementing GRI to encourage rainwater stewardship is especially important in a metropolitan area (such as Vancouver) where density and impermeable surfaces continue to increase annually. The Metro Vancouver Regional Growth Strategy anticipates Vancouver will grow by more than 150,000 residents by 2041 (Conger, et al., 2019).

These GRI initiatives are categorized in the RCS into three distinct groups of implementation action plans that address major contributors to the city's stormwater infrastructure:

1. Streets and Public Spaces (S&PS);
2. Buildings and Sites (B&S);
3. Parks and Beaches (P&B).

The Buildings and Sites implementation action plan (see Section 7.2 of the RCS) plays a critical role in ensuring the success of the RCS. Private properties account for approximately 62% of the City's impervious areas, typically comprised of rooftops, sidewalks, parking areas, etc. (Conger, et al., 2019). Diverting rainwater from the municipal systems through GRI has the potential to create a lasting positive impact on the quantity and quality of Vancouver's stormwater. GRI tools such as living roofs, permeable pavements, and rainwater harvesting can all be applied at various buildings and sites to improve stormwater management. Living roofs in particular provide an excellent method of stormwater capture, as they can replace conventional impervious roofs that are often underutilized. They can also be combined with water harvesting methods, such as water retention layers, to irrigate living roofs, stormwater tanks or rainwater barrels.

However, one challenge that the City faces is that this initiative is relatively new, and the technologies have not been implemented on a wide scale within the City. The City of Vancouver must determine the best methods to develop educational information and disseminate it to private organizations, property owners, and the general public. The RCS aims to address this issue through one implementation program and two enabling programs:

B&S-06/12 - 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-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.

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.

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.

Figure 3: Rain City Strategy - Buildings and Sites Initiatives (Conger, et al., 2019).

Project Purpose

One of the new initiatives to address education and information is the creation of a Living Roof Webpage. The webpage is intended to be developed in the near future and serve as a landing page for

designers, contractors, owners, and the general public to learn about living roofs, obtain relevant documents and promote the installation of living roofs in suitable locations throughout Vancouver. The Living Roof Webpage is envisioned to include a dedicated webpage, a guidelines document (that addresses design, installation, and maintenance issues), and (potentially) associated design standards (engineering drawings) that can act as off-the-shelf solutions for applicants. In turn, this webpage will better support the successful implementation of the RCS, and optimize its associated environmental, social, and economic benefits.

Currently, no webpage exists for living roofs on the City of Vancouver website. The City intends to use the webpage as a starting point to encourage installation of living roofs on suitable locations throughout Vancouver. Development of a useful, yet easy-to-navigate living roof webpage requires diligent investigation and understanding of what constitutes suitable, helpful content and how best to convey the information in an effective manner. This report intends to undertake a review of best practices through research of other various jurisdictions and provide 'topic' and 'content source' recommendations to support the development of a living roof webpage. The report will help to inform and develop content for:

i) Living Roof Webpage;
ii) Design Guidelines Documents; and
iii) Associated Minimum Design Standards (drawings).

Scope of Work

The scope of work completed for this project includes:

- Brief background summary overview of green and blue-green roof systems (summarized with profile graphics and a table) with reference to:
    - Roof Categories (extensive, semi-intensive, intensive, other),
    - Roof System components and functions (e.g. roof deck, insulation, root barrier, moisture barrier, growing medium/soil type and depth, plants, other) that contribute to performance,
    - Roof Ecosystem services/co-benefits (rainwater management, biodiversity enhancement, carbon sequestration, provision of amenity space, property value uplift, etc.),
    - Indicators used to measure and assess green and blue-green roof performance,
    - Common implementation barriers/challenges (i.e. issues to consider when wanting to avoid installation and maintenance failures);
- Review of current green roof-related COV Bylaws, Policies, Bulletins, Guidelines, and Standards to identify gaps and opportunities for a potential future COV resource Portal;
- Confirmation of staff-proposed Search Criteria to guide selection and review of information sources;
- Best practices jurisdictional review of approximately four to six jurisdictions with applicable information sources on green and/or blue-green roof webpage content, guidelines (design, installation, maintenance), and standards.

    - The review shall reflect Search Criteria requirements. One information source must include Guidelines for the Planning, Construction, and Maintenance of Green Roofs (FLL, 2018),
    - Time permitting, this review may include interviews with knowledge holders;
- Recommendations (and, where applicable, brief supporting rationale) on topics and actual content of particular webpages, guidelines, and standards most suitable for the City to consider or include when developing our own Portal, including specific reference to:
    - COV Webpage (suggested Topic List, suggested content from other jurisdictions to be considered for inclusion under each topic, brief commentary on suggested layout/graphic design characteristics (the organization, look, and feel of the webpage, etc.)),
    - COV Guidelines (suggested Topic List, suggested content from other jurisdictions to be considered for inclusion under each topic – should address issues applicable to the four roof types), and,
    - COV Design Standards (what drawing types should populate the drawing package, and suggestions for any particular drawings from other jurisdictions to be considered for inclusion);
- Time permitting, develop a conceptual organization and actual write-up of the proposed COV webpage content;
- Provide any recommendations for further studies (research, best practices, or in situ) to support the development of a COV Portal (Webpage, Guidelines (design, installation, maintenance) and Standards).

The report provides a summary of the research completed and makes recommendations based on the scope of work described above.

Appendices at the end of the report provide additional information, such as the recommended written content and layout for the webpage, suggested documents to be made available on the webpage, a draft layout of the design guidelines, and recommended drawing details.

Overview of Living Roof Technology

1. OVERVIEW OF LIVING ROOF TECHNOLOGY

The history of living roofs dates back thousands of years to ancient Mesopotamia, with some of the oldest living roofs built from the fourth millennium until 600 B.C.E. in efforts to improve thermal insulation and to provide natural landscapes within urban areas as clear goals of their designs (Magill, Midden, Groninger, & Therrell, 2011). In Canada, early primitive examples of living roofs can be found in provinces such as Newfoundland and Labrador and Nova Scotia, which were imported by the Vikings, and later, French colonists (Peck & Kuhn, 2009).

However, the technology was not widely modernized until the 1960s and 1970s, when extensive research on living roofs was completed, mainly in Germany. Individual components of the living roofs such as waterproofing membranes, root barriers and growing media were tested and developed, causing the living roof industry to develop rapidly throughout the 1980s. By 1989, 1,000,000 m^2 of living roofs had been installed and by 1996, the total had reached 10,000,000 m^2 (Magill, Midden, Groninger, & Therrell, 2011). The expansion of living roofs continued throughout Europe and provided learning experiences, which led to the development of more sophisticated installation and maintenance methods, including the creation of standardized guidelines such as the *Forschungsgesellschaft Landschaftsentwicklung Landschaftbau (FLL).* The FLL document (translation: Landscape Research, Development and Construction Society) Design Guidelines), currently serves as a widely accepted standard for living roof design installation and maintenance (Magill, Midden, Groninger, & Therrell, 2011).

Canada and North America are currently 10 years or further behind European living roof infrastructure and design, with the first modern living roofs established in the early 1990s (Peck & Kuhn, 2009). However, as much of the technology and research has already been developed in Europe, the ability to adopt the technology is easier than ever before.

1.1. Typical Living Roof Assembly

Living roofs (otherwise known as green roofs, blue roofs, blue-green roofs, and eco-roofs) are defined as the roof of a building that is partially or completely covered with vegetation, a growing medium and installed over a waterproofing membrane (Droguett, 2011).

Living roofs are often defined as sustainable solutions that create use for an otherwise underutilized space. Living roofs have the same general construction that consists of a living roof system installed over a waterproofing membrane installation. The waterproofing membrane can be installed in two configurations of either a conventional or inverted roof system. The roof system will consist of the same layers, with a slightly different arrangement, as shown below (from the top surface down):

Conventional Vs. Inverted Roof Assemblies	
Conventional Roof Assembly	**Inverted Roof Assembly**
• Plants/vegetation • Engineered growing media • Irrigation system (optional) • Filter fabric • Drainage layer/water retention layer • Root barrier • Waterproofing membrane • Insulation • Vapour barrier • Roof structure	• Plants/vegetation • Engineered growing media • Irrigation system (optional) • Filter fabric • Drainage layer/water retention layer • Insulation • Vapour barrier • Root barrier • Waterproofing membrane • Roof structure

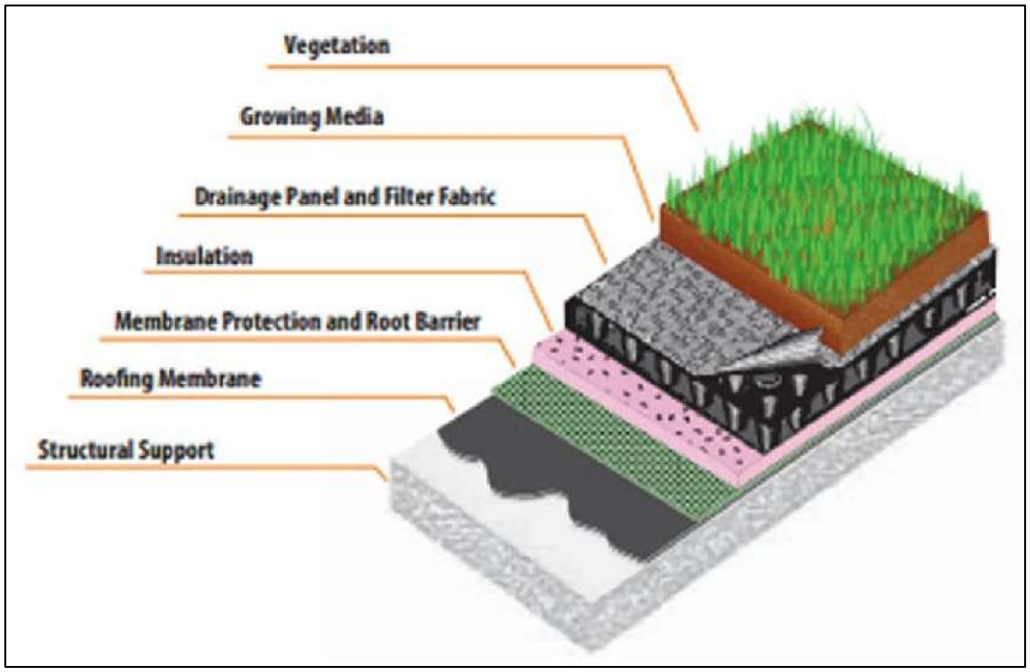


Figure 4: Typical Inverted Living Roof Section (Office of the Chief Building Official, City of Toronto, 2010).

Plants/vegetation can create virtually endless combinations, depending on the depth and composition of the growing media. It is recommended to have a horticultural specialist or landscape architect provide recommendations for your plant selections to ensure the vegetation will thrive in the microclimate. In general, it is important to aim to prioritize appropriate native species and plant a wide range of plants to encourage biodiversity. Plantings are typically provided in three main methods; cuttings, plugs, and vegetated mats or trays (Lösken, et al., 2018).

Engineered growing media is the main differentiator between the various living roof categories and will dictate the overall effectiveness and functionality of the roof assembly. A deeper growing media will allow for a wider variety of uses, a higher rate of water retention and increased biodiversity of vegetation as it provides the structure for the vegetation roots. The media is typically designed and premixed by a manufacturer and ideally composed of a lightweight combination of organic and inorganic materials to include minerals, nutrients, and adequate void space to allow for water infiltration (Lösken, et al., 2018).

Irrigation systems that are permanently installed may be required for a living roof system depending on the complexity of the installation and the variety of vegetation installed. In some cases, a hose bib at the roof level with regular manual irrigation by maintenance staff may be sufficient. Automatic irrigation systems can vary from drip irrigation, spray systems or sub-surface capillary mats. Irrigation is most critical during the first year of the installation when the vegetation is taking root and maturing. Whether an irrigation system is installed or not, the system should be adequately irrigated to prevent the vegetation from drying out and becoming a fire hazard. (Lösken, et al., 2018).

Filter fabric is typically installed below the growing media to create separation between the growing media and the drainage layer. The filter fabric typically consists of a geotextile layer. The material is intended to be porous enough to allow water to drain through to the drainage layer, but fine enough to prevent the soil from being washed out with the water and eroding away the growing media.

Drainage layer/water retention layer consists of a porous media that allows for water to drain from the growing media and flow to the roof drains. The media must have voids larger than what is found in the growing media to encourage drainage and typically is constructed of aggregates or geocomposites. Geocomposites are typically made with prefabricated trays that include depressions throughout the layer to retain water and provide a source of passive irrigation for the vegetation. Drains must be installed at adequate intervals to allow the entire roof to drain. Often, overflow drains or “scupper” drains are installed in the roof parapet to allow excess water to drain in the case of flooding due to clogged drains or inadequate drainage capacity (Lösken, et al., 2018).

Root barrier typically delineates the lowest layer of the living roof assembly and the upper layer of the conventional roof assembly. Vegetation roots are particularly adept at penetrating through solid layers and forming cracks, which is not ideal for a waterproofing membrane. The root barrier provides an additional layer of protection for the waterproofing membrane and the sub-structure by preventing the roots from penetrating further into the roof assembly. The root barrier is typically manufactured from high-density polyethylene (HDPE) or polyvinyl chloride (PVC). Some root barriers also include chemicals to improve root resistance, however this is not recommended as there becomes an increased risk of chemical leeching (Lösken, et al., 2018).

Waterproofing membrane is one of the most important layers in the roof assembly since it serves as the main layer of protection for the roof structure. The waterproofing membrane prevents water ingress, provides UV protection, and prevents structural damage due to pedestrian or animal traffic. The membrane can be made from a variety of materials such as layers of sandwiched felt and hot applied asphalt, two-ply modified bitumen, or synthetic rubber sheeting (EPDM, PVC) (Lösken, et al., 2018).

Insulation improves the thermal resistance of the roof assembly and prevents thermal bridging between the outdoor and indoor environments. The insulation is typically extruded, rigid insulation board. The

insulation can also be installed above the waterproofing membrane in an inverted roof membrane assembly.

Vapour barrier is typically installed over the building structure with the primary function of preventing any condensation due to thermal bridging from contacting the base building structure. The vapour barrier is typically made of a plastic, waterproof material. It can be a liquid applied material or a vinyl sheeting that must be laid across the roof. The vapour barrier can also be installed above the waterproofing membrane in an inverted roof membrane assembly (Lösken, et al., 2018).

Roof structure consists of the base building structural frame. The frame is typically constructed from concrete slab, steel, or wood-frame. The structure provides the support for the entire roofing system and must be designed to adequately support the weight of the living roof system. If a living roof is being proposed as a retrofit for an existing building, a structural assessment may be required to determine the roof's weight restriction. Structural reinforcement may be required in order to support the living roof assembly (Lösken, et al., 2018).

1.2. Living Roof Categories

While the general installation is the same for living roofs, they are typically divided into three main categories:

1. **Extensive Roofs**
2. **Intensive Roofs**
3. **Semi-Intensive Roofs**

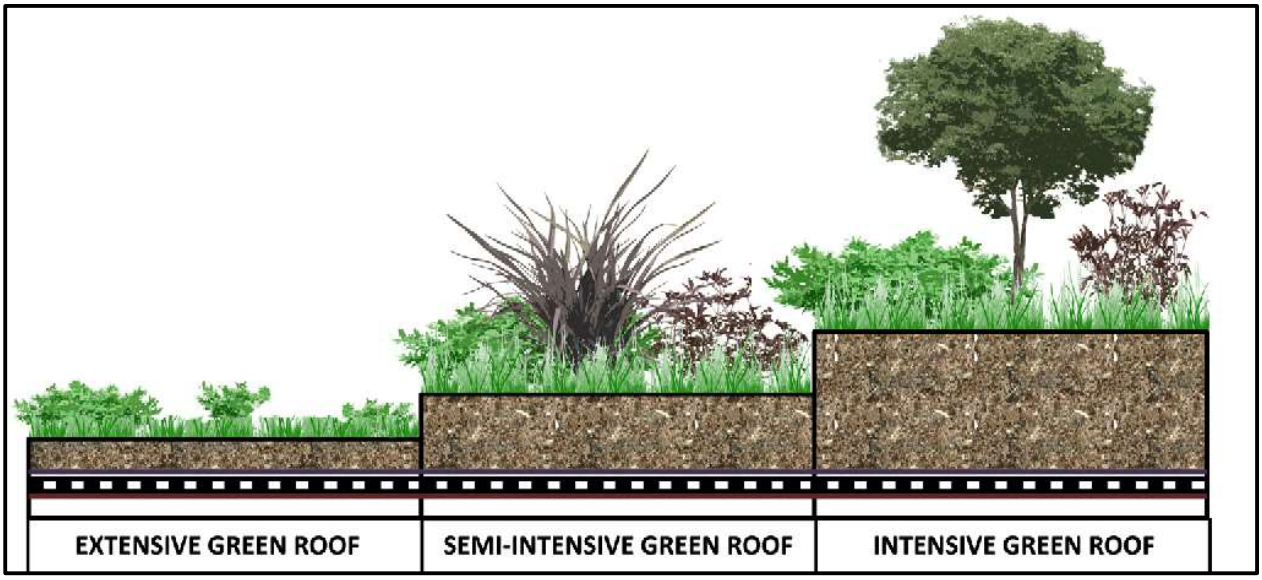


Figure 5: Living roof categories (Fernández-Cañero, Emilsson, Fernandez-Barba, & Ángel Herrera Machuca, 2013)

The main difference between the three roofs is based on the depth of their growing media and, by association, the variety of plants and vegetation that can be incorporated into the roof system.

Extensive roofs are typically categorized by a growing media depth of 15 cm (6") or less and a weight of around 72-170kg/m² (16-35lb/ft²), when saturated (Peck & Kuhn, 2009). The limited depth of the growing media means that there are limits to the vegetation which can survive in the shallower soils and

extreme weather conditions. Shallow-rooted hearty vegetation such as mosses, succulents, herbs, and grasses are often found in extensive roof installations (Lösken, et al., 2018). The soil depth and vegetation mean that these roofs are typically more drought-resistant and may not require a permanent, automatic irrigation system, depending on the specific micro-climate of the roof (Lösken, et al., 2018). These roofs are typically not intended to be accessible to the public and are expected to be self-sustaining once established.

Intensive Roofs are typically characterized by a growing media depth greater than 15cm (6") and an average weight that ranges between 195-970kg/m² (40-200lb/ft²) when fully saturated (Peck & Kuhn, 2009) (Amercian National Standards Institute, 2017). The increased soil depth allows for a potentially limitless variety of plants/vegetation to be installed on the roof, assuming the structure can support the weight of the vegetation. This also expands the range of uses for the living roof such as the incorporation of walking paths, inclusion of water elements and creation of multiple micro-climates within a single application. These roof systems also typically require a permanent irrigation system to be installed and more maintenance requirements due to the quantity and variety of vegetation installed (Lösken, et al., 2018).

Semi-intensive Roofs are typically defined by a combination of both extensive and intensive areas of roofing within a single application. The growing media will fluctuate both above and below the 15cm (6") depth as described above and will have an average weight that ranges between 120-250kg/m² (25-50lb/ft²) when fully saturated (Amercian National Standards Institute, 2017). A semi-intensive roof system allows for both intensive and extensive vegetation to be incorporated into the living roof system without the cost of completing a fully intensive roof. This can also be helpful where weight restrictions are a limiting factor to the design.

Comparison of Living Roof Typologies			
Component	**Extensive**	**Semi-Intensive**	**Intensive**
Soil Depth	<15 cm (6")	Fluctuates between 12-25 cm (5-10")	>15 cm (6")
Weight	72-170kg/m² (16-35lb/ft²)	120-250kg/m² (25-50lb/ft²)	195-970kg/m² (40-200lb/ft²)
Vegetation	Shallow rooted hearty vegetation such as mosses, succulents, herbs, and grasses	A mixture of shallow rooted hearty vegetation, various shrubs, and small trees, depending on soil depth	A potentially limitless variety of plants/vegetation, depending on soil depth
Maintenance Levels	Low	Medium	High
Cost	Low	Medium	High
Rainwater retention	Low	Medium	High
Biodiversity	Low	Medium	High
Permanent Irrigation	No	Depends	Yes
Suitability	Large areas	Areas where biodiversity or	Great for high visibility areas

	Limited additional structural capacity	accessibility is needed, but structural support is a constraint	Often accessible
Limitations	Usually no/limited access Can be unattractive, especially in winter	Irrigation may be more complex and plant propagation between intensive & extensive areas may occur	More complex to design and install Limited to structures with high weight capacity

1.3. Combining Roof Technologies

The three categories of roofs can also be combined with each other at a site or with several other types of roofing technology to maximize the use of the roofing space. These technologies include:

Biosolar Roofs incorporate solar panels with living roofs. Solar panels can provide an on-site source of renewable energy and are an ideal addition to a living roof due to the unobstructed sunlight. In the right climate, the payback period for solar panels can create an attractive option to occupy some of the rooftop space. This can create some competition for living roof vegetation, as constant obstruction by solar panels may lead to plants wilting due to a lack of sunlight. Some solutions to this include:

- Ensuring adequate space between solar panels and the vegetation (minimum of 20 cm of vertical separation) to ensure there is enough sunlight and rainwater that reaches the plants (Lösken, et al., 2018).
- Planting differing varieties of vegetation below the solar panels that thrive in shade and create greater biodiversity (Kessling, Choen, & Jasso, 2017). The plants should also be chosen carefully to ensure they do not grow beyond the height of the solar panels and obstruct their sun exposure.

Combining solar panels with living roofs has also been shown to create improved efficiencies. In some studies, it was noted that vegetation installed in the form of a living roof below the solar panels helped to control the temperature at the underside of the PV panel, which in turn increased the efficiency of the panel by up to 20% (Velazquez, 2021). Biosolar roofs can also make the cost-benefit analysis more attractive by shortening the payback period for a living roof installation (Kessling, Choen, & Jasso, 2017).

Figure 6: Poorly designed solar-green roof (LivingRoofs.org, n.d.).

Figure 7: Well designed solar-green roof (LivingRoofs.org, n.d.).

Blue-Green Roofs incorporate a water retention system within the drainage layer of the living roof to reduce stormwater runoff. Blue-roofs can be installed as standalone installations or as part of a living roof to create a blue-green roof. Blue roofs can either be “active” or “passive”. Active blue roof systems simply delay the stormwater runoff rate during a storm event by using a system of valves and controls to limit the rate of drainage based on design setpoints. More complex versions can use integration of building automation systems (BAS) and weather forecasting in order to improve stormwater retention (Massachusetts Department of Environmental Protection, 2016). Passive blue roofs temporarily retain stormwater on the roof through a number of means, such as flow-restricting roof drains to allow ponding water, modular tray systems to increase infiltration through media, and check dams installed to extend the drainage path to roof drains (Massachusetts Department of Environmental Protection, 2016).

Combining a blue roof system with a living roof creates several synergies. Retaining stormwater on the roof reduces the total quantity of water that enters the municipal stormwater system. This reduces the strain on the municipal system and can reduce the frequency of overflow of Vancouver’s combined sewer system (CSO) during extreme rain events, preventing raw sewage and pollution from entering the waterways. It allows stormwater to be collected and retained as a method of natural irrigation in order to maintain vegetation and reduce reliance on municipal water supply for irrigation. A blue-green roof can also reduce the urban heat island effect by creating a cooling effect on the roof, thereby reducing cooling load requirements (Massachusetts Department of Environmental Protection, 2016).

Installing a blue-green roof does require an increased level of diligence. The design of the roof structure must be adequate to support both the vegetated roof and the weight of a full water storage layer. The system must also be managed diligently as the risk of water damage is increased due to the continually wet surface. The cost of installation will increase in comparison to an equivalent living roof installation (Massachusetts Department of Environmental Protection, 2016).

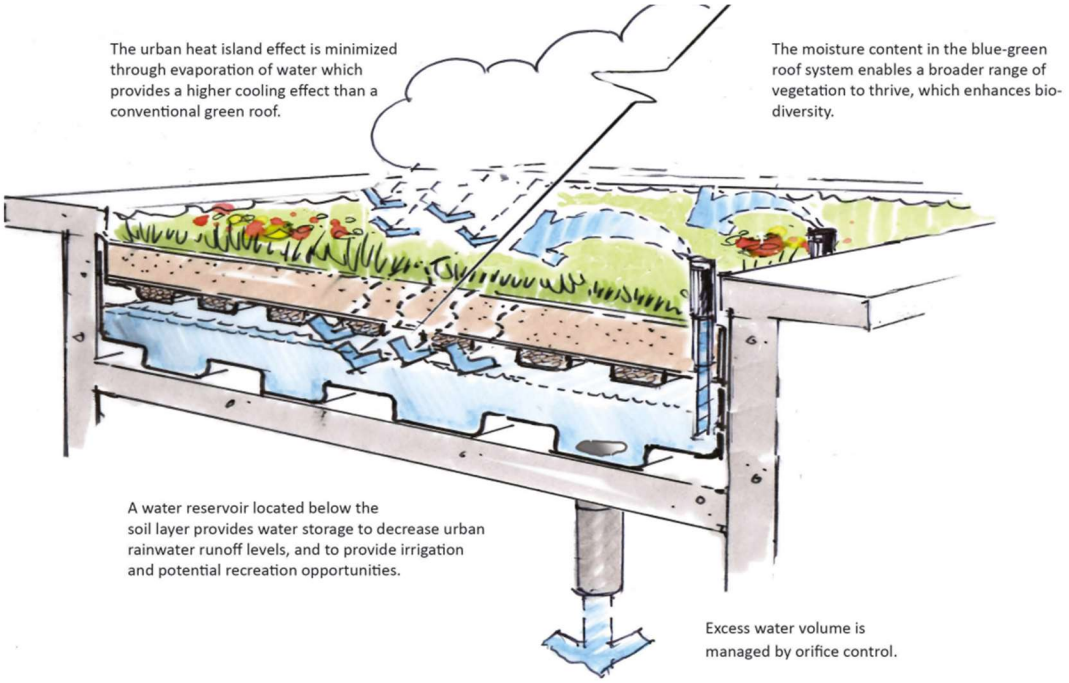


Figure 8: Typical blue-green roof design (Conger, et al., 2019).

Rainwater Harvesting can be incorporated into living roofs to divert stormwater and reduce strain on the municipal stormwater system. On-site management of rainwater is an important tool to mitigate increasing precipitation and prevent pollution of Vancouver's waterways, while adding resiliency to the City's drainage system (Director of Planning - City of Vancouver, 2018). These systems usually include the installation of a rainwater storage system (such as a rain barrel or a stormwater retention tank), which is connected to the stormwater drain piping/downspouts from the roof level. Reclaimed rainwater can be utilized for various building functions, including irrigation, car washing, and servicing fixtures such as toilets. In more robust systems, reclaimed stormwater can be chemically treated on site to a potable level of drinking water to be used on site. This, of course, comes with additional costs associated with installation and continual maintenance to ensure water quality and permitting for potable water (Lösken, et al., 2018).

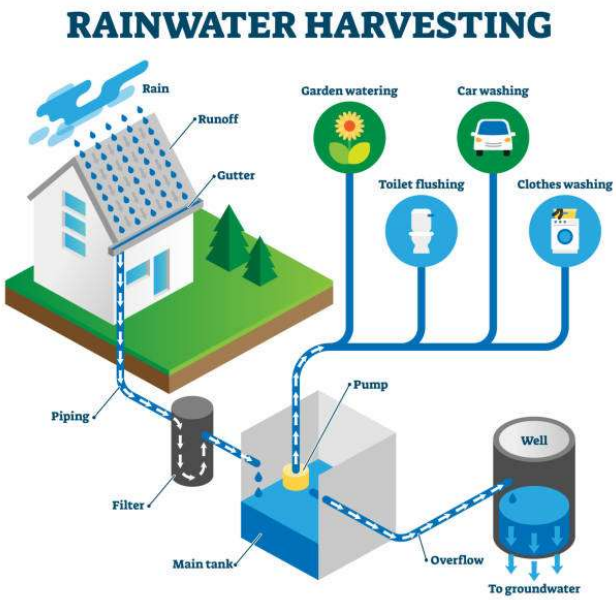


Figure 9: Typical rainwater harvesting uses (VectorMine).

The City of Vancouver has a number of requirements that must be met and approved prior to installing and operating a rainwater harvesting system. The requirements include:

- Development of a rainwater management plan;
- Proven ability to capture 48mm of rainfall in 24 hours;
- Water is treated to remove 80% of total suspended solids;
- Specifications of water treatment system that meets the Washington State Department of Ecology's Technology Assessment Protocol – Ecology Program (TAPE) or Environmental Technology Verification (ETV) Canada;

Details on the rainwater management requirements can be found in the City of Vancouver's Rainwater Management Bulletin and the Stormwater Source Control Design Guidelines, available on the City of Vancouver website.

1.4. Co-benefits of Living Roofs

Living roofs create a plethora of benefits that are useful for a range of stakeholders including the building owner, building occupants, contractors, and the general public. The various benefits are divided into two main categories – private (direct) and public (indirect). The list below is intended to serve as a starting point. However, it is worth noting that this list is not exhaustive. In addition, each property is unique, so all the benefits may not apply to every living roof project. There may also be additional benefits that are not listed below.

1.4.1. Private Benefits (Direct)

1. **Improved insulation** – living roofs increase the thickness of insulation on the roof and reduce solar heat gain through the roof. Modeling research has suggested that a 20cm (8") deep growing media is equivalent to an insulation rating of R20 (Peck & Kuhn, 2009). This can improve indoor comfort and save energy.

2. **Energy savings** – through improved insulation and increased evaporation, the cooling load in the building is reduced, which reduces strain on the building HVAC system and lowers energy costs. Cooling savings are typically more substantial than heating savings (Peck & Kuhn,

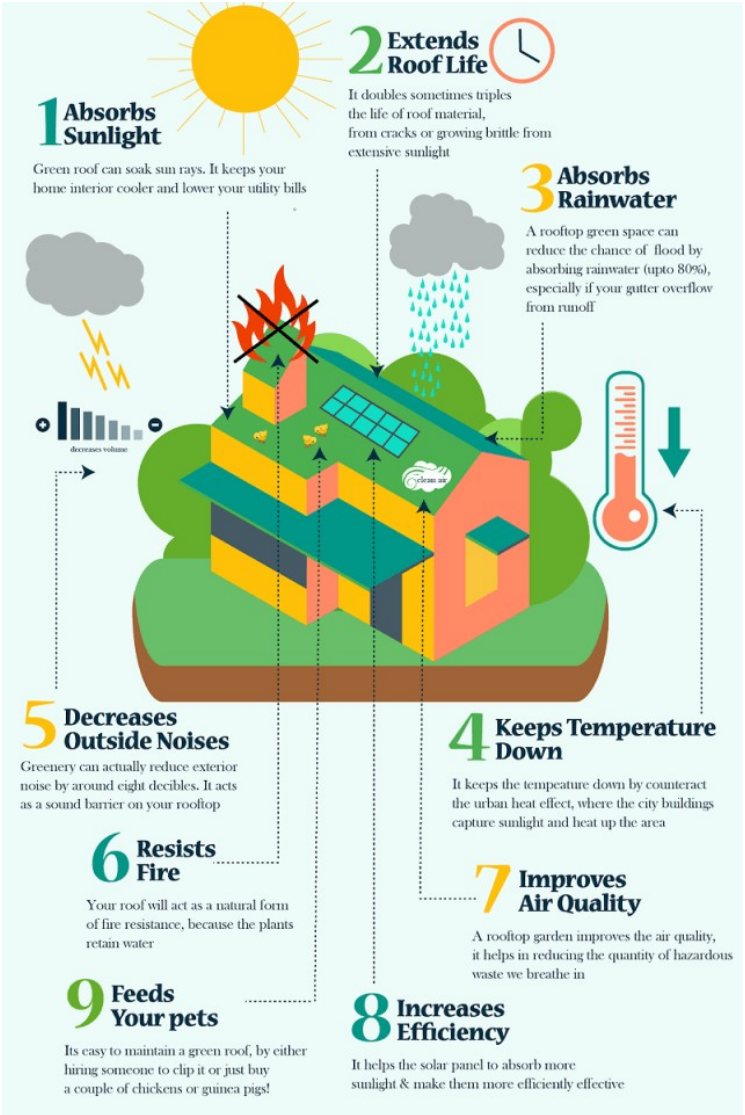


Figure 10: Depiction of various benefits of living roofs (Evolve Home Design + Build, n.d.)

2009). This is especially relevant in Vancouver where Energy Step Code compliance is anticipated to become more stringent in the coming decade.

3. **Health and well-being** – living roofs can provide an outdoor amenity space for building occupants or the general public to connect with the natural environment. A connection to natural space has been shown to improve mental health and reduce stress levels (Peck & Kuhn, 2009).

Figure 11 - Roofing Repairs (Cambie Roofing Team, 2019)

4. **Roof longevity** – living roofs have been shown to increase the lifespan of waterproofing membranes when compared to conventional roofing systems. The vegetation provides additional protection from UV, pedestrian traffic, and animals. An extended service life can help justify the additional installation costs through reduced maintenance costs and reduce overall waste during the life of the building. Some studies suggest that the total life cycle costs of a living roof are equivalent to conventional roof systems (Peck & Kuhn, 2009).

5. **Sound attenuation** – the additional thickness of a living roof creates an improved insulation layer and can reduce noise transmission through the roof. A growing medium with a depth of 12cm (5”) can reduce sound transmission by 40 dB (Peck & Kuhn, 2009). This can be especially beneficial in a wide range of settings where quiet is preferred, such as offices, libraries, performing arts centres, recording studios, etc. It is also beneficial in busy urban areas with a high level of exterior noise.

Figure 12: Sound attenuation (Zonco Systems, n.d.)

6. **Temperature control for solar panels** – Solar panels have been shown to be more efficient when they operate at lower temperatures. Living roofs help to maintain a cooler surface temperature (compared to a conventional roof) through evaporation and a lower heat gain coefficient (Kessling, Choen, & Jasso, 2017).

7. **Fire protection** – water retention in a living roof serves as a natural flame retardant and can help slow the spread of flames in the event of a fire. It should be noted that this applies to a well-maintained roof. Dry or dead vegetation on a living roof can have the opposite effect, providing additional fuel to a fire (Amercian National Standards Institute, 2017).

Figure 13: LEED credit categories (Garni Paradisi, n.d.)

8. **LEED credits –** Living roofs can contribute towards LEED certifications through multiple credits such as Sustainable Sites, Water Efficiency, Energy and Atmosphere and Innovation and Design Process (LiveRoof, n.d.).

9. **Community resistance to development** – Resistance within a community can become a barrier to many new development projects, even if the project is expected to provide positive services to the surrounding neighbourhood. Installation of a living roof can create a positive reception from the community, whether it improves the building aesthetically or provides publicly accessible green space.

10. **Improved health and horticultural therapy –** horticultural therapy has been shown to help increase the rate of recovery for sick individuals and reduce drug use (Peck & Kuhn, 2009). A living roof at a location such as a hospital provides an opportunity to take advantage of this space and serves as a learning opportunity.

11. **Increased property value** – living roofs with accessible amenity space can typically create a higher property value and be used as a selling feature for new tenants/owners.

1.4.2. Public Benefits (Indirect)

1. **On-site stormwater management** – Installation of a living roof system reduces the amount of stormwater that reaches the municipal system as it is absorbed and evaporated through the growing media and vegetation. While a portion of the stormwater does infiltrate through the growing media and enter the municipal stormwater system, it does so at a reduced rate, meaning an overall reduced strain on the municipal system and a reduced frequency of CSO. In one study completed in Portland, Oregon, an intensive living roof with a growing media depth of 20-40 cm (8-16”) retained approximately 10-15 cm (4-6”) of rainwater (Peck & Kuhn, 2009). In jurisdictions where site stormwater discharge is metered, this provides additional cost savings to the building owner.

Roof Type	Run-off Percentage
Standard	81%
Standard with 50mm of gravel	77%
Green roof with 50mm of substrate	50%
Green roof with 100mm of substrate	45%
Green roof with 150mm of substrate	40%

Figure 14: Comparison of stormwater run-off based on growing media depth (Green Roof Organisation, 2021).

Figure 15: Biodiversity (Coperincus Climate Change Service, n.d.)

2. **Biodiversity** – Living roofs have the potential to contribute to the local ecosystems through planting a diverse range of vegetation and creating animal habitats. Planting native vegetation species and including natural habitat components (bird houses, water sources, etc.) can promote improved biodiversity (Rahaim, John; Joslin, Jeff; Kelley, Gil; Brask, Anne; Cheng, Kay; Perry, Andrew; Olsen, Kerby; Swae, Jon; Chen, Gary;, 2015). Increasing plant biodiversity in a living roof also provides the system with a greater chance of survival in the case that not all the plant species are able to survive installation or are subject to infestation. Living roofs can also create natural bridges throughout dense, urban areas where much of the natural habitat has been lost. It should be noted that the animal habitats will largely be limited to airborne fauna, such as birds, butterflies, and bees.

3. **Urban heat island** – Overheating is a common phenomenon in increasingly dense urban centres due to the increase in paved surfaces that absorb heat, resulting in temperature differences of up to 12°C in urban areas compared to surrounding environments (Prairie Climate Centre, n.d.). Installing living roofs can help to reduce the urban heat island effect by reducing the amount of solar heat gain. On a large implementation scale, this can reduce energy consumption, improve citizens' health and quality of life.

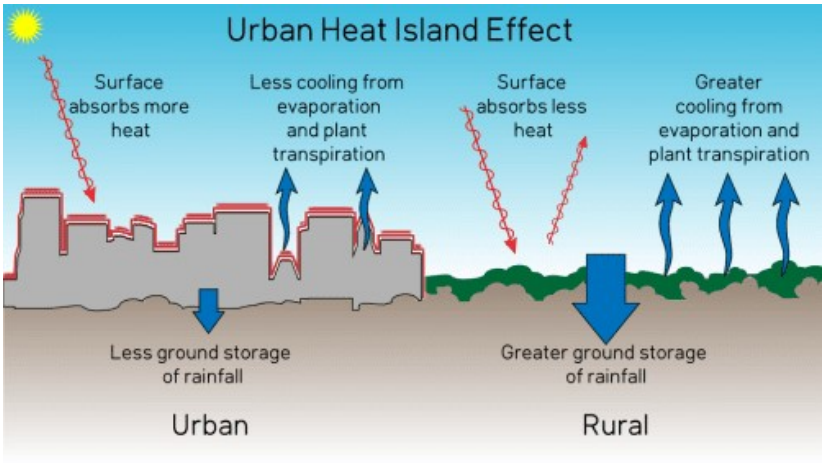


Figure 16: Urban heat island effect (Forestell, 2020)

4. **Policy/planning compliance –** As building regulations continue to shift and develop, there is an increasing focus on sustainability and energy efficiency. In cities such as Vancouver, the BC Energy Step Code is becoming more frequently used as jurisdictions aim to meet their emissions targets. Implementing a living roof can help achieve these targets and contribute toward limiting global warming.

5. **Air quality –** Air quality in urban areas is often poor in comparison to surrounding environments due to the large concentrations of vehicles, people, and operations. Living roofs filter out some of the airborne particulate matter by trapping it on the surfaces of the vegetation. Some estimates suggest that a grass roof with 2,000 m² of grass could cleanse 2,000 kg of air pollutants per year (Peck & Kuhn, 2009). While this is not a complete solution to address air quality, it can contribute towards the overall improvement of the quality of living in urban areas.

6. **Food production –** Food transportation is an energy-intensive process due to the large distances between rural agricultural areas and densely populated urban areas. Living roofs provide an opportunity to implement urban agriculture and provide access to locally grown fruits and vegetables within urban centers, which can reduce energy consumption and carbon emissions associated with transportation (Rahaim, John; Joslin, Jeff; Kelley, Gil; Brask, Anne; Cheng, Kay; Perry, Andrew; Olsen, Kerby; Swae, Jon; Chen, Gary;, 2015).

Figure 17: Urban rooftop garden example (Wade, 2014).

Urban agriculture can also provide an opportunity for education within the local community to understand the importance of urban agriculture and demonstrate how to grow various fruits and vegetables in an urban environment. Urban agriculture does have its own limitations; an intensive roof system is required to achieve adequate soil depth and water retention. Additionally, an increased level of maintenance and irrigation is required in comparison to a conventional living roof (Rahaim, John; Joslin, Jeff; Kelley, Gil; Brask, Anne; Cheng, Kay; Perry, Andrew; Olsen, Kerby; Swae, Jon; Chen, Gary;, 2015).

7. **Biophilia –** The presence of natural vegetation has been shown to improve mental health, reduce stress and improve overall quality of life. Creating natural visual stimulation has even been shown to improve productivity. Humans have an innate instinct to connect with nature and other living things (McCain & Vidovich, 2020). Living roofs provide an opportunity for building occupants to connect with nature. Occupants of surrounding buildings can also benefit from being able to see a living roof on a nearby building.

8. **New jobs/economic growth** – promoting living roof installation throughout a jurisdiction can generate economic growth by increasing demand for living roof technicians/installers and continual maintenance/service. This can help develop and expand a new industry where there previously was none before.

9. **Education** – Living roofs provide an excellent educational tool. As the living roof industry is still relatively young in the North American market, new installations create an opportunity for all members of the community (designers, contractors, owners, and government) to learn about these systems and how to improve upon design, installation, and maintenance. The roofs can also serve as an educational tool for the general public, providing the opportunity to learn about native plants, local ecosystems, and the water cycle. This can be an especially important tool for institutional properties, such as schools and universities.

10. **Water Equity –** ensuring access to clean, potable water supply for all Vancouver residents is important to maintaining the community. However, low-income, and rural communities are disproportionately affected by the contamination of local water supplies caused by urban areas.

Ensuring freshwater stewardship and preventing water pollution allows all residents of the lower mainland to have access to clean water. Living roofs can contribute toward water equity by reducing pollution of the waterways through on-site infiltration and treatment.

11. **Carbon sequestration** – as the world works to reduce carbon emissions and remove CO_2 from the atmosphere, trees, shrubs, and porous landscaping become a vital tool to achieve these goals. Replacing natural landscapes with a built structure/environment removes some of the carbon sequestration that was previously provided by the soil and vegetation. Installing a living roof on a new or existing structure can reduce this effect. Several studies have been completed to show the additional carbon sequestration provided by living roofs. In a Michigan-based study, extensive living roof systems were found to sequester 375 g C/m² in above and below ground biomass and substrate organic matter over two years (Getter, Rowe, Robertson, Cregg, & Andersen, 2009)

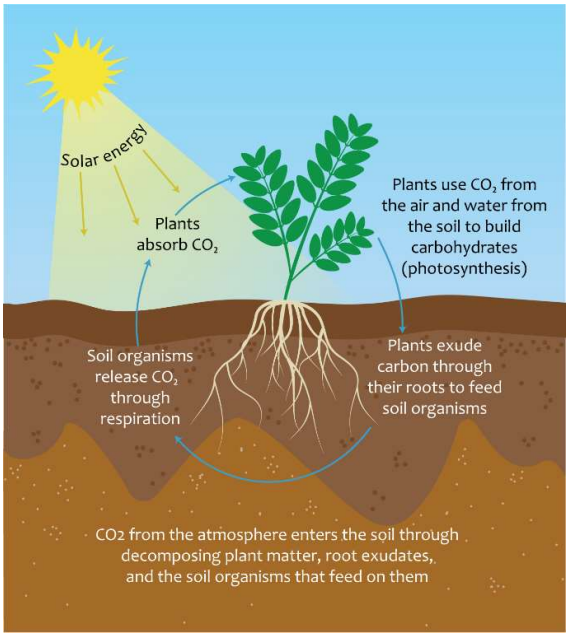


Figure 18: Carbon sequestration cycle (Lavallee, 2020)

A summary of the co-benefits is included below:

Co-Benefits of Living Roofs	
Private Benefits (Direct)	**Public Benefits (Indirect)**
12. Improved insulation	12. On-site stormwater management
13. Energy savings	13. Biodiversity
14. Health and well-being	14. Reduce urban heat island effect
15. Roof longevity	15. Policy/planning compliance
16. Sound attenuation	16. Air quality
17. Temperature control for solar panels	17. Food production
18. Fire protection	18. Biophilia
19. LEED credits	19. New jobs/economic growth
20. Community resistance to development	20. Education
21. Improved health and horticultural therapy	21. Water Equity
22. Increased property value	22. Carbon sequestration

1.5. Connection to Reconciliation and First Nations Philosophies

The implementation of living roofs has a strong connection to the overarching philosophies of many First Nations. Xʷməθkʷəy̓əm sniẇ (Musqueam) teachings and practices, for example, often centre around

intrinsic connections to their lands and waters, the importance of sharing the land, and several other responsibilities (Musqueam Indian Band, 2022).

The urbanization and densification of the natural land in Vancouver has been detrimental to not only the land on which buildings are constructed, but to the entire surrounding ecosystem, including waterways, biodiversity, and wildlife habitats. Buildings interrupt the natural landscape as part of the construction process, (e.g., steel, concrete, fuel). While imperfect, living roofs represent a step towards acknowledging the impact buildings have on their surrounding environment and reducing the disruption they create. The living roof sandwiches the building between the native soil below and the living roof above to create a bridge that connects the two environments. Connecting the building to the surrounding environment via a living roof helps to emphasize the stewardship role needed by humans toward the land they build upon.

1.6. Advantages and Disadvantages Summary

So far, the discussion has been centered around the different technologies available for living roofs, along with various advantages and disadvantages that come along with the installations. A summary of the advantages and disadvantages is provided below:

Advantages and Disadvantages of Living Roof Technologies	
Advantages	**Disadvantages**
1. On-site stormwater management 2. Extended waterproofing membrane service life 3. Improved insulation 4. Reduced heating load/energy consumption 5. Improved air quality and carbon sequestration 6. Improved biodiversity 7. Job creation/economic growth 8. Contributes to LEED certification 9. Improved aesthetic value	1. Higher installation costs 2. Higher regular maintenance requirements 3. May require structural assessment/reinforcement for existing building

1.7. Barriers to Implementation

This report has discussed the many advantages of living roof installations. However, if all these advantages exist, why aren't living roofs a standard, rather than an exception?

There are barriers that currently prevent living roof technology from becoming commonplace. Some of these issues are site-specific, while others are more widespread regional issues.

1.7.1. Site Specific Barriers

The largest and most common barrier to an installation is the cost of installation and maintenance (Roehr, 2022). However, this is often a misunderstood barrier that is related to education about living roofs. While the initial capital costs are higher for living roofs compared to conventional roofing systems,

the long-term benefits (such as extended roof membrane life and reduced cooling load costs) make the cost nearly equal (Credit Valley Conservation Authority, 2010).

One of the major contributors to determining the feasibility of a living roof system is the structural weight capacity of the existing building's roof. As mentioned in Section 1.2, the weight of a living roof can vary greatly, depending on the system chosen and the depth of the soil media. In the case of existing buildings, the structural capacity is limited based on the original design. A structural survey will often be necessary in the case of replacing a conventional roof system with a living roof system. This can be especially significant for low-rise, steel-framed industrial buildings, which are typically designed for minimal roof loading. While not extremely common, a weight restriction may limit a property to installing a simplistic extensive living roof or could prevent a living roof system from being feasible (Roehr, 2022). In some cases, structural reinforcement can be installed to support the additional weight of a living roof, but this can become cost-prohibitive in cases where the reinforcement is not a simple design (Peck & Kuhn, 2009). Fortunately, engineered growing media technology has continued to develop and provides several lightweight options in order to reduce the weight concerns and make living roofs an accessible option for the majority of existing structures (Roehr, 2022).

Competition for space can be another factor that limits living roof installations. For example, some high-rise towers have relatively small floor plates. These buildings will have multiple uses competing for this roof space such as mechanical equipment, elevator overruns, private balconies/terraces, or other space programming needs (childcare, etc.). These various uses may take priority over the living roof installation and cause a reduction in the space available for use. Designers should work to find ways to harmonize the various competing uses of a rooftop to ensure living roofs do not get removed from the final design. This can be further supported through the implementation of legislation from the City to ensure that living roofs are a requirement rather than a voluntary inclusion over a percentage of suitable rooftop space on suitable building types and that the roofs advance various City policies and strategies.

Roof slope can have a large impact on the feasibility of a living roof. A peaked or steep-sloped roof with a pitch greater than just 10° (17%) is difficult to maintain and prevent soil erosion from occurring. Additional anti-shear measures will likely be required in order to ensure soil stability (Office of the Chief Building Official, City of Toronto, 2010). This makes installation on conventional detached homes and townhouses difficult due to the roof shapes.

Site location can also play a factor in the success of the living roof installation. For example, a site located next to a high-rise building may constantly be within the high-rise building's shadow and have difficulties with access to sunlight. This can stunt the growth of the vegetation and lead to frequent replanting. These steps should be considered at the early design stage to ensure the living roof is feasible and the correct vegetation is selected for the project.

1.7.2. Regional Barriers

Lack of knowledge can be an issue for an entire region, based on the local industry's level of understanding and comfort with living roofs (Roehr, 2022). For example, North America is generally regarded as being behind Europe in the development of living roof technology (Peck & Kuhn, 2009). This means designers, installers and operators are all less comfortable with the technology and the buildings industry as a whole will lack experience in this field. This can make it difficult for a building owner to find

a qualified team to make their project a success. Additionally, a general lack of installations means that studying living roofs becomes difficult due to inadequate precedence cases.

Policy and legislation can be a difficult barrier to living roof installations. There are two sides to this issue: on one hand, policies may restrict when and where a living roof can be installed. This could be due to access restrictions, building height restrictions or others.

On the other, jurisdictions must take the lead to make living roofs commonplace in their local regions. Cities such as Toronto, Portland, and San Francisco all are regarded as leading North American cities for living roof systems. One commonality they each share is that they have implemented by-laws or ordinances that require living roof systems to be installed on new construction. Since the initial installation cost of a living roof system is higher than a conventional roof, it is unlikely that a developer will voluntarily install a living roof system. Their individual interests are better served by installing a conventional roof system to maximize their returns (Roehr, 2022). Additionally, providing legislation requiring living roofs can give designers and installers guidance on the requirements that jurisdictions require in order to make a living roof system a success.

Insurance and liability are one of the major barriers to living roofs in Vancouver. Similar to the knowledge issue mentioned above, many insurance providers in British Columbia lack the knowledge and experience with living roof systems to adequately assess the level of risk associated with a living roof installation (Roehr, 2022). This can deter interest from any owners or developers who may otherwise be intent on installing a living roof system.

1.8. Measuring Living Roof Performance and Success

While proper design and installation of a living roofs is necessary, the success of a living roof system should be continually monitored after installation to measure the performance and ensure a long-lasting system. This type of monitoring is typically completed and paid for by the building owner after the roof has been installed. The details of these roof performance metrics (frequency of measurement, benchmark values, etc.) will vary from project-to-project and should be detailed in the design specifications and maintenance plans, which are turned over to the owner at the project completion. Characteristics that should be monitored include:

1. Soil erosion
2. Vegetation survival rates
3. Soil moisture retention
4. Changes in rainwater runoff rates
5. Rainwater runoff quality
6. Roof temperatures
7. Range of biodiversity

Website Layout & Content

2. WEBPAGE LAYOUT & CONTENT

The City of Vancouver is currently exploring the merits and content of a potential Buildings & Sites (B&S) webpage. This B&S webpage is envisioned to serve as a 'higher-level' landing page for RCS implementation initiatives on private property and would include links to other RCS and B&S 'subject matter' webpages in other City departments.

One of the three main deliverables for this Scholars project is to provide content and layout for a subject matter webpage dedicated to blue/green roofs that would nest within the proposed B&S webpage. The Living Roof Webpage will focus specifically on the implementation of living roofs as one of the major GRI tools throughout the city. The webpage is envisioned to include:

- Overview of living roof typologies and components
- Links to relevant internal bylaws, policies, and other documents related to living roofs
- Overview of benefits of living roofs
- Overview of best practices to enhance QA/QC at design, installation, and maintenance phases
- Overview of common implementation barriers and common solutions
- Links to external reference documents for use by designers, contractors, etc.
- A suite of typical design drawings (See Section 4 for further details)
- Other supporting information such as case studies, etc.

2.1. City of Vancouver Website Content and Layout

While the City of Vancouver's existing website does currently have a dedicated webpage for the Rain City Strategy and the positive effects of GRI tools, there is a limited amount of information related to the actual GRI that is recommended and how it can be implemented.

The current webpage for the RCS and GRI can be found by navigating through the following:

Home > Home, property, and development > Water, sewer, and energy > One Water > Green rainwater infrastructure

There is no specific webpage for living roofs other than the general GRI webpage mentioned above.

The webpage is somewhat hidden from the main page and cannot be easily accessed unless the user knows exactly what to search for. It would be ideal if this information were in one central location for the various sustainability measures.

The webpage is generally well laid out with an introduction describing what GRI is and the rationale behind the city's vision for GRI. In addition, there is a navigation menu along the left column which helps a user to find related content that may be useful for them (see Figure 19). This is generally a good layout for the webpage as it will be familiar to users and easy to navigate.

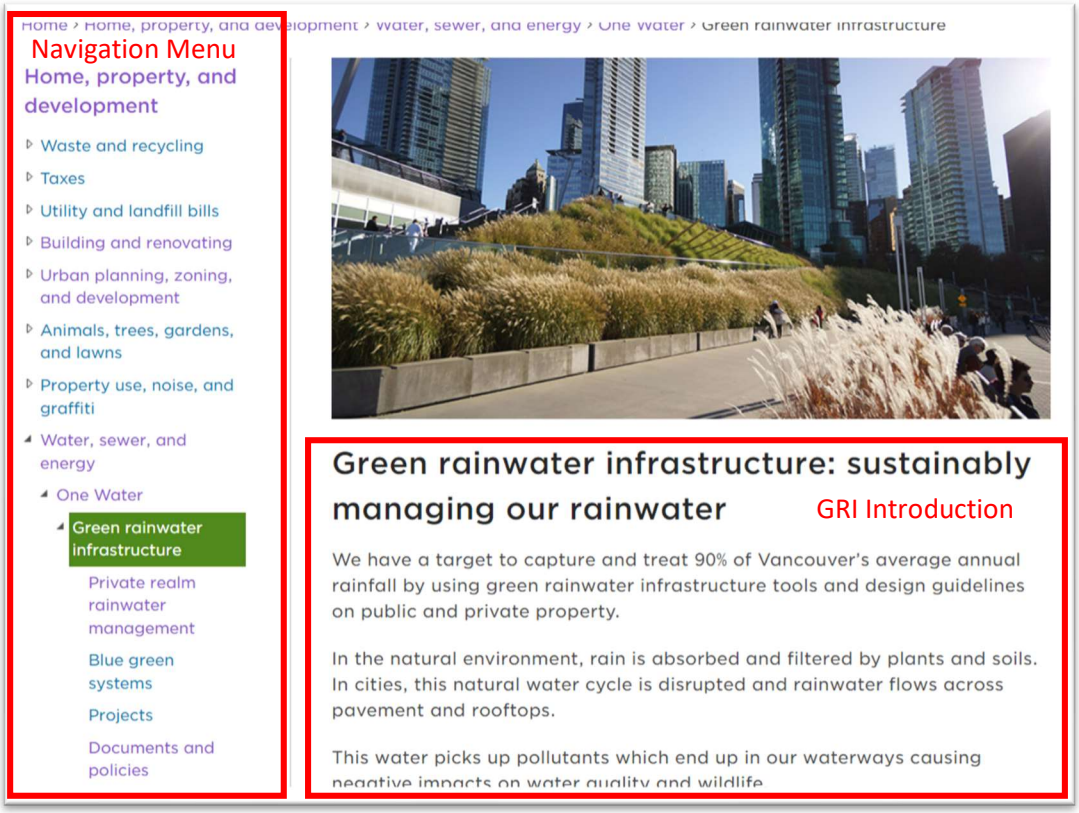


Figure 19: City of Vancouver website – GRI webpage.

In addition, the GRI webpage provides a section with various documents that are relevant to GRI, such as the Rain City Strategy, GRI typologies and transformative action plans. The webpage also includes some links to examples of GRI tools that have been installed throughout the city (see Figures 20 & 21).

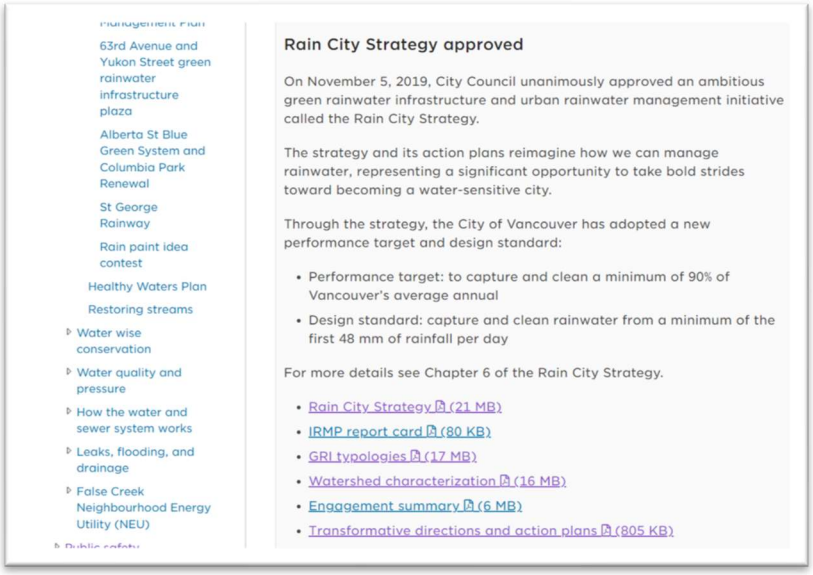


Figure 20: GRI webpage – links to relevant GRI documentation.

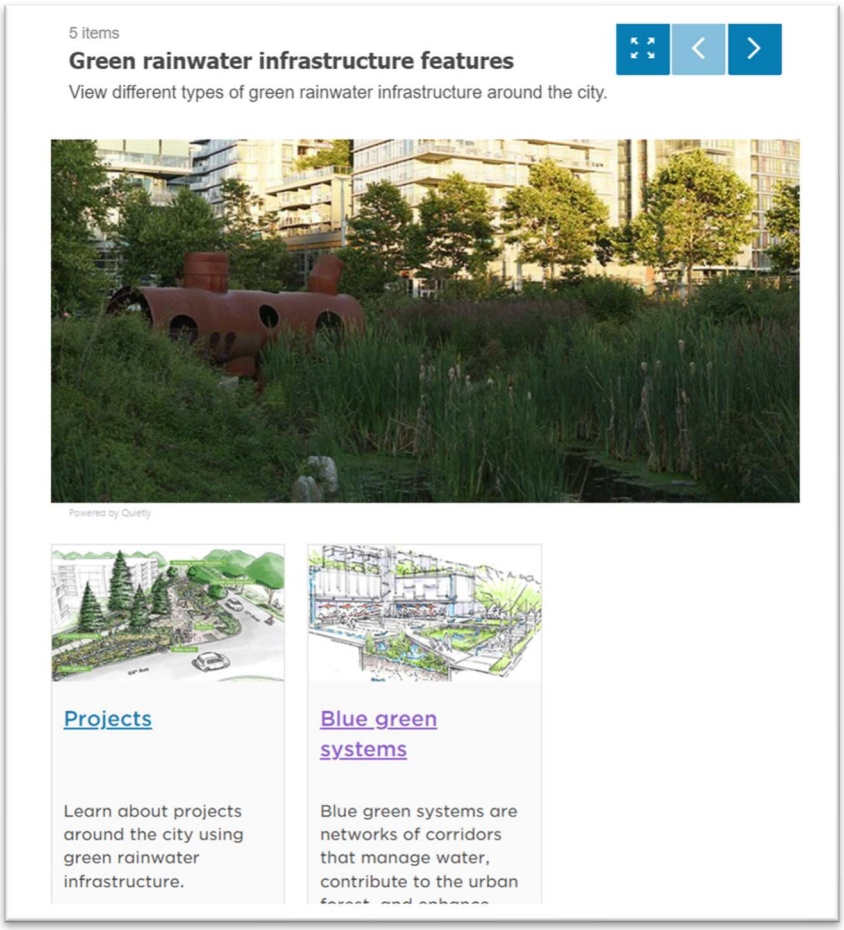


Figure 21: GRI webpage - GRI examples from around the city.

Lastly, there are some expandable headings that contain headings for various info about how GRI can be implemented and how it contributes towards achieving the goal of the Rain City Strategy (see Figure 22). These headings provide a great framework for disseminating information in a compact and easy-to-use manner that is organized and digestible for the general public.

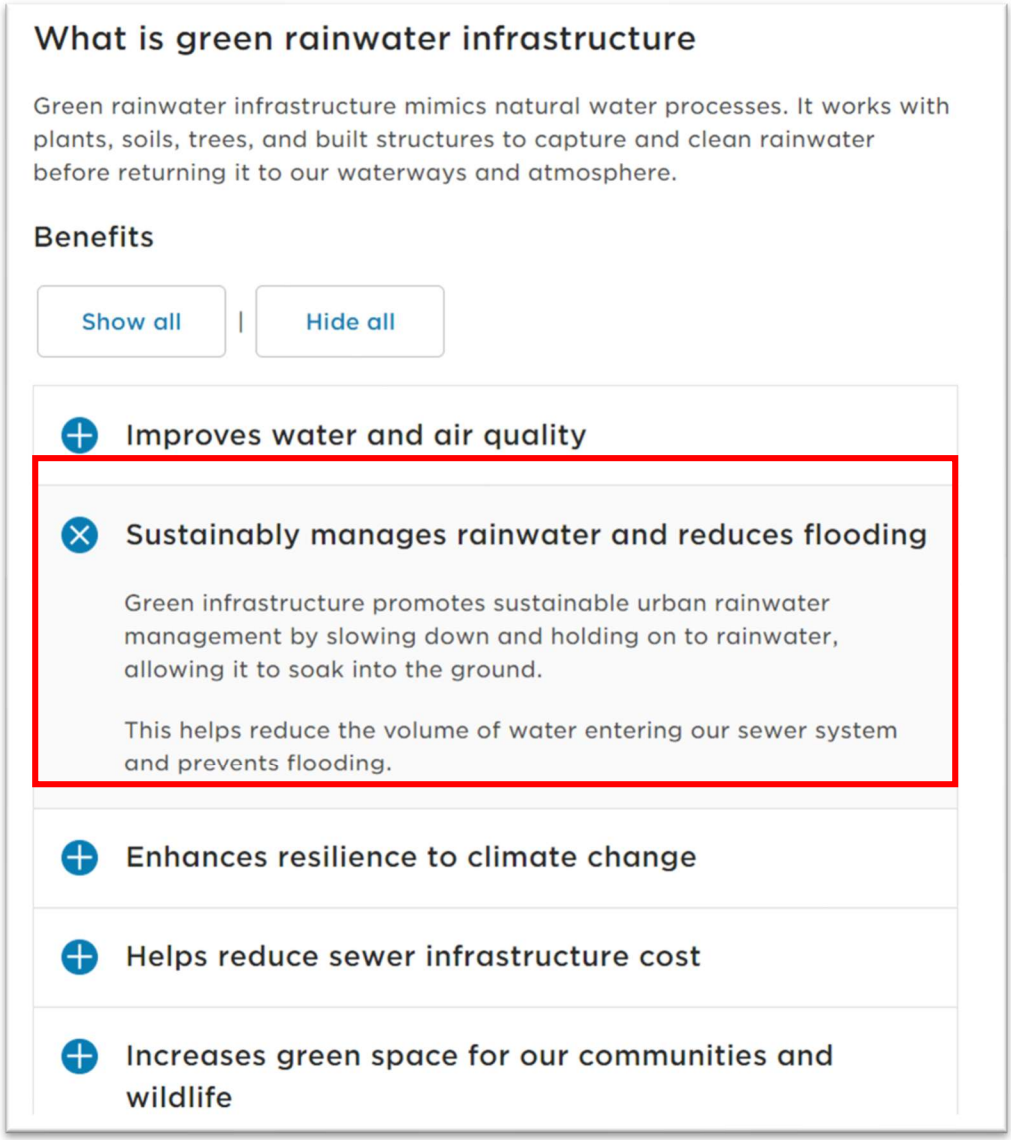


Figure 22: GRI webpage - expandable menus.

Other webpages within the City of Vancouver websites, such as the Climate Change Adaption Strategy webpage, also provide useful layouts and content to serve as precedent for the living roof webpage. The webpage can be accessed from the home page via:

Home > Green Vancouver > Climate Change Adaptation Strategy

The Climate Change Adaptation Strategy webpage contains a layout that includes the use of tiles as links to a subset of webpages related to various climate change contributors. The tiles provide good visual stimulation and, when the cursor hovers over the individual tiles, a description of the webpage content appears to provide context (see Figure 23).

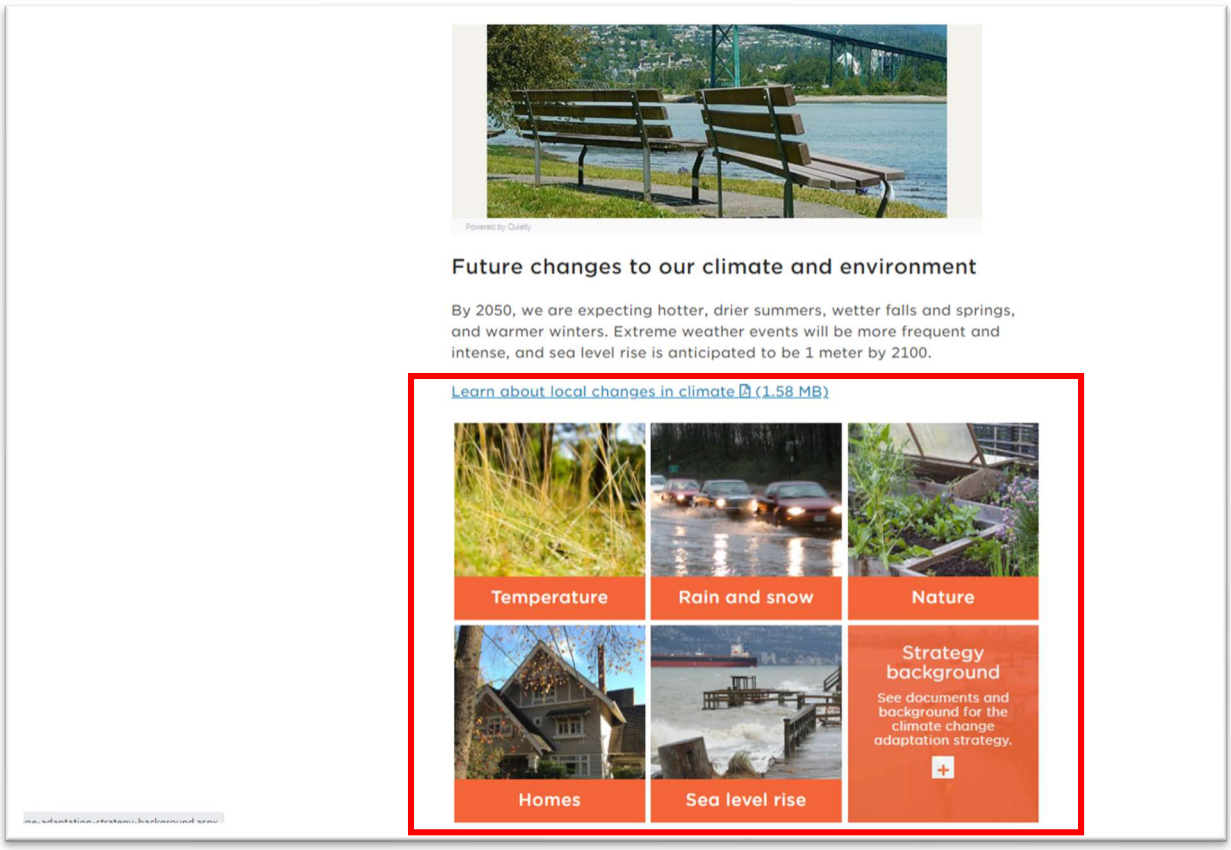


Figure 23: Climate Change Adaptation Strategy webpage - webpage tiles.

2.2. Comparison to Other Jurisdiction Webpages

The layout shown above provides some excellent foundations for the proposed layout of the living roof webpage. In addition to this, part of the scope of work for this project includes a review of the webpage layouts in other jurisdictions. The intent is to determine the most intuitive organization and visualization to make the living roof webpage informative and easy to navigate for the public and internal staff.

Comparative jurisdictions that were reviewed included:

1. The City of North Vancouver
2. The City of San Francisco
3. The City of Toronto
4. The City of Portland
5. The Capital Regional District (Vancouver Island)

The comparative review considered two major factors in determining the quality of the webpage:

1. Organization/ease of webpage navigation
2. Webpage content/links included

2.2.1. Webpage Layouts/Organization

There are a wide range of layouts between the various jurisdictions reviewed. Some, like the City of North Vancouver, have a simplistic site that includes infographics with a brief overview of the different living roof systems and links to schematics at the bottom of the page. While this layout is effective, it generally does not contain enough detail to meet the City of Vancouver's intended purpose.

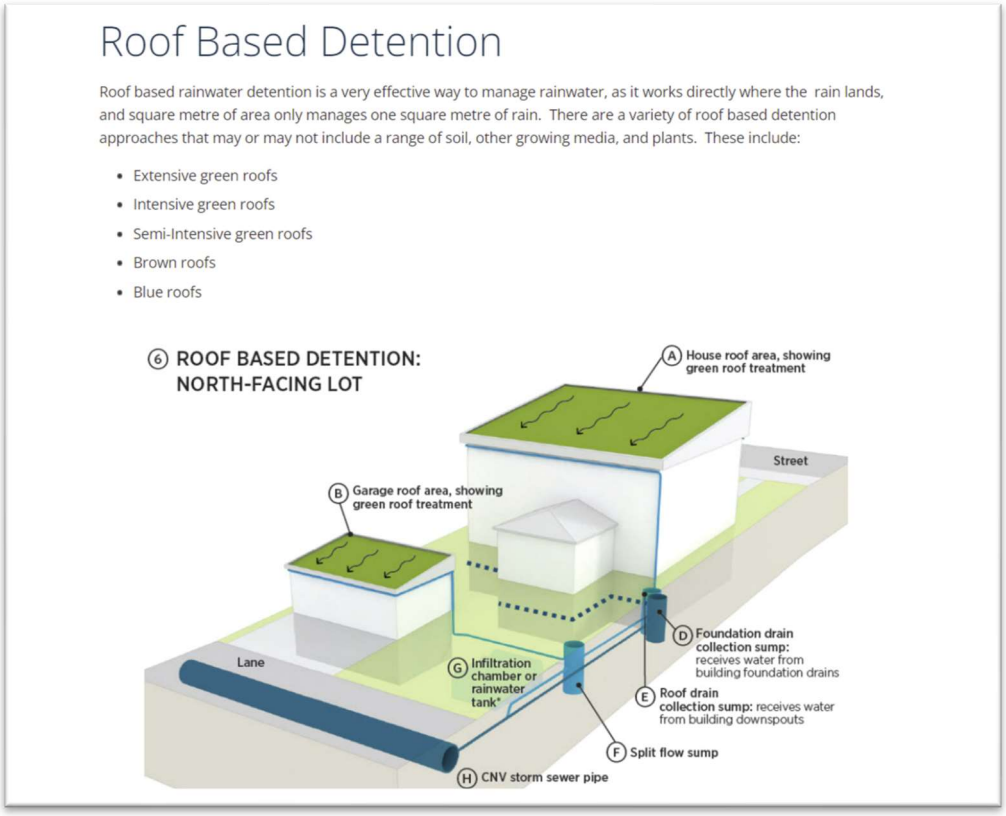


Figure 24: City of North Vancouver Website - Roof Based Detention Webpage.

The City of San Francisco's Resilience and Sustainability webpage provides some useful layouts as well that can likely be adopted for the City of Vancouver's B&S webpage. There is a brief overview of the Resilience and Sustainability group's importance and goals. This is followed by a breakdown of the various initiatives that are being completed by the City, which are organized into tiles that link to further subpages. The webpage is relatively easy to navigate, and it is not difficult to find relevant information on the page.

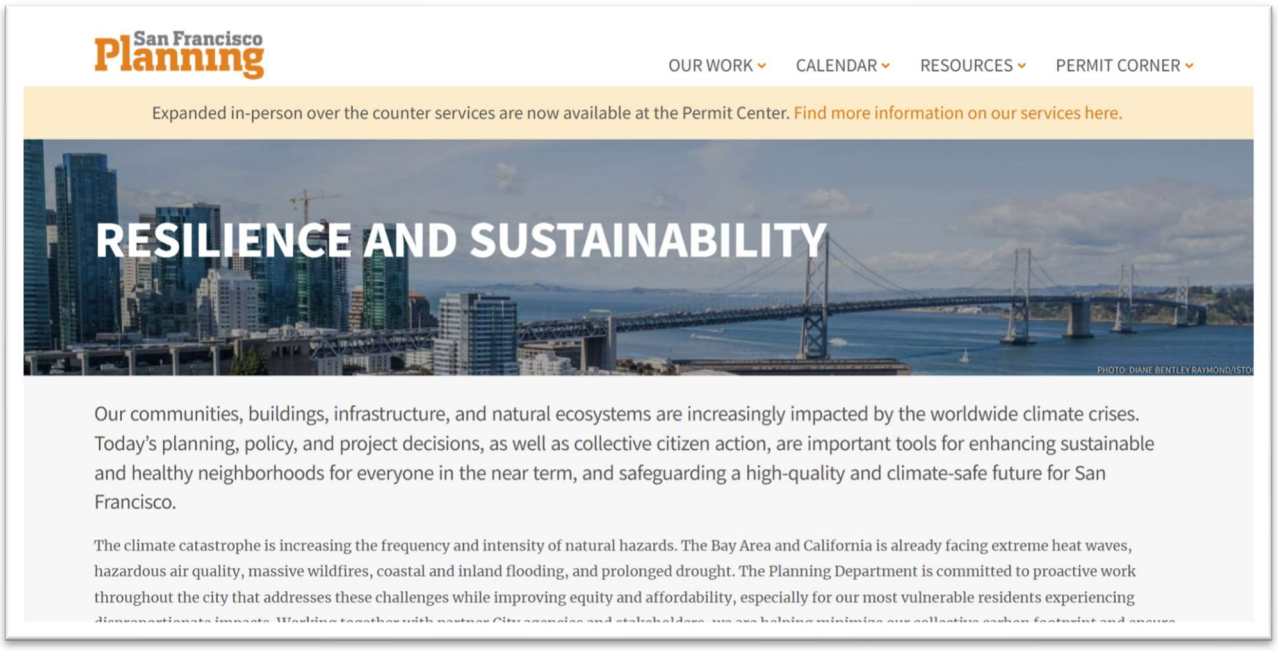


Figure 25: City of San Francisco website - Resilience and Sustainability webpage.

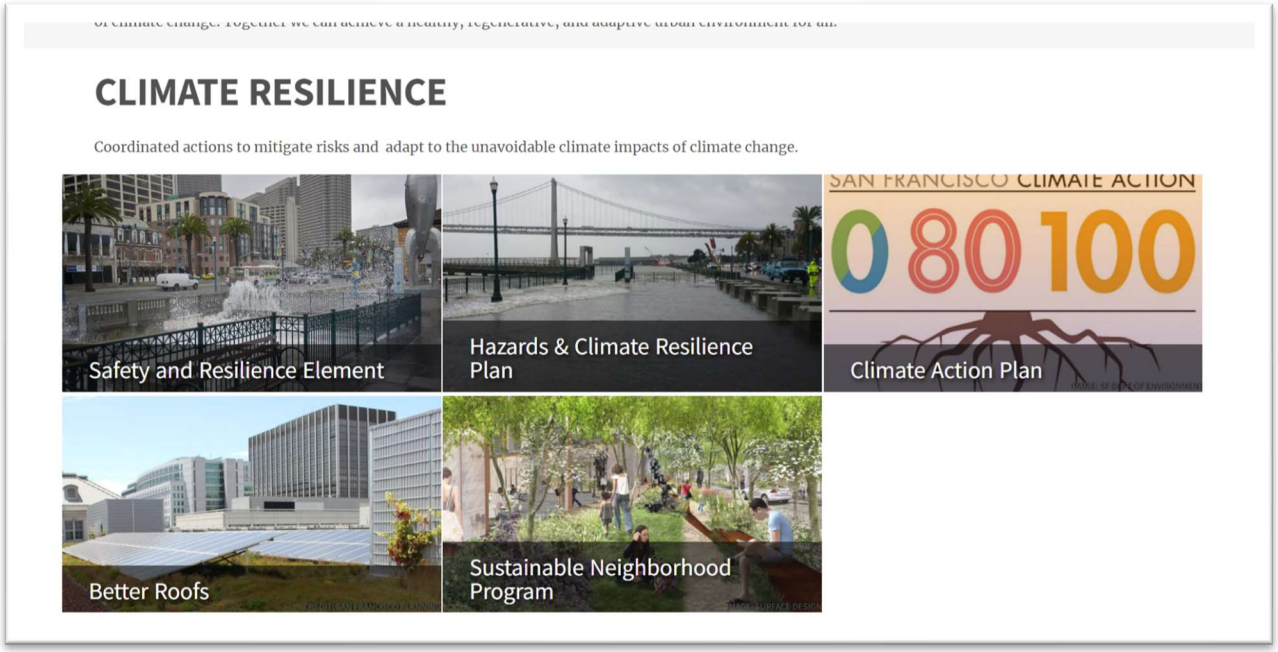


Figure 26: Resilience and Sustainability webpage - tiles organized for each initiative.

The City of San Francisco has a unique layout for their Better Roofs webpage. They include a brief overview of the Better Roofs Initiative and then include tabs below, which can be cycled through and contain various information such as case studies, cost-benefit analysis, and links to supporting info, such as design guidelines and ordinances. This layout is easy to navigate and provides information that is well suited to the specific needs of the City of Vancouver, compared to the City of North Vancouver.

However, the San Francisco webpage categories are not well organized and are somewhat hidden at the bottom of the page.

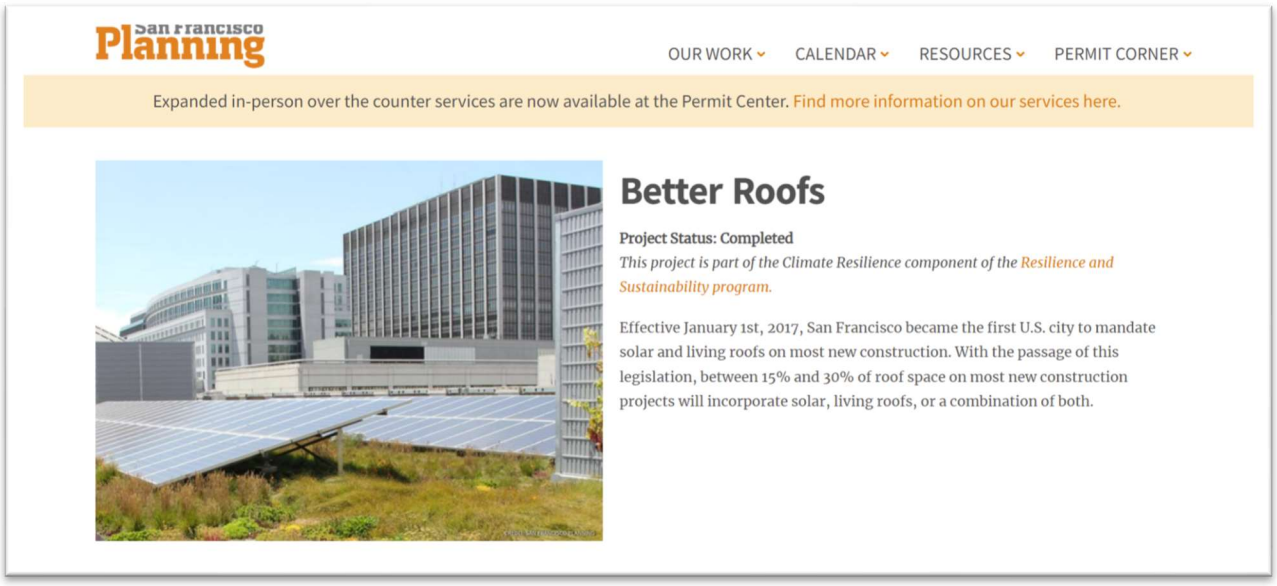


Figure 27: City of San Francisco - Better Roofs webpage.

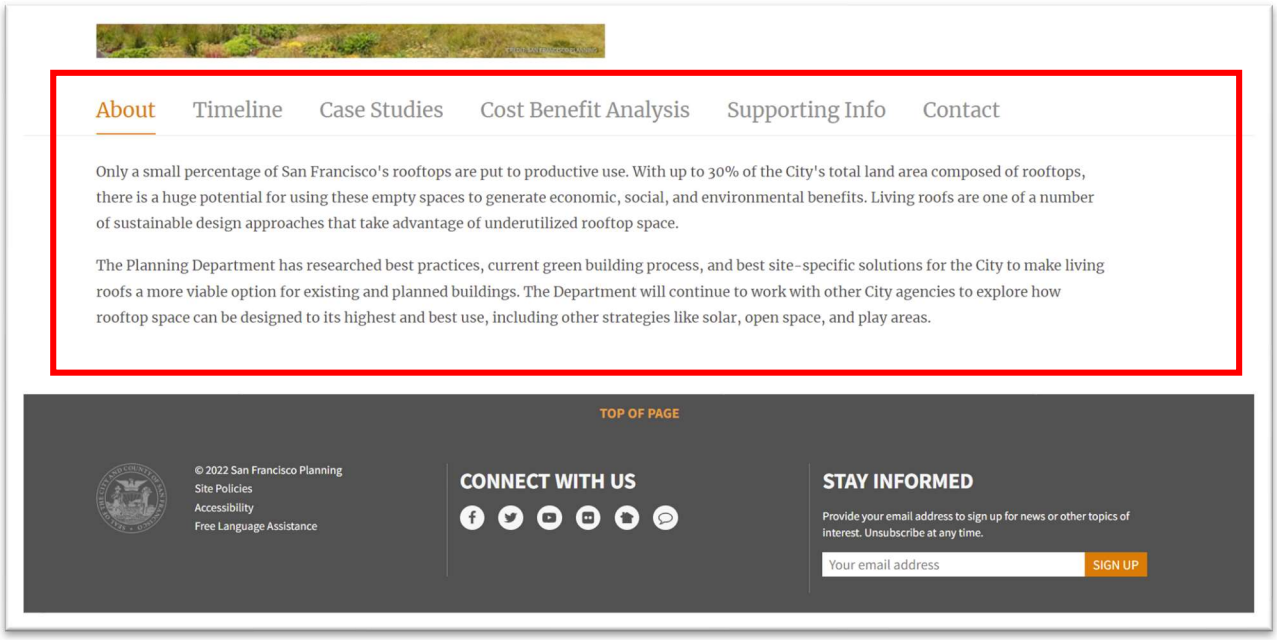


Figure 28: City of San Francisco Better Roofs webpage - tabs for various information.

The City of Toronto's Official Plan and Guidelines webpage provides a similar layout to the City of San Francisco's Resilience and Sustainability webpage. While there is no introductory text at the top of the page, tiles are included that provide links to various subpages, including the green roofs webpage, making it easy to navigate to the information needed. The tiles also provide a brief description of what is

included under each link. However, without any imagery, this is not as visually appealing as the San Francisco and Vancouver websites

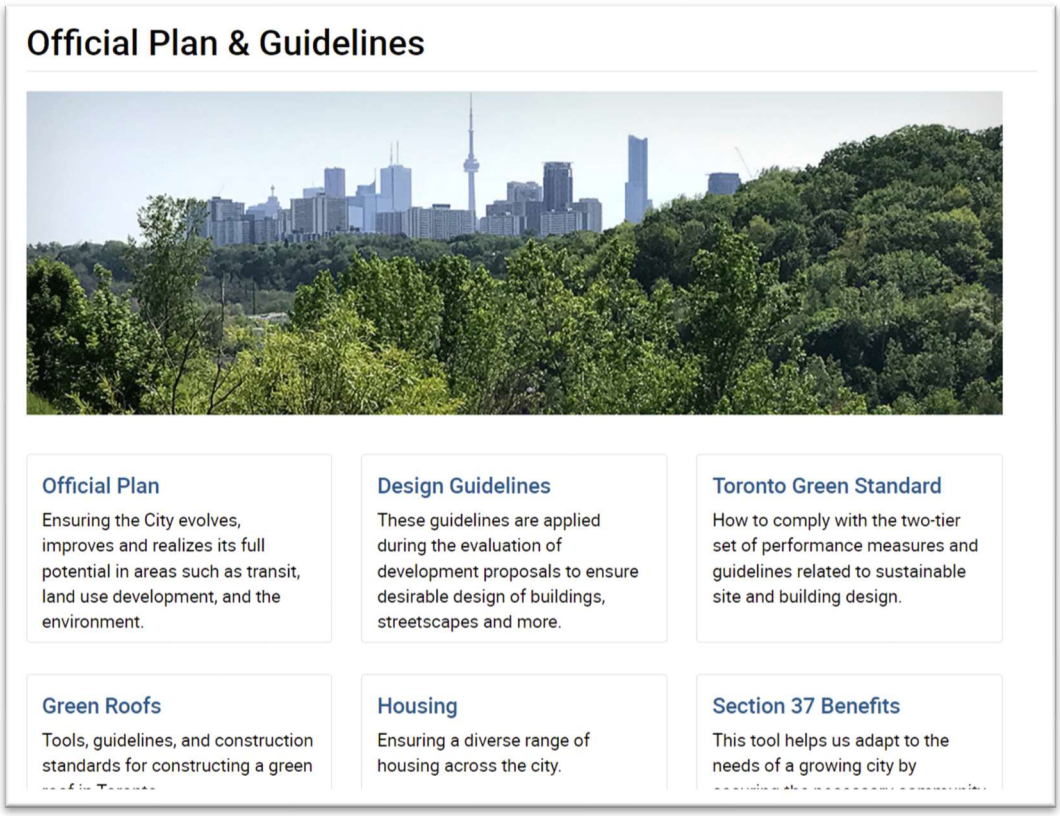


Figure 29: City of Toronto website - Official Plan & Guidelines webpage.

Since the City of Toronto has a green roof by-law, the dedicated Green Roof webpage is much more developed. The general layout includes an overview of the by-law requirements and then several expandable menus that provide additional details on topics, such as sizing of living roofs and useful templates/forms. The webpage also includes a side navigation bar, which contains links to other relevant webpages. The sidebar is a very useful addition as it can help users navigate to related topics they may not otherwise be able to find.

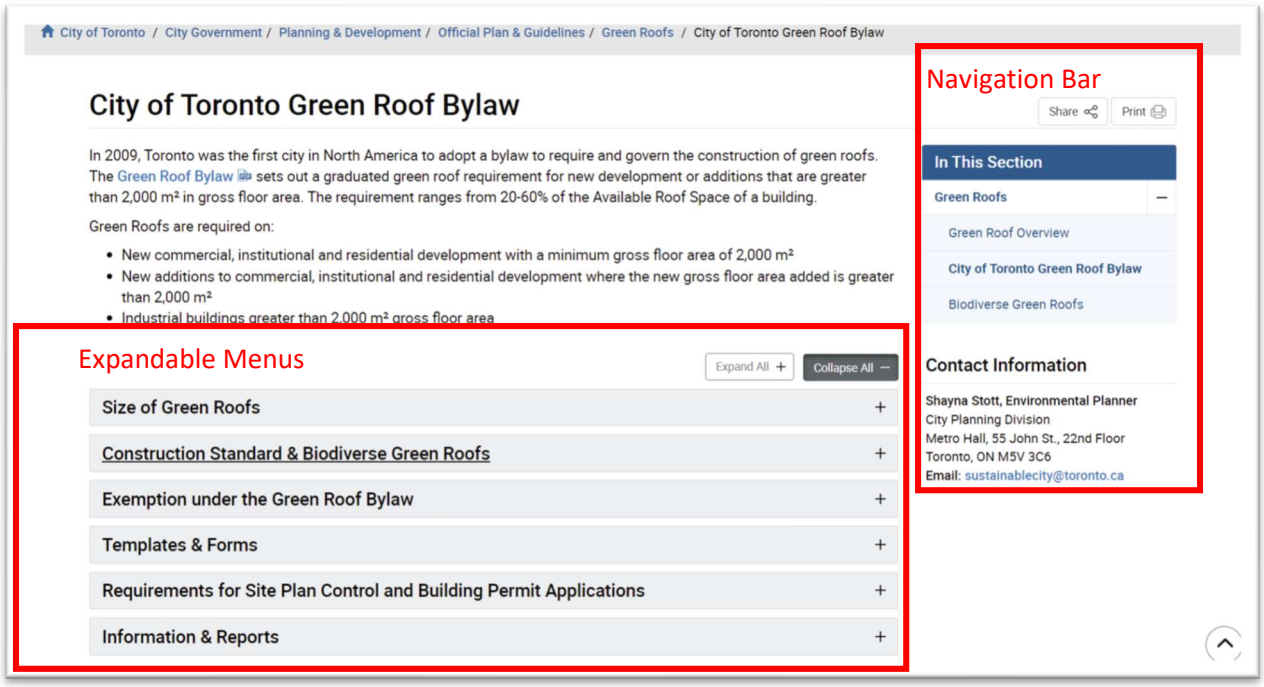


Figure 30: Green Roof By-Law webpage – expandable menus and navigation bar.

The City of Portland's equivalent to the B&S initiative is the Managing Rain on Your Property webpage. The webpage provides some good context and recommendations for how to manage stormwater. However, the page does not have any imagery or colours to help break up the text. The webpage also makes effective use of the side navigation bar to allow users to explore various rainwater management tools.

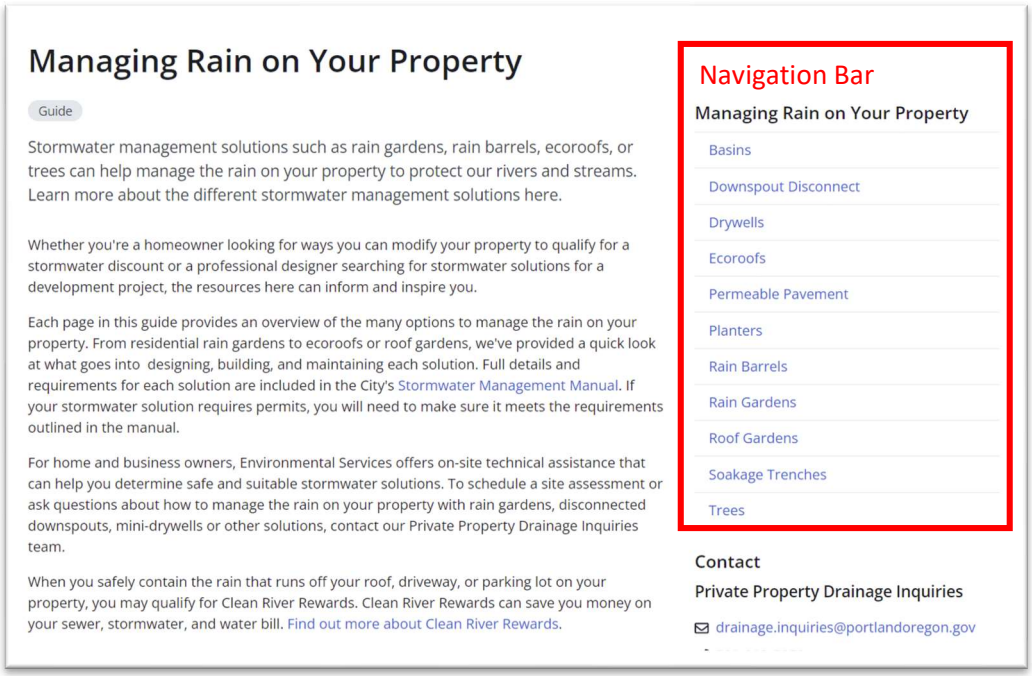


Figure 31: City of Portland website - Managing Rain on Your Property

The City of Portland's living roof webpage is their Eco-roofs site. The page provides some useful information on living roof technologies with an overview of the system components, maintenance requirements and costs/permits. There is even an index at the top of the webpage to help jump directly to the various sections. However, the webpage is relatively long and includes a lot of text, which can be intimidating to some users.

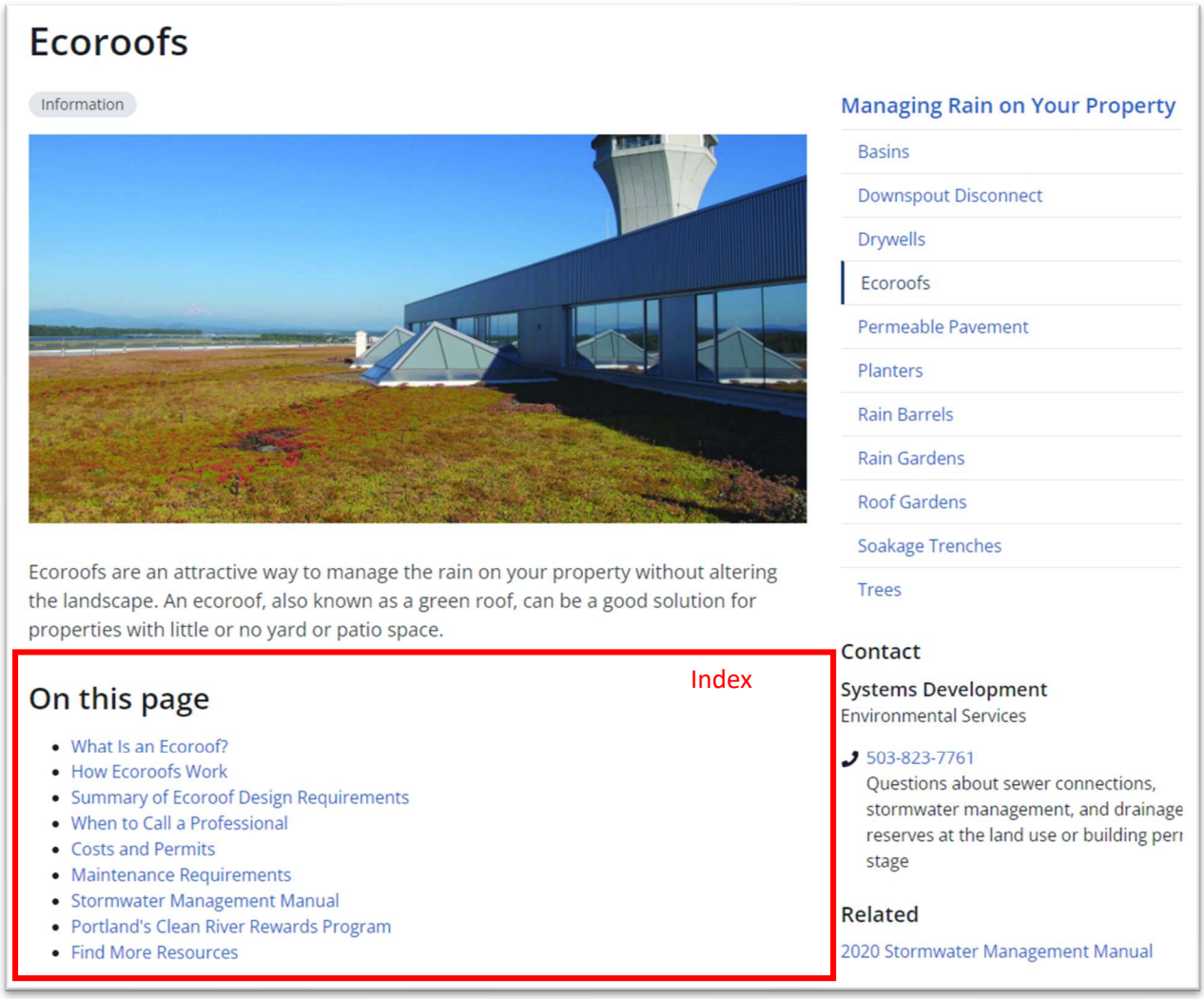


Figure 32: City of Portland - Eco-roofs webpage.

Last, the Capital Regional District (CRD) website includes a webpage for Green Stormwater Infrastructure (GSI). The webpage provides a brief overview of the various advantages of stormwater management and includes a large list of appendices with additional information on stormwater management along the right-side menu. A navigation menu is shown along the left side of the webpage to help navigate through the various types of GSI.

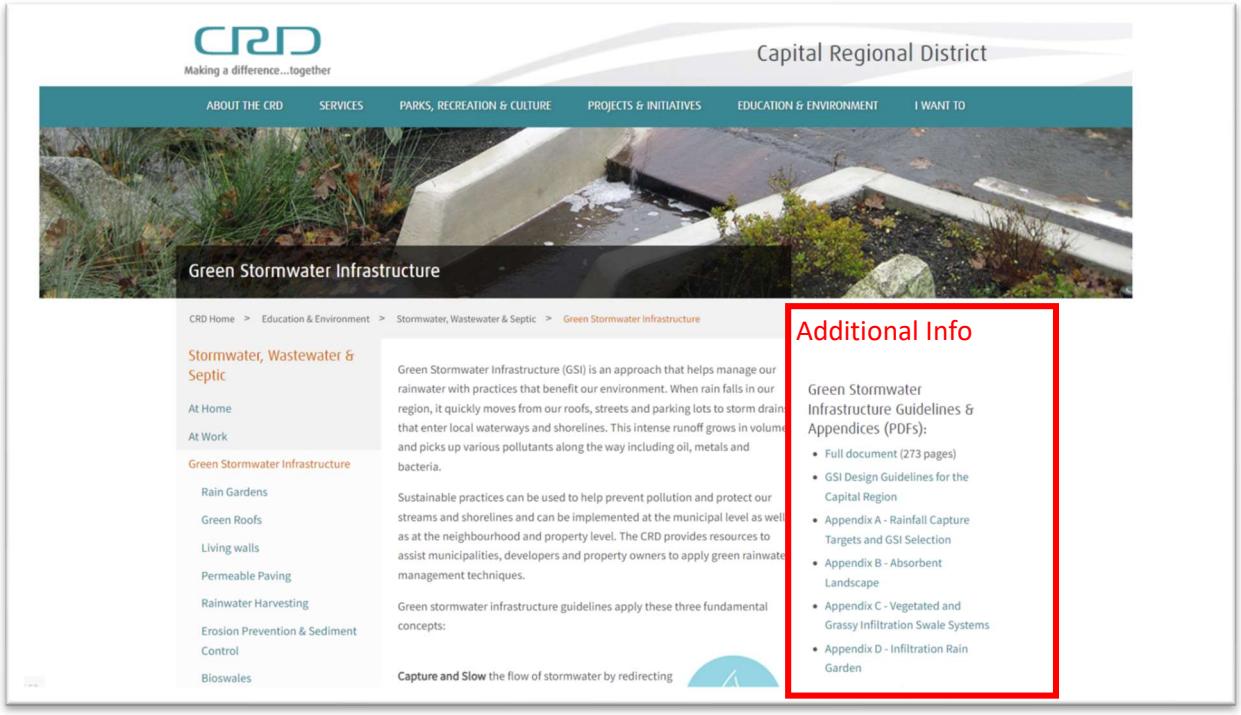


Figure 33: CRD Website - Green Stormwater Infrastructure webpage.

The Green Roofs webpage provides an excellent level of detail regarding green roofs, such as installation, types of green roofs and highlighting the various co-benefits. However, the layout of the information is just a long wall-of-text that can be very intimidating for users to read though. Having a series of tabs of drop-down menus along with images might make the content easier to digest. Similar to the GSI webpage, the Green Roofs webpage contains useful links along the right-side menu and a useful navigation bar along the left side.

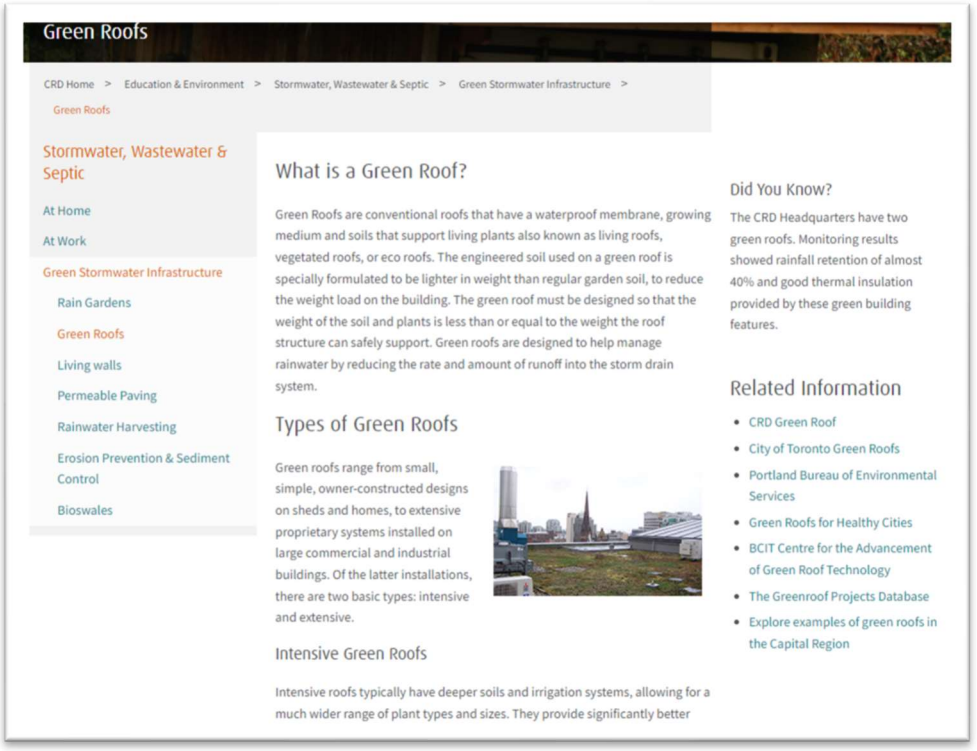


Figure 34: CRD Website – Green Roofs webpage.

2.2.2. Recommended Layout

While each of the websites reviewed had their own advantages and disadvantages, certain features stood out as commonalities in the various layouts:

1. **Tiles on main B&S Site –** The tiles serving as links to the various GRI tools are visually appealing and provide a concise way to organize the webpage information and make it digestible for a user. Additional descriptive text should be incorporated that appears when the cursor is hovered over each tile. The City of Vancouver already includes this on some of their webpages and should consider continuing to use this style when designing the B&S webpage.
2. **Expandable menus on the Living Roofs webpage –** The information available regarding living roofs is important to provide to the public but presenting it as a long continuous stream of text makes it difficult for users to absorb the content and can be intimidating. Using expandable menus allows the user to find the information they need quickly, without having to scroll through pages of text first. This is another item that the City of Vancouver already includes in their webpage design and should be encouraged for use on the Living Roofs webpage.
3. **Navigation Menu –** several of the websites reviewed include a navigation bar along the left side of the webpage. This is an ideal and intuitive element to include in the webpage layout, as it allows users to cycle through the various GRI sub-webpages and learn about the various related topics, rather than having to navigate back to a homepage to continue exploring the website. Both the CRD and the City of Portland websites provide good examples of this element.
4. **Relevant Information Side-bar –** Including a sidebar with related documents, external websites, and information on relevant contacts is another excellent item to include in the layout of the

webpage to make information easily accessible to users. Both the CRD website and the City of Toronto provide good examples of these sidebars.

While there is no singular right way to design a webpage, these recommendations can help to improve the overall appearance and ease of use of the webpage. A sample layout of the typical webpage is included in Appendix A.

2.2.3. Overview of Website Content

Throughout the review of the various jurisdiction websites, several commonalities were noted. In almost all cases, the main GRI page and the living roofs webpages included a banner image at the top and a general overview of the webpage topics:

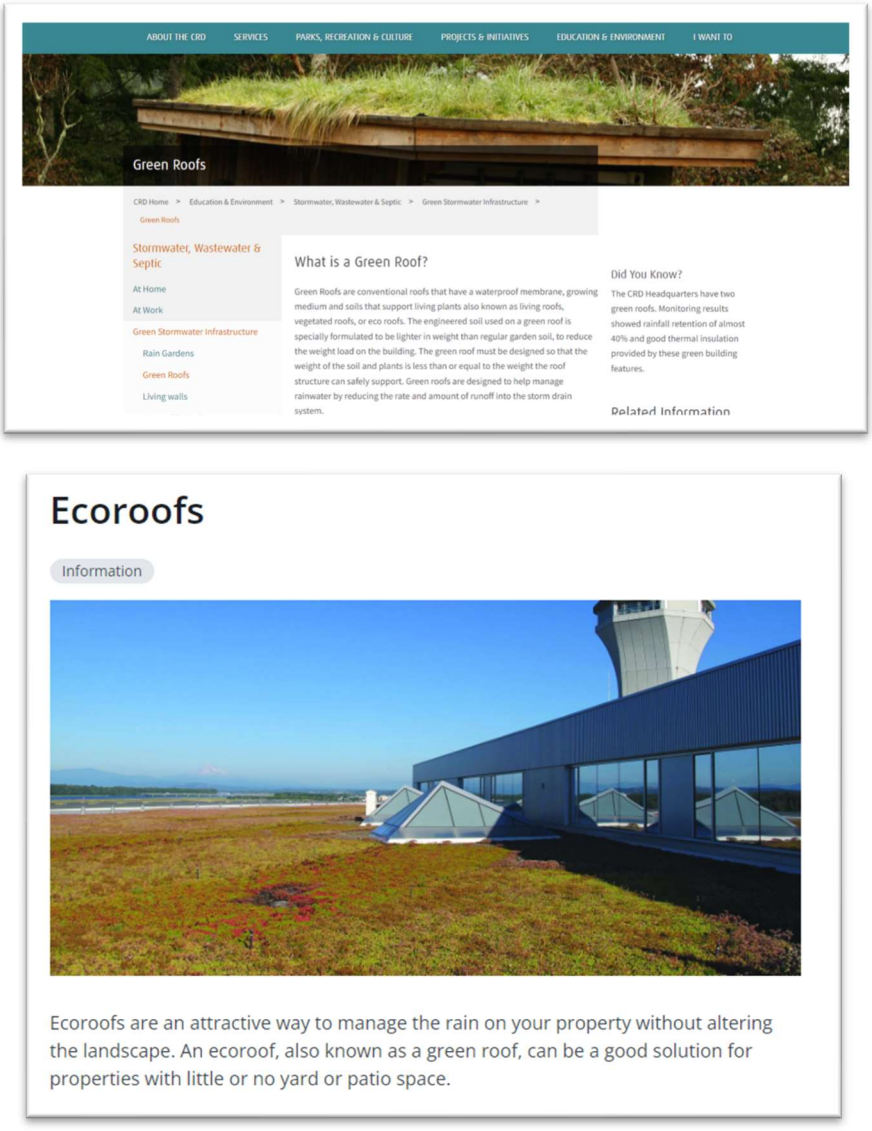


Figure 35: Examples of banners and introductory text - CRD Region (top) and the City of Portland (bottom)

In addition, the comparable websites typically included a breakdown of the various types of living roofs, along with a discussion about the advantages and disadvantages of the different types. In some cases, such as the City of Portland's website, a diagram is included to help provide a visual representation of the roof types and their various layers, and to make comprehension easier for those new to living roof systems.

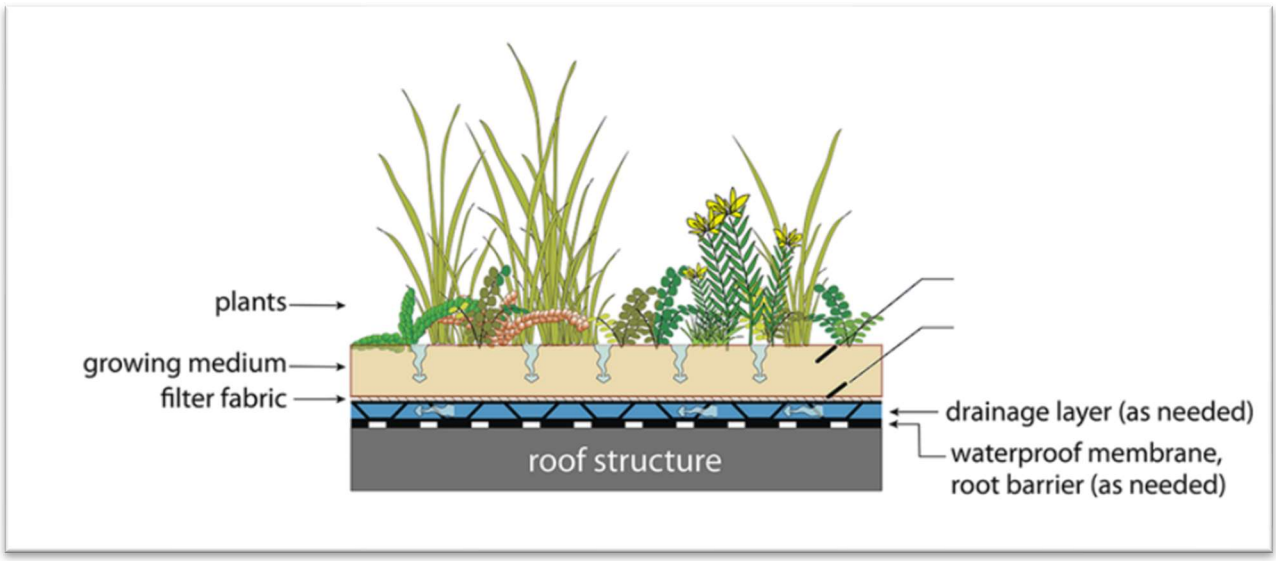


Figure 36: Typical living roof section – the City of Portland website.

In some cases, case studies are included within the jurisdiction webpages. San Francisco and the City of Toronto both provide case study examples that can be used by owners/designers/contractors to better understand typical conditions of a living roof project and provide insight on expected costs, timing, etc.

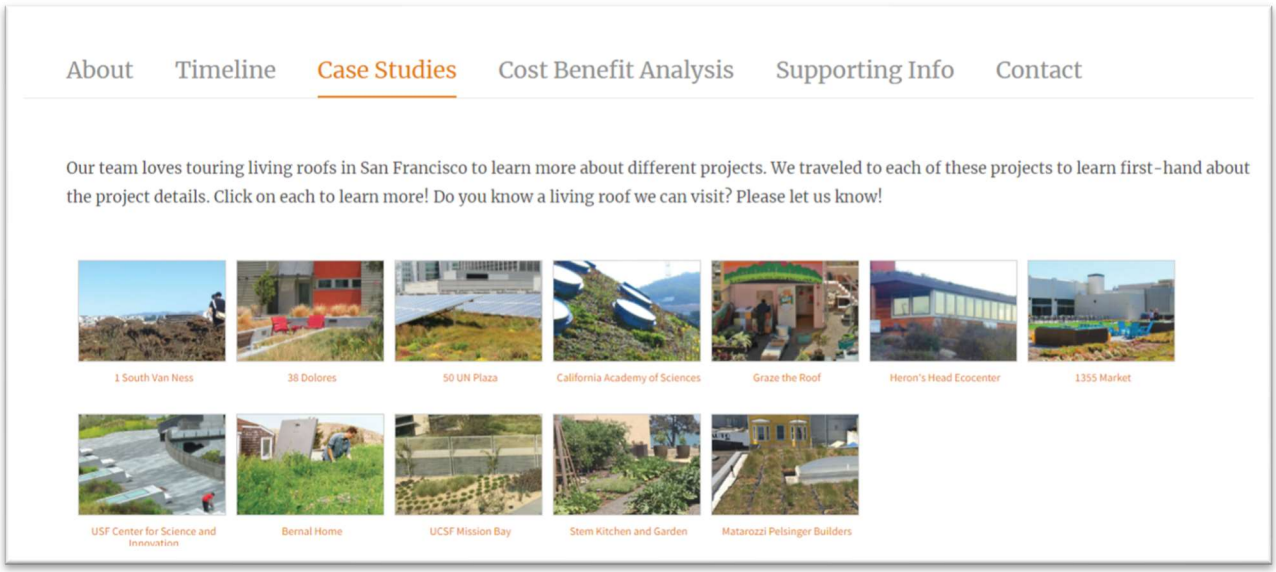


Figure 37: List of case studies available – the City of San Francisco website.

Some jurisdictions even include interactive maps which contain a database of living roof projects around the city/region. The City of San Francisco has their own interactive map that is managed internally and contains details of each project such as address, size, date of installation and the system designer. This can be particularly useful for owners/designers/contractors that are interested in reviewing various design strategies from around the city to serve as precedent. The CRD uses an externally managed site via GreenRoofs.com to track the various living roof projects across the city. The added benefit of the CRD's source is that there are several Vancouver projects which are already available. An internally managed site would be preferred, but if this is not feasible, the Living Roof webpage should include, at a minimum, the external website as a link.

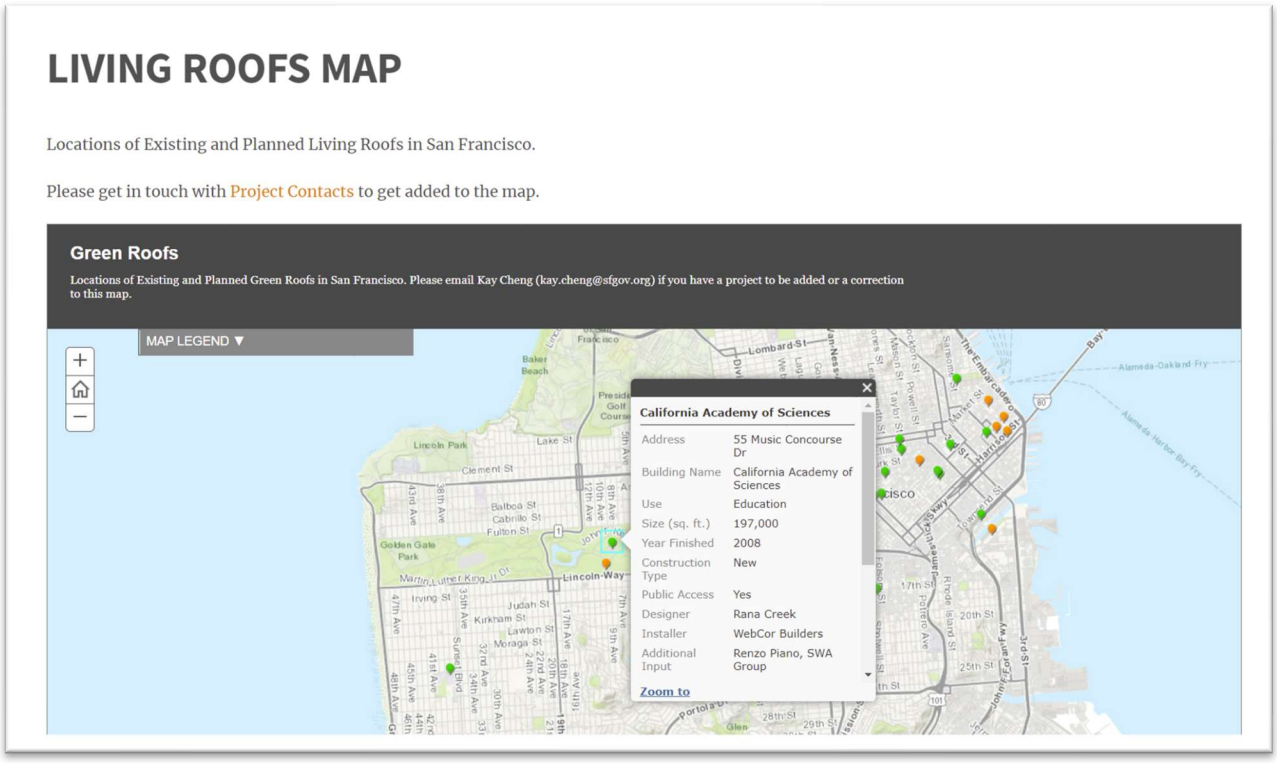


Figure 38: Interactive green roofs map - City of San Francisco website.

In almost all of the websites reviewed, sidebars have been included. These sidebars contained links to useful documentation or external websites that provide additional tools and information related to living roofs. The CRD Green Roof webpage provides the best example of this with links to several other jurisdictions, as well as informational websites such as Green Roofs for Healthy Cities (GRHC) and BCIT Centre for the Advancement of Green Roof Technology.

Each of the websites reviewed provided valuable information that can serve as a basis to include on the proposed City of Vancouver webpage. Research revealed that the best comparison websites were the City of Portland, City of San Francisco and the CRD. A qualitative matrix that outlines the findings and categories used to complete this analysis is included in Appendix E.

2.2.4. Recommended Content

Based on the research completed, several recommendations for content on the proposed webpage are shown below. In some cases, the recommendations extend beyond what was noted during the website

research and are based on a combination of design guidelines review, interviews with internal members of the City of Vancouver, and feedback from industry stakeholders. Ideally, items two to six should be included under expandable headings, as mentioned in Section 2.1. Items seven to nine should be included as hyperlinks in the information sidebar.

1. **Living Roof Banner and Overview of Living Roof Technologies** – Including an overview of living roofs and background on their importance provides readers with the mindset and general knowledge to introduce them to the topic of living roofs. A banner image at the top of the page provides a sense of connection to the topic and visual stimulation for overall improved aesthetic appeal.
2. **Breakdown of Living Roof Components –** Providing a generic overview of the various components of the living roof can help building owners, operators, and the general public gain a high-level understanding of the major layers that are included in a living roof. The intent would be to provide high-level information that is easy to understand and does not overwhelm readers with technical details (which should be reserved for the design guidelines). Ideally, the text should be accompanied by a cross-section of a typical living roof system to illustrate the various layers of the installation. One option, depending on the City's website design capabilities, would be to make the diagram interactive, by having each layer of the roof system be expandable to learn more about each layer.
3. **Overview of Living Roof Categories –** A breakdown of the three main types of roof systems (extensive, intensive, semi-intensive) is essential for any living roof webpage. Providing users with this basic knowledge allows them to understand the different options of living roofs available and their various advantages and disadvantages.
4. **Overview of Roof Functionalities -** The webpage should also break down the various functionalities of living roofs that are being emphasized by the City of Vancouver and how the roof installation/composition will be affected based on its function. The four functions to be emphasized include:
    a. Rainwater management
    b. Enhancing biodiversity
    c. Providing activity/amenity space
    d. Rooftop agriculture
5. **Co-benefits of Living Roofs** – Providing an understanding of the various benefits of living roof systems will encourage implementation of living roof systems through education and understanding of the many positive influences that a living roof can have onsite. The content here should focus on the positive contributions a living roof creates, such as rainwater retention, improved aesthetics, improved thermal barrier, enhanced biodiversity, and reducing the urban heat island effect. Similar to describing the living roof components, the co-benefits should be clearly laid out in plain language to allow the benefits to be understood by anyone who is new to living roof systems.
6. **FAQ Section –** A list of frequently asked questions was developed to provide additional education to the general public. By implementing this FAQ section, the webpage provides timely answers to common questions, which can save time for both visitors of the webpage and City employees.
7. **Synergies with Existing City of Vancouver Strategies** – The City of Vancouver has a number of ongoing strategies that align with living roofs and GRI technologies. Including links to relevant

strategies may be useful for webpage visitors that are looking for connections between living roofs and other various initiatives that may align with their goals for their property. Providing these links also makes it easier to navigate between the various city strategies, rather than having to search each one individually.

8. **Recommended Links/Documents –** There is a wide range of internal documents (by-laws, studies, bulletins, etc.) and external documents (design guidelines, living roof expertise, design standards, etc.) that can provide additional information for owners, designers, and contractors alike. Providing hyperlinks to the various websites can help the living roof webpage achieve its intent of disseminating information and serving as a source of education on living roof systems.
9. **Recommended Tools –** Based on the research completed, a few tools have been developed that can potentially be loaded onto the living roof webpage for download and used by citizens, including a roof maintenance checklist and a roof design checklist. Links to various external tools could be added to this section as well such as a green roof calculator and stormwater retention calculator. While this is not an exhaustive list, more tools should be added to the webpage as they are developed by the City.

A detailed breakdown of suggested content for the living roofs webpages including text and suggested sample images, documents and tools is included in Appendix A.

2.2.5. Recommended Additional Research

While this section of the report aims to develop the layout and content for the GRI and living roofs webpage, it is important to note that there are limitations to the extent of the research that can be completed within the report timeframe. As a result, there are areas where additional research and development is recommended to further enhance the content of the webpage. Further research and development are recommended for the following:

1. **Pathways Study** – the Pathways Study is currently being completed by the City of Vancouver to better understand how GRI tools can be combined on a range of representative building typologies to meet Vancouver's rainwater management design standards. Updating the information available on the webpage once the study is completed can provide additional insight into GRI implementation and help advance any GRI initiatives that are already in place.
2. **Case Studies –** Many other jurisdictions include some case studies of living roofs throughout the City to promote awareness of living roofs and show that these systems can be successfully implemented in the local climate. The City of Vancouver has several roofs that should be ideal case studies (I.e., the Convention Centore and the Central Vancouver Public Library). However, most of these are publicly-owned buildings. Additional research should be completed to investigate where living roofs have been successfully installed at private properties and promote these cases. Contacting local architectural firms and researching recent permit applications within the building permits department would be a great start to determining a suitable case study.
3. **Cost Benefit Analysis –** The initial capital premium that comes with a living roof installation is one of the main barriers to widespread implementation. However, it is important to look at the entire lifecycle of a living roof system to understand the potential savings. A full life cycle cost-benefit analysis of green roof installations should be considered by the City to justify the case for living roofs installations. An excellent example of a cost-benefit analysis can be found on the City of San Francisco's website.

4. **Interactive Living Roof Map –** As mentioned in Section 2.2.3, several major cities have interactive maps available that track existing living roof projects. This is an excellent tool, as it provides a source for citizens to locate living roofs installed near them and visit them if they are interested in learning more about a living roof in-person. However, this can be a labour-intensive task as a suitable platform must be developed and all the data for existing living roof projects must be found and uploaded into a GIS-based system. The City should consider investing in a living roof map similar to what the City of San Francisco and New York City have implemented.
5. **Living Roof Costing Form –** As building owners are often wary of the cost of a living roof installation, developing a tool such as a costing spreadsheet can help building owners estimate the cost of a typical living roof installation. The City should consider working with local contractors and designers to develop a costing tool that would allow building owners to determine a rough estimate of the cost of a living roof. There are, of course, limitations to a tool like this, as it cannot account for the unique conditions of each building, which would need to be stated in a disclaimer as part of the tool. However, it can serve as an educational tool for anyone who is curious about how financially feasible a living roof installation is for their building.

Design Guidelines

Photo By: Sempergreen

3. DESIGN GUIDELINES

A major component of interest for this project is recommendations for the general layout of Living Roof Best Practices Design Guidelines for the City of Vancouver. The scope of work includes a review of existing design guidelines from the City of Vancouver. The review also includes a comparison against various jurisdictions to determine the major topics of focus that are common among the guidelines reviewed. Based on the findings, the aim is to provide a general content outline of best practices for the City of Vancouver to use when developing its own design guidelines in the near future.

3.1. Review of Existing City of Vancouver Design Guidelines

A review of the existing design guidelines for the City of Vancouver provides a benchmark for comparison against other jurisdictions and can identify where there are variances between Vancouver's existing guidelines and the other jurisdictions.

Currently, there is no requirement to install living roofs on new or existing buildings in Vancouver. Additionally, there is no formal design guideline document for living roofs. This is one of the major drivers for this research. The development of a guideline document can provide a single reference for guidance surrounding the design, installation, and maintenance of living roof systems. A formal design guideline would also allow for customization of the guidelines to suit requirements that are specific to Vancouver (climate, local by-laws, etc.).

The Vancouver Building By-Law (VBBL) is based on the BC Building Code and serves as one of the major guiding documents for building design and construction within the City. The by-law contains two major sections that discuss living roof systems, Section 3.1.14.4 and Section A-5.6.1.2.(2). These clauses provide a general basic overview of how living roofs should be installed such as the inclusion of a root barrier and that the roof assembly is designed to accommodate rainwater harvesting. The VBBL also references multiple important external standards that are intended to provide supplemental support in living roof design such as ANSI/SPRI VF-1 – External Fire Design Standard for Vegetative Roofs.

A gap analysis of the existing bylaws and standards was completed. The analysis found that while there are several components that are mentioned in the current state of the by-laws, there is minimal actual design, installation, and maintenance guidance. For example, the VBBL mentions that a living roof must include a root barrier. However, there are no specifications around materials options for the root barrier, no guidance on installation, and no language explaining the significance of the root barrier. A summary of the gap analysis can be found in Appendix D.

3.1.14.4. Green Roof Assemblies

1) A *green roof assembly* is permitted in *combustible* and *noncombustible construction* if

a) the *green roof assembly* is designed and constructed in conformance with ANSI/SPRI VF-1 "External Fire Design Standard for Vegetative Roofs",

b) gravity loads on the *building* structure are determined by ASTM E2397-11 "Standard Practice for Determination of Dead Loads and Live Loads Associated with Vegetative (Green) Roof Systems",

c) the *green roof assembly* is designed and constructed with a root barrier,

d) the *green roof assembly* is designed and constructed with water retention materials to support vegetative growth, and

e) the drainage layer of the *green roof assembly* is designed to accommodate rainwater harvesting and conforms to f) ASTM E2398-11 "Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Vegetative (Green) Roof Systems".

2) In addition to the requirements in Sentence (1), the roof assembly which supports a *green roof assembly* shall conform with Subsection 3.1.15., except for Part 9 *buildings*.

3) In addition to the requirements in Sentence (1), the roof assembly which supports a *green roof assembly* shall conform with Part 5.

Figure 39: Vancouver Building By-Law - Section 3.1.14.4 (Council of the City of Vancouver, 2019)

In addition to the referenced standards, the VBBL also references the German Landscape Research, Development and Construction Society's (FLL) "Guidelines for the Planning, Construction and Maintenance of Green Roofing". The FLL is widely considered to be one of the most developed and comprehensive design guidelines for the design, installation, and maintenance of living roofs. However, the language in the VBBL does not require that the FLL is used in the design of living roofs. Instead, it references the FLL as a resource that can be used for additional design guidance.

A-5.6.1.2.(2) Vegetated Roofing Systems. The integrity of some assemblies installed to provide the required protection from the ingress of precipitation in vegetated roofing systems can be compromised due to an inadequate resistance to the penetration of plant roots and rhizomes. Additional information on vegetated roofing systems and the performance of protective materials can be found in the German Landscape Research, Development and Construction Society's (FLL) "Guidelines for the Planning, Construction and Maintenance of Green Roofing" and in the National Roofing Contractors Association's "Vegetative Roof Systems Manual."

Figure 40: Vancouver Building By-Law - Section A-5.6.1.2.(2) (Council of the City of Vancouver, 2019)

The FLL guideline is extremely detailed and is mainly aimed at an audience of professional designers (engineers, architects, etc.). While useful in the right context, the FLL provides a level of detail that goes beyond the understanding of the average citizen, such as a building owner or operator. A design guideline for the City of Vancouver should be aimed to reach a wider audience to make living roof information more accessible and widely understood. A design guideline for the City of Vancouver can help to compliment the existing Sections of the VBBL and provide guidance that is more regionally focused and builds upon the existing design guidelines.

3.2. Comparing Other Jurisdiction Design Guidelines

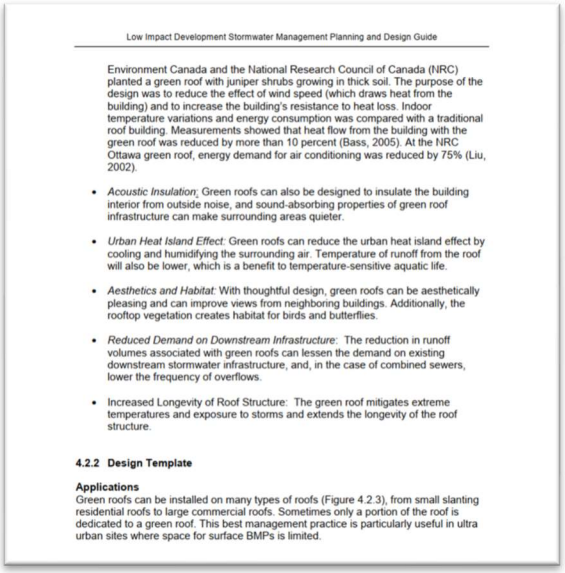
A wide range of jurisdictions have been selected to ensure the recommendations reflected a diverse range of existing design guidelines. Existing guidelines reviewed are from the following jurisdictions:

Jurisdictions Reviewed	
Jurisdiction	**Document**
The City of Portland	Eco-roof Handbook
The City of Toronto	Toronto Green Roof Construction Standard
FLL (Germany)	Guidelines for Planning, Construction and Maintenance of Green Roofs
The City of San Francisco	Living Roof Manual
GRO (United Kingdom)	The GRO Green Roof Code
CVC (Credit Valley Conservation Authority - Peel Region)	Low Impact Development Stormwater Management Planning and Design Guide
CMHC (Canada Mortgage and Housing Corporation)	Design Guidelines for Green Roofs
The City of Denver	Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West

The review of the design guidelines considers how the design guidelines are presented, the organization of the information, the subject matter topics, and the quality/detail of the topic content.

3.2.1. Guidelines Presentation

Creating a visually appealing document that is well presented is something that is often overlooked when developing a technical guideline. However, it is critical that a document such as a living roof design guideline be visually appealing and engaging for the reader. A well-presented guideline can draw interest from readers and improve the effectiveness of the guideline's dissemination of information. Throughout the course of this review, it was noted that no two guidelines reviewed are exactly the same. Each is unique and contains a wide variety of presentations. There are simplified formats (such as the CVC and FLL design guidelines), which provide a basic text with headers and minimal drawings and imagery to compliment the concepts within the guidelines.



Low Impact Development Stormwater Management Planning and Design Guide

Environment Canada and the National Research Council of Canada (NRC) planted a green roof with juniper shrubs growing in thick soil. The purpose of the design was to reduce the effect of wind speed (which draws heat from the building) and to increase the building's resistance to heat loss. Indoor temperature variations and energy consumption was compared with a traditional roof building. Measurements showed that heat flow from the building with the green roof was reduced by more than 10 percent (Bass, 2005). At the NRC Ottawa green roof, energy demand for air conditioning was reduced by 75% (Liu, 2002).

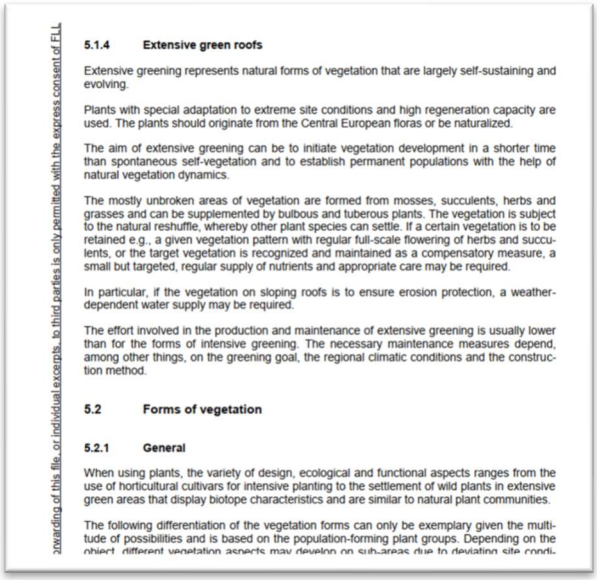
- *Acoustic Insulation:* Green roofs can also be designed to insulate the building interior from outside noise, and sound-absorbing properties of green roof infrastructure can make surrounding areas quieter.
- *Urban Heat Island Effect:* Green roofs can reduce the urban heat island effect by cooling and humidifying the surrounding air. Temperature of runoff from the roof will also be lower, which is a benefit to temperature-sensitive aquatic life.
- *Aesthetics and Habitat:* With thoughtful design, green roofs can be aesthetically pleasing and can improve views from neighboring buildings. Additionally, the rooftop vegetation creates habitat for birds and butterflies.
- *Reduced Demand on Downstream Infrastructure:* The reduction in runoff volumes associated with green roofs can lessen the demand on existing downstream stormwater infrastructure, and, in the case of combined sewers, lower the frequency of overflows.
- Increased Longevity of Roof Structure: The green roof mitigates extreme temperatures and exposure to storms and extends the longevity of the roof structure.

4.2.2 Design Template

Applications

Green roofs can be installed on many types of roofs (Figure 4.2.3), from small slanting residential roofs to large commercial roofs. Sometimes only a portion of the roof is dedicated to a green roof. This best management practice is particularly useful in ultra urban sites where space for surface BMPs is limited.

Figure 41: Typical excerpt - CVC design guidelines.



5.1.4 Extensive green roofs

Extensive greening represents natural forms of vegetation that are largely self-sustaining and evolving.

Plants with special adaptation to extreme site conditions and high regeneration capacity are used. The plants should originate from the Central European floras or be naturalized.

The aim of extensive greening can be to initiate vegetation development in a shorter time than spontaneous self-vegetation and to establish permanent populations with the help of natural vegetation dynamics.

The mostly unbroken areas of vegetation are formed from mosses, succulents, herbs and grasses and can be supplemented by bulbous and tuberous plants. The vegetation is subject to the natural reshuffle, whereby other plant species can settle. If a certain vegetation is to be retained e.g., a given vegetation pattern with regular full-scale flowering of herbs and succulents, or the target vegetation is recognized and maintained as a compensatory measure, a small but targeted, regular supply of nutrients and appropriate care may be required.

In particular, if the vegetation on sloping roofs is to ensure erosion protection, a weather-dependent water supply may be required.

The effort involved in the production and maintenance of extensive greening is usually lower than for the forms of intensive greening. The necessary maintenance measures depend, among other things, on the greening goal, the regional climatic conditions and the construction method.

5.2 Forms of vegetation

5.2.1 General

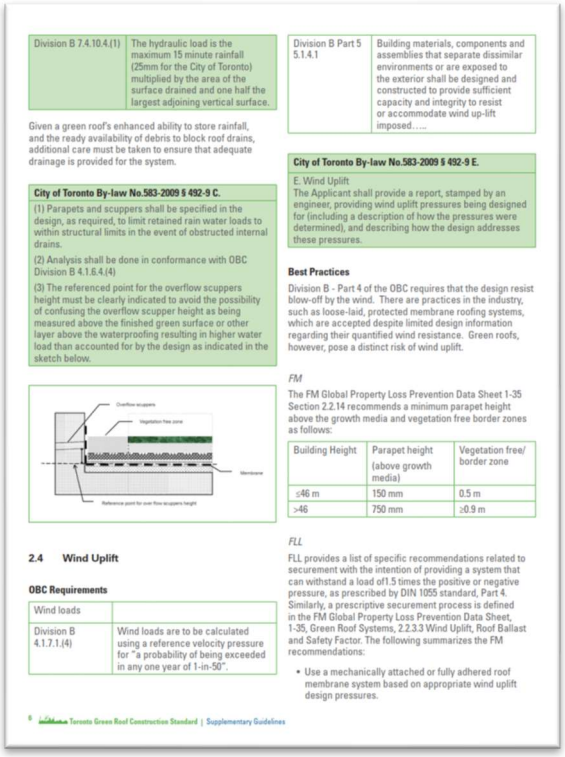
When using plants, the variety of design, ecological and functional aspects ranges from the use of horticultural cultivars for intensive planting to the settlement of wild plants in extensive green areas that display biotope characteristics and are similar to natural plant communities.

The following differentiation of the vegetation forms can only be exemplary given the multitude of possibilities and is based on the population-forming plant groups. Depending on the object, different vegetation aspects may develop on sub-areas due to deviating site condi-

Figure 42: Typical excerpt - FLL design guidelines.

While these guidelines are effective at delivering their message and disseminating important content, they do not present in a visually appealing manner. This can make it difficult to maintain a reader's interest, especially when the reader may not be technically well versed in living roof design or interested in detailed design requirements.

Other design guidelines provide an improved method of delivering their content in a visually appealing way with tools such as summary tables, text columns and adding colour to headings and footers. Some examples of this are found in the City of Toronto and GRO guidelines.



Division B 7.4.10.4.(1)	The hydraulic load is the maximum 15 minute rainfall (25mm for the City of Toronto) multiplied by the area of the surface drained and one half the largest adjoining vertical surface.

Given a green roof's enhanced ability to store rainfall, and the ready availability of debris to block roof drains, additional care must be taken to ensure that adequate drainage is provided for the system.

City of Toronto By-law No.583-2009 § 492-9 C.

(1) Parapets and scuppers shall be specified in the design, as required, to limit retained rain water loads to within structural limits in the event of obstructed internal drains.

(2) Analysis shall be done in conformance with OBC Division B 4.1.6.4.(4)

(3) The referenced point for the overflow scuppers height must be clearly indicated to avoid the possibility of confusing the overflow scupper height as being measured above the finished green surface or other layer above the waterproofing resulting in higher water load than accounted for by the design as indicated in the sketch below.

2.4 Wind Uplift

OBC Requirements

Wind loads	
Division B 4.1.7.1.(4)	Wind loads are to be calculated using a reference velocity pressure for "a probability of being exceeded in any one year of 1-in-50".

Division B Part 5 5.1.4.1	Building materials, components and assemblies that separate dissimilar environments or are exposed to the exterior shall be designed and constructed to provide sufficient capacity and integrity to resist or accommodate wind up-lift imposed…..

City of Toronto By-law No.583-2009 § 492-9 E.

E. Wind Uplift

The Applicant shall provide a report, stamped by an engineer, providing wind uplift pressures being designed for (including a description of how the pressures were determined), and describing how the design addresses these pressures.

Best Practices

Division B - Part 4 of the OBC requires that the design resist blow-off by the wind. There are practices in the industry, such as loose-laid, protected membrane roofing systems, which are accepted despite limited design information regarding their quantified wind resistance. Green roofs, however, pose a distinct risk of wind uplift.

FM

The FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.14 recommends a minimum parapet height above the growth media and vegetation free border zones as follows:

Building Height	Parapet height (above growth media)	Vegetation free/ border zone
≤46 m	150 mm	0.5 m
>46	750 mm	≥0.9 m

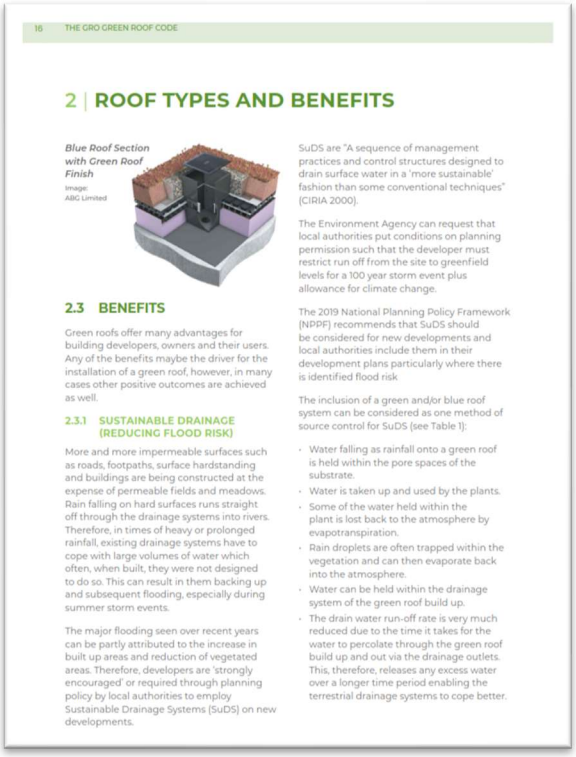
FLL

FLL provides a list of specific recommendations related to securement with the intention of providing a system that can withstand a load of1.5 times the positive or negative pressure, as prescribed by DIN 1055 standard, Part 4. Similarly, a prescriptive securement process is defined in the FM Global Property Loss Prevention Data Sheet, 1-35, Green Roof Systems, 2.2.3.3 Wind Uplift, Roof Ballast and Safety Factor. The following summarizes the FM recommendations:

- Use a mechanically attached or fully adhered roof membrane system based on appropriate wind uplift design pressures.

8 Toronto Green Roof Construction Standard | Supplementary Guidelines

Figure 43: Typical excerpt – The City of Toronto guidelines.



16 THE GRO GREEN ROOF CODE

2 | ROOF TYPES AND BENEFITS

Blue Roof Section with Green Roof Finish

Image: ABG Limited

2.3 BENEFITS

Green roofs offer many advantages for building developers, owners and their users. Any of the benefits maybe the driver for the installation of a green roof, however, in many cases other positive outcomes are achieved as well.

2.3.1 SUSTAINABLE DRAINAGE (REDUCING FLOOD RISK)

More and more impermeable surfaces such as roads, footpaths, surface hardstanding and buildings are being constructed at the expense of permeable fields and meadows. Rain falling on hard surfaces runs straight off through the drainage systems into rivers. Therefore, in times of heavy or prolonged rainfall, existing drainage systems have to cope with large volumes of water which often, when built, they were not designed to do so. This can result in them backing up and subsequent flooding, especially during summer storm events.

The major flooding seen over recent years can be partly attributed to the increase in built up areas and reduction of vegetated areas. Therefore, developers are 'strongly encouraged' or required through planning policy by local authorities to employ Sustainable Drainage Systems (SuDS) on new developments.

SuDS are "A sequence of management practices and control structures designed to drain surface water in a 'more sustainable' fashion than some conventional techniques" (CIRIA 2000).

The Environment Agency can request that local authorities put conditions on planning permission such that the developer must restrict run off from the site to greenfield levels for a 100 year storm event plus allowance for climate change.

The 2019 National Planning Policy Framework (NPPF) recommends that SuDS should be considered for new developments and local authorities include them in their development plans particularly where there is identified flood risk

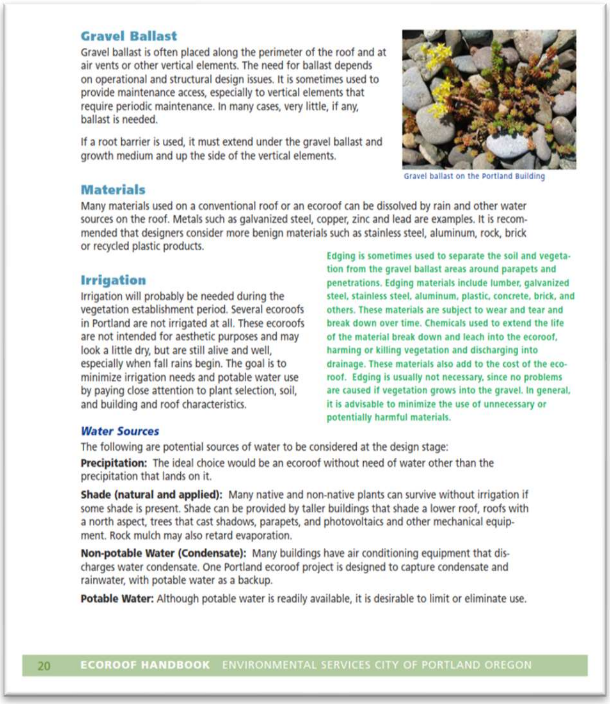
The inclusion of a green and/or blue roof system can be considered as one method of source control for SuDS (see Table 1):

- Water falling as rainfall onto a green roof is held within the pore spaces of the substrate.
- Water is taken up and used by the plants.
- Some of the water held within the plant is lost back to the atmosphere by evapotranspiration.
- Rain droplets are often trapped within the vegetation and can then evaporate back into the atmosphere.
- Water can be held within the drainage system of the green roof build up.
- The drain water run-off rate is very much reduced due to the time it takes for the water to percolate through the green roof build up and out via the drainage outlets. This, therefore, releases any excess water over a longer time period enabling the terrestrial drainage systems to cope better.

Figure 44: Typical excerpt - GRO guidelines.

While there is still a high ratio of text-to-images on each page, the use of colour breaks up the various headers and provides a more visually appealing document. Highlighting certain areas of text also draws the eye to what is important within each page. The use of tables, images and drawing details illustrate the discussion topics and ensure some of the more technical topics are explained concisely to maximize the learning opportunities.

The presentations above can be further improved upon by creating more visually appealing diagrams, improved organization of the text, and creating a lower text-to-image ratio on each page to create a more engaging and appealing document. The guidelines from the GRO and the City of San Francisco provide good precedence of these principles.



Gravel Ballast

Gravel ballast is often placed along the perimeter of the roof and at air vents or other vertical elements. The need for ballast depends on operational and structural design issues. It is sometimes used to provide maintenance access, especially to vertical elements that require periodic maintenance. In many cases, very little, if any, ballast is needed.

If a root barrier is used, it must extend under the gravel ballast and growth medium and up the side of the vertical elements.

Gravel ballast on the Portland Building

Materials

Many materials used on a conventional roof or an ecoroof can be dissolved by rain and other water sources on the roof. Metals such as galvanized steel, copper, zinc and lead are examples. It is recommended that designers consider more benign materials such as stainless steel, aluminum, rock, brick or recycled plastic products.

Edging is sometimes used to separate the soil and vegetation from the gravel ballast areas around parapets and penetrations. Edging materials include lumber, galvanized steel, stainless steel, aluminum, plastic, concrete, brick, and others. These materials are subject to wear and tear and break down over time. Chemicals used to extend the life of the material break down and leach into the ecoroof, harming or killing vegetation and discharging into drainage. These materials also add to the cost of the ecoroof. Edging is usually not necessary, since no problems are caused if vegetation grows into the gravel. In general, it is advisable to minimize the use of unnecessary or potentially harmful materials.

Irrigation

Irrigation will probably be needed during the vegetation establishment period. Several ecoroofs in Portland are not irrigated at all. These ecoroofs are not intended for aesthetic purposes and may look a little dry, but are still alive and well, especially when fall rains begin. The goal is to minimize irrigation needs and potable water use by paying close attention to plant selection, soil, and building and roof characteristics.

Water Sources

The following are potential sources of water to be considered at the design stage:

Precipitation: The ideal choice would be an ecoroof without need of water other than the precipitation that lands on it.

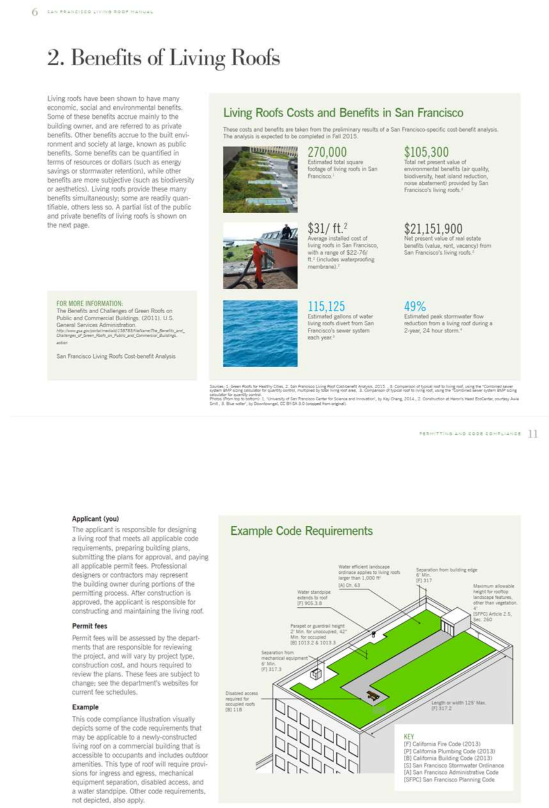
Shade (natural and applied): Many native and non-native plants can survive without irrigation if some shade is present. Shade can be provided by taller buildings that shade a lower roof, roofs with a north aspect, trees that cast shadows, parapets, and photovoltaics and other mechanical equipment. Rock mulch may also retard evaporation.

Non-potable Water (Condensate): Many buildings have air conditioning equipment that discharges water condensate. One Portland ecoroof project is designed to capture condensate and rainwater, with potable water as a backup.

Potable Water: Although potable water is readily available, it is desirable to limit or eliminate use.

20 ECOROOF HANDBOOK ENVIRONMENTAL SERVICES CITY OF PORTLAND OREGON

Figure 45: Typical excerpt - City of Portland guidelines.



2. Benefits of Living Roofs

Living Roofs Costs and Benefits in San Francisco

270,000

$105,300

$31/ ft.²

$21,151,900

115,125

49%

Example Code Requirements

Figure 46: Typical excerpt - City of San Francisco guidelines.

The use of colourful text within the body of the documents breaks up the document and highlights important information. Using distinct colour backgrounds enhances the images and organizes the pages in general. The City of San Francisco guidelines especially provide an excellent text-to-image ratio, which creates a visually appealing document.

Overall, the City of San Francisco and the City of Portland guidelines contain the best presentation of the guideline documents. Recommendations for creating a visually appealing guideline include:

- Use of colour in the text, headers and footers and image backgrounds
- Low text-to-image ratio
- Use of summary tables to highlight essential information
- Include inset boxes with additional links to more info for each chapter where applicable

3.2.2. Guidelines Organization

The organization of the guidelines is important to ensure the contents are easy to navigate and information can be easily accessed. The order in which the information is presented is also important to ensure a reader does not get lost in the document. An organized document will create a streamlined train of thought and prevent the need to flip between different sections of the guidelines. The majority of the guidelines follow a common pattern that is organized into three major sections:

1. Introduction to Living Roofs
2. Design Guidelines for Living Roofs
    a. Design
    b. Installation
    c. Maintenance
3. Miscellaneous Additional Information

Introduction to Living Roofs should provide a general overview of living roof technology while evaluating the pros and cons. The intent is to inform the reader about what living roofs are and how they work, without becoming overly technical on design and installation details. Section 1 of this report is intended to closely resemble what an Introduction to Living Roofs portion of a Guideline would ideally include.

Design Guidelines for Living Roofs provide the technical details of how a living roof system is designed, installed, and maintained. Each layer of a living roof is discussed in detail and important design considerations are discussed for each layer. Important additional design considerations should be included in this section such as rainwater retention rates, soil slopes and gradings, live and dead load calculations, and drainage system design. This section should also discuss installation processes and key considerations such as timing for installations, construction staging, construction safety, and waterproofing testing. Last, maintenance best practices should be discussed to ensure that the roof system can be properly operated and serviced to reach a full service life. Maintenance practices may include debris removal, irrigation, pruning, or clearing drains.

Miscellaneous Additional Information can vary between guidelines and will depend on the information available for each jurisdiction. Based on the design guidelines reviewed, some recommendations for this section include:

1. Case studies of existing living roofs that are local to the area
2. Frequently asked questions
3. Typical construction costs
4. Additional links to relevant codes or standards
5. Glossary of terms
6. Useful templates and forms (i.e., calculating water flow rates, permit application forms, etc.)

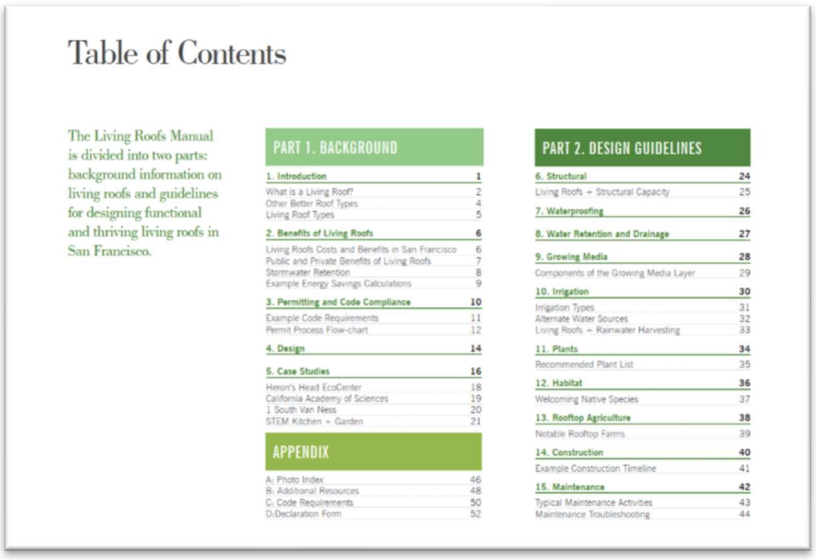


Table of Contents

The Living Roofs Manual is divided into two parts: background information on living roofs and guidelines for designing functional and thriving living roofs in San Francisco.

PART 1. BACKGROUND

APPENDIX

PART 2. DESIGN GUIDELINES

Figure 47: Typical table of contents - San Francisco design guidelines.

3.2.3. Guidelines Content

While developing the complete content for the design guidelines is excluded from the scope of work for this report, there are general trends about the content of the report that have been observed and summarized here.

The development of the content for a living roof guideline is a challenging task. One of the major tasks is determining an appropriate level of detail for the content. If the guidelines are too technical, they will not be easily digestible for the reader, who may quickly lose interest in the topic. However, an equally concerning issue is that of an inadequate amount of information included in the guidelines, such that it does not provide technical information for designers, contractors, or owners. A balance should be created between the two extremes mentioned above to ensure the guidelines are informative, yet interesting to the reader.

The existing guidelines reviewed varied in their level of detail from one to another. In some cases, such as the CVC guidelines, the technical content was relatively limited and contained just brief summary information on each individual topic. A single paragraph or two provided an overview of the main components with no major details to aid in the design of the living roof system. While they are easy to read, the level of detail does not provide an adequate amount of assistance to help guide designers or installers to create living roof systems that are in line with the City's expectations. On the other end of the spectrum, the FLL design guidelines provide a very technical, very detailed discussion of each topic, such as the recommended amount of seed grains per square meter for various types of seeding procedures and plant species. While the amount of detail and quality of information provided is impressive and indeed, very useful, this amount of detail exceeds what the intended audience of the design guidelines will understand. The guidelines should be designed to work in conjunction with the FLL and help make the information easier to understand. The level of detail in the FLL is better left for a design standard used by landscape architectures or other design professionals.

While the guidelines are intended to provide technical information about living roof design, installation, and maintenance practices, they are not meant to serve as a design standard or a code. The audience will range widely from building owners and operators to design professionals, such as architects and engineers. Striking a balance that appeals to all groups is important. The City of San Franciso design guidelines provide an excellent example of striking the balance for these categories. The guidelines provide a moderate level of detail on the design and installation process so that an individual can speak intelligently with designers about living roofs. However, the document is not so overwhelming that it cannot be easily understood.

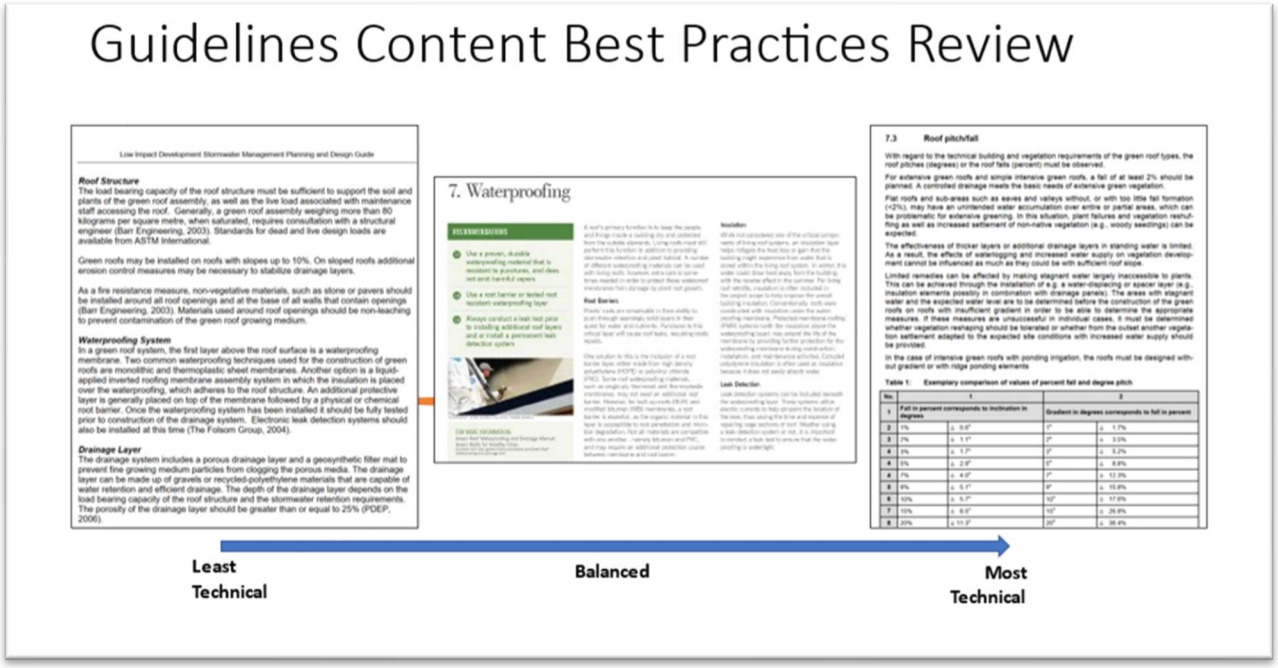


Figure 48: Variation in levels of detail per design guidelines.

Based on the review of each guideline, a qualitative decision matrix was developed to determine which topics were the most frequently discussed and determine the topics most important for inclusion in the guidelines. This includes City of Vancouver employees, designers, researchers, and various other industry experts. The results of the decision matrix are included in the appendices of this report.

3.3. Guidelines Outline

The design guidelines are expected to follow the general outline below with the major components based on the review of comparative jurisdictions. Further details for the headings below are provided in Appendix C.

PART A – INTRODUCTION TO LIVING ROOFS

1. Document Purpose
2. Definition and History of Living Roofs
3. Rain City Strategy and Green Rainwater Infrastructure
4. Overview of Living Roof Components
5. Living Roof Categories
6. Living Roof Functions
7. Combining Living Roof Technologies
8. Co-benefits of Living Roofs
9. Designer Roles

PART B – DESIGN GUIDELINES

1. DESIGN
   - 1.1. Building Structure
   - 1.2. Waterproofing
   - 1.3. Root Barrier
   - 1.4. Drainage Layer
   - 1.5. Filter Fabric
   - 1.6. Growing Media
   - 1.7. Irrigation
   - 1.8. Vegetation/Plants
   - 1.9. Habitat Design/ Rooftop Agriculture
   - 1.10. Wind Design
   - 1.11. Fire Safety Considerations
   - 1.12. Rainwater Retention
   - 1.13. Area Drains & Scuppers
   - 1.14. Roof Slope
   - 1.15. Roof Access
   - 1.16. Permitting & Submission Requirements

2. INSTALLATION
   - 2.1. Site preparation/Planning
   - 2.2. Waterproofing Membrane
   - 2.3. Growing Media Installation
   - 2.4. Vegetation Installation
   - 2.5. Fall Protection/Construction Safety

3. MAINTENANCE
    3.1. Maintenance plan
    3.2. Fertilization
    3.3. Irrigation
    3.4. Weeding
    3.5. Removal of Biomass

PART C – ADDITIONAL INFORMATION

1. Case Studies
2. Links to Relevant Related Documents (VBBL, FLL, RCS, etc.)
3. Glossary of Terms

3.4. Importance of Living Roof Policy

While the development of a living roof design guideline is an important tool for advancing greater implementation of the technology throughout Vancouver, it is necessary to understand the context within which guidelines such as this are developed.

Design guidelines are intended to inform best practices for implementation of living roof systems, but do not have the legislative power to require living roof installations on new or existing buildings. As a result, without legislation in place, the design guidelines are only useful to those who voluntarily choose to implement a living roof on their property. The majority of the design guidelines reviewed are in jurisdictions where there is legislation requiring living roof installations, which gives the guidelines further importance to aid in the standardization of design requirements. The City of London provides an excellent example of this. Their 2018 Green Roofs report shows that green roof legislation, which was implemented in 2008, has had lasting positive impacts on the city's implementation of living roofs. The report shows that between 2014 and 2017 the area of green roofs in the Central Activity Zone of London has increased from a density of 0.89m^2 per resident to 1.27m^2 per resident (Grant & Gedge, 2018). Implementing legislation is necessary in order to make living roofs a common installation.

Legislation can promote living roofs by providing incentives as well. A number of comparable jurisdictions provide rebates for living roof systems. An example of this can be seen in the City of Toronto, which provides rebates for structural assessments of existing building roofs and even provides incentives of up to \$100/m^2 of installed living roof (City of Toronto, 2022). Providing incentives can help to address the issue of higher capital costs for installations, one of the largest barriers to living roofs.

Jurisdictions with Living Roof Policies		
Jurisdiction	**Legislation**	**Link to Document/Webpage**
City of Denver	Green Buildings Ordinance	https://www.denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Community-Planning-and-Development/Green-Buildings-Ordinance/Complying-with-the-Green-Buildings-Ordinance

City of London	Living Roofs and Walls Policy	https://www.london.gov.uk/sites/default/files/living-roofs.pdf
City of Portland	City of Portland Green Building Policy	https://efiles.portlandoregon.gov/Record/7477192/
City of San Francisco	Bulletin no. 11: better roofs ordinance	https://sfplanning.org/resource/zoning-administrator-bulletin-no-11-better-roofs-ordinance
City of Toronto	Green Roof Bylaw	https://www.toronto.ca/legdocs/municode/1184_492.pdf

Design Drawing Standards

Photo By: Sempergreen

4. DESIGN DRAWING STANDARDS

Design drawings play a key role in the success of any construction project as they assist with the interpretation of the design details and specifications. They provide an additional level of communication that can clarify instructions and provide information that is otherwise difficult to convey through written words. These drawings can be useful for permit reviewers and contractors alike and are an important part of any design package.

4.1. Existing Standard Drawings

Part of the scope of work of this research project is to review the various design drawings available within other jurisdictions and determine what drawings should ideally be made available as standard sets on the City of Vancouver website.

It was noted that the majority of the jurisdictions did not include a set of standard recommended living roof drawings available for download and use.

The City of Toronto does have some standard drawings available for Green Infrastructure, however, these typically apply to areas of a project that would be integrated with public spaces or the public services of a project, such as planting details, rain gardens and catch basins.

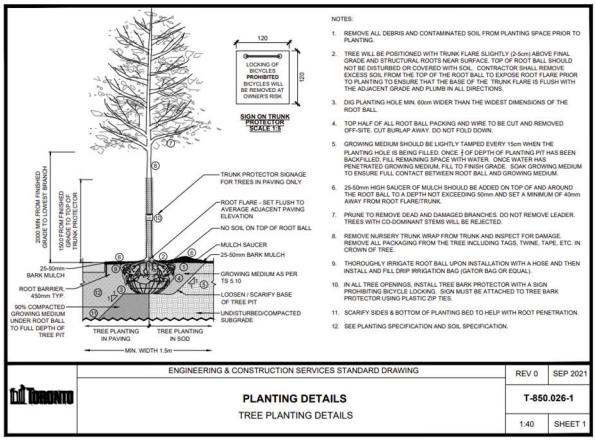


Figure 49: Typical planting details drawing - City of Toronto (City of Toronto, 2021).

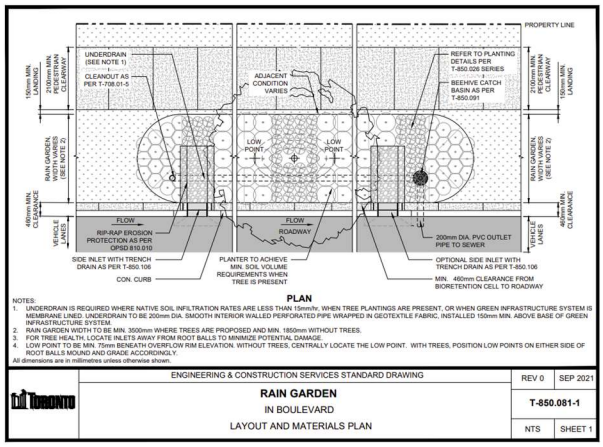


Figure 50: Typical rain garden plan drawing - City of Toronto (City of Toronto, 2021).

While no set of typical standard drawings were noted on the websites reviewed, there are many drawings and details found in the various design guidelines which have common aspects and should be considered for development and inclusion on the City of Vancouver website. In most cases, a plan drawing is recommended to provide an overview of the roof area and a basic layout of the amount of the total roof area that will be covered by the living roof system. The roof plan may also include areas where other technologies are being combined with a living roof such as solar panels. Both the City of Portland and the City of Toronto provide good examples of typical plan drawings, as illustrated below. Since every building is different, it may not be feasible to include this drawing as part of a drawing set that can be used for submittal, but it can serve as an excellent example of what the City of Vancouver would like to see included in permit packages.

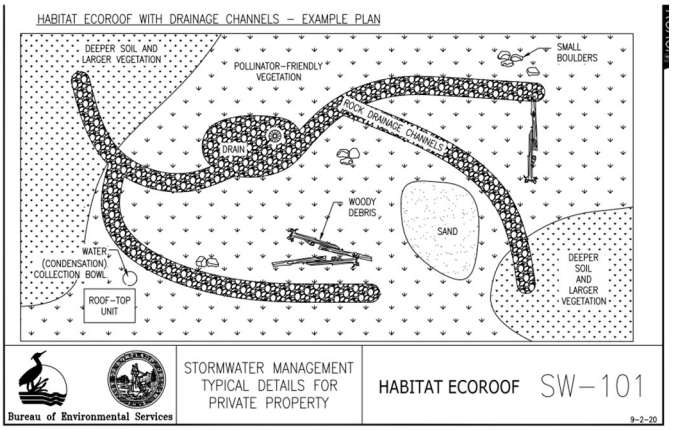


Figure 51: Living roof plan drawing - City of Portland (Aiona, Coker, Dunlap, Simpson, & Stevens, 2020).

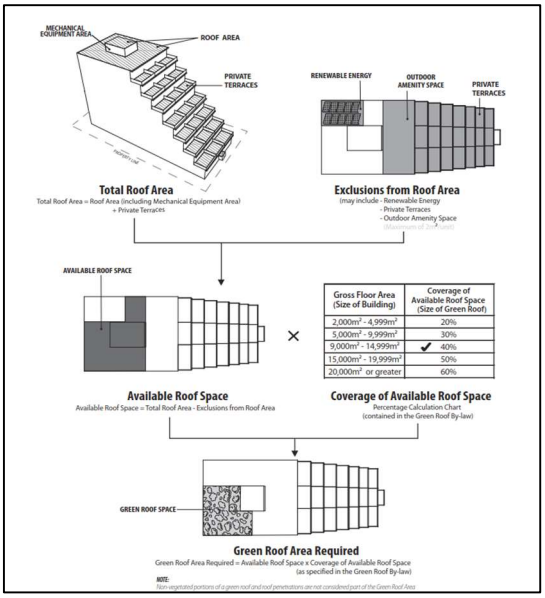


Figure 52: Typical roof plan drawing - City of Toronto (Office of the Chief Building Official, City of Toronto, 2010).

In nearly every design standard reviewed, drawings included a section of a typical living roof that details the various layers included in the living roof system and their specified thickness. This should be a drawing that is available as part of the standard drawing set. It is an essential drawing that shows the type of roof system that is proposed for installation and helps any reviewers understand the typology of the roof that is being planned. Some typical examples are shown below.

Figure 53: Typical living roof composition section (City of San Francisco, n.d.).

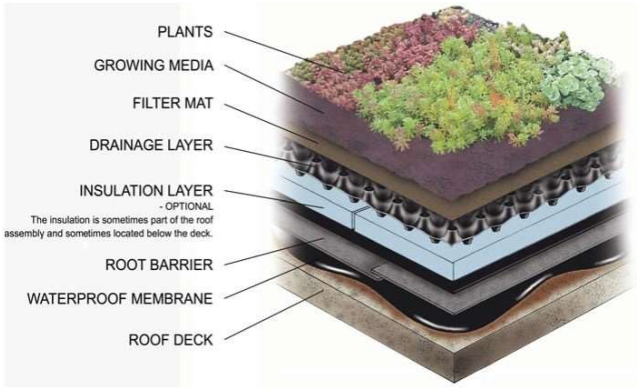


Figure 54: Typical living roof composition section (Tolderlund, 2010).

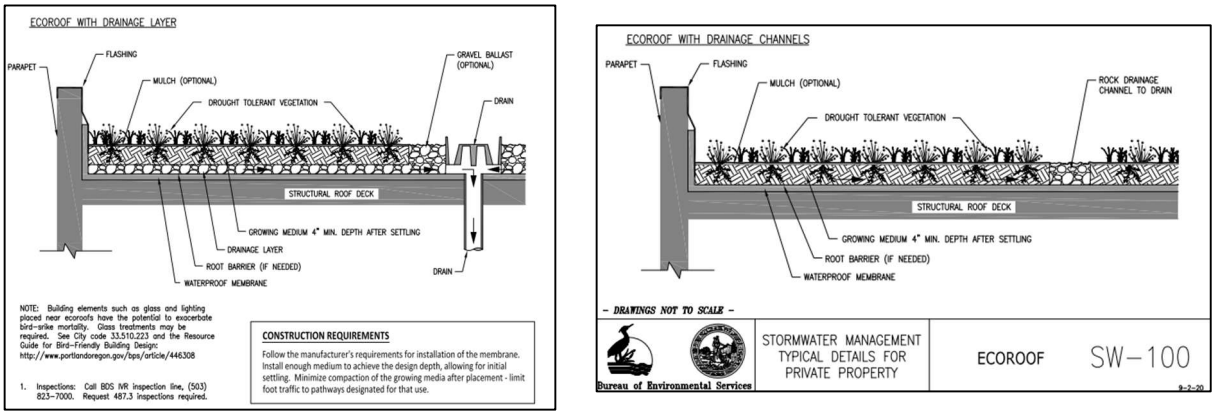


Figure 55: Typical living roof sections - City of Portland (Aiona, Coker, Dunlap, Simpson, & Stevens, 2020).

There are also specific details that should be considered as part of a standard drawing set that will help to provide sufficient detail for a well-executed design. Suggested drawings could include details of border zones at roof perimeters, terminations of waterproofing membranes, and drainage details. Each of these details represents an important part of the roof design that will play an integral role in developing a successful roof installation. Details often provide further clarification of how installations should be properly completed and can help to prevent misinterpretation between designers and installers.

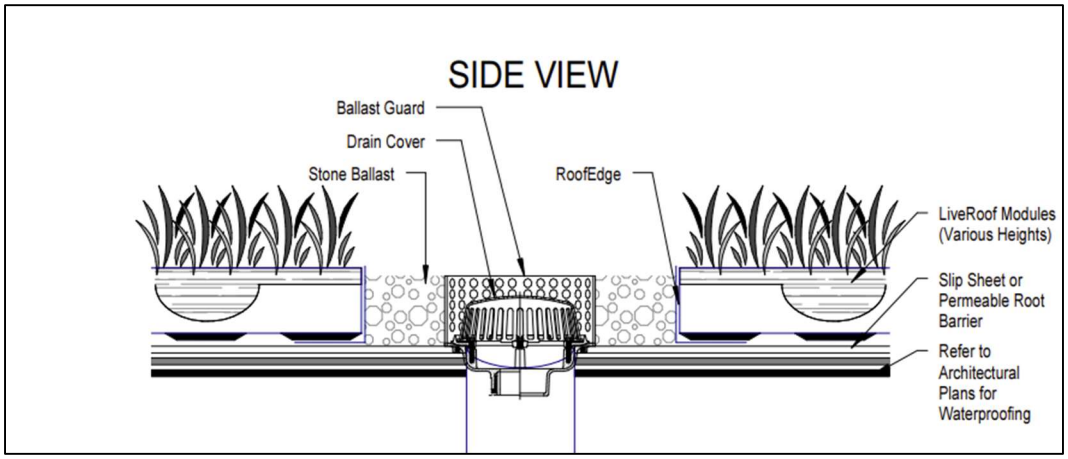


Figure 56: Typical drain and edging details (LiveRoof, 2022)

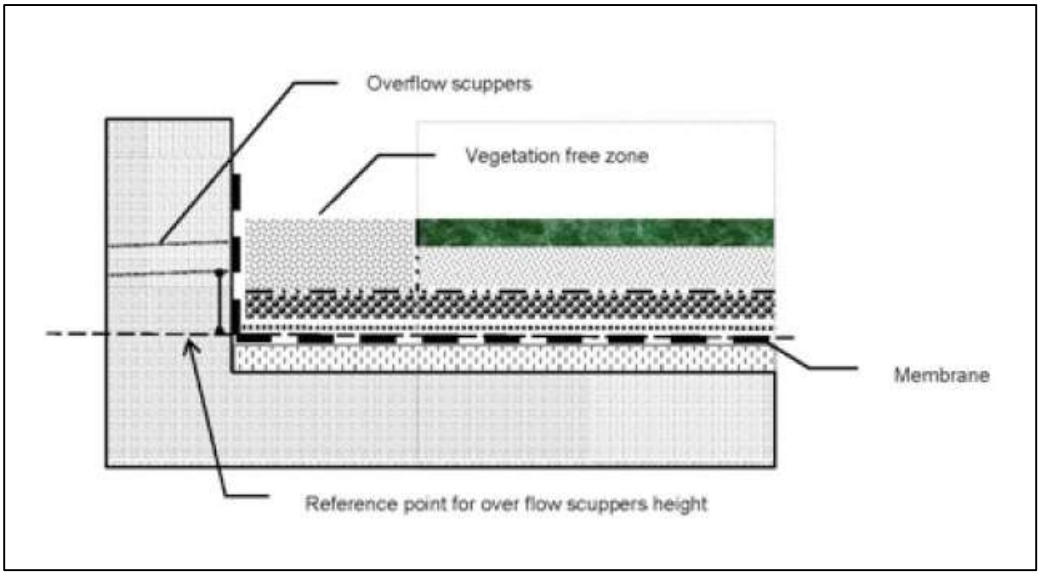


Figure 57: Typical border zone and overflow scupper details (Office of the Chief Building Official, City of Toronto, 2010).

Finally, a standardized schedule should be considered in the drawing set. The schedule could include tables listing proposed construction materials, such as membranes, growing media mixtures, and a list of plant species to be incorporated into the living roof systems. This will help plan reviewers to easily review the proposed installation materials and expedite the permitting process as well as making tendering a more straightforward process for contractors.

4.2. Recommended Drawings

A full list of recommended typical drawings is included below:

1. Typical roof plan
2. Typical detail showing structural connections and any modifications (existing building only)
3. Typical section details for roof drains

4. Section showing breakdown of living roof layers
5. Typical section for parapet details at roof perimeter
6. Section for border zones @ roof edge and surrounding drains
7. Detail showing membrane termination
8. Upturned roof barrier at transition from living roof area to conventional roof
9. Fire separation details
10. Footings for solar panels or other roof attachments
11. Typical layout for calculations on drawings (like tables)
12. Schedule of materials
13. Typical planting list

Appendices

5. CONCLUSION & NEXT STEPS

5.1 Conclusion

Over the course of this report, a number of different jurisdictions were reviewed to investigate typical layouts and content pertaining to:

1. Living Roofs Webpages (design and content)
2. Living Roof Design Guidelines (content topics and organization)
3. Living Roof Standard Drawings

Overall, there is an extensive amount of precedence that is available for use in developing both a webpage and guideline documents. The existing City of Vancouver website already has many of the recommended layout options such as the Climate Change Adaptation Strategy webpage and the Green Rainwater Infrastructure webpage (See section 2 for further details). The living roofs webpage can likely be easily created without major redesign to the current website layout.

The proposed content of the Living Roof Webpage can be quite detailed, depending on the quantity of information the City wishes to convey. The webpage is intended to serve as a landing page for delivering information related to living roofs and will be accessed by a wide range of users ranging from design professionals to citizens who have never seen a living roof before. To achieve the goals of the Rain City Strategy, it is just as important to make the content digestible and easy to understand as it is to provide technical guidance to industry experts. Additionally, making the content engaging for users by including images and explanatory diagrams will help to improve the delivery of the information and make the webpage more appealing overall. There are several webpages which can help to provide good examples of how to design a Living Roof Webpage with a variety of different levels of content.

The development of design guidelines is a critical step to promoting greater implementation of living roofs throughout Vancouver. A design guideline furthers the goals of the Rain City Strategy by providing detailed information on the design, installation, and maintenance of living roof systems. A number of well written guidelines were reviewed as part of this project and used to help provide an overall outline for the guidelines along with some recommended points of discussion. Similar to the content of the webpage, it is important to make sure that the content of the guidelines is not too simple that it is rendered useless, but not so complex that it becomes overwhelming and difficult to navigate. A balanced amount of information with links to relevant standards and diagrams to help with living roof design is a great way to ensure the information is conveyed in a digestible manner. A number of guidelines, both within North America and beyond, are available to use as reference points when developing guidelines for the City of Vancouver. Documents such as the FLL, the City of Portland Eco-roof Handbook and the San Francisco Living Roof Manual are all useful resources.

The jurisdictions reviewed did not contain a wide library of standard drawings available for reference and use by the public. This serves as an opportunity for Vancouver to take a leadership position within the living roof industry by developing a set of standardized drawings. There are a number of drawings that should be considered such as typical drain details, parapet terminations and typical sections of a living roof system. These drawings will help to further the Rain City Strategy by providing the public with

standardized examples of how a typical living roof system should be designed and installed to meet the requirements of the City of Vancouver.

5.2 Next Steps

As mentioned in both Sections 2 and 3, the research for this project was limited due to timing and the scope of work. There are several components that should be researched further that will improve the content of the webpage and guidelines by providing a more comprehensive understanding of living roof systems. This includes research into typical living roof costs (both installation and maintenance) and development of case studies to serve as examples for living roof installations. Additional tools for use by the public such as fact sheets, FAQs and development of standardized drawings should be pursued.

Beyond the development of further tools and content, the City's next steps are to begin developing their webpage and guidelines based on the findings in this report as well as the recommendations provided via other industry experts. This report should serve as a starting point of how to develop the webpage and guidelines, while allowing for room to expand further through additional research and reporting. A summary of recommended next steps is included below.

1.2.1 Website Layout and Content

1. **Pathways Study** – use the pathways study (once complete) to provide additional insight into GRI implementation and help advance any GRI initiatives that are already in place.
2. **Case Studies –**Additional research should be completed to investigate where living roofs have been successfully installed at private properties and promote these cases.
3. **Cost Benefit Analysis –** A full life cycle cost-benefit analysis of green roof installations should be considered by the City to justify the case for living roofs installations. An excellent example of a cost-benefit analysis can be found on the City of San Francisco's website.
4. **Interactive Living Roof Map –**The City should consider investing in researching and developing a living roof map similar to what the City of San Francisco and New York City have implemented.
5. **Living Roof Costing Form –** The City should consider working with local contractors and designers to develop a costing tool that would allow building owners to determine a rough estimate of the cost of a living roof.
1. Create a detailed outline of the building permit process for a green roof, including a simple flow chart to illustrate the process.

1.2.2 Living Roof Design Guidelines

1. Complete additional research into design guideline options through RFP;
2. Begin developing content of design guidelines based on the outline provided;
3. Further research additional jurisdictions, as needed for reference of design guidelines; and,
4. Develop the general template/page layout for the design guidelines.

1.2.3 Design Drawing Standards

Develop standardized drawings including:

a. Typical roof plan;
b. Typical detail showing structural connections and any modifications (existing building only);
c. Typical section details for roof drains;
d. Section showing breakdown of living roof layers;
e. Typical section for parapet details at roof perimeter;
f. Section for border zones @ roof edge and surrounding drains;
g. Detail showing membrane termination;
h. Upturned roof barrier at transition from living roof area to conventional roof;
i. Fire separation details;
j. Footings for solar panels or other roof attachments;
k. Typical layout for calculations on drawings (like tables);
l. Schedule of materials; and,
m. Typical planting list.

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Appendices

APPENDICES

APPENDIX A – PROPOSED WEBPAGE LAYOUT AND CONTENT

APPENDIX B – DESIGN AND MAINTENANCE CHECKLISTS

APPENDIX C – PROPOSED DESIGN GUIDELINES LAYOUT & CONCEPTS

APPENDIX D – EXISTING BY-LAWS GAP ANALYSIS MATRIX

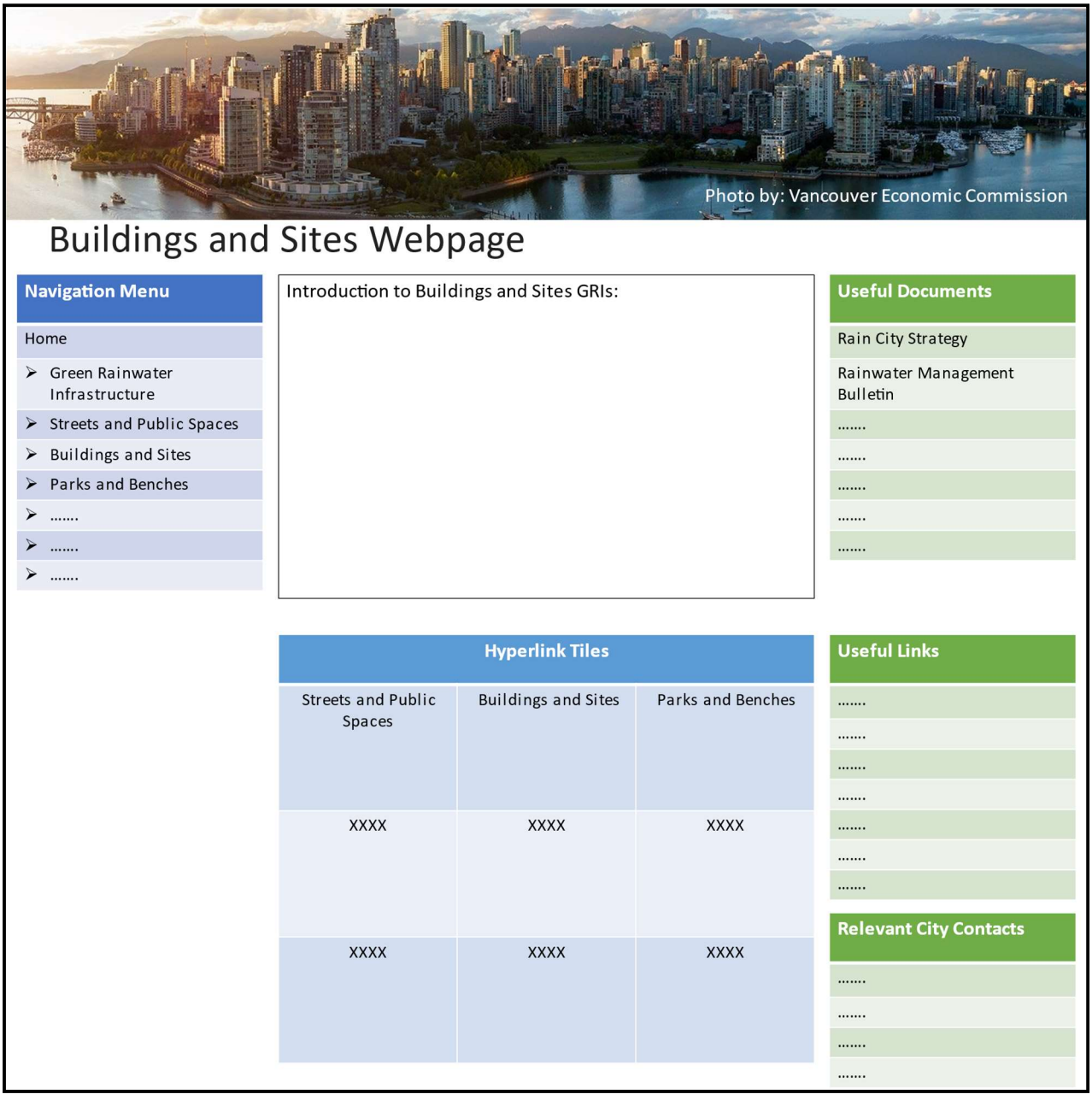
APPENDIX E – DECISION MATRIX – WEBSITE ANALYSIS

APPENDIX F – DECISION MATRIX – DESIGN GUIDELINE ANALYSIS

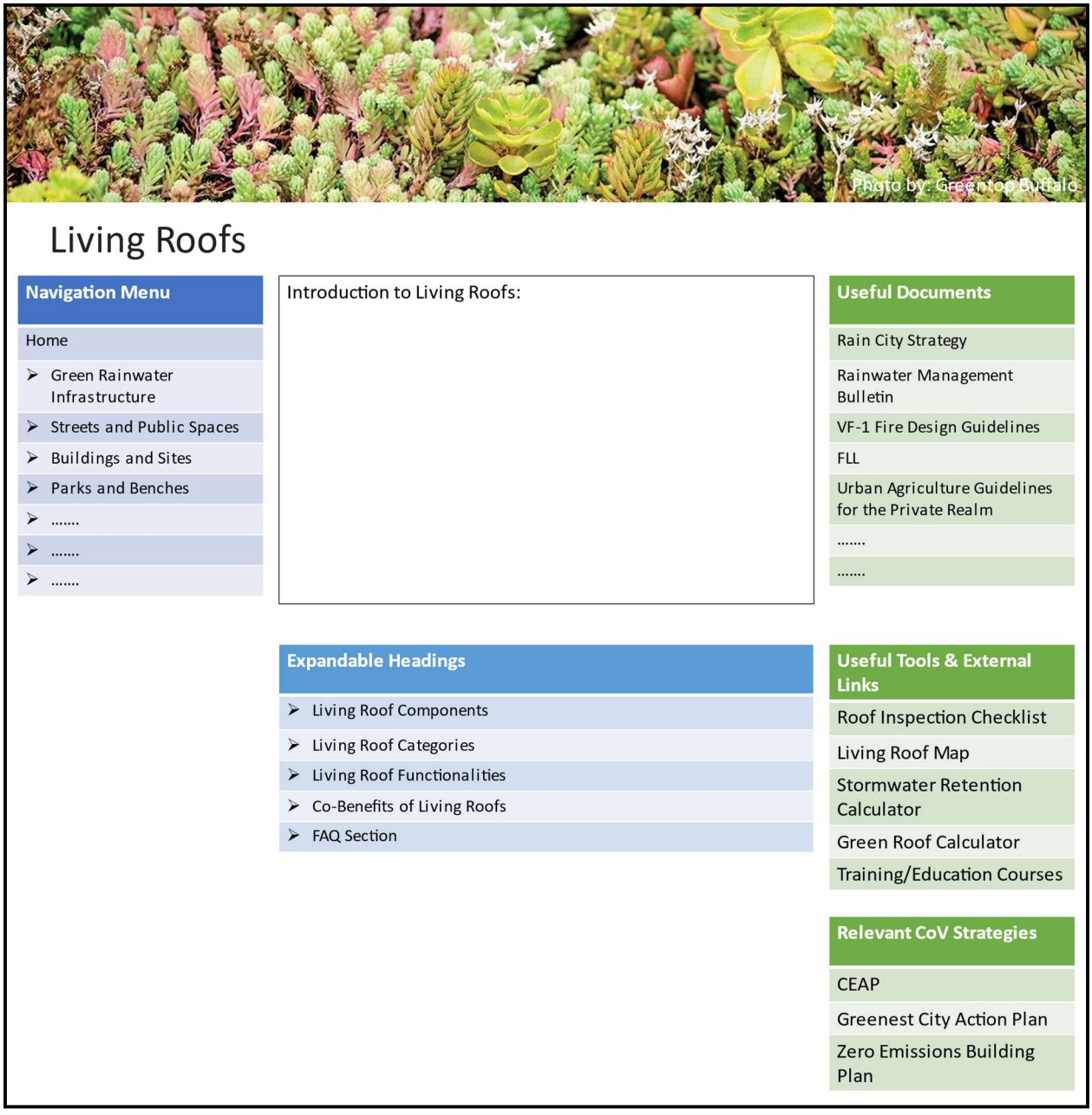
APPENDIX A – PROPOSED WEBPAGE LAYOUT AND CONTENT

A schematic layout of the Buildings and Sites, and the Living Roofs webpages are provided below. Recommended content for the Living Roofs webpage is provided following the schematic layouts.

Buildings and Sites Webpage Schematic



Living Roofs Webpage Schematic



Living Roofs Webpage Content

1. *Introduction to Living Roofs*

As climate change continues to impact the Lower Mainland, extreme weather events, such as heat waves and heavy rainfall events, are becoming increasingly frequent. Average rainfall in the Georgia Depression has increased by 14% over the last century (23% increase in the spring season) and is projected to increase up to an additional 17% over the next 60 years. This increase will require

Vancouver to implement preventative strategies to ensure climate preparedness to meet these challenges. Living roofs are one of several techniques the City is encouraging to help manage rainwater on-site. Living roofs are becoming more common as benefits continue to be documented. There are a wide range of benefits that come with Living Roof installations such as increased biodiversity, improved thermal insulation, and reducing the urban heat island effect. Additionally, the increasing prevalence of living roofs is making these systems more affordable. A range of information is included below to help understand living roofs better including:

a. Living roof components
b. Living roof categories
c. Living roof functionalities
d. Co-benefits
e. FAQ section

2. Living Roof Components

Living roofs (otherwise known as green roofs, blue roofs, blue-green roofs, and eco-roofs) are defined as the roof of a building that is partially or completely covered with vegetation, a growing medium and installed over a waterproofing membrane.

Living roofs have the same general construction that consists of a living roof system installed over a waterproofing membrane installation. The roof system will consist of the same layers, with a slightly different arrangement, as shown below (from the top surface down):

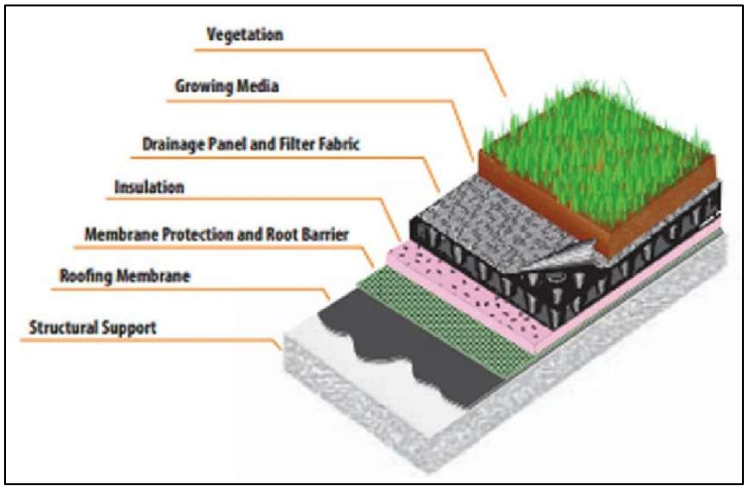


Figure 58: Typical Inverted Living Roof Section (Office of the Chief Building Official, City of Toronto, 2010).

Plants/vegetation can create virtually endless combinations, depending on the depth and composition of the growing media. It is recommended to have a horticultural specialist or landscape architect provide recommendations for your plant selections to ensure the vegetation will thrive in the microclimate. In general, it is important to aim to prioritize appropriate native species and plant a wide range of plants to encourage biodiversity.

Engineered growing media is the main differentiator between the various living roof categories and will dictate the overall effectiveness and functionality of the roof assembly. A deeper growing media will

allow for a wider variety of uses, a higher rate of water retention and increased biodiversity of vegetation as it provides the structure for the vegetation roots. The media is typically designed and premixed by a manufacturer and ideally composed of a lightweight combination of organic and inorganic materials to include minerals, nutrients, and adequate void space to allow for water infiltration.

Irrigation systems that are permanently installed may be required for a living roof system depending on the complexity of the installation and the variety of vegetation installed. In some cases, a hose bib at the roof level with regular manual irrigation by maintenance staff may be sufficient. Automatic irrigation systems can vary from drip irrigation, spray systems or sub-surface capillary mats. Irrigation is most critical during the first year of the installation when the vegetation is taking root and maturing.

Filter fabric is typically installed below the growing media to create separation between the growing media and the drainage layer. The filter fabric typically consists of a geotextile layer. The material is intended to be porous enough to allow water to drain through to the drainage layer, but fine enough to prevent the soil from being washed out with the water and eroding away the growing media.

Drainage layer/water retention layer consists of a porous media that allows for water to drain from the growing media and flow to the roof drains. The media must have voids larger than what is found in the growing media to encourage drainage and typically is constructed of aggregates or geocomposites.

Root barrier typically delineates the lowest layer of the living roof assembly and the upper layer of the conventional roof assembly. Vegetation roots are particularly adept at penetrating through solid layers and forming cracks, which is not ideal for a waterproofing membrane. The root barrier provides an additional layer of protection for the waterproofing membrane and the sub-structure by preventing the roots from penetrating further into the roof assembly.

Waterproofing membrane is one of the most important layers in the roof assembly since it serves as the main layer of protection for the roof structure. The waterproofing membrane prevents water ingress, provides UV protection, and prevents structural damage due to pedestrian or animal traffic.

Insulation improves the thermal resistance of the roof assembly and prevents thermal bridging between the outdoor and indoor environments. The insulation is typically extruded rigid insulation board.

Vapour barrier is typically installed over the building structure with the primary function of preventing any condensation due to thermal bridging from contacting the base building structure.

Roof structure consists of the base building structural frame. The frame is typically constructed from concrete slab, steel, or wood-frame. The structure provides the support for the entire roofing system and must be designed to adequately support the weight of the living roof system. If a living roof is being proposed as a retrofit for an existing building, a structural assessment may be required to determine the roof's weight restriction. Structural reinforcement may be required in order to support the living roof assembly.

3. *Living Roof Categories*

While the general installation is the same for all living roofs, they are typically divided into three main categories:

1. **Extensive Roofs**
2. **Intensive Roofs**
3. **Semi-Intensive Roofs**

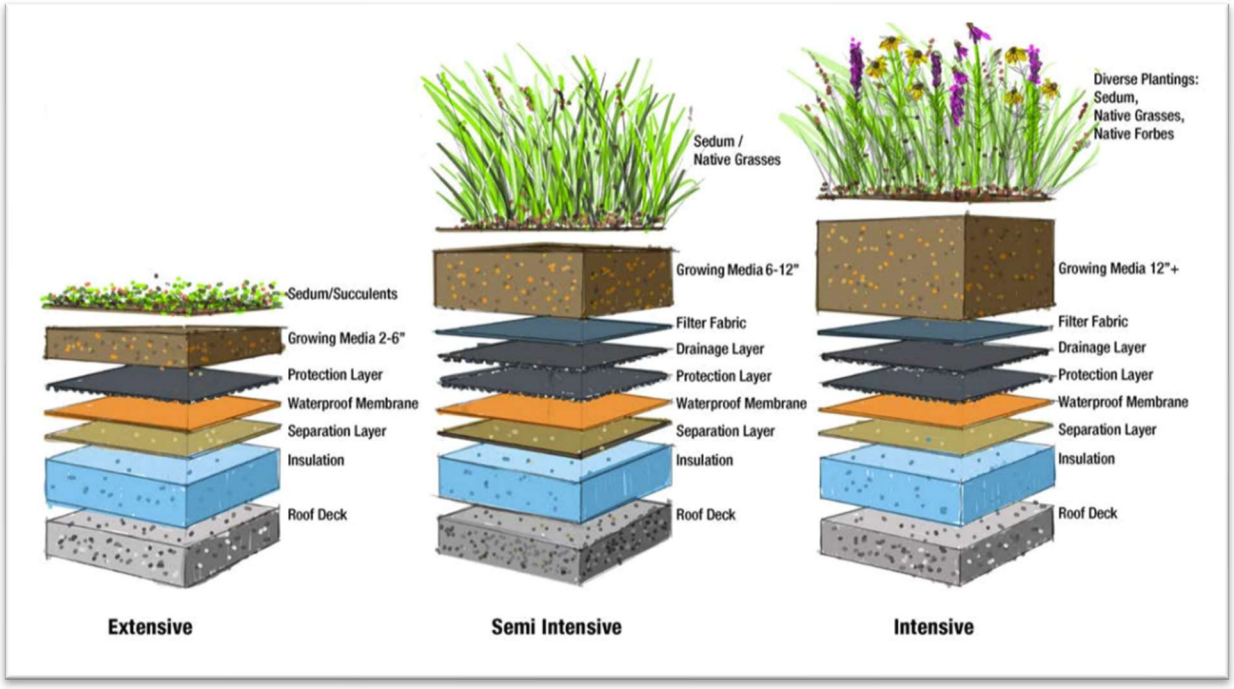


Figure 59: Three major living roof categories (Rainscaping Iowa, 2015)

The main difference between the three roofs is based on the depth of their growing media and, by association, the variety of plants and vegetation that can be incorporated into the roof system. A summary table is provided below:

Comparison of Living Roof Categories			
Component	**Extensive**	**Semi-Intensive**	**Intensive**
Soil Depth	<15 cm (6")	Fluctuates between 12-25 cm (5-10")	>15 cm (6")
Weight	72-170kg/m² (16-35lb/ft²)	120-250kg/m² (25-50lb/ft²)	195-970kg/m² (40-200lb/ft²)
Vegetation	Shallow rooted hearty vegetation such as mosses, succulents, herbs, and grasses	A mixture of shallow rooted hearty vegetation, various shrubs, and small	A potentially limitless variety of plants/vegetation, depending on soil depth

		trees, depending on soil depth	
Maintenance Levels	Low	Medium	High
Cost	Low	Medium	High
Rainwater retention	Low	Medium	High
Biodiversity	Low	Medium	High
Permanent Irrigation	No	Depends	Yes
Suitability	Large areas Limited additional structural capacity	Areas where biodiversity or accessibility is needed, but structural support is a constraint	Great for high visibility areas Often accessible
Limitations	Usually no/limited access Can be unattractive, especially in winter	Irrigation may be more complex and plant propagation between intensive & extensive areas may occur	More complex to design and install Limited to structures with high weight capacity

4. Living Roof Functionalities

The City of Vancouver hopes that living roofs will help to advance multiple co-benefits and promote four major functions:

a) **Rainwater management** – The primary function of living roofs as the City aims to encourage stormwater management on site. There are several ways to maximize stormwater retention through a living roof. One is by increasing the growing media depth and coverage of a living roof. Increased growing media volume will allow more moisture to be retained on site and diverted from the municipal water systems. This will also allow more vegetation to be planted and allow additional evapotranspiration to occur. Additionally, adding a water retention layer below the growing media can serve as a reservoir to store water on site for the vegetation. Water can also be stored in rain barrels or a stormwater tank for other uses on site such as irrigation, car washing or toilet flushing.

b) **Enhancing biodiversity –** Enhancing biodiversity allows a building site to return a portion of the land back to its natural state by installing a living roof system. Maximizing biodiversity is an important function for living roofs as they provide micro-climates and habitats for various birds, insects and in some cases, small mammals. Living roofs can also serve as a natural corridor to help species navigate across urban landscapes such as downtown Vancouver. Maximizing biodiversity is largely dependent on the size of the roof and the depth of the growing media. Varying the depth of the growing media between intensive and extensive levels across a single living roof can provide a diverse range of vegetation and habitats to support a wide variety of wildlife.

c) **Providing activity/amenity space –** Vancouver is becoming an increasingly urban environment as densification continues across the City. Ensuring there is adequate outdoor space for amenities and activity use (seating areas, daycare centres, recreation spaces, etc.) should be prioritized to promote

a healthy, active lifestyle. Living roofs provide opportunities to create outdoor amenity spaces which can be enjoyed by the building occupants or the general public. However, accessible amenity roofs present some additional challenges including rooftop access, fire safety requirements (paths of egress, fire suppression), fall protection at the roof perimeter, roof access security and higher structural support requirements. An appropriate design professional should always be consulted in order to ensure accessible roofs are a feasible option.

d) Rooftop agriculture - Food transportation is an energy-intensive process due to the large distances between rural agricultural areas and densely populated urban areas. Living roofs provide an opportunity to implement urban agriculture and provide access to locally grown fruits and vegetables within urban centers, which can reduce energy consumption and carbon emissions associated with transportation. Urban agriculture can also provide an opportunity for education within the local community to understand the importance of urban agriculture and how to grow various fruits and vegetables in an urban environment. Urban agriculture does have its own limitations, as an intensive roof system is required to achieve adequate soil depth and water retention. Additionally, an increased level of maintenance and irrigation is required in comparison to a conventional living roof. Testing/permits are also required to ensure the roof-grown food is safe for consumption.

5. Co-benefits of Living Roofs

Living roofs create a plethora of benefits that are useful for a range of stakeholders including the building owner, building occupants, contractors, and the general public. The various benefits are divided into two main categories – private (direct) and public (indirect). The list below is intended to serve as a starting point. However, it is worth noting that this list is not exhaustive. In addition, each property is unique, so all the benefits may not apply to every living roof project. There may also be additional benefits that are not listed below.

Co-Benefits of Living Roofs	
Private Benefits (Direct)	**Public Benefits (Indirect)**
1. Improved insulation 2. Energy savings 3. Health and well-being 4. Roof longevity 5. Sound attenuation 6. Temperature control for solar panels 7. Fire protection 8. LEED credits 9. Community resistance to development 10. Improved health and horticultural therapy 11. Increased property value	1. On-site stormwater management 2. Biodiversity 3. Reduce urban heat island effect 4. Policy/planning compliance 5. Air quality 6. Food production 7. Biophilia 8. New jobs/economic growth 9. Education 10. Water Equity 11. Carbon sequestration

6. FAQ Section

A list of frequently asked questions was developed in order to help provide additional education to the general public. By implementing this FAQ section, the webpage provides timely answers to common questions, which can save time for both visitors of the webpage and City employees. A list of FAQs are provided below. It should be noted that the questions were not provided with answers, which will need to be developed prior to inclusion in the webpage.

Living Roofs FAQs
1. Are roof planters considered living roofs?
2. How can I find a building with a roof that could be converted into an urban farm?
3. Will a building permit be required to install an urban farm on a roof?
4. What Building Code considerations should I be aware of, e.g.: load bearing, anchoring of structures, etc.
5. What's required to be shown on permit drawings to demonstrate compliance with VBBL?
6. Does the living roof need to meet the roof material flame spread classification and listing requirements?
7. What applies for intensive living roofs (VBBL regulations only cover extensive roofs)?
8. Integration with rainwater retention (blue/green roofs).
9. What do we do with respect to green wall systems? (commonly linked issue)

7. Relevant Existing City of Vancouver Strategies

The City of Vancouver has several ongoing strategies that align with living roofs and GRI technologies in general. The following is a list of links that should be considered for inclusion on the webpage:

List of Relevant Strategies	
Strategy	**Link to Strategy**
Climate Emergency Action Plan	https://vancouver.ca/files/cov/climate-emergency-action-plan-summary.pdf
Greenest City Action Plan	https://vancouver.ca/files/cov/Greenest-city-action-plan.pdf
Rain City Strategy	https://vancouver.ca/files/cov/rain-city-strategy.pdf
Biodiversity Strategy	https://vancouver.ca/files/cov/biodiversity-strategy.pdf
Urban Forest Strategy	https://vancouver.ca/files/cov/urban-forest-strategy.pdf
Renewable City Action Plan	https://vancouver.ca/files/cov/renewable-city-action-plan-summary.pdf
GRI Typologies	https://vancouver.ca/files/cov/one-water-gri-typologies.pdf

Zero Emissions Building Plan	https://vancouver.ca/files/cov/zero-emissions-building-plan.pdf
Rainwater Barrels	https://vancouver.ca/home-property-development/rain-barrels.aspx
Water Harvesting Permits	https://vancouver.ca/home-property-development/operating-permit.aspx
Urban Farming	https://vancouver.ca/people-programs/growing-food-for-sale.aspx
Water Conservation Action Plan & One Water	https://vancouver.ca/parks-recreation-culture/water-priority-action-plan.aspx
Vancouver Bird Strategy	https://vancouver.ca/files/cov/vancouver-bird-strategy.pdf

8. Recommended Documents:

There are a wide range of internal documents (by-laws, studies, bulletins, etc.) and external documents (design guidelines, living roof expertise, design standards, etc.) that can provide additional information for owners, designers, and contractors alike. Based on the research completed, a list of relevant documents has been included with links below to help with living roof design, installation, and maintenance.

List of Useful Documents	
Document/Website	**Link to Strategy**
GRI Typologies	https://vancouver.ca/files/cov/one-water-gri-typologies.pdf
Watershed Characterization	https://vancouver.ca/files/cov/one-water-watershed-characterization.pdf
Vancouver Building By-Law	https://vancouver.ca/your-government/vancouver-building-bylaw.aspx
Sewer and Watercourse bylaw	https://bylaws.vancouver.ca/8093c.PDF
Zoning and Development bylaw	https://vancouver.ca/home-property-development/zoning-and-land-use-policies-document-library.aspx#regulation
Green Roofing Guide	https://vancouver.ca/files/cov/green-roofing-guide.pdf
Integrated Rainwater Management Plan	https://vancouver.ca/files/cov/integrated-stormwater-management-best-practice-toolkit-volume-2.pdf
Rainwater Management Bulletin	https://bylaws.vancouver.ca/bulletin/bulletin-rainwater-management.pdf
Roof Mounted Energy Technologies Bulletin	https://bylaws.vancouver.ca/bulletin/bulletin-roof-mounted-energy-technologies-and-green-roofs.pdf

Consideration for Green Building Policy	https://guidelines.vancouver.ca/policy-green-buildings-for-rezonings.pdf
Childcare Design Guidelines	https://guidelines.vancouver.ca/guidelines-childcare-design.pdf
Urban Agriculture Guidelines for the Private Realm	https://vancouver.ca/files/cov/urban-agriculture-guidelines.pdf
Urban Agriculture Garden Guide	https://vancouver.ca/files/cov/urban-agriculture-garden-guide.pdf
Invasive Species Information	https://bcinvasives.ca/wp-content/uploads/2021/05/PlantWise-GMI-Brochure-2021-WEB.pdf https://bcinvasives.ca/play-your-part/plantwise/grow-me-instead/
FLL Guidelines	https://commons.bcit.ca/greenroof/files/2019/01/FLL_greenroofguidelines_2018.pdf
ANSI/SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems	https://www.spri.org/download/ansi-spri_standards_2020_restructure/rp-14/ANSI_SPRI-RP-14-2016-Wind-Design-Standard-for-Vegetative-Roofing-Systems.pdf
ANSI/SPRI VF-1 Fire Design Standard for Vegetative Roofs	https://www.spri.org/download/ansi-spri_standards_2020_restructure/vf-1/ANSI_SPRI-VF-1_External-Fire-Design-Standard-for-Vegetative-Roofs_2017.pdf
ANSI/SPRI VR-1 Procedure for Investigating Resistance to Root Penetration on Vegetative Roofs	https://www.spri.org/download/ansi-spri_standards_2020_restructure/vr-1/ANSI-SPRI-VR-1-2018-Procedure-for-Investigating-Resistance-to-Root-or-Rhizome-Penetration-on-Vegetative-Roofs.pdf
ASTM E2396 Standard Test Method for Saturated Water Permeability of Granular Drainage Media	https://www.astm.org/e2396_e2396m-19.html
ASTM E2397 Standard Practice for Determination of Dead Loads and Live Loads	https://www.astm.org/e2397_e2397m-19.html
ASTM E2398 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Vegetative (Green) Roof Systems.	https://www.astm.org/e2398_e2398m-19.html
ASTM E2399 Standard Test Method for Maximum Media Density for Dead Load Analysis of Vegetative (Green) Roof Systems.	https://www.astm.org/e2399_e2399m-19.html

ASTM E2432 Standard Guide for General Principles of Sustainability Relative to Buildings.	https://www.astm.org/e2432-19.html
ASTM E2777 Standard Guide for Vegetative (Green) Roof Systems.	https://www.astm.org/e2777-20.html
ASTM D8014 Standard Guide for Selection of Membranes Used in Vegetative Roofing Systems.	https://www.astm.org/d8014-17.html
RCABC Best Practices for Roofing Systems	https://rpm.rcabc.org/index.php?title=Main_Page
Additional Relevant Standards	https://www.wbdg.org/resources/extensive-vegetative-roofs

9. Recommended External Links and Tools

Based on the research completed, a list of relevant tools has been included with links below to help with living roof design, installation, and maintenance.

List of Relevant External Links and Tools	
Tool Name	**Link to Tool**
GRHC Recommended Training Courses	https://greenroofs.org/green-roof-professional
Green Roof Calculator	https://greenroofs.org/green-roof-energy-calculator
Green Roof Projects Map (GreenRoofs.com)	https://www.greenroofs.com/projects/
Wind-Roof Calculators (National Research Council Canada)	https://nrc.canada.ca/en/research-development/products-services/software-applications/wind-roof-calculators-internet-wind-rci
Stormwater Retention Calculator	https://pac.portland.gov/?_ga=2.53555617.825205794.1650984092-1784736543.1650984092
Roof Inspection Checklist	(Included in Appendix B)
Roof Design Checklist	(Included in Appendix B)
RCABC Best Practices for Roofing Systems	https://rpm.rcabc.org/index.php?title=Main_Page
LEED Canada Green Building Council	https://www.cagbc.org/our-work/certification/leed/
WELL Certified Buildings	https://www.wellcertified.com/
Smart Blue Roof study by Credit Valley Conservation	https://cvc.ca/project/smart-blue-roof/
Blue-green roof study (via BCIT website)	https://circuit.bcit.ca/repository/islandora/object/repository%3A2009
CleanBC Incentive Search Tool	https://betterbuildingsbc.ca/incentive-search-tool/

APPENDIX B – DESIGN AND MAINTENANCE CHECKLISTS

Design Checklist

STEPS TO A LIVING ROOF

CITY OF VANCOUVER | GREENEST CITY

PART A - DESIGN

☐ **Outline the Project Goals**
- What is the project aiming to achieve?
- Is the roof intended to be accessible?

☐ **Complete a structural review to determine load requirements (dead, live, snow, wind)**
- Structural review required for existing building where a living roof will be added.
- Can the structure support a living roof as-is? Or is reinforcement required?

☐ **Determine feasible roof types (extensive vs. semi-intensive vs. Intensive)**
- Which roof types can be structurally supported?
- Which roof types meet your goals?
- Combination of the roof types?

☐ **Determine feasible plants based on local climate**
- What plants suit the feasible roof types?
- What plants are native to your climate?
- How diverse can your vegetation be?

☐ **Select the appropriate roof type**
- Green vs blue vs blue-green
- Extensive vs. semi-intensive vs. Intensive
- Can be a combination of multiple

☐ **Complete a cost-benefit analysis**
- Compare install & maintenance costs to savings over life cycle
- Account for direct & indirect benefits

☐ **Complete permit package including specifications, plan and drawings**
- Typically completed by a specialist
- Further details on city website

☐ **Submit permit package to city for review and comments**

- Multiple sets of revisions may be required, depending on project complexity

☐ **Use approved permit package to solicit bids from various contractors**
- A minimum of three bids are recommended to provide adequate comparison
- Further details can be found on city website (Link to contractor list)

☐ **Select preferred contractor based on bid packages received**
- Selection can be based on a number of factors including cost, timing, project duration, contractor expertise, level of communication, familiarity

PART B - INSTALLATION

☐ **Understand the client's wants/needs**
- What type of roof do they want?
- What is most important (cost, timing, sound reduction, LEED credits, etc.)

☐ **Examine existing conditions**
- Understand roof membrane type and condition
- Existing equipment review/planning
- Site context/building features

☐ **Construction Planning**
- Understand traffic patterns and traffic bylaws
- Understand ventilation requirements
- Develop construction sequence
- Review building accessibility and configuration

☐ **Structural Reinforcement/Retrofit (if necessary)**
- Determine where reinforcement is required
- Method of reinforcement
- Options for access and feasibility

☐ **Safety Plan**
- Fire watch
- Suspended access systems
- Guardrails/bump lines

☐ **Remove Existing Membrane and Prepare Structure (if necessary)**
- Examine concealed structure for issues
- Implement repairs to deck if needed
- Store and salvage applicable materials

☐ **Install Roofing Membrane (waterproofing, vapour barrier, insulation)**
- pay attention to penetrations, terminations to prevent leaks
- slope and drainage need special attention to prevent ponding/leaks

☐ **Install Root Barrier**
- Only required for some membrane systems
- Avoid chemical barriers as they can leech into stormwater and vegetation

☐ **Protection Layer**
- Only required for some membrane systems

☐ **Install Drainage Layer**
- Can be a variety of materials ranging from gravel/stone ballast to prefabricated plastic
- May be more complex if the system is intended to function as a blue roof

PART C - MAINTENANCE

Design and include a maintenance plan that discusses best practices including:

- ☐ Irrigation schedule and benchmarks
- ☐ Fertilization recommendations
- ☐ Weeding best practices and frequency
- ☐ Best practices for replanting and plant schedule
- ☐ Recommendations for Inspection/drainage cleaning
- ☐ Inspection and clearing of debris from growing media and access pathway

Inspection Checklist

LIVING ROOF INSPECTION CHECKLIST

CITY OF VANCOUVER | GREENEST CITY

Regular inspection and maintenance of your living roof has many benefits including extended roof life, leak prevention, improved stormwater retention, fire safety and richer biodiversity.

PRE-INSPECTION

- ☐ Review inspection logbook
- ☐ Review green roof maintenance plan
- ☐ Review weather forecast
- ☐ Personal Protective Equipment (steel toe boots, gloves, eyewear, etc.)
- ☐ Inform a colleague/friend you will be on the roof

DURING MAINTENANCE

- ☐ Inspect and clear walkways/pathways
- ☐ Inspect vegetation for sparse/dying areas
- ☐ Inspect vegetation for insect infestation
- ☐ Check soil conditions (dry/saturated, too shallow/deep, soil migration, soil depth)
- ☐ Check for wind scouring
- ☐ Inspect and clear area drains
- ☐ Clear debris/dead vegetation
- ☐ Inspect border zones for debris build-up
- ☐ Inspect membrane for tears, debonding, open seams, etc. (where visible)
- ☐ Irrigate vegetation (if there is no automated system)
- ☐ Prune/trim vegetation
- ☐ Remove weeds

OPTIONAL ITEMS (IF PRESENT)

- ☐ Fall arrest system clear/accessible
- ☐ Inspect irrigation lines for damage/blockage
- ☐ Review tools/maintenance materials in shed/storage area
- ☐ Check stormwater retention tank for leaks/blockage

POST INSPECTION

- ☐ Update inspection logbook
- ☐ Notify others of any critical issues (leaks, safety hazards, etc.)
- ☐ Inform a colleague/friend that you have completed your inspection
- ☐ Ensure roof access has been locked or ladder has been removed

NOTE: This list does not substitute for a green roof maintenance plan. This list is intended for use by building operators or owners in addition to a maintenance plan. This is a general list of items to be reviewed and should not be considered exhaustive. Not all items listed below will apply to every living roof. If the inspector/user is unfamiliar with living roofs, we recommend completing additional research and contacting qualified professionals with any questions.

ROOF MAINTENANCE LOG BOOK

Date	Time In	Time Out	Irrigation	Pruning/ Debris	Drainage	Maint. Supplies	Inspection Notes

APPENDIX C – PROPOSED DESIGN GUIDELINES LAYOUT & CONCEPTS

PART A – INTRODUCTION TO LIVING ROOFS

1. **Document Purpose** – This section should provide an overview of the scope and intended audience of the guidelines. This would ideally include what the document is intended to be used for (design guidance and to provide a general understanding of living roof technology).

2. **Definition and History of Living Roofs** – describe what living roofs are, including a brief history of the technology development and the important role living roofs play in urban landscapes.

3. **Rain City Strategy and Green Rainwater Infrastructure** – discuss the Importance of rainwater infrastructure, introduce the rain city strategy and any other relevant City of Vancouver strategies that influence living roofs. Ensure to discuss the importance of on-site rainwater management (48mm of rainfall or 90% capture and manage on site)

4. **Overview of Living Roof Components –** provide a general review of the major living roof components (structure, waterproofing, growing media, vegetation, etc.). Extensive detail is not required here as additional information will be provided in Part B – Design Guidelines.

5. **Living Roof Categories** – discuss the three main categories of living roofs (extensive, semi-intensive and intensive) and their defining factors.

6. **Living Roof Functions** – discuss the four main roof functions along with how the design will be impacted when considering each of these four functions of a living roof:
    - water management (main function)
    - biodiversity (co-function)
    - active amenity programming (co-function)
    - urban agriculture (co-function)

    Rainwater management should be emphasized as the main intended function of the living roof to help the city meet its rainwater management goals. This section should include a discussion of their relevance to the various City of Vancouver strategies.

7. **Combining Living Roof Technologies –** review the various other technologies that can be used in conjunction with a living roof system. The discussion should include how each of these technologies will impact the living roof system, where applicable:
    - Biosolar roofs
    - Blue-green roofs
    - Rainwater harvesting

8. **Co-benefits of Living Roofs** – review the various co-benefits that living roofs provide (both public and private) that are available for living roofs such as urban heat island effect, improved insulation, horticultural therapy, and biodiversity.

9. **Designer Roles** – this section is intended to discuss the importance of developing an integrated design process with the appropriate professionals early in the project. Bringing together a team of specialized professionals will help to ensure a project runs smoothly and is designed efficiently with all parties having a similar understanding of the project scope. Include an overview of which professionals may be helpful for this project. Ensure that the document includes a disclaimer to note the difference between a design guideline and a bylaw or code. A disclaimer for design by a professional. (See San Francisco Guidelines).

PART B – DESIGN GUIDELINES

1. *DESIGN*

1.1. Building Structure – The section should discuss the main types of building structures (concrete, wood, steel) and some of the important variations between the structure types. The section should mention the potential load restrictions that will apply to an existing structure and could place limitations on the roof typologies that are viable options for installation. Recommendations regarding hiring a professional structural engineer should be included along with a brief discussion of both live and dead load calculations. Ideally, this section should also include some references to relevant codes and standards (see Appendix A for a list of some relevant standards).

1.2. Waterproofing – Waterproofing membranes are a key component that should be discussed in detail to stress the importance of this layer. Discussions should include the types of waterproofing membranes that are available (modified bitumen, BUR, PVC, TPO, etc.), a breakdown of the inverted roof membrane system vs. a conventional installation and a discussion surrounding the various layers of the waterproofing membrane (vapour barrier, rigid insulation, and waterproofing membrane). Ideally, schematic images should be included here to make the breakdown of the waterproofing membrane easier to comprehend. Reputable waterproofing membrane manufacturers should be included in this section as well, such as Soprema, which has a suite of educational information available for review on their website.

1.3. Root Barrier – The importance of the root barrier should be stressed to ensure an understanding of the necessity of the layer as well as understanding the various materials available for root barriers (HDPE, PVC, etc.). Discussion should also include mention of root barriers which can include chemicals to improve root resistance. However, this is not recommended as the chemicals create an increased risk of chemical leeching into the rainwater runoff. This section should also mention the use of a protection layer between the membrane and root barrier to provide additional protection of the waterproofing system. The root barrier typically marks the differentiation between the conventional roof system and the living roof system. Ideally, this section should make note of the importance of delineating responsibilities when developing a specification package to ensure contractors/installers are aware of their roles during the project. If two different installers are used for the conventional roof system and the living roof system, this should be clearly specified to avoid any confusion. This section may also mention the potential for installing leak detection systems as part of the assembly. It can be notoriously difficult to determine the source of water leaks as water can travel once it

gets beneath the waterproofing layer. Thus, the location where a leak is discovered inside the building may be several meters away from the source of the leak. The installation of a leak detection system can make maintenance and repairs much easier in the future.

1.4. **Drainage Layer –** Drainage layers serve an important role in ensuring the proper operation of the living roof system. This section should specify the importance of the drainage layer in preventing water from standing on the living roof system. Sloping the roof to adequately drain will stop water from standing on the roof and contributing to a deteriorating membrane. The importance of this layer to create rainwater detention by draining at a slow rate and decreasing the rate of surface runoff. This is a key component of discussion in this section to achieve the City's goals of GRI implementation. Discussion should include the various materials that the drainage layer can be made of (PVC, mineral aggregates and geocomposites). The importance of ensuring adequate voids to allow water to pass through the drainage layer should be stressed. The inclusion of geocomposites with water retention should be recommended for intensive roof systems as they provide a method of water diversion by collecting water for use by the vegetation and helping to maintain healthy vegetation during dry spells. Standards for drainage layer design, sloping considerations and surface water runoff calculators should be included within this section.

1.5. **Filter Fabric** – The filter layer creates a necessary layer of separation between the drainage layer and the growing media. It prevents the growing media from being washed away with the infiltrating water and helps to reduce erosion of the growing media. Discussion within this section should include the description of the layer and its role along with the typical material construction (typically geotextile fabric). The section should include a discussion of ensuring the layer is porous enough with voids to let water penetrate the fabric without allowing the growing media to pass. This can not only prevent erosion, but also prevent clogging of the roof area drains.

1.6. **Growing Media** – Growing media should be a significant discussion point in the design guidelines as it plays a major role in defining the living roof system. The depth of the growing media will influence rainwater infiltration, the type of vegetation that can be installed and, indirectly, biodiversity. The discussion for this section should include a wide variety of topics including soil composition, pH levels, soil weight, ratios of organic to inorganic materials and porosity. Rainwater infiltration should also be discussed in this section as the soil plays an important role in diverting rainwater from entering the municipal system. Ideally, schematic images in this section should help to illustrate the differences between the various growing media features and their effects on the living roof system.

1.7. **Irrigation** – The inclusion of an irrigation system is not always required and varies based on the type of living roof installed and the specific climate created. In general, an irrigation system is recommended for Vancouver-based projects due to the dry climate that is typically present during the summer months. This section should discuss the advantages of irrigation systems and their contribution to maintaining ideal soil conditions and improving longevity of

vegetation. This is especially important during the first year of the roof, as the vegetation is establishing itself.

1.8. **Vegetation/Planting** – The combination of vegetation that can be used on a living roof assembly will vary from site to site and will be largely dependent on the growing media that is installed. This section should emphasize the importance of creating a high rate of biodiversity through a wide variety of plant selections. The section should also emphasize the implementation of native plants in order to maximize the integration of the living roof with the surrounding environment and maximize the chance of successful plant propagation. Recommendations from this section should include involving a landscape architect and include references to the various City of Vancouver strategies that should be consulted such as the biodiversity strategy and recommended plant lists.

1.9. **Habitat Design/ Rooftop Horticulture** – a focus on habitat design and rooftop agriculture should be included that emphasizes the importance of installing a living roof that maximizes the biodiversity of the space. This can be achieved through varying soil depth, creating variations in the vegetation used and various areas of sun, shade, and the use of water to create a rich variety of micro-climates within the area. Site conditions such as building height, sun exposure and wind exposure will also play a role in developing an appropriate habitat design.

1.10. **Wind Design** – The importance of wind load considerations should not be overlooked during the design of a living roof system. High winds can create negative pressure on roofs which allows for uplift of roofing materials and can create a safety hazard due to falling debris. Wind load is especially important in the design of living roof systems for high-rise buildings such as many of the towers in downtown Vancouver, which can be exposed to high winds. This section should discuss some of the common ways to address wind lift issues and the importance of designing living roof systems to withstand adequate winds. Inclusion of a qualified engineer to assist with the design is highly recommended. The section should also include links to relevant documentation for wind design such as “Prediction of wind-induced failure of loose laid roof cladding systems” by Kind and Wardlaw, as referenced in ANSI/SPRI VF-1 Fire Design Standard for Vegetative Roofs.

1.11. **Fire Safety Considerations** – The importance of fire safety in designing a living roof system to be compliant with fire design requirements should be discussed in the design guidelines. Including components such as border zones around the perimeter of the roof and installing fire breaks to prevent flame spread are necessary in living roof design. Additionally, reducing the use of combustible materials in design and ensuring dead and decaying vegetation are removed. ANSI/SPRI VF-1 Fire Design Standard for Vegetative Roofs provides an excellent reference for the fire safety considerations and should be referenced, among other documents in this section.

1.12. **Rainwater Retention** – rainwater retention and rainwater detention both achieve the goal of reducing the rate of rainwater discharge from a site. Rainwater detention refers to slowing the rate at which water is released into the municipal stormwater system. Rainwater retention

means diverting the rainwater from the municipal system and storing on site for re-use. Rainwater retention is one of the GRI of the Rain City Strategy to help manage water on-site, reduce surface runoff rates and prevent pollution from entering local waterways. Discussion in this section should center around the requirements of rainwater retention as outlined in the RCS and how living roofs contribute towards that goal. This section should also touch upon the requirements for a rainwater management plan to be submitted. Discussion about various rainwater harvesting techniques should be included in this section. This section should also include links to relevant documents such as a sample rainwater management plan, stormwater runoff calculator and the rainwater harvesting webpages such as the rainwater barrel webpage on the City of Vancouver website.

1.13. **Area Drains & Scuppers** – adequate drainage is necessary to create a well-functioning living roof system. Area drains must be adequately spaced and placed in locations at the lowest points of the roof in order to ensure adequate drainage. Additionally, the drains must be adequately sized to accept the necessary design rainfall events and prevent the roof from flooding. In many cases, parapet scuppers are recommended, which act as an emergency relief for the water if the main drains back-up and the roof floods. This guidelines section should also discuss designing drains with an adequate buffer zone to prevent overgrowth from vegetation and prevent clogging of the drains. This section should include schematic drawings showing ideal drain designs in order to help illustrate the topics discussed.

1.14. **Roof Slope** – the sloping of the roof affects several elements of a living roof system. As mentioned previously, drainage paths will rely on adequate slope to maintain an adequate rate of discharge. Additionally, slope can affect the feasibility of a living roof installation. Roofs with significant slope (beyond 17%) will require additional methods of stabilization to ensure the growing media does not erode. This section should focus on the considerations of roof slope and the methods to address issues related to roof slope.

1.15. **Roof Access** – installing a living roof on a new or existing building can present challenges related to accessing and maintaining the space. This can especially be a challenge for an existing building where roof access did not previously exist. The issue of access can be further complicated if the roof is intended to be accessible to the building occupants/public. Issues of barrier-free access, emergency exit routes and occupancy constraints make the design of the living roof system more complicated. This section should focus on the various issues and how they should be addressed. Relevant sections of the VBBL and various standards should be included here.

1.16. **Permitting & Submission Requirements** – the process of permitting and submissions is largely a designer's job. They should be regularly consulting with the permitting department to ensure that all aspects of the submission meet the requirements for approval. This section should focus on the permitting process within the City of Vancouver and ideally, would include a checklist of the necessary documents that are required for a successful submission. It is also recommended that the links to the relevant City contacts are included in this section.

2. *INSTALLATION*

2.1. Site preparation/Planning – Site preparation and planning is foundational to any major project. This section should discuss some of the major steps that are included at the beginning of a project such as scheduling of various trades, staging of the project (if necessary), progress meetings, material disposals and safety measures to help ensure a successful project. This stage is intended to help discover and resolve any unforeseen issues before they become critical to the project. A kick-off meeting is often recommended to have all parties meet on site and ensure all parties have an equal understanding of the project scope.

2.2. Waterproofing Membrane – Proper installation of the waterproofing membrane is essential to the success of a living roof system. This section should focus on the various aspects that exhibit best practices for membrane installations. Membrane installations should be completed in a timely manner to prevent exposure of the structure to the rain, UV, or other weathering elements. The membrane should be inspected throughout the installation process to ensure details such as upturns, lap joints and terminations are installed as specified. The membranes should be water tested after installation to ensure there are no leaks present before the roof is covered. The membrane should be covered as soon as possible with a protective layer after installation to prevent potential damage due to foot traffic and prevent damage/punctures from dropped tools. This section should include references to relevant standards for waterproofing installations and images of typical installation defects that should be reviewed.

2.3. Growing Media Installation – A discussion surrounding growing media installation should include topics such as the various ways that the growing media are installed, such as blown-in soil or hoisted via crane. Discussion should also include salvaging and staging growing media on an existing living roof if there are materials that are expected to be re-used as part of the replacement roof. This can be a difficult portion of the project as the structure must be able to support the extra weight from storing the media in concentrated areas of the roof. Additionally, the growing media should not be allowed to dry out significantly as this may cause erosion during high wind events. The soil should be maintained in a moist condition, especially if there is a delay in the installation of the vegetation. This section should also include images of various installation practices, where possible.

2.4. Vegetation Installation – The installation of the vegetation will vary widely for each individual project. However, the focus of this section should center around the different types of plantings that are available (mats, plugs, seeding) and the various strategies for each method. The section should also focus on timing of the installation. The ideal seasons to install the vegetation are in the spring or fall in order to avoid extreme periods of drought or potential frost. Emphasis in this section should also be placed on the importance of sufficient irrigation early in the vegetation's life to encourage root establishment. This section should also reference relevant documents such as the City of Vancouver's recommended plant list.

2.5. Fall Protection/Construction Safety – Construction safety is one of the most important portions of any major project. This section should focus on the importance of proper safety measures such as ensuring all personal protective equipment is utilized, guardrails/fall

protection is installed around the perimeter of the roof and all project members have received adequate training for their respective roles. This section should also provide links to relevant safety resources such as WorkSafeBC.

3. MAINTENANCE

3.1. Maintenance plan – a maintenance plan should be provided for each new living roof application in the City of Vancouver. These plans should include a list of maintenance tasks that are required and their frequency of completion. Ideally, they should include a maintenance contract from a reputable landscaper. A maintenance plan is crucial to the success of a living roof system as the early stages of the living roof will require extra attention to ensure establishment of roots. This section should also reference relevant standards such as *CSA-S478-95 – Guideline on Durability in Buildings*.

3.2. Fertilization – fertilization requirements will vary for each project. In some cases fertilizers may not be required. However for more intensive systems, it is important to test the soil conditions periodically and fertilize at least once a year, depending on the type of roof. Discussions could also include the various types of fertilizers. A schedule, if necessary, should be included as part of the maintenance plan.

3.3. Irrigation – irrigation methods and frequency will vary for each project and should be continually updated based on the condition of the vegetation and the climate. This should be included in the maintenance plan.

3.4. Weeding – weed removal is typically required on intensive roof systems due to the ideal growing conditions. Roofs should be monitored for weeds as their root systems can be aggressive and cause damage to the roofing system if left unchecked.

3.5. Removal of Biomass – Dead or dying vegetation is a fire hazard and should be removed on a regular basis to prevent any potential damage to the property. The roof should be regularly inspected and maintained as part of the maintenance plan. Biomass may also clog the area drains and prevent adequate drainage during storm events. Drains should be checked regularly and cleared of any debris.

PART C – ADDITIONAL INFORMATION

1. Case Studies – This section should include relevant case studies of existing roofs from around Vancouver. As mentioned in this report, further research and collaboration between the City of Vancouver and private property owners will be required to develop the information needed to create a relevant case study.

2. **Glossary of Terms** – Consideration should be given to creating a glossary of terms that can be referred to by the user in order to provide additional context for the technical terms used within the guidelines.

3. **Links to Relevant Related Documents (VBBL, FLL, RCS, etc.)** – A list of relevant documents should be included throughout the document and summarized in this section. Refer to Appendix A for a full list of recommended documents.

APPENDIX D – EXISTING BY-LAW GAP ANALYSIS MATRIX

Existing City of Vancouver By-Laws Gap Analysis			
Component		Included	Excluded
Types of Green Roofs		X	
Ext. Vs. Semi-Int Vs. Int.		X	
Permitting Process			X
Benefits of Green Roofs			X
Finding Design Professionals			X
Designer Roles			X
Case Studies			X
% Green Roof Coverage			X
Waterproofing layer		X	
Protection Board			X
Root Barrier		X	
Filter Layer			X
Roof Drain Inspection Chambers			X
Drainage Layer		X	
Growing Media		X	
Vegeatation/Plants			X
Habitat Design			X
Rooftop Agriculture			X
Soil Slope			X
Live/Dead Load Calcs		X	
Wind Design		X	
Building Height		X	
Fire Protection		X	
Border Zones		X	
Rainwater Retention			X
Flow Control Calcs			X
Drainage System/Overflow			X
Rainwater harvesting		X	
Pollution Prevention			X
Roof Slope		X	
Walkways/Access		X	
Bird-Friendly Design			X
Staging of soils in installation			X
Optimal times for planting			X
Occupancy			X
Building Code References		X	
Zoning Requirements			X
Submittal Requirements			X
Construction Requirements			X
Typical Details			X
Waterproofing Testing			X
Fall Protection/Construction Safety			X
Irrigation		X	
Maintenance Plan			X
Fertilization		X	
Weeding		X	
Removal of Biomass		X	
Repairs/Re-planting			X
Fall-Protection Equipment			X
Inspection & Testing Methods			X
Insurance			X
Cost Estimates			X
Public Incentives for Implementation			X
General Installation Instructions			X
Descriptions of significance of components			X
Relevance to Vancouver Climate/Conditions			X
Includes all relevant standards			X
TOTAL Categories		19	38

APPENDIX E – DECISION MATRIX – WEBSITE ANALYSIS

Website Comparison Matrix										
Component		Vancouver	Portland	Toronto	San Francisco	CRD	North Vancouver		# of times discussed	Importance (H/M/L)
Layout/Visual Experience										
Green Roof Web Portal			X	X	X	X	X		5	H
Green Infrastructure Parent Portal			X		X	X	X		4	H
Banner Pictures		X	X		X	X	X		5	H
Side Navigation Bar		X	X	X		X	X		5	H
Additional Information Sidebar		X	X			X			3	M
Tabular Headings					X				1	L
Expandable windows		X		X			X		3	M
Tiles for sub websites		X		X	X				3	M
Text box with general info		X	X	X	X	X	X		6	H
SUBTOTAL		6	6	5	6	6	6			
Content										
General Introduction to Green Roofs			X	X	X	X	X		5	H
Discussion on Types of Green Roofs				X		X	X		3	M
Cross section of green roofs			X			X			2	M
Advantages and Disadvantages			X	X	X	X	X		5	H
Design requirements			X	X		X			3	M
Costing and permits			X						1	L
Maintenance Requirements			X						1	L
When to call a professional			X				X		2	M
Case Studies				X	X				2	M
Cost-Benefit Analysis					X				1	L
External Links to Websites		X	X		X	X			4	M
External links to docs/guidelines		X	X	X	X	X	X		6	H
Important Contacts		X	X	X	X				4	H
Interactive Map					X	X			2	M
List of Experts (Contractors/Consultants)									0	L
FAQ Section									0	L
SUBTOTAL		3	10	7	8	8	5			
TOTAL		9	16	12	14	14	11			

APPENDIX F – DECISION MATRIX – DESIGN GUIDELINE ANALYSIS

Guideline Document Comparison Matrix													
Component		Vancouver By-Laws	Portland	Toronto	FLL	San Francisco	GRO (UK)	CVC (Peel Region)	CMHC	Denver		# of times discussed	Importance (H/M/L)
Types of Green Roofs		X	X	X	X	X	X	X	X	X		9	H
Ext. Vs. Semi-Int Vs. Int.		X	X	X	X	X	X		X	X		8	H
Permitting Process			X			X			X			3	L
Benefits of Green Roofs			X	X	X	X	X	X	X	X		8	H
Finding Design Professionals				X		X		X	X	X		5	M
Designer Roles						X	X		X	X		4	M
Case Studies			X			X		X	X	X		5	M
% Green Roof Coverage			X		X							2	L
Waterproofing layer		X	X	X	X	X	X	X	X	X		9	H
Protection Board			X	X	X	X	X	X		X		7	H
Root Barrier		X	X	X	X	X	X	X	X	X		9	H
Filter Layer				X	X	X	X	X	X	X		7	H
Roof Drain Inspection Chambers					X	X				X		3	L
Drainage Layer		X	X	X	X	X	X	X	X	X		9	H
Growing Media		X	X	X	X	X	X	X	X	X		9	H
Vegeatation/Plants			X	X	X	X	X	X	X	X		8	H
Habitat Design			X		X	X			X	X		5	M
Rooftop Agriculture						X	X		X	X		4	M
Soil Slope			X	X	X		X					4	L
Live/Dead Load Calcs		X	X	X	X	X	X	X	X	X		9	H
Wind Design		X	X	X	X		X	X	X	X		8	H
Building Height		X			X				X	X		4	M
Fire Protection		X	X	X	X	X	X	X	X	X		9	H
Border Zones		X	X	X	X	X	X	X	X	X		9	H
Rainwater Retention			X	X	X	X	X	X	X	X		8	H
Flow Control Calcs			X	X	X		X					4	M
Drainage System/Overflow			X	X	X	X	X	X	X	X		8	H
Rainwater harvesting		X	X		X	X				X		5	M
Pollution Prevention			X		X	X		X	X	X		6	M
Roof Slope		X	X	X	X		X	X	X	X		8	H
Walkways/Access		X	X		X	X	X		X	X		7	H
Bird-Friendly Design			X									1	L
Staging of soils in installation			X				X		X			3	L
Optimal times for planting			X				X		X			3	L
Occupancy				X	X				X	X		4	M
Building Code References		X	X	X	X	X	X	X	X			8	H
Zoning Requirements			X		X	X	X		X			5	M
Submittal Requirements			X		X	X	X					4	M
Construction Requirements			X		X	X	X		X			5	M
Typical Details			X		X			X				3	L
Waterproofing Testing			X	X	X		X	X		X		6	M
Fall Protection/Construction Safety					X	X	X			X		4	M
Irrigation		X	X	X	X	X	X	X	X	X		9	H
Maintenance Plan			X	X	X	X		X	X	X		7	H
Fertilization		X	X		X	X	X	X	X	X		8	H
Weeding		X	X		X		X	X	X	X		7	H
Removal of Biomass		X	X		X		X	X		X		6	M
Repairs/Re-planting			X	X	X		X		X	X		6	M
Fall-Protection Equipment					X		X			X		3	L
Inspection & Testing Methods				X	X				X	X		4	M
Insurance									X	X		2	L
Cost Estimates			X						X	X		3	L
Public Incentives for Implementation									X	X		2	L
TOTAL Categories		19	41	27	42	33	36	27	40	41			